BRIMSTONE

DETAILED UXO RISK ASSESSMENT

STAGE 2 DETAILED UXO RISK ASSESSMENT

Client:			
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EXECUTIVE SUMMARY

RESULT: Brimstone concludes that unexploded ordnance (UXO) poses a **MODERATE RISK** to the proposed works.

THE SITE: The Site is located in Colindale, within the London Borough of Hendon, approximately 700m north-east of Hendon railway station. It is bound to the north by open ground within Rushgrove Park, to the east by Silk Stream, to the south by Crossway, ad to the west by residential structures and associated garden areas on Rushgrove Avenue.

The Site comprises a section of a park, consisting primarily of undeveloped ground with mature vegetation present intermittently throughout. A large hardstanding sports court is present in the centre of the Site, with hardstanding footpaths intersecting the east, south and west of the Site.

Grid Reference: TQ XXXXX XXXXX **What3Words:** XXXX.XXXX.XXXX

THE PROPOSED WORKS: Development works will comprise the construction of a 10.5m diameter and 10m deep shaft, and associated pipe works to and from an existing sewer.

At the time of writing, Brimstone was not aware of any proposed SI works taking place on Site.

UXO RISK ASSESSMENT:

German UXO:

- London was the most frequently and heavily bombed British city during WWII, with most damage being sustained by the central and eastern boroughs. Whilst the Site was situated on the north-western periphery of the city, approximately 10km away from the primary Luftwaffe target area in the region (the City of London), the wider area would have been vulnerable to overspill or inaccurate bombing. Consequently, the wider Site area experienced a moderate bombing density, as indicated by official wartime figures.
- London bomb census mapping records 16 HE bomb strikes within a 500m radius of the Site; the closest of these was plotted 90m south-west. In addition, a local bomb plot map for the Borough of Hendon records 17 HE bombs, two UXBs, eleven incendiary bomb 'concentrations', one oil bomb, two AA shells and seven unexploded AA shells within a 400m radius of the Site. The closest of these was an unexploded AA shell 40m south-west of the Site, whilst the closest HE bomb strike is recorded approximately 80m east.
- Written incident reports for Hendon were also analysed, recording 27 incidents within a 500m radius of the Site. These account for 13 HE bombs, at least 74 incendiary bombs, one V1 strike, one AA shell, and five unexploded AA shells. The closest of these was an incendiary bomb strike approximately 25m west of the Site. These incidents are plotted on a map at **FIGURE 6**. The fact that all three record sets record different bomb strikes on Site highlights the difficulty in wartime record keeping, and this raises the possibility that additional bomb strikes occurred unrecorded.
- The fact that all three record sets record different bomb strikes on Site highlights the difficulty in wartime record keeping, and this raises the possibility that additional bomb strikes occurred unrecorded.

- Despite the recorded bomb strikes, a Middlesex County Council war damage map records no damage to the structures directly west and 30m east of the Site, with the closest recorded damage approximately 180m east of the Site. Moreover, no immediately obvious signs of bomb damage, such as cratering in the open ground, can be seen on Site in WWII-era aerial photography. It should be noted, however, that any UXB strike to the areas of the Site occupied by water is unlikely to have left incontrovertible evidence of its existence.
- Indeed, the ground conditions throughout the Site were likely unconducive to the visual detection of UXBs, with any evidence of a UXB strike potentially being obscured by vegetation and filling in over time, leaving little evidence of its occurrence. This ground cover also suggests that the Site would not have been accessed regularly, further increasing the likelihood of a UXB strike on Site going unnoticed and unreported. Whilst the undamaged residences to the west likely provided a degree of access and observation, the extent to which this occurred cannot be confidently confirmed.
- In summary, evidence has been found to suggest that the Site area was subject to relatively significant bombing during WWII. In conjunction with wartime conditions on Site unconducive to the visual detection of UXBs, it cannot be ruled out that a UXB landed on Site unnoticed and unrecorded, remaining undisturbed beneath the limited post-conflict ground works. As such, a **Moderate Risk** of encountering a German UXB on Site has been assessed.

British / Allied UXO:

- No evidence of historic military activity within the Site boundary has been found and it is unlikely that any has occurred historically. Consequently, the risk from associated UXO is Low.
- Numerous (>30) permanent heavy anti-aircraft (HAA) batteries were active within range of the Site during WWII. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. The risk of encountering unexploded HAA shells is considered to be homogenous with that of German UXBs and as such, has been assessed as **Moderate**.

Likelihood of UXO Remaining and UXO Encounter:

- The risk associated with any deep or shallow buried German UXBs / AA shells will likely not be mitigated at all across the Site. The risk associated with any very shallow buried AA shells will have been partially mitigated with laying of hardstanding on previously undeveloped ground and landscaping of the open ground.
- Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

RECOMMENDED RISK MITIGATION MEASURES: The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings	Prior to all intrusive works commencing.
Intrusive Magnetometer Probe Survey	Of all pile positions.
EOD Engineer - On Site Supervision	Watching brief of all open excavations and magnetometer survey of all borehole locations.

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QUALITY POLICY

Brimstone Site Investigation Ltd, known as Brimstone, is committed to the delivery of unexploded ordnance (UXO) risk mitigation services, including safe removal and disposal of explosive ordnance, in the UK and overseas. Since our incorporation in 2016 it has been our goal to provide unsurpassed and unbiased UXO risk mitigation services. Brimstone is a client-centric organisation, with the aim to provide the client the services they need, to the agreed requirement, in accordance with national and international standards or standard operating procedures.

We are committed to providing a safe, cost-effective, and quality service, underpinned by our core values:

- **Integrity:** We are unwavering in our commitment to providing pristine, unbiased counsel and superior services. Our ethical compass guides every interaction, ensuring we maintain the highest standards of conduct in all our endeavours.
- **Professionalism:** We embody professionalism at every level, conducting our business with unparalleled excellence. Our commitment to quality guarantees top-tier service and a seamless experience for every client.
- **Knowledge:** We are devoted to perpetual growth, consistently expanding our expertise to stay at the forefront of industry innovation and strategy. Our thirst for knowledge ensures we are equipped to lead and succeed in an evolving marketplace.
- **Innovation:** We champion innovation, continuously advancing our services and processes. Our pursuit of inventive strategies and pioneering solutions ensures we not only meet but exceed the evolving needs of our clients and the industry.

We are committed to the applicable requirements of the ISO 9001:2015 standards. We set and review quality monitoring objectives using the plan, do, check, act cycle to measure the performance of our quality management system. Brimstone wholly endorses the ethos of 'continual improvement efforts' and allocates resources to meet this requirement.

This policy applies to the whole of the Brimstone services and involves all personnel including the managing director. All personnel are responsible for helping manage quality, seeking improvement through constant review, and by encouraging supplier and subcontractor involvement. We are committed to achieving customer satisfaction using quality procedures, which will be operated to meet or exceed the applicable requirements of ISO 9001.

Aaron Florence
Founder and Managing Director
Brimstone Site Investigation Ltd.

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1 INTRODUCTION

1.1 Background

XXXX XXXX (the Client) has commissioned Brimstone to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the XXXX XXXX, London site (the Site).

1.2 Legislation

There are no regulations that specifically govern the UXO risk mitigation industry in the UK. However, there are two pieces of legislation that require consideration. It is industry best practice (and common sense) to frame your site in the context of UXO, and to put in place measures to protect people from risks. In 2009, CIRIA published Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681. This publication, though not legally binding, provides the gold-standard framework to which UXO and construction companies operate.

1.2.1 Construction Design and Management Regulations (CDM) 2015

The regulations identify the client, the CDM coordinator, the designer, and the principal contractor as responsible parties. Under the regulations, responsible parties are held accountable for the way a construction project is managed and for the health and safety of workers. Responsible parties must:

- Provide an appropriate assessment of potential UXO risks, or ensure an assessment is completed by another party.
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks.
- Ensure the preparation of an emergency response plan.

1.2.2 The Health and Safety at Work Act 1974

The Health and Safety at Work Act 1974 had a transformative impact on health and safety, saving thousands of lives since its enactment. Employers must consider their employees, workers not in their employment, and members of the public. The act places a duty on every employer ‘as far as is reasonably practicable’ to protect workers from risks. It also says that information must be provided about aspects of health and safety that affect their role.

1.3 Commercial Contractor and the Authorities

1.3.1 Commercial Contractors

If your site has been given a moderate or high-risk rating, then control measures will be recommended. The measures will be specific to the scope of works on site, usually in relation to the depth and extent of excavations, piling and similar activities. There are a range of different methods at Brimstone’s disposal, including:

- Non-intrusive surveying (including drone surveying)
- Intrusive surveying
- Search and clear
- Watching brief
- Support to geotechnical investigations
- Target investigation
- Site-specific training packages
- Site safety briefings

Our UXO Engineers can assess suspicious items on site when they are found. This will avoid unnecessary site

evacuations. If our engineer(s) decide the item is UXO, they will coordinate with the authorities, manage disruptions, and advise on control measures, such as evacuations and a cordon.

1.3.2 UK Authorities

If Brimstone is not on site and a suspicious item is found, the local police must be immediately called on the non-emergency number. Police will visit the site. They will then inform the Joint Services Explosive Ordnance Disposal (JSEOD) office, which will coordinate the callout of an army or navy response team.

A precautionary cordon will initially be put into effect, with possible evacuation of homes and businesses, road and rail closures. The cordon may be extended following the advice from JSEOD's response team.

To manage their resources, JSEOD triages incidents. A consideration of the type, size and location of the UXO is made. If an incident is not given a high priority rating, a team may not be available for up to two days following the initial report.

The use of JSEOD is under the Military Aid to Civil Authorities (MACA) framework, therefore the budget and personnel is limited, and there are no statutory obligations made of the MOD. Often the MOD will recommend involvement of a commercial UXO contractor to manage the ongoing risk – this is especially true of former airfields and training areas where contact with land service ammunition can be frequent.

1.4 UXO Risk in the UK

Fortunately, to the best of our knowledge, there has not been a single post-war incident in the UK where a construction worker has been killed or injured because of an item of UXO exploding. There have been cases in mainland Europe where UXO had been struck and then exploded, killing workers. In 2019, a WWII general purpose bomb spontaneously detonated in a field north of Frankfurt, Germany.

However, the incident in Frankfurt is not comparable to the UK, due to the way different countries manufactured ordnance. Bombs made in different countries have different associated hazards. British WWII bombs, for example, have a fuzing system which uses chemicals which makes them very unsafe. Please see **APPENDIX 1** for recent examples of UK UXO incidents.

Between 2013 and 2016 JSEOD responded to 7,500 callouts. These callouts range from falsely identified objects, inert objects, small items of UXO and large WWII German unexploded bombs (UXBs). Each year the construction industry inadvertently unearths UXO; often this goes unreported. UXO contamination comes from three main sources:

- **Enemy action:** during WWI and WWII the air forces of Germany, and to a lesser extent Italy, bombed targets throughout the UK. The German navy bombarded several coastal targets in eastern England during WWI and then in WWII German long-range artillery on the French coast bombarded parts of Kent.
- **Allied military activity:** during WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre; predominantly the US and Canada.
- **UK military activity:** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as anti-aircraft gun and rocket batteries during WWI and WWII.

1.5 UXO Detonations

A detonation is a violent chemical reaction which creates a huge volume of gas. This reaction appears to happen instantaneously – the velocity of the shockwave moving is up to 9,000m per second. This chemical reaction is started using a small amount of very sensitive explosives called primary explosives. These types of explosives are highly sensitive to shock, friction, heat, and spark. As the explosive charge undergoes high order decomposition (detonation), the brisance, or shattering effect, causes the casing to splinter, projecting razor-sharp shrapnel across long distances.

The blast wave effect and the shrapnel effect can cause significant damage. Calculating safety distances is a

complex process. As a rule of thumb, in open ground, a 250kg explosive charge (as would be found inside a typical 500kg bomb) would require an omnidirectional safety distance of at least 1.6km.

Bombs work by amplifying the explosive charge from the sensitive primary explosive through to the main charge or fill of the item. This process is called an explosive train, if any link in that chain is broken, the item will fail to function as intended. This can be due to mechanical, electrical, or manufacturing tolerances or faults. Amongst other reasons, detonation of UXO could occur under the following circumstances:

- **UXO body impact:** A substantial impact onto the main body of a UXO; borehole rigs, piling rigs, jack hammers and mechanical excavator buckets.
- **Fuse impact:** Environmental conditions during decades of burial can result in the primary explosives located in the fuse pocket to crystallise and become shock sensitive. It would then take a relatively small impact or friction impact to cause the fuse to function and detonate the UXO.
- **Re-starting a timer:** A small proportion of German WWII bombs used clockwork fuses. In 2002, an Army EOD Engineer reported that the clockwork fuse in a UXB re-started. Decades of burial causes substantial corrosion in WWII German UXBs and therefore an incident such as this is extremely rare.

2 ASSESSMENT METHODOLOGY

2.1 Introduction

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is a publication which originated from round table best practice discussions from industry leaders.

