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UXO RISK ASSESSMENT - 39 DEANS GATE, MANCHESTER

An initial risk assessment found that the site is in an area designated as 'Moderate Risk' from Unexploded Ordnance (UXO) and in close proximity to a 'High Risk' area and to the recorded location of a bomb strike.

On this basis, a *Detailed Risk Assessment Report* (appended) was undertaken for the site in view of the proposed works; erection of a 17 storey building comprising office use (Use Class E(g)(i)) and flexible ground floor commercial units (Use Classes E(a),(b),(c) and sui generis 'drinking establishment'), new electricity sub-station, basement cycle parking and rooftop plant enclosure, together with access, servicing and associated works following demolition of the existing building. The detailed risk assessment finds that that UXO poses a **Moderate Risk** to the proposed works.

This is due to an elevated likelihood of German UXO remaining present in undisturbed virgin WWII-era soils. On this basis, intrusive site investigation and foundation piling activities are at risk due to the high force and the blind nature. Consequently, the following activities are recommended:

1. Prior to any intrusive works, an appropriately experienced person must give a *UXO Safety Awareness Briefing* (toolbox talk) to all personnel conducting intrusive works.
2. For intrusive site investigation, an appropriately qualified *EOD Engineer* (banksman) is required to provide a watching brief on all exploratory holes (trial pits, boreholes etc.). The EOD engineer is able to give the above recommended briefings, will identify UXO objects in open excavations and will clear exploratory hole locations using a portable magnetometer.
3. Prior to foundation piling, an *Intrusive Magnetometer Probe Survey* is recommended to clear all pile locations. This can be done using open-hole drilling techniques and an EOD engineer to use a portable magnetometer within each hole to clear to the maximum bomb penetration depth. One open hole per planned piled foundation location is usually required.

**the intrusive magnetometer probe survey method is dependent upon the ground conditions;
consequently, this will be finalised following site investigation.*



If any additional information is needed, do not hesitate to ask.

Yours sincerely,

Molly Brown
Geo-Environmental Engineer

Encl.
Detailed UXO Risk Assessment Report

STAGE 2 DETAILED UXO RISK ASSESSMENT

Report Reference: DRA-19-1118



INTEGRITY • PROFESSIONALISM • KNOWLEDGE

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39 Deansgate, Manchester

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EXECUTIVE SUMMARY

RESULT: Brimstone Site Investigation concludes that UXO poses a **MODERATE RISK** to the proposed works.

THE SITE: The Site (centred on the National Grid Ref: SJ 83764 98515) is located in central Manchester, approximately 500m south-west of Manchester Victoria Railway Station. It is bound to the west by Deansgate (road), to the north by St Mary's Gate (road), and to the south and east by neighbouring buildings. The Site (covering approximately 0.12ha) is occupied by Speakers House. The existing building has a net area of 3,754m² (40,408sq. ft) with accommodation arranged over ground, mezzanine, and eight upper floors. The ground floor, circa 1,116m² (12,013sq. ft) is occupied by a variety retail tenants whilst the upper floors are currently used as offices, with an area in excess of 2,638m² (28,395sq. ft). The building does not include a basement level.

THE PROPOSED WORKS: Erection of a 17 storey building comprising office use (Use Class E(g)(i)) and flexible ground floor commercial units (Use Classes E(a),(b),(c) and sui generis 'drinking establishment'), new electricity sub-station, basement cycle parking and rooftop plant enclosure, together with access, servicing and associated works following demolition of the existing building.

UXO RISK ASSESSMENT:

German UXO:

- Greater Manchester was the 11th most heavily bombed British conurbation during WWII. Like today, The Site occupied a city central location during the Blitz with confirmed Luftwaffe bombing targets in the vicinity. Consequently, it experienced a high bombing density, the result of four major raids (defined as >100 tonnes of HE bombs dropped) and some medium scale attacks.
- A bomb plot and damage map covering all air raids on the city was analysed, as were individual incident reports covering the two heaviest attacks. These confirm that the study area was affected by three major air raids resulting in at least two HE parachute mines, five HE bombs, and numerous IBs within a 400m radius of The Site. NB: this map does not record Salford Borough (which occupied part of the 400m radius to the west of The Site) and therefore multiple additional bombs likely occurred within the vicinity. Furthermore, inconsistencies highlighted on the bomb plot map suggest that multiple bomb strikes are missing.
- The high density of bombing makes it impossible to identify individual bombload alignments in relation to The Site, however it can be said that an aircraft likely flew over The Site whilst dropping their bombloads.
- Records of exploded and unexploded HE bombs dropped during the Manchester Blitz give a failure rate of 16.6%; a significantly higher figure than the widely accepted 10% average for Britain as a whole.
- At the commencement of the Blitz, The Site was entirely occupied by multi-storey commercial buildings. A comparison of the historical records confirms that all these buildings sustained damage beyond repair, the result of a large fire caused by IBs during the first few hours of the first major raid on the city.
- The Site would have been immediately abandoned until the ruins could be cleared, likely post-war. As the following raids occurred during the hours of darkness, there is a higher likelihood that any subsequent UXB fall on Site occurred unobserved. NB: during the first two major raids, the performance of voluntary fire watchers has been shown to be inadequate.

- For the majority of the Luftwaffe bombing campaign, The Site would have been in a state of ruin with photographic evidence indicating that a basement level on Site probably suffered collapse. Any subsequent HE UXB strike would not have created any obvious evidence of its incidence. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small entry hole, easily obscured within bomb site wreckage.

British UXO:

- 31 HAA gun batteries were within range of The Site during WWII. The frequency and intensity of Luftwaffe air raids over the wider area suggests these batteries would have expended a vast quantity of AA ammunition. For the same reasons as above, any unexploded unobserved AA shell strike to the ruins would have likely gone unreported. However, such a strike is unlikely to have penetrated undisturbed earth below.
- No evidence of, or likelihood of, historic British / Allied military activity on or use of The Site has been found. Consequently, the risk from associated UXO is considered to be low.

Likelihood of UXO Encounter:

- Any small items of UXO (AA shells and 1kg / 2kg IBs) hidden within the WWII-era rubble on Site will likely have been removed when the ruins were cleared and all material removed from The Site immediately post-war.
- During the 1960s, the pile foundations will have partly mitigated the risk from German HE UXBs remaining on Site. However, it is quite possible that a deep buried HE UXB could still remain in-situ, occupying undisturbed earth in between individual piles.
- An elevated likelihood of German UXO remaining up to the present day has been identified across the entire Site. The likelihood of a UXB encounter has been partly reduced as a result of post-war ground works. However, all intrusions within undisturbed virgin WWII-era soil will be exposed to a potential HE UXB encounter. NB: piling is the engineering activity most at risk of initiating a German UXB at depth, due to the forces involved and the 'blind' nature of the intrusion.

RECOMMENDED RISK MITIGATION MEASURE: Brimstone has identified an elevated UXO risk on Site. The measures detailed below are recommended to mitigate the UXO risk on Site to ALARP level.

Risk Mitigation Measure	Recommended For?
UXO Safety Awareness Briefings	Prior to all intrusive works within both Risk Zones
EOD Engineer - On Site Supervision	Open excavations within areas of MODERATE RISK
Intrusive Magnetometer Probe Survey	All pile positions within areas of MODERATE RISK

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1 INTRODUCTION

1.1 BACKGROUND

Kames Property Income Fund, referred to hereon in as *The Client*, has commissioned Brimstone Site Investigation, referred to hereon in as *BSI*, to carry out a Stage 2 Detailed Unexploded Ordnance (UXO) Risk Assessment of the proposed intrusive ground works at the 39 Deansgate, Manchester site, referred to hereon in as *The Site*.

1.2 LEGISLATION

1.2.1 Introduction

There is no legal requirement for assessing the risk posed by UXO at UK construction sites, nor is there any specific legislation covering the management and mitigation of UXO risk. However, there are two main pieces of UK legislation that require responsible parties carrying out ground works to undertake comprehensive and robust assessments of potential risks and hazards to their employees.