2.2 Source, Pathway, Receptor, Consequence Risk Model

The Source, Pathway, Receptor, Consequence (SPRC) risk model can be applied to buried UXO as follows:

- **Sources:** UK and Allied UXO sources include military firing ranges, bases, storage depots, munitions factories, anti-aircraft batteries, amongst others. There are many wartime causes of UXO contamination. The source for enemy contamination is overwhelmingly from WWII German air raids.
- **Pathways:** the pathway describes how the UXO reaches receptors. Usually, UXO is buried and therefore pathways can be any activity which involve breaking ground. Examples include ground investigation works, site enabling works and excavations.
- **Receptors:** receptors are the people, assets and infrastructure that can be adversely affected by UXO exposure. This includes site personnel, plant, equipment, buildings, the general public, and the environment.
- **Consequence:** the consequences of an inadvertent UXO detonation are catastrophic. They include injury and loss or life, as well as damage to property. Fortunately, the likelihood of UXO detonating is low, even when it is uncovered during works. However, another consequence to consider is delays to works, which itself can be a risk.

2.3 Assessment Structure

In accordance with CIRIA C681 this assessment addresses the following considerations in the appropriate order:

- The likelihood that the site was contaminated with UXO.
- The type of UXO that could have contaminated the site, and their associated hazards.
- The likelihood that UXO remains on the site.
- Theoretical bomb penetration depths.

- The likelihood that UXO will be uncovered during the proposed works.
- Risk rating and risk mapping (as appropriate).
- Risk mitigation recommendations.

2.4 Information Sources

To complete this risk assessment, Brimstone has gathered information from a wide range of sources. Brimstone's research team has completed detailed historical research, including access of original archived records. The list below is a general list of information sources that are consulted during the research process. For Site-specific sources consulted for this risk assessment, please refer to **APPENDIX 5**.

- The National Archives,
- Local archive centres,
- Ministry of Defence,
- The Council for British Archaeology,
- Groundsure mapping services,
- Historical aerial photography (Historic England, Britain from Above, NCAP),
- Google open-source mapping,
- The British Geological Survey,
- Open sources; published book, articles, web resources,
- Site-specific information supplied by the Client,
- Brimstone's library and historical database, and
- Brimstone's former armed forces employees.

2.5 As Low as Reasonably Practicable Principle

The ALARP (as low as reasonably practicable) principle corresponds to the actions that should be taken to reduce risks. The term 'ALARP' is in the Health and Safety at Work Act 1974, which says that risks must be controlled in a reasonable way.

Infinite time, effort and money could be spent trying to eliminate risk entirely. HSE uses the example that spending £1m to prevent five employees bruising their knees is disproportionate, whereas spending the same amount to prevent an explosion which could kill 150 people is proportionate.

Using this principle, Brimstone aims to reduce client costs by recommending strategies that are proportionate to the assessed risks, if any elevated risk is found at all.

2.6 Risk Tolerances

The Brimstone risk assessment process divides UXO risk into two tolerances:

- **Tolerable:** Low Risk and Low-Moderate Risk ratings are tolerable. Where the risk cannot be completely discounted, it may be a useful strategy to opt for a low-cost measure, such as a UXO safety briefing from a qualified UXO engineer.
- **Intolerable:** Moderate, Moderate-High, and High-Risk ratings are intolerable. Proactive risk mitigation measures should be put in place. Various strategies are at Brimstone's disposal to meet your project-specific needs.

2.7 Reliance and Limitations

This report has been prepared using published information and information provided by the Client. Brimstone is not liable for any information which has become available following the publication of this report. No third-party liability or duty of care is extended. Any third-party using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 The Site

The Site is located in Colindale, within the London Borough of Hendon, approximately 700m north-east of Hendon railway station. It is bound to the north by open ground within Rushgrove Park, to the east by Silk Stream, to the south by Crossway, ad to the west by residential structures and associated garden areas on Rushgrove Avenue.

The Site comprises a section of a park, consisting primarily of undeveloped ground with mature vegetation present intermittently throughout. A large hardstanding sports court is present in the centre of the Site, with hardstanding footpaths intersecting the east, south and west of the Site.

Grid Reference: TQ XXXXX XXXXX **What3Words:** XXXX.XXXX.XXXX

FIGURE 1: Site Location Maps **FIGURE 2:** Recent Aerial Photograph

3.2 The Proposed Works

Development works will comprise the construction of a 10.5m diameter and 10m deep shaft, and associated pipe works to and from an existing sewer.

At the time of writing, Brimstone was not aware of any proposed SI works taking place on Site.

FIGURE 3: Existing Site Plan

4 SITE HISTORY

4.1 Site Introduction

Site-specific history can be assessed by reviewing historical mapping, historical aerial photography and by carrying out additional Site-specific research where appropriate. Below are descriptions of a selection of records relevant to the Site:

4.2 Mapping

The below table describes the composition of the Site, structural changes in pre- and post-WWII Ordnance Survey (OS) editions, and relevant points of interest. All maps were retrieved from National Library Scotland (NLS) online database and the Landmark Promap OS database.

Period	Map Date	Map Scale	Review
Pre-WWI	**1895**	**1:2,500**	A vast majority of the Site comprises a section of Brent Reservoir, with areas of marshland present along the eastern and western borders.

	1912	**1:2,500**	No significant changes appear to have taken place within the Site boundary. The residential development of the wider Site area has begun, with multiple rows of houses now present approximately 250m south-east of the Site.
Pre-WWII	**1935**	**1:10,560**	**FIGURE 4.1:** The reservoir on Site has been drained, and a vast majority of the Site now comprises undeveloped ground, with a small section of Silk Stream present in the north-eastern and south-eastern extents. Residential structures are now present directly west of the Site, on Rushgrove Avenue, and approximately 30m east of the Site on Colin Gardens.
Post-WWII	**1956-57**	**1:2,500**	**FIGURE 4.2:** The small waterway, Silk Stream, has been rerouted and now runs along the south-western border of the Site. A large tennis court has been constructed in the centre of the Site, with a footpath in the west. Mature vegetation is now recorded throughout the Site.

4.3 Photography/Aerial Photography

The below table describes the composition of the Site visible in post-WWII aerial photography, including areas of possible structural clearance, damage and other possible features of note. All photographs were retrieved from Historic England's (HE) Royal Air Force (RAF) Photography Archive.

Period	Photo Date	Review
Post-WWII	**20th April 1946**	**FIGURE 5:** This vertical image displays the entire Site approximately a year after the end of WWII. The Site composition matches that of the 1935 OS mapping described above: largely comprising undeveloped ground with no immediately obvious purpose. No immediately obvious signs of bomb damage, such as cratering in the open ground, are visible on Site. The same can be said for neighbouring residential structures directly west and approximately 30m east of the Site, all of which appear to have survived the war externally intact. It should be noted, however, that the open ground on Site appears poorly maintained, which may potentially be obscuring evidence of bombing / damage.

4.4 Additional Site-Specific History

Some sites will have been occupied by landmarks or significant buildings historically and in such cases specific written histories including significant wartime details are occasionally available in the public domain. No such information was available.

5 UXO RISK - GERMAN BOMBING

5.1 WWI Bombing History

5.1.1 Britain during WWI

During World War I (WWI), an estimated 9,000 German bombs were dropped on London, Eastern England and South-Eastern England during some 51 Zeppelin airship raids and 52 fixed-wing aircraft raids. London suffered the worst of the bombing with an estimated 250 tonnes of HE and incendiary bombs recorded across the Capital, over half of which fell on the City of London district.

The WWI bombing campaign waged by Germany was on a far smaller scale than the WWII campaign, in terms of the number of raids, the weight of ordnance dropped during each attack and the size of the bombs used. When coupled with the fact that most WWI-bombed locations have since been redeveloped, German WWI UXB finds are extremely rare. Furthermore, most air raids took place during daylight hours and as it was the first time Britain had experienced strategic aerial bombardment, the raids often attracted public interest and even spectators, increasing the chances of any UXBs being reported.

5.1.2 Site Specific

A collection of written reports describing each air raid in the region was reviewed (I. Castle, 2024). A WWI-era London bomb plot map held at the National Archives does not record any air raids over West Hendon during WWI. Therefore, the risk from associated WWI-era German UXBs is deemed insignificant and will not be discussed further.

5.2 WWII Bombing History

5.2.1 London

In the summer and autumn of 1940, the Luftwaffe targeted the RAF's airfields and support network with the intention of achieving air supremacy prior to a planned amphibious invasion of south-east England. The resulting Battle of Britain campaign (July to October) resulted in many air raids across England, although these were mainly concentred in the south-east. During this period, a few small-scale raids affected the outer London boroughs.

In early September 1940, the Luftwaffe changed their tactics and commenced an indiscriminate carpet-bombing campaign against London. The resulting nine-month Blitz began on 7th September 1940 and ended on 12th May 1941 - the heaviest raid of the Blitz. The vast majority of the Luftwaffe units based in occupied Europe were then redeployed to the Russian front.

During 1943, a number of small-scale fighter bomber raids were carried out against the Capital, then in 1944, the Luftwaffe commenced Operation Steinboch. This campaign comprised 31 major raids against London and other southern England targets, executed by inexperienced Luftwaffe crews, between January and May. However, poor navigation and improved defences resulted in unsustainable Luftwaffe losses, many formations being broken up by the RAF over the Home Counties. The final large-scale Luftwaffe raid on the Capital took place during May 1944, with all air raids ceased by the end of June.

Between 1940 and 1944, there were a total of 71 major air raids on Greater London resulting in some 190,000 bombs being dropped, killing over 29,000. In total some 50,000 tonnes of HE bombs and 110,000 tonnes of incendiary bombs (mainly of the 1kg type) were dropped during the Blitz over Britain. The army BDUs successfully dealt with approximately 40,000 UXBs during the war.

Immediately following the final air raids on London, the Luftwaffe launched the V Weapons campaign, commencing in June 1944. The V1 (Flying Bomb or Doodlebug) and later the V2 (Long Range Rocket) were launched from occupied Europe. 2,419 of the former and 517 of the latter were recorded in the London Civil Defence region.

Both carried a large 1,000kg HE warhead and were constructed of thin sheet steel, rather than the thick steel used on the Luftwaffe's free fall bombs. V Weapons were designed to detonate on the surface (like parachute mines), as opposed to free fall bombs which were designed to have some penetration ability through multi-storey buildings.

Consequently, any V Weapons which failed to detonate broke up on impact, resulting in an easily identifiable debris field. Although there is a negligible risk from unexploded V Weapons on land today, they caused widespread destruction throughout London and therefore, at V Weapon impact sites, the assessment of pre-1944 UXB risk can be hampered.

5.2.2 Site Specific

The Site is located approximately 10km north-west of the Luftwaffe's primary aiming point for indiscriminate air raids, the City of London. However, the area may still have been vulnerable to overspill / inaccurate bombing. RAF Hendon, approximately 1km north of the Site, was identified as a primary bombing target by the Luftwaffe. Hendon railway sidings, approximately 280m south-east of the Site, may have provided a target of opportunity.

5.2.3 Bombing Decoy Sites

In mid-1940 bombing decoys were introduced. The decoys used either:

- A system of lighting to simulate an urban area or a military airfield's runway,
- Deliberately started fires to simulate a previously bombed target,
- Dummy buildings and vehicles to simulate a military facility.

792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. No decoys were operational within a significant radius of the Site during WWII. The closest was approximately 8.7km to the north.

5.3 WWII Bombing Records

5.3.1 Introduction

The bomb census recorded the location and type of bomb strikes to help with intelligence gathering and planning. It was compiled using information recorded by ARP wardens. These records were gathered by the Ministry of Home Security to calculate bombing density within administrative areas.

The bomb census was unreliable in the early stages of the war, though by 1941 procedures had been standardised. The quality of the census records also depended on where in the UK the records were produced. Some records are held at the National Archives and some are held at local borough archives.

Relevant records held at the National Archives, the London Metropolitan Archives and Barnet Archives were obtained for this risk assessment.

5.3.2 Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Metropolitan Borough of Hendon. It gives a breakdown of the types of large German bombs reported and is understood to not include UXBs.

Admin Area	Hendon
Area Acreage	10,373
High Explosive Bombs (all types/weights)	467
High Explosive Parachute Mines	9
Flam (Oil) Bombs	31
40kg Phosphorus Incendiary Bombs (IBs)	4
40kg 'Fire Pot' IBs	6
V1 Flying Bomb	13
V2 Long Range Rocket	2
Total (excluding V-Weapons and 1kg / 2kg IBs)	517
Bombs Per 1,000 Acres	**49.8**

1kg / 2kg incendiary bombs and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are not included in the above figures. The latter were not dropped on London. Small IBs were however dropped in vast numbers (>100,000) over the capital.

5.3.3 Bomb Census Maps

Brimstone has reviewed a collection of original consolidated and weekly bomb census maps for the wider study area. These small-scale maps cover the entire bombing campaign and record all types of bomb. Relevant maps are displayed at **FIGURE 5**.

- Approximately 16 x 'iron' bombs are plotted within a 500m radius of the Site.
- The closest strike is plotted 90m south-west of the Site.

5.3.4 Hendon ARP Incident Book

Brimstone has reviewed an original ARP incident logbook for the Borough of Hendon, held at Barnet Archives. This logbook records bombing incidents over the Borough, covering the entire bombing campaign and giving varying levels of detail regarding the date of the incident, the location of its occurrence, number of fatalities and the extent of the damage caused. The incidents recorded within a 500m radius of the Site are transcribed below and presented on a bombing overlay at **FIGURE 6**.

ID	Date	Time	Location *Relative to the Site*	Type of bomb	Number of Bombs
1	19/09/1940	22:35	Colin Gardens / Colin Crescent *Approximately 170m north-east of the Site.*	UXAA	1
2	20/09/1940	21:25	146 Colin Gardens *Approximately 220m south-east of the Site*	HE	1
3		22:50	Colin Gardens and Colin Crescent *Approximately 120m east of the Site*	IB	Unknown
4	22/09/1940	00:01	Nufix Factory, Rookery Way. *Approximately 260m south-west of the Site*	AA	1
5		10:30	Woodfield Ave, Junior School *Approximately 220m north-west of the Site*	UXAA	1
6	23/09/1940	22:45	28 New Way Road *Approximately 370m west of the Site*	IB	5
7			61 New Way Road *Approximately 170m west of the Site*	IB	5
8			9 Hillfield Avenue *Approximately 330m west of the Site*	IB	10
9	24/09/1940	22:40	Colin Crescent, Colin gardens, Crossway *Approximately 140m east of the Site*	IB	43
10		n/a	Silkfield Road *Approximately 210m south-west of the Site*	UXAA	1
11	05/10/1940	21:15	New Way Road / Woodfield Ave. *Approximately 240m west of the Site.*	HE	1

12			Silkfield Road between Rushgrove Ave and Hillfield Ave *Approximately 170m south-west of the Site.*	HE	1
13			Colindale Junior School, Woodfield Ave. *Approximately 200m north-west of the Site.*	HE	1
14	08/10/1940	21:25	The Lonings *Approximately 320m north-west of the Site.*	HE	1
15		23:10	Colin Crescent *Approximately 180m east of the Site.*	HE	1
16		23:20	91 & 93 Colin Crescent *Approximately 190m east of the Site.*	HE	1
17			Colindeep Lane, waste ground near tunnel *Approximately 340m north of the Site.*	HE	1
18	11/10/1940	21:15	159 Colin Crescent *Approximately 210m south-east of the Site.*	HE	1
19		21:25	Waste ground rear of works, Rookery Way *Approximately 270m south of the Site.*	HE	1
20	15/10/1940	23:00	Nufix Factory, Rookery Way *Approximately 275m south-west of the Site.*	HE	1
21	16/10/1940	22:55	Railway between Colin Crescent and Edgworth Close *Approximately 300m east of the Site.*	IB	Unknown
22		23:50	Colin Crescent and Deerfield Cottages *Approximately 260m south-east of the Site.*	IB	Unknown
23		22:50	Lynton Ave. Rushgrove Ave. *Approximately 70m west of the Site.*	IB	8

24	18/10/1940	19:47	Colindeep Kane / Colin Crescent *Approximately 280m north-east of the Site.*	UXAA	1
25	10/01/1941	22:00	Junction Colindeep Lane and Sheaveshill Avenue. *Approximately 450m north-west of the Site.*	HE	2
26	17/04/1941	21:30	55 Lynton Ave *Approximately 140m north-west of the Site.*	UXAA	1
27	31/10/1944	21:01	Court Way / Sheaveshill Ave *Approximately 400m north-west of the Site.*	V1	1

5.3.5 Hendon Borough Bomb Map

Brimstone has reviewed a local bomb plot map for the Borough of Hendon, held at Barnet Archives. This map covers the entire bombing campaign and records all types of bombs. It also records the number of casualties, and structures damaged by bombing; stating that 242 people were killed, and 18,740 houses were damaged within the borough. A section of the map covering the study area is displayed at **FIGURE 7**.

- 17 HE bombs, two unexploded HE bombs, eleven incendiary bomb 'concentrations', one oil bomb, two AA shells, and seven unexploded AA shells are recorded within a 500m radius of the Site.
- The closest of these incidents to the Site is an unexploded AA shell approximately 40m south-west of the Site. The closest HE bomb strike is recorded approximately 80m east.

5.3.6 V Weapons

Brimstone has reviewed a collection of original consolidated V1 Bomb Plot Maps, as well as a contemporary plot map of V2 Rocket incidents, produced using collections of original written incident reports.

No V1 or V2 strikes are plotted within or adjacent to the Site boundary. The closest V1 strike (1st June 1944) is plotted approximately 400m to the north-west in written records (see ***Section 5.3.4***) and the closest V2 strike (16th September 1944) occurred approximately 1.8km to the south-west.

Neither of these incidents occurred in close proximity to the Site. Furthermore, several blocks of buildings that survived the conflict intact will have shielded the Site from the 1,000kg HE blast. Therefore, these incidents are insignificant.

5.3.7 Middlesex County Council War Damage Map

Brimstone has reviewed an original war damage map covering the study area. The map was produced by the Engineer and Surveyors Department of the Middlesex County Council and was updated throughout the bombing campaign. It should be noted that this map only records substantial structural bomb damage, and as such any minor blast / fire damage occurring to structures will not have been recorded in this source. A section of the map covering the study area is displayed at **FIGURE 8**.

None of the structures in the immediate vicinity of the Site have been shaded, suggesting that they sustained minor bomb damage at most. Structures approximately 180m east and 200m south-east of the Site have been shaded red, indicating 'Total damage'.

5.3.8 Abandoned Bomb Register

Due to the overstretched bomb disposal units during WWII, many bombs were intentionally left undisturbed. UXBs were triaged based on where they were and how big they were. If they didn't pose a significant risk, they were 'abandoned'. The locations of these bombs were recorded on the abandoned bomb register.

The abandoned bomb register is a public record document held at the Parliamentary Archives of the House of Commons, from which Brimstone has obtained a copy. The register should not be relied on for completeness or accuracy. The closest abandoned bomb is recorded approximately 440m south-west of the Site.

5.3.9 Secondary Source / Anecdotal Evidence

A search of online resources, as well as a review of local history publications was carried out with the intention of locating any eyewitness accounts of local bombing incidents. However, no such evidence was found.

5.4 Likelihood of UXB Contamination

Where detailed bombing records exist, it is possible to predict whether any UXBs could be found on a site. This likelihood is discussed in the following table:

Density of Bombing	
Number of Air Raids in the Vicinity:	A comparison of the bombing incident records confirms that at least eight air raids affected the study area. Note, this number may be higher as London was bombed many times during the first month of the Blitz, for which weekly plot maps are unavailable.
Intensity of these Air Raids:	All bombs dropped locally were likely part of large-scale indiscriminate carpet-bombing raids, all of which were carried out at night.
Bomb Strike Positions	
Closest Bomb Strikes	HE bombs: approximately 80m east. 1kg / 2kg IBs: approximately 40m south-west.
Alignment of recorded Bomb Strikes:	For districts with a very high bombing density, such as that within which the Site was situated, accurate analysis for the alignment of bomb strikes is not always possible. As it has not been possible to identify the bomb sticks over the Site, there may have been multiple occasions during which a UXB (unobserved and unplotted) could have been released over and landed within the Site boundary. For most small IB spreads (covering a wide area) it is impossible to correctly identify the aircraft's flightpath and thus bomb-stick alignment. Furthermore, such bombs were significantly affected by the wind, further hampering analysis.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of the Site:	None.
UXBs recorded in close proximity to the Site:	Closest plotted UXB strike to the Site is approximately 300m north-west. An unexploded AA shell is recorded 40m south-west of the Site.

5.5 Likelihood of Subsequent UXB Detection

A range of circumstances determine whether a UXB strike location would have been identified, during and after the war. This is discussed in the following table. This includes level of access to the Site during WWII, bomb damage, as well as the ground cover during WWII. This is discussed in the following tables.

Historic Access
A UXB falling on a site which was frequently accessed would have had a better chance of being found. ARP Wardens actively searched for UXBs in heavily bombed residential areas. The importance of a site or nearby buildings and infrastructure was also a factor. Many industrial facilities had fire watchers tasked with extinguishing incendiary bombs and reporting UXBs.
As all air raids in the immediate vicinity occurred during the hours of darkness, there is a greater probability that any UXB strike to the Site could have occurred unobserved as residents / employees were inside. Furthermore, no evidence of fire watchers providing night-time observation in the vicinity was found. These factors decrease the likelihood that any UXB fall would have been witnessed and reported. As the Site comprised an area of undeveloped ground, it cannot be assumed that it experienced a frequent level of access throughout WWII; this is further emphasised by the ground cover identifiable in post-WWII aerial photography, which appears poorly maintained. It is therefore conceivable that any UXBs dropped on Site could have fallen unnoticed. Whilst the adjacent undamaged residential structures may have provided the Site with a degree of access / monitor, this cannot be guaranteed, nor can the precise level of access / monitor throughout wartime. Furthermore, areas in the north-east and south-east of the Site were occupied by Silk Stream. This section of the Site is highly unlikely to have been frequently accessed, and any access it did experience was likely limited to the surface of the water. The submarine sections of the Site were likely not accessed at all during WWII.

Bomb Damage
As the bombing campaign continued, damaged areas became vulnerable to unreported UXBs. Bomb site wreckage or soil disturbance at a bomb crater could obscure evidence of a subsequent UXB strike.
No obvious signs of bomb damage, such as cratering in the open ground, are visible on Site in post-WWII aerial photography. The same can be said for neighbouring structures to the west and approximately 30m east of the Site, where no signs of significant bomb damage are visible, such as structural clearance, ruined structures or roofing repairs. However, it should be noted that the open ground on Site appears poorly maintained in consulted aerial photography, potentially masking evidence of bomb damage.

Ground Cover Type
A UXB which falls on open field could easily go unnoticed, whereas a UXB dropped on a hard-surfaced car park would have been easily observed.
As mentioned briefly above, the Site comprised undeveloped land during WWII which appears to have been largely overgrown / unmaintained. A small UXB entry hole could easily have been obscured within such ground cover. Over time, changing environmental conditions could have caused such a hole to infill, erasing any evidence of a UXB. Note, the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 20cm, creating a small easily obscured entry hole. Furthermore, a small waterway is present in the north-east and south-east of the Site. A UXB falling in this location would have likely disappeared beneath the waterline immediately and left no evidence of its incidence. Therefore, evidence of a UXB in these sections of the Site is highly unlikely to have been observed and reported at the time of occurrence.

6 WWII GERMAN BOMBS

6.1 Bombs Dropped on the UK

Nazi Germany used different types of ordnance against the UK for different effects. Some types were designed to cause fires, others for their destructive blast effect and other for their penetration capability. Each type of ordnance was fitted with at least one fuze. For some bombs multiple fuzes were used. Many different types of fuzes were available for use – each with its own set of associated hazards.

Data sheets on those bombs most likely to be encountered today are included at **APPENDIX 2**.

- **HE bombs – moderate NEQ (net explosive quantity):** the most common types of HE bombs dropped were the SC (general purpose - GP) and SD (semi-armour piercing - SAP) series of bombs. The NEQ is between 30-50%. SAP bombs are engineered to attack light fortifications, whereas GP bombs are used in a mixed destructive blast and anti-personnel fragmentation role. 70% of bombs dropped on the UK were the 50kg type.
- **HE bombs – high NEQ:** blast bombs and parachute mines have bodies made of thin steel, allowing for larger HE charges. These were designed to detonate above ground, maximising the blast effect. Parachute mines were weapons slowed by parachutes and designed to detonate without penetrating the ground. Although, in some marshland areas, partially buried parachute mines have been observed. Consequently, it is highly unlikely that any unexploded blast bombs remain buried in the UK today.
- **HE bombs – low NEQ:** The PC series were armour piercing bombs used against heavy fortifications and reinforced bunkers. They were not commonly used over the UK.
- **Small incendiary bombs:** The 1kg and 2kg incendiaries were the most dropped bomb. Up to 620 x 1kg incendiaries could be packed into the largest container unit, which opened at a pre-determined height scattering its payload over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. Variants of the 1kg and 2kg incendiary bombs contained a small HE charge designed for an anti-personnel role, and to increase its incendiary effect.
- **Large incendiary bombs - Thick skinned:** The C50 has a thick body and contained a mixture of incendiary liquids and white phosphorus. Another version of the C50 had a white phosphorus fill. The C50 'firepot' contained thermite incendiary containers (aka firepots) and a small HE charge.
- **Large incendiary bombs - Thin skinned:** The Flam 250 and Flam 500 models had thin steel bodies designed to break up on impact, spreading their oil-incendiary mixture, which was ignited by a small HE charge. Consequently, it is highly unlikely that any unexploded Flam bombs remain buried in the UK today. Their unreliability meant withdrawal from frontline use by January 1941.

- **Submunitions:** The SD2 'butterfly' bomb was a 2kg submunition dropped on several British cities and towns. It contained a 225gram HE charge. SD2s had no ground penetration ability so the vast majority were recovered at the time. However, SD2s are still found across Britain today.
- **V1 flying bombs and V2 rockets:** In the final year of WWII Germany began using pilotless weapons against England. Both V Weapons had 1,000kg HE warheads. Due to their light-body construction, they had no penetration ability, and any impact left a noticeable debris field. As such, there is negligible risk from unexploded V Weapons today.

6.2 Bomb Failures

Records from September 1940 to July 1941 show that an average of 84 UXBs were dropped on civilian targets each day. Around 8% of these were time delay bombs – designed to strike the ground and start a predetermined countdown which could last days.

There is a generally accepted 10% failure rate for WWII German HE bombs. This is estimated from records gathered by bomb disposal units. These statistics do not account for UXBs that went by unnoticed.

Failures can happen for different reasons, including:

- Equipment or human error in arming the bombs before release,
- Failure of a mechanism within the fuze (out of tolerance),
- Jettisoning payloads if the bomber was under attack or crashing, or
- Partially functioned bombs (e.g. cracks in the cast TNT).

6.3 Bomb Ground Penetration

6.3.1 Introduction

Using data gathered during WWII by the Ministry of Home Security, estimations can be made about how deep a bomb is likely to penetrate the ground. Over one thousand incidents were reported by the bomb disposal units to support this research. Further tests were carried out, dropping bombs of different sizes into chalk and measuring the depths they reached. This research is held at the National Archives. The estimates are:

Bomb weight (kg)	Ground Type (m)									
	Sand		Gravel		Chalk		Clay		Sandstone	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1	2.7	6.0
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8	4.6	10.4
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8	5.8	13.1
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9	7.3	16.5

Different layers of geology affect penetration depths. For example, 1m of made ground, then 1m of gravel before reaching clay – as is many areas of London – is not easily calculated from the data above.

When calculating how deep a bomb could have reached, we must make three assumptions:

- **Impact velocity:** German bombing raids were carried out at altitudes in excess of 5,000m. The velocity of impact is roughly $313ms^{-1}$ (not accounting for resistance). It is the same velocity regardless of mass.
- **Impact angle:** strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.

- **Bomb design:** Some larger German bombs were occasionally fitted with 'kopfrings' - a metal ring, triangular in cross section, fitted around the nose of the bomb to help prevent penetration. It must be assumed that no 'kopfrings' were fitted.

6.3.2 The J-Curve Effect

During WWII, Bomb Disposal Units (BDUs) reported that most buried UXBs were found horizontal or upturned. This observation confirmed the 'J-curve effect'. As an HE bomb penetrates the ground, slightly offset from the vertical, its passage underground creates a 'J' shape.

This is relevant because the J-curve effect results in a horizontal offset between the buried UXB and its point of entry. This distance is estimated to be one third of the theoretical penetration depth. A low altitude attack, meaning a low impact angle, could produce an even greater offset, of up to 15m.

6.3.3 Site Specific Geology

BGS Mapping	**Superficial Deposits:** Alluvium (Clay, Sand, Silt, Gravel)	**Bedrock Deposits:** London Clay Formation (Clay, Sand, Silt)
SI Data	No recent SI data was provided by the Client. However, local British Geological Survey (BGS) borehole logs were available. The closest BGS SI through the same mapped geology as the Site is located approximately 600m north-west of the Site. This SI (May 1989) encountered the following ground conditions: - 0.15m of topsoil - 2.45m of firm brown finely fissured clay - 6.40m of firm brown fissured silty clay - 6.00m of stiff dark greyish brown clay	

6.3.4 Site Specific Maximum Bomb Penetration Depth

During WWII, the Luftwaffe dropped many different types of HE bomb. The SC (general purpose) series was by far the most numerous and of this series, the SC 500 model (weighing 500kg) was the largest of the most commonly deployed and therefore this will be used as the benchmark weapon for the Site-specific bomb penetration depth calculations.

In order to calculate the most likely maximum depth to which a bomb would penetrate, Brimstone has taken the average of the average and maximum figures for the predominant Site-specific geology (clay) in the table above. This gives a likely maximum bomb penetration depth of 14.25m below WWII ground level for a 500kg bomb.

Note, the Ministry of Home Security data indicates that the maximum bomb penetration depth could be down to 19.8m for a 500kg bomb, or 24.9m for a 1,000kg bomb; however, in line with the ALARP principle, it is not considered to be a likely scenario that a bomb would penetrate so deeply. Furthermore, while evidence indicates that a 1800kg HE bomb could penetrate to over 30m, these types of bombs were not dropped frequently. For example, War Office statistics confirm that between October 1940 and May 1941 the majority of HE UXBs (>90%) were either 50kg or 250kg, with the 500kg bombs making up most of the remaining 10%.

7 UXO RISK - BRITISH/ALLIED ACTIVITY

7.1 Introduction

The table below lists potential sources of UXO (excluding enemy action). Those which are potentially relevant to the Site are discussed in the subsequent section(s).

Potential UXO Source	Potentially Significant
Army or RAF training areas / ranges	×
Military bases and other installations	×
Munitions and explosives factories	×
Military storage depots	×
Defensive fortifications	×
Wartime site requisitions	×
WWII defensive mining (landmines)	×
WWII Home Guard activity	×
Wartime anti-aircraft fire	✓

7.2 Potential Sources of UXO

7.2.1 Introduction

Research has not located any evidence of significant British or Allied army, RAF or Royal Navy activity specifically on Site and none is likely to have occurred historically. The only likely potential source of British UXO contamination is therefore WWII AA artillery fire.

7.2.2 WWII Anti-Aircraft Fire

Anti-Aircraft (AA) Command was a British Army command established in 1939 to defend the UK during the anticipated German bombing campaign. It controlled the Territorial Army AA artillery and searchlight units. From 1940 to 1945 BDUs dealt with 7,000 unexploded AA shells in Britain. There were three main types of AA battery used for home defence (see below). Data sheets on these AA defences are included at **APPENDIX 3**.

- **Heavy Anti-Aircraft (HAA):** large-calibre guns (3.7” and 4.5”) for engaging high-altitude bomber formations. Hundreds of permanent batteries were constructed in and around major cities and military bases during the 1930s. Some 2,000 of these guns were available during the Blitz. Each gun could fire between 10 and 20 rounds per minute and consequently HAA batteries could expend large quantities of shells during each engagement.

  British time fuses were poorly manufactured during WWII, and this led to high failure rate for HAA shells, up to 30%. Unexploded HAA shells had the potential to land up to 27km from their battery, although more typically landed within a 15km radius.

- **Light Anti-Aircraft (LAA):** smaller calibre guns for engaging dive bombers and low altitude intruders. As such, they were mostly used to defend specific industrial and military targets which were subject to precision bomber attack. LAA guns were either .303” calibre machine guns or 20mm and 40mm calibre cannon. The latter were fitted with simply impact fuses and small incendiary or HE bursting charges.

  The 40mm Bofors gun could fire 120 x HE shells / minute to a ceiling of 1,800m. Each shell was designed to self-destruct if it didn’t strike an aircraft, however, inevitably some failed and fell back to earth.

- **Z (Rocket) Batteries**: a Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotated Projectile (UP) rockets to a maximum altitude of 5,800m; a ground range of some 9,000m. They were deployed in cities all around the UK from 1941 and proved to be an effective addition to the existing AA guns.

  The rockets measured 0.9m (2") and 1.8m (3") in length with four stabilising fins at the base and were fitted with 3.5kg or 8.2kg HE warheads. The larger warhead had an effective airborne blast radius of up to 20m. Some variants deployed a form of aerial mine described as a "small yellow bomb" which was designed to detach from the rocket at height and descend on a parachute with the objective of becoming snagged on target aircraft and then detonating.

Unlike bombs which were designed to strike the ground, AA projectiles and rockets were designed to function in the air. Due to their shape, and centre of gravity they would often not strike the ground nose first. This coupled with the lower mass of AA UXO resulted in shallower ground penetration depths, compared to UXBs. Although, in very soft conditions, unexploded AA projectiles have been found deeper than 1.5m bgl.

Numerous (>30) permanent HAA batteries were active within range of the Site during WWII. LAA guns likely defended vulnerable points within the borough. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. Consequently, there is an elevated likelihood of unexploded AA shells striking the Site and penetrating to a shallow depth.

8 UXO RISK MITIGATING CIRCUMSTANCES

8.1 Introduction

Works on a UXO contaminated site could result in the partial or complete removal of UXO risk. Construction or earthworks may have uncovered any UXO contamination, which would then have been reported and removed by the authorities. A site may have been subject to an explosive ordnance clearance (EOC) task conducted by the armed forces. EOC tasks involve surveying, subsequent target investigation and removal of UXO. Although the effectiveness of historic EOC tasks will have often been unsatisfactory.

8.2 Explosive Ordnance Clearance Tasks

The division of EOC tasks has been complex throughout British military history. It used to be the case that anything under the water level would be dealt with by navy units, and anything on land would be dealt with by army units. In recent years, RAF Explosive Ordnance Disposal (EOD) capability has been discontinued, and now only the Royal Navy and the British Army have EOD units. In the army, the Royal Logistics Corps and Royal Engineer EOD units have been amalgamated to form 29 EOD & Search Group. Often taskings are assigned to either the naval or army elements based on where in the country the threat is and the nature of the threat.

Brimstone has access to a database of historic EOC tasks. This database is only complete up until the early 2000s and therefore does not include recent EOC tasks. No such database for the RAF and Royal Navy EOD units is easily accessible. A search of this database has not resulted in any Army EOC tasks in the vicinity of the Site.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. No recent incidents within close proximity to the Site were identified.

8.3 Ground Works

It is unlikely that any of the post-WWII ground works occurring on Site required shallow (1-2m bgl) or deep (>2m bgl) excavations. Contemporary aerial photography appears to indicate that post-WWII works are limited to the laying of hardstanding and landscaping. These activities would likely have disturbed soil at very shallow (<1m bgl) depths only.

8.4 Deductions

The risk associated with any deep or shallow buried German UXBs / AA shells will likely not be mitigated at all across the Site. The risk associated with any very shallow buried AA shells will have been partially mitigated with laying of hardstanding on previously undeveloped ground and landscaping of the open ground.

Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

9 CONCLUSION

9.1 Accuracy of Historical Records

Occasionally, the accuracy of some historical records can prove to be poor when compared with other sources of information. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the study area. Three record sets recording German bombing were consulted for the production of this report, all of which record a different number of bomb strikes within the wider Site area. This highlights the difficulty of accurate record keeping during periods of frequent and intense bombing, raising the possibility that additional bomb strikes occurred unrecorded in the local area.

9.2 The Risk of UXO Contamination on Site

9.2.1 Key Findings – German UXO Risk

- London was the most frequently and heavily bombed British city during WWII, with most damage being sustained by the central and eastern boroughs. Whilst the Site was situated on the north-western periphery of the city, approximately 10km away from the primary Luftwaffe target area in the region (the City of London), the wider area would have been vulnerable to overspill or inaccurate bombing. Consequently, the wider Site area experienced a moderate bombing density, as indicated by official wartime figures.
- London bomb census mapping records 16 HE bomb strikes within a 500m radius of the Site; the closest of these was plotted 90m south-west. In addition, a local bomb plot map for the Borough of Hendon records 17 HE bombs, two UXBs, eleven incendiary bomb 'concentrations', one oil bomb, two AA shells and seven unexploded AA shells within a 400m radius of the Site. The closest of these was an unexploded AA shell 40m south-west of the Site, whilst the closest HE bomb strike is recorded approximately 80m east.
- Written incident reports for Hendon were also analysed, recording 27 incidents within a 500m radius of the Site. These account for 13 HE bombs, at least 74 incendiary bombs, one V1 strike, one AA shell, and five unexploded AA shells. The closest of these was an incendiary bomb strike approximately 25m west of the Site. These incidents are plotted on a map at **FIGURE 6**. The fact that all three record sets record different bomb strikes on Site highlights the difficulty in wartime record keeping, and this raises the possibility that additional bomb strikes occurred unrecorded.
- The fact that all three record sets record different bomb strikes on Site highlights the difficulty in wartime record keeping, and this raises the possibility that additional bomb strikes occurred unrecorded.

- Despite the recorded bomb strikes, a Middlesex County Council war damage map records no damage to the structures directly west and 30m east of the Site, with the closest recorded damage approximately 180m east of the Site. Moreover, no immediately obvious signs of bomb damage, such as cratering in the open ground, can be seen on Site in WWII-era aerial photography. It should be noted, however, that any UXB strike to the areas of the Site occupied by water is unlikely to have left incontrovertible evidence of its existence.
- Indeed, the ground conditions throughout the Site were likely unconducive to the visual detection of UXBs, with any evidence of a UXB strike potentially being obscured by vegetation and filling in over time, leaving little evidence of its occurrence. This ground cover also suggests that the Site would not have been accessed regularly, further increasing the likelihood of a UXB strike on Site going unnoticed and unreported. Whilst the undamaged residences to the west likely provided a degree of access and observation, the extent to which this occurred cannot be confidently confirmed.
- In summary, evidence has been found to suggest that the Site area was subject to relatively significant bombing during WWII. In conjunction with wartime conditions on Site unconducive to the visual detection of UXBs, it cannot be ruled out that a UXB landed on Site unnoticed and unrecorded, remaining undisturbed beneath the limited post-conflict ground works. As such, a **Moderate Risk** of encountering a German UXB on Site has been assessed.

9.2.2 Key Findings - British UXO Risk

- No evidence of historic military activity within the Site boundary has been found and it is unlikely that any has occurred historically. Consequently, the risk from associated UXO is **Low**.
- Numerous (>30) permanent heavy anti-aircraft (HAA) batteries were active within range of the Site during WWII. Luftwaffe activity was frequent and intense over the wider area and therefore these guns would have expended a vast quantity of ammunition. The risk of encountering unexploded HAA shells is considered to be homogenous with that of German UXBs and as such, has been assessed as **Moderate.**

9.3 Site-Specific UXO Hazards

Different types of UXO pose differing types of hazard, depending on their structural design, Net Explosive Quantity (NEQ), fill type and likely contamination depth. The table below lists the main types of UXO most often encountered on urban UK sites and their relative hazard levels.

UXO Type	NEQ (NEQ Range)	Likely Burial Depth	Hazard Posed
WWII German General Purpose HE Bombs	25kg - 220kg (most commonly deployed bomb weights)	Deep burial (>2m)	**HIGH**
WWII British Heavy Anti-Aircraft Shells (HAA Shells)	1.1kg - 1.7kg	Shallow burial (1-2m)	**MODERATE-HIGH**
WWII British Land Service Ammunition (LSA)	<2kg	Shallow burial (1-2m)	
WWII German 2kg Incendiary / HE Bombs (IBs)	680g incendiary hazard + ~500g explosive hazard	Shallow burial (1-2m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (1-2m)	**MODERATE**
WWII British Light Anti-Aircraft Shells (LAA Shells)	4g - 70g	Very shallow burial (<1m)	**LOW-MODERATE**
Small Arms Ammunition (SAA)	<1g	Very shallow burial (<1m)	**LOW**
Inert/Practice Item	0g	Very shallow burial (<1m)	

9.4 The Likelihood of UXO Encounter

9.4.1 Introduction

This report assesses the risk of UXO in relation to the proposed works, not simply the risk that UXO remains buried on Site. The likelihood of UXO encounter during intrusive ground works will vary depending on the type of UXO and the type of construction methods employed during the project. With increased soil disturbance i.e. more excavations, the likelihood of encountering UXO increases.

Within an area of elevated UXO contamination likelihood, the sub-surface volume of potential UXO contamination will comprise the natural soil / geology in between WWII ground level and the maximum bomb penetration depth. Therefore, any intrusions into this layer will be at risk of UXO encounter.

Any post-WWII fill material deposited on a site is unlikely to be contaminated with UXO and therefore the risk of encountering UXO on such a site could vary with depth.

In the wake of the initial nine-month Blitz, many cities and towns were left with vast quantities of bomb site rubble that required removal and relocation. This material was put to use for in a variety of ways, for example >750,000 tons of London's rubble was used to build runways for new RAF and USAAF airfields and much of Liverpool's rubble was used to create and maintain sea / flood defences throughout Merseyside.

It is quite possible that unexploded British AA projectiles and German 1kg incendiaries were overlooked during removal, resulting in UXO contaminated fill material ending up on otherwise low UXO risk sites, possibly many miles from any high bombing density areas.

9.4.2 German UXBs

Although most German UXBs came to rest several metres below WWII ground level, these weapons can be found at any level between just below WWII ground level and the maximum bomb penetration depth. There are a number of reasons why these heavy bombs might be found at surprisingly shallow depths.

- **Tip and run:** When enemy aircraft had to take evasive action to escape RAF fighter intercepts or AA defences, they often dropped their bomb loads from a reduced height, potentially resulting in extreme J-curve effect.
- **Deflection:** the shape of German bomb nose sections meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hardstanding.
- **Aircraft Crash Site:** if an aircraft was unable to dump its bomb load before impacting the ground, due to mechanical fault, any externally fitted bombs could have become buried on impact.

German 1kg / 2kg incendiaries were cylindrical and approximately 50mm in diameter. They had tail sections, and so landed nose first. Within soft ground this could result in full penetration of the bomb below the surface. Such UXBs are usually found close to the surface.

9.4.3 British / Allied UXO

The nature of British/Allied military activity involving LSA and SAA and the smaller size of these munitions (in relation to German HE bombs) indicates that any resulting UXO contamination on a site will be limited to shallow depths, usually within 1.5m of the surface, notwithstanding added material to raise the ground level.

Domestic military LSA and SAA contamination will either be the result of expending blinds (dud ammunition) which bury into the ground on impact or munitions purposefully buried, for a number of reasons. Either way, these types of UXO are all found at shallow depth.

9.4.4 Deductions

An elevated likelihood of UXO contamination (German) and likelihood of that UXO remaining up to the present day has been identified across the entire Site. Therefore, all the proposed works are considered to be exposed to a UXO encounter.

10 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating the Site, remaining within the Site up to the present day and being encountered during the proposed works, inform the overall risk rating. Please refer to the UXO hazard table presented in ***Section 9.3*** for a breakdown of the most common hazards and their associated risk. The colour of each respective type of hazard indicates the associated risk, as defined within the aforementioned table. The UXO risk to the proposed works has been assessed as **Moderate.**

Risk Table					
Risk Zone	**UXO Type (Hazard)**	**Likelihood of UXO Contamination**	**Likelihood of UXO Remaining**	**Likelihood of UXO Encounter**	**Overall Risk Rating**
Moderate	**WWII German GP HE Bombs**	Moderate	Moderate-High	Moderate	**MODERATE**
	HAA Shells	Moderate	Moderate	Moderate-High	
	LSA	Low	n/a		**LOW**
	German 2kg IBs	Low	n/a		
	German 1kg IBs	Low	n/a		
	LAA Shells	Low	n/a		
	SAA	Low	n/a		

11 RISK MITIGATION RECOMMENDATIONS

Brimstone has identified an elevated UXO risk to the proposed works. The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on Site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Prior to all intrusive works commencing.
EOD Engineer - On Site Supervision: Watching brief for open excavations below WWII ground level. Portable magnetometer instruments for clearing ground ahead of borehole positions and shallow excavations (where / when appropriate). Positive identification of suspicious (non UXO) objects. Liaison during confirmed UXO incidents. Provision of additional UXO Safety Awareness Briefings.	Watching brief of all open excavations and magnetometer survey of borehole locations.
Intrusive Magnetometer Probe Survey: A range of intrusive magnetometer methodologies can be deployed to survey the ground (down to the maximum bomb penetration depth) prior to deep intrusive works; pile foundations. The appropriate technique is governed by a number of factors, the most important being the site-specific ground conditions.	Of all/any pile positions.

FIGURES: 1 - 8

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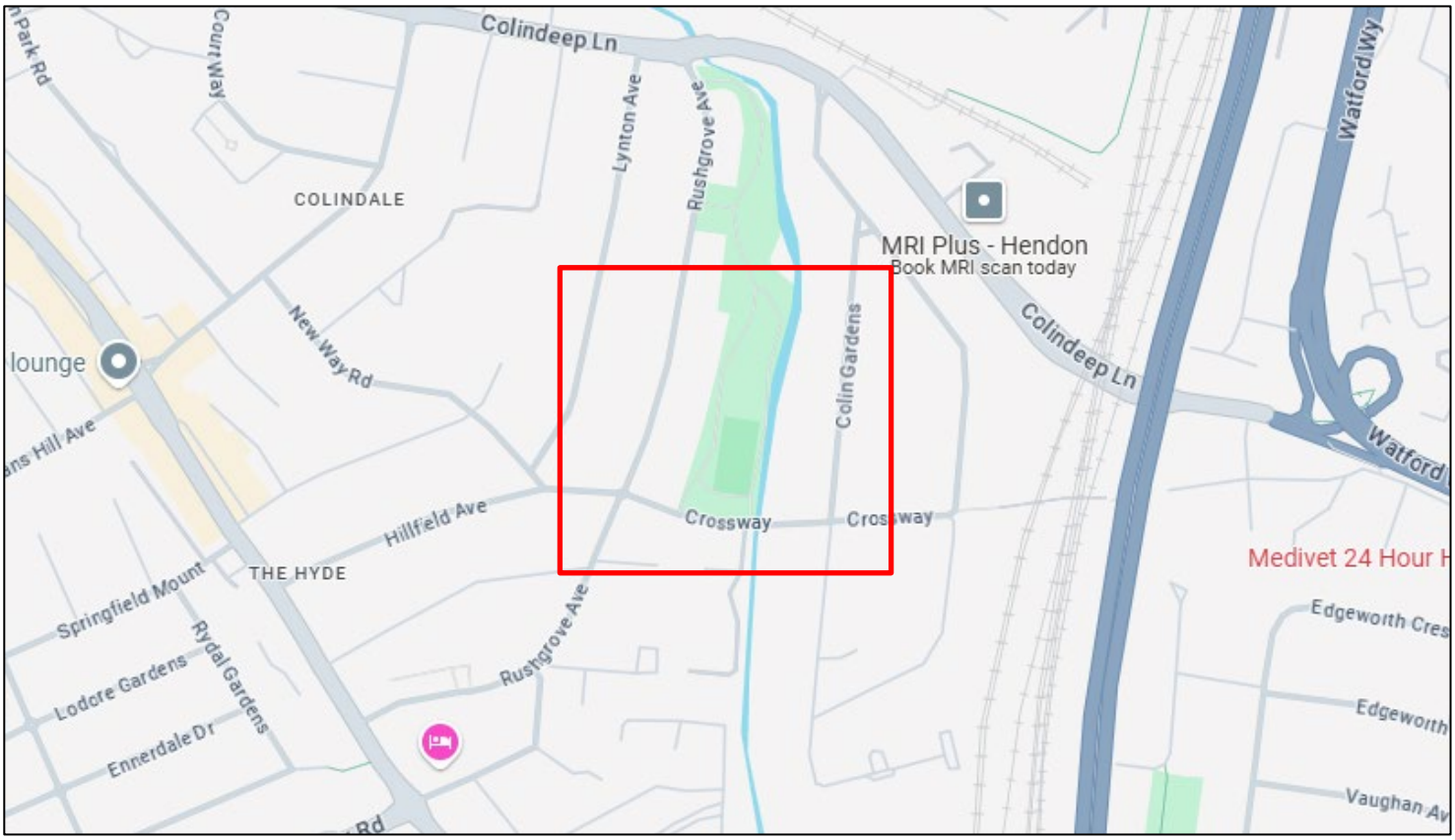
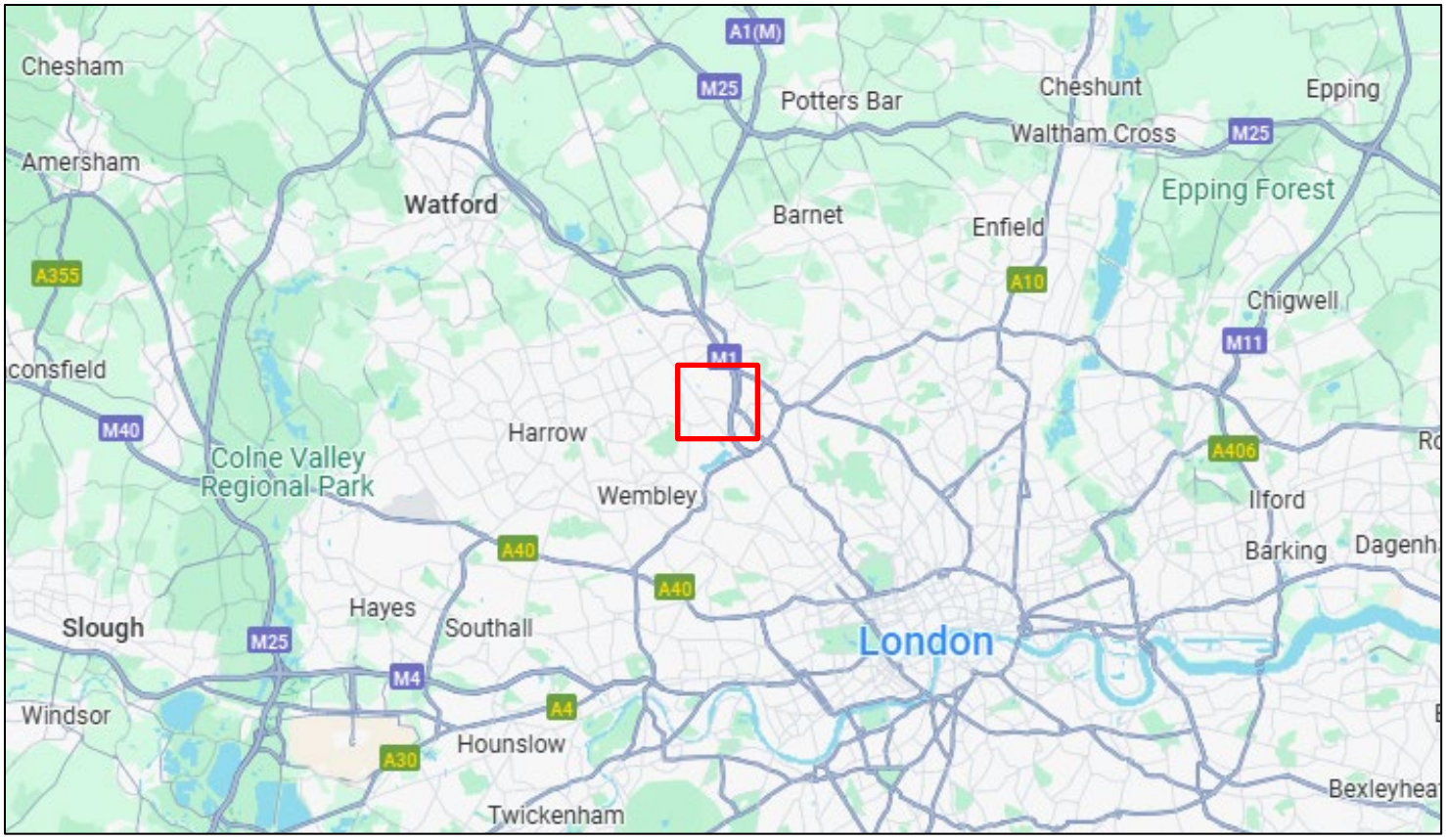
Title:	Site Location Maps	FIGURE: 1





Project:	
Client:	
Report Ref:	**DRA-25-1850**
General Site Location:	Info Source: Google (open-source)

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Title: Recent Aerial Photograph

FIGURE: 2

Project:

Client:

Report Ref: **DRA-25-1850**

Approx. Site Boundary:

Info Source: Google (open-source)

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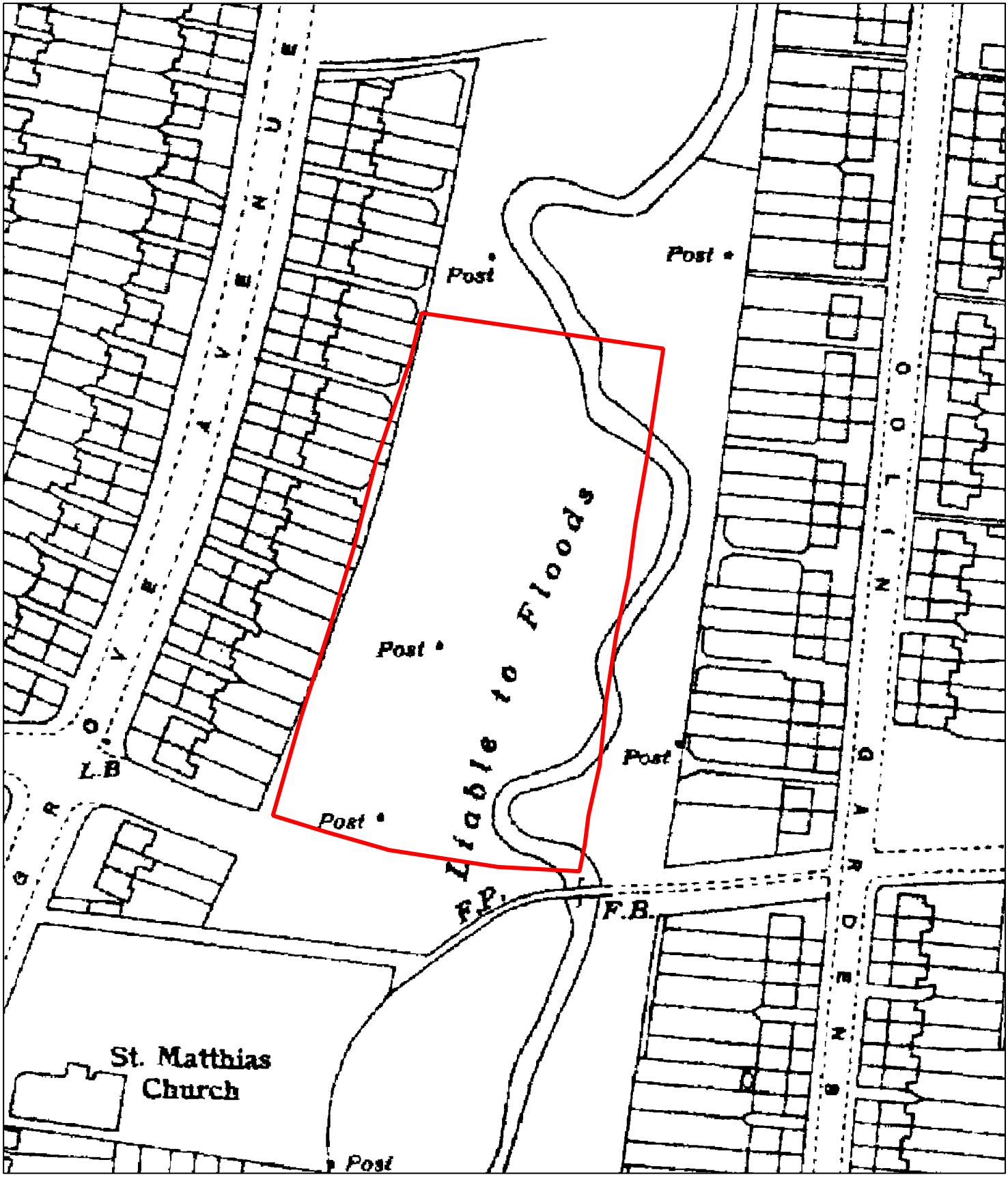
Title: Historical OS Mapping - 1935

FIGURE: 3.1



Project:

Client:

Report Ref: DRA-25-1850

Approx. Site Boundary:

Info Source: Landmark Maps

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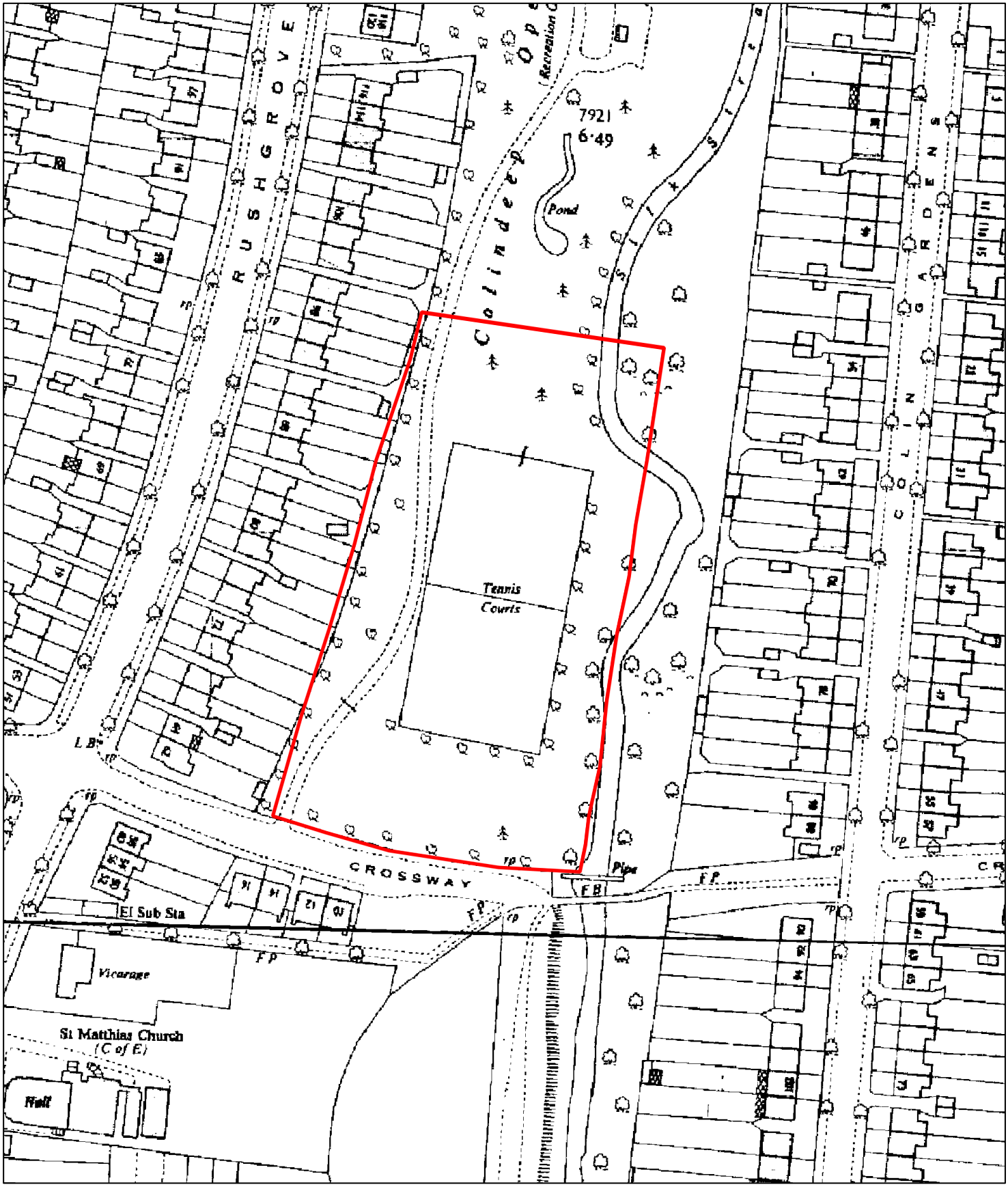
Title: Historical OS Mapping – 1956-57

FIGURE: 3.2



Project:	
Client:	
Report Ref:	**DRA-25-1850**
Approx. Site Boundary:	Info Source: Landmark Maps

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Title:	Historical Aerial Photography – 20th April 1946	FIGURE: 4

Project:	
Client:	
Report Ref:	DRA-25-1850
Approx. Site Boundary:	Info Source: Historic England

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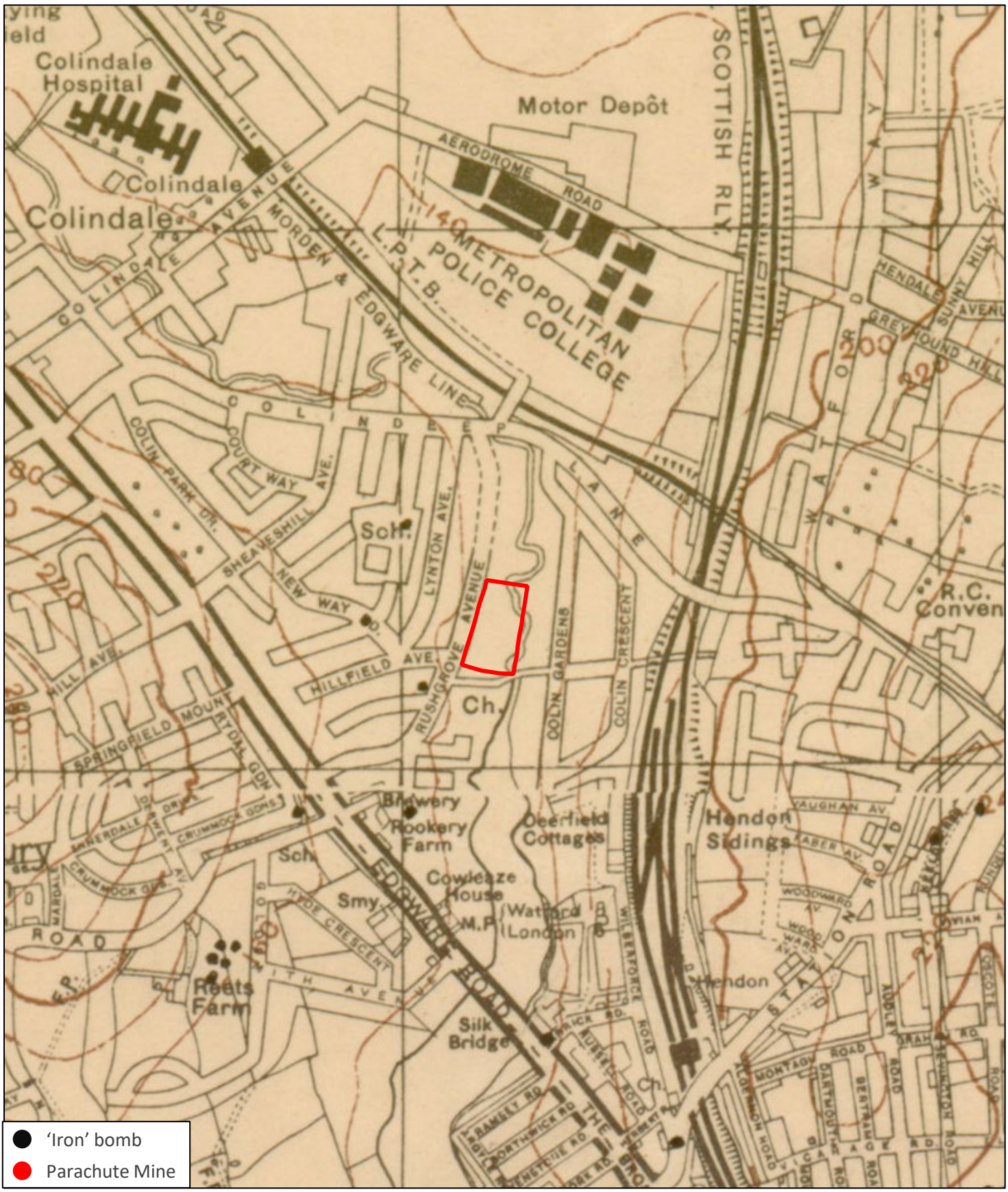
Title: Consolidated Bomb Census Mapping – Night Bombing Up to 07/10/1940

FIGURE: 5.1



Project:

Client:

Report Ref: **DRA-25-1850**

Approx. Site Boundary:

Info Source: The National Archives

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N

Title: Consolidated Bomb Census Mapping – Night Bombing 07/10/1940 to 06/06/1941

FIGURE: 5.2

Project:

Client:

Report Ref: **DRA-25-1850**

Approx. Site Boundary:

Info Source: The National Archives

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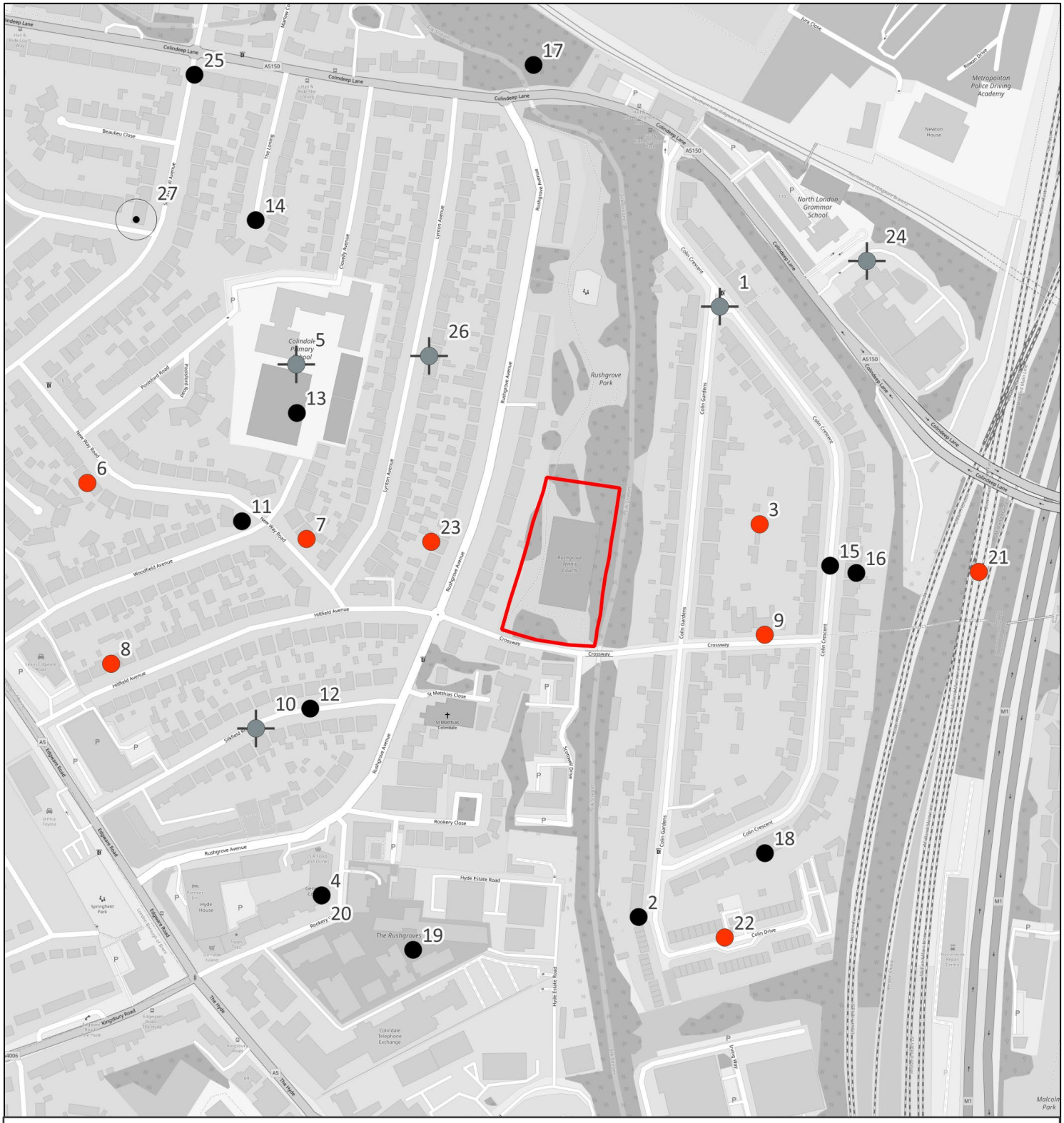
Title: Bomb Plot Overlay

FIGURE: 6



(Unexploded)

Incendiary

High Explosive

AA Shell

V1 Rocket

Note: Numbers correspond to ID of bombing incident at **Section 5.3.4**

Project:

Client:

Report Ref: **DRA-25-1850**

Approx. Site Boundary:

Info Source: The National Archives

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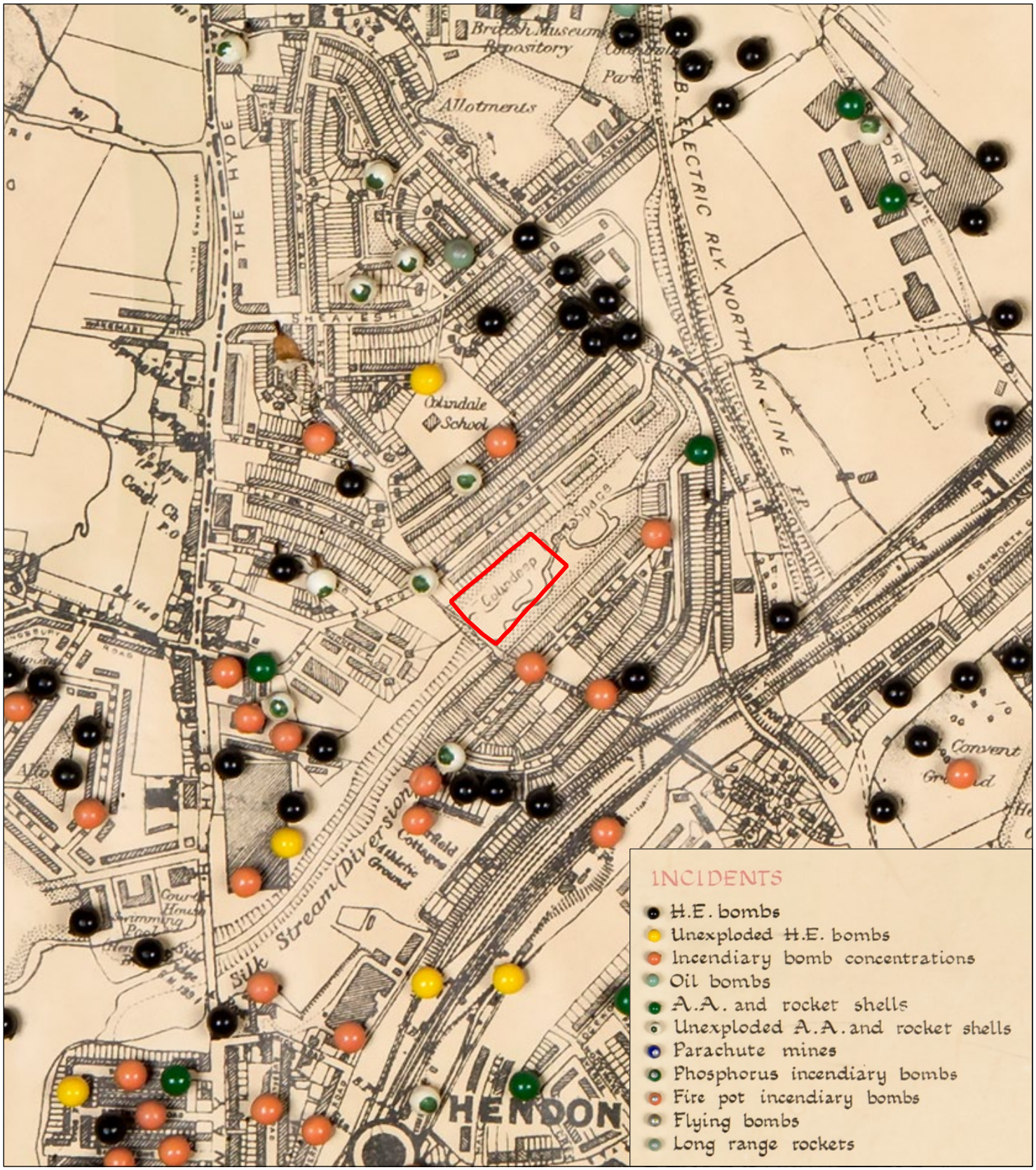
Title:	Hendon Bomb Map	FIGURE: 7



Project:	
Client:	
Report Ref:	DRA-25-1850
Approx. Site Boundary:	Info Source: London Metropolitan Archive

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Title: MCC Bomb Damage Mapping

FIGURE: 8

Key:

- Category 1: Total damage
- Category 2: Some repairs possible, could become Category 1
- Category 3: Borderline areas, uncertain whether repairs possible, demolition may be necessary

Project:	
Client:	
Report Ref:	**DRA-25-1850**
Approx. Site Boundary:	Info Source: London Metropolitan Archives

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APPENDICES: 1 - 5

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Recent German UXB Finds in the UK + Historical Analysis

The Ministry of Defence (MOD) says that bomb disposal teams around the UK deal with approximately 60 German WWII-era UXBs per year.

- ***20th February 2024*** – An SC500 (standard 500kg HE bomb) was found during shallow excavations in a residential garden in Keyham, Plymouth. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest at approximately 1 to 2m bgl.*
- ***10th February 2023 –*** An SC250 (standard 250kg HE bomb) was dredged out of the River Yare in Great Yarmouth. The UXB detonated unexpectedly in situ during an attempt to disarm it. *Historical Analysis: The UXB landed in the River Yare; the precise location of its initial impact is unknown. UXBs in water are often affected by migration, whereby the item can travel along the riverbed.*
- ***26th February 2021 –*** An SC1000 (standard 1,000kg HE bomb) was discovered during shallow excavations in Exeter, adjacent to the University of Exeter. The item was detonated in situ and caused structural damage to nearby properties, leaving some inhabitable. *Historical Analysis: The UXB landed in undeveloped land of no obvious significance. It came to rest at approximately 2 to 3m bgl with its nose facing upwards, highlighting the potential of J-curve occurring.*
- ***23rd May 2019*** - An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Kingston upon Thames, London. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest approximately 3 to 4m bgl.*
- ***11th February 2018*** – An SC500 (standard 500kg bomb) was discovered in George V Dock in London during planned work at London City Airport. *Historical Analysis*: *George V Dock was identified as a primary target by the Luftwaffe during WWII and was bombed on multiple occasions.*
- ***15th May 2017 -*** An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Aston, Birmingham. *Historical Analysis: The UXB landed in a small back garden belonging to a terraced house, part of a row. It J-Curved under a neighbouring garden and came to rest at just 1.4m bgl. NB: These houses had not sustained bomb damage.*
- ***2nd March 2017 -*** A 250kg HE bomb was found during deep excavations at a building site in Brondesbury Park, London. *Historical Analysis: UXB landed in a large residential back garden. A single storey building was built on top of the UXB post-WWII.*

Recent Allied UXB finds in Europe

- ***27th June 2024*** – A 250kg HE UXB of Allied origin was discovered in a wooded area in Gruenheide (Germany).
- ***26th April 2024*** – A 500kg American HE UXB was discovered during construction work in Mainz (Germany), nearby the MEWA Arena stadium.
- ***3rd April 2024 –*** A 500kg UXB of Allied origin was discovered during construction work on a shipping channel in Deutz, Cologne (Germany). The device was defused in situ.
- ***28th March 2024*** – A 500lb American HE UXB was discovered during construction work in Aachen (Germany). The device was defused in situ.
- ***11th August 2023 –*** A 250kg HE UXB of Allied origin was discovered in Lublin (Poland). The device was discovered in an area where an aircraft factory had been located prior to WWII.
- ***8th August 2023*** – An unexploded "one-tonne shell" (1000kg HE UXB) of anticipated Allied origin was discovered near Dusseldorf city zoo (Germany).
- ***5th July 2023*** – A UXB of unspecified origin and calibre (alleged to have been Russian but no confirmation) was discovered on a construction site in Hohenschönhausen, Berlin (Germany). The device was defused in situ.
- ***17th March 2022*** – A farmer ploughing a field discovered a British INC30 (incendiary) bomb, which contained phosphorous, in Viersen (Germany). The plough became embedded in the device, which did not explode.

NB: Domestic UXO finds in the UK are too numerous to list. Between 2006 and 2009, over 15,000 items of British / Allied UXO (excluding small arms ammunition) were found on UK construction sites (CIRIA).

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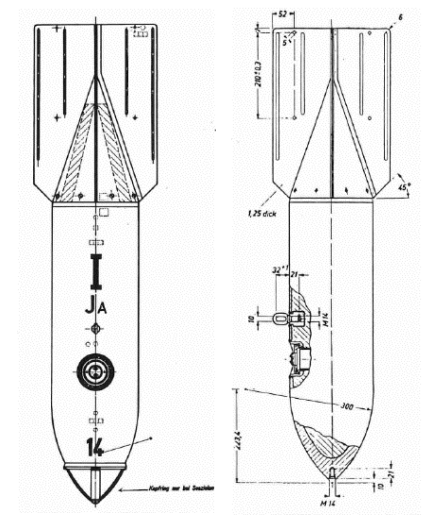
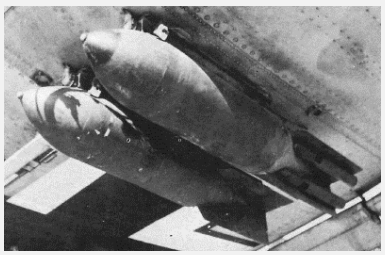
SC 50

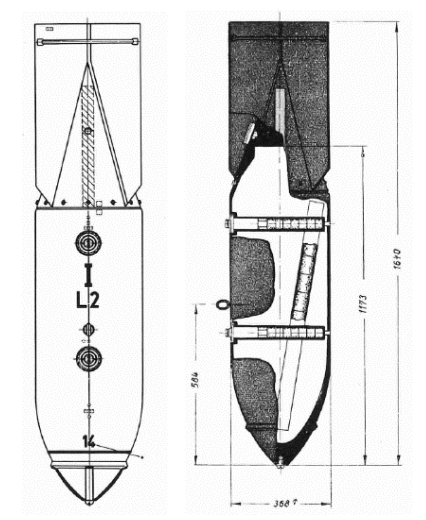
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Additional fittings: Kopfring nose for limited penetration and Stabbo nose for dive-bombing.





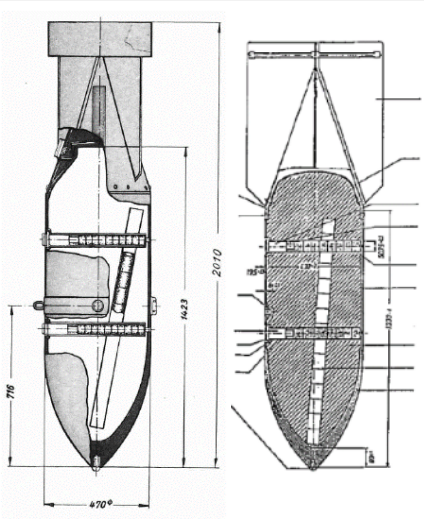
SC 250

Bomb Weight:	245-256kg (540-564lb)
Explosive Weight:	125-130kg (276-287lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	1 or 2 electrical impact fuse(s) or mechanical delayed action fuse(s)
Body Dimensions:	1,173mm length x 368mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Kopfring nose for limited penetration. Stabbo nose for dive-bombing.



SC 500

Bomb Weight:	480-520kg (1,058-1,146lb)
Explosive Weight:	220kg (485lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	2 electrical impact fuses or mechanical delayed action fuses
Body Dimensions:	1,423mm length x 470mm diameter
Appearance:	Bomb body and tail painted grey/green or buff with a yellow stripe on the tail unit. Steel construction.
Variants:	3 x variants. Kopfring nose for limited penetration.



Project:

Client:

Report Ref: **DRA-25-1850**

Info Source: *W, Ramsey.1988 / various news sources*

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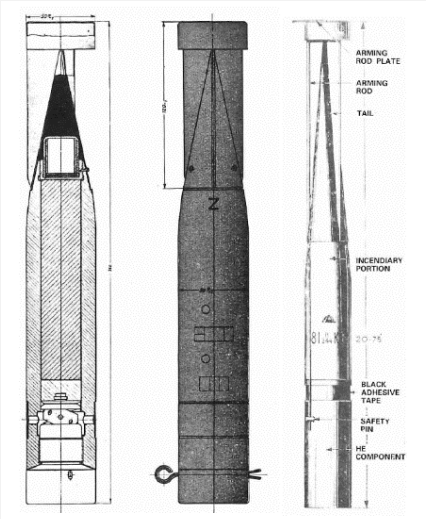
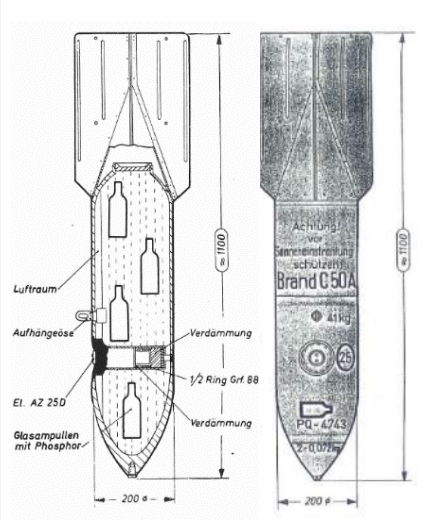
B-1E Sub-Munition

Bomb Weight:	1-1.3kg (2.2-2.87lb)
Incendiary Weight:	680g (1.4lb)
Filling:	Thermite
Fuse Type:	Simple impact fuse
Body Dimensions:	247mm length x 50mm diameter
Appearance:	Grey body and dark green painted tail unit. Magnesium alloy case.
Operation:	Small percussion charge ignites Thermite (>1,000°C burn).
Variants:	Most common variant: B 2EZ (2kg) included a small HE charge
Remarks:	Drop containers varied in size. The smallest cluster bomb held 36 x B-1Es and the largest 620 x B-1Es.



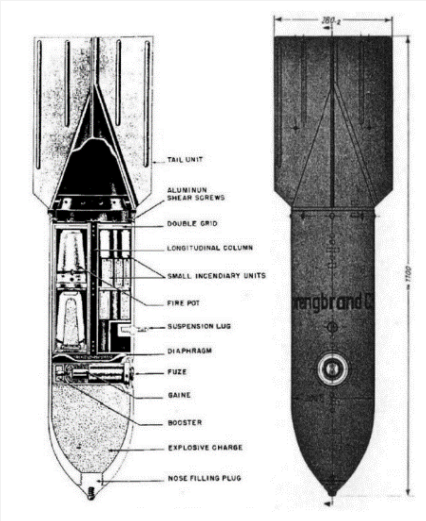
Brand C50

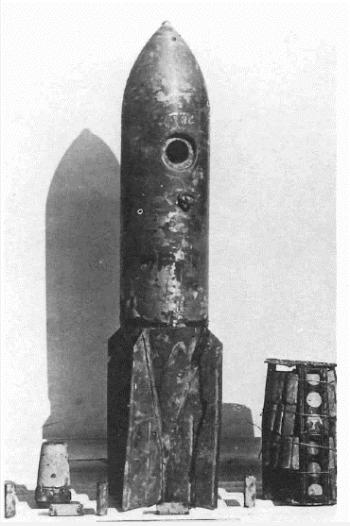
Bomb Weight:	41kg (90.4lb)
Incendiary Weight:	13kg (30lb)
Filling:	Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type:	1 x electrical impact fuse
Bomb Dimensions:	762mm length x 203mm diameter
Appearance:	bomb body and tail painted grey or green with the rear of the bomb painted red and a red band around the centre of the body.
Variants:	C 50 B: 77% White Phos fill C 250 A: 87.7% Petroleum, 11.7% Polystyrene, 0.5% White Phos (185kg version)



Spreng-Brand C50 - *Fire Pot*

Bomb Weight:	34kg (75lb)
Explosive Weight:	9kg (20lb)
Filling:	TNT burster charge, 6 x Thermite containers (fire pots) and 67 x small triangular incendiary elements.
Fuse Type:	1 x electrical impact fuses or aerial burst fuse
Bomb Dimensions:	711mm length x 203mm diameter
Appearance:	Bomb body and tail painted grey/green or pale blue with red base plug and red or green incendiary markings. Steel construction.
Operation:	A charge blows off the base plate, firing a plume of incendiary mixture 100 yds. Approx 1 second later the HE charge detonates.





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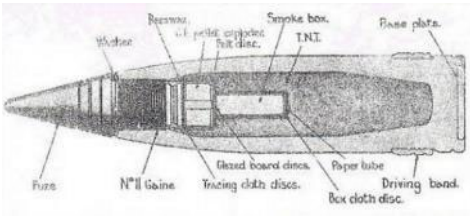
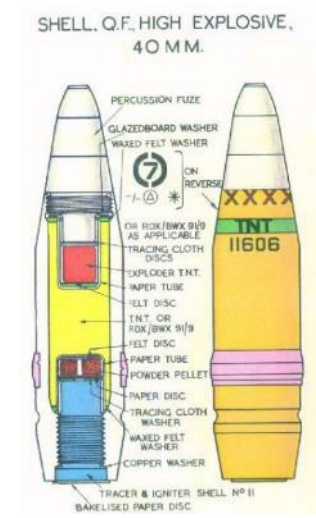
HAA Battery - 3.7” QF Shell

Shell Weight:	12.7kg
Shell Dimensions:	94mm x 438mm
Fill Weight:	1.1kg
Fill Type:	TNT
Fuse Type:	Mechanical Time Delay fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	10 - 20 rpm
Ceiling:	9,000 - 18,000m
Variants:	HE or shrapnel shells. Note, the 4.5” gun was also used in an HAA role throughout the UK.



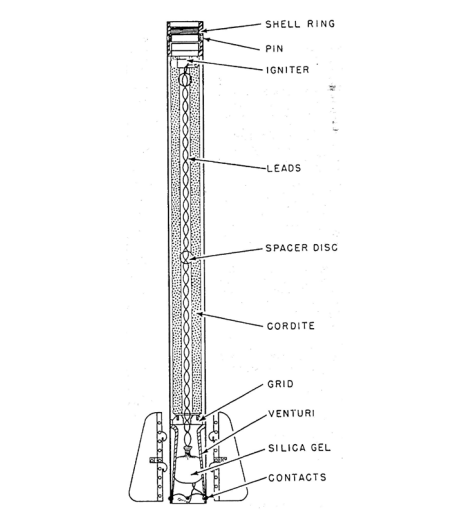
LAA Battery - 40mm Bofors Shell

Shell Weight:	0.84kg
Shell Dimensions:	40mm x 180mm
Fill Weight:	70g
Fill Type:	TNT
Fuse Type:	Impact fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	120 rpm
Ceiling:	7,000m
Variants:	HE or AP shells. Both with rear tracer compartment



Z Battery - 3” U.P Rocket

Rocket Weight:	24.5kg
Warhead Weight:	1.94kg
Filling:	TNT warhead. Black Powder solid fuel rocket motor.
Fuse Type:	Mechanical Time Delay fuse
Rocket Dimensions:	1,930mm x 76mm
Ceiling:	6,770m
Operation:	Fired from single, tandem and (later) 36 x rail launchers (Z Batteries). Limited use throughout the UK.



Project:

Client:

Report Ref: **DRA-25-1850**

Info Source: *W, Ramsey.1988 / various news sources*

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AA	*Anti-Aircraft (defences)*
AFS	*Auxiliary Fire Service*
AP	*Anti-Personnel*
ARP	*Air Raid Precautions*
ASW	*Anti-Submarine Warfare*
BDU	*Bomb Disposal Unit (historic term for EOD)*
Bgl	*Below Ground Level*
EOC	*Explosive Ordnance Clearance*
EOD	*Explosive Ordnance Disposal*
FP	*Fire Pot (German bomb)*
GI	*Ground Investigation*
HAA	*Heavy Anti-Air (gun battery)*
Ha	*Hectare (10,000m2)*
HE	*High Explosive*
IB	*Incendiary Bomb*
Kg	*Kilogram*
LAA	*Light Anti Air (gun battery)*
LCC	*London County Council*
LRRB	*Long Range Rocket Bomb (V2)*
LSA	*Land Service Ammunition*
Luftwaffe	*German Air Force*
OB	*Oil Bomb (German bomb)*
PM	*Parachute Mine (German bomb)*
RAF	*Royal Air Force*
RFC	*Royal Flying Corps*
RN	*Royal Navy (British)*
RNAS	*Royal Naval Air Service*
ROF	*Royal Ordnance Factory*
SAA	*Small Arms Ammunition*
SD2	*2kg AP bomb (German bomb)*
SI	*Site Investigation*
U/C	*Unclassified (German) bomb*
UP	*Unrotating Projectile (British 3" AA rocket)*
USAAF	*United States Army Air Force*
UX	*Unexploded*
UXB	*Unexploded Bomb*
UXO	*Unexploded Ordnance*
V1	*German Flying (pilotless) bomb - "Doodlebug"*
V2	*German LRRB - "Big Ben"*
WAAF	*Women's Auxiliary Air Force*
WWI	*World War One*
WWII	*World War Two*

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