1.2.2 Construction (Design & Management) Regulations 2015

Construction Design & Management (CDM) Regulations outlines the responsibilities of all involved parties, primarily the Client, the CDM Co-ordinator, the Designer and the Principal Contractor. CDM2015 states that a party has the 'legal responsibility for the way that a construction project is managed and they are accountable for the health and safety of those working on or affected by the project'. All parties are obliged to:

- Provide an appropriate assessment of potential UXO risks at the site or ensure such 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 presented by the project.
- Ensure the preparation of a suitably robust emergency response plan.

1.2.3 The Health and Safety at Work Act 1974

Section 3 of this legislation covers the general public and other contractors on a site. It states that 'it is the duty of every employer to conduct his/her undertaking in such a way as to ensure,

so far as is reasonably practicable, that persons not in his/her employment who may be affected are not thereby exposed to risks to their health or safety’.

‘In such cases as may be prescribed, it shall be the duty of every employer and every self-employed person, in the prescribed circumstances and in the prescribed manner, to give to persons (not being his/her employees) who may be affected by the way in which he/she conducts his/her undertaking, the prescribed information about such aspects of the way in which he /she conducts his/her undertaking as might affect their health or safety’.

1.3 UXO - THE ROLE OF COMMERCIAL CONTRACTORS AND THE AUTHORITIES

1.3.1 Commercial Contractors

If an elevated UXO risk is identified during the Stage 1 and Stage 2 Risk Assessment process, risk mitigation measures will be recommended. Commercial UXO contractors can provide geophysical surveys during the pre-construction phase. Such surveys are designed to identify potential UXO targets which can then be intrusively investigated. Subsequent UXO clearance or avoidance can then be recommended as appropriate.

In addition, EOD Engineers can be deployed to sites before and / or during the construction phase to provide UXO awareness briefings to staff, a watching brief for excavations and reactive response to any suspicious finds.

Having a qualified EOD Engineer on site will avoid unnecessary (potentially costly) call-outs to the authorities when a suspicious item is encountered, as the engineer will be able to identify whether or not the item is UXO and whether or not it is inert or live. If a high risk UXO item is identified the engineer will co-ordinate with the authorities, limiting disruption on site and putting in place safety measures, with immediate effect.

1.3.2 UK Authorities

If a suspected item of UXO is discovered at a UK site where no commercial UXO contractor is in attendance or quickly available, the local Police force will evacuate the site and establish a precautionary safety cordon, which could require the evacuation of neighbouring properties. They will then contact the MOD’s Joint Services Explosive Ordnance Disposal (JSEOD) office.

Based on the Police assessment, JSEOD will prioritise the incident based on criteria such as the likely type and size of the item and the site's location / population density in the vicinity. The availability of JSEOD's resources will also be a factor. If an incident is not given high priority, an EOD Engineer may not be made available for up to two days after the find was originally reported. During this period, a Police cordon would likely remain in place.

On assessing the item, the EOD Engineer may need to widen the Police cordon and order an evacuation of a larger area. NB: for German high explosive (HE) UXB finds in urban areas this usually results in the evacuation of thousands of people and the closure of local roads.

At low profile (usually rural) sites where UXO finds are frequent, for example on former military land, JSEOD's limited resources will usually require it to recommend involvement of a commercial UXO contractor to manage the ongoing UXO risk. Most UXO found at such sites is small enough to be covered by the commercial UXO contractor's clearance license, allowing for most, if not all, UXO to be disposed of quickly and safely as and when it is encountered.

1.4 UXO RISK IN THE UK

Fortunately, inadvertent initiations of UXO are rare, however, the legacy of UXO can cause significant delays to construction projects throughout the UK, with associated increases in costs. A list of recent German UXBs finds and examples of WWII UXB detonation incidents can be found at **APPENDIX 1**. In many cases these unforeseen problems can be avoided if an appropriate risk management procedure has been carried out at the initial stages of the project design process.

Thousands of items of British / Allied UXO and several German UXBs are exhumed by the construction industry and the general public each year, however, the vast majority go unreported in the media due to the potential negative impacts on companies and their projects. NB: the former tends to be smaller in size than German UXBs and therefore pose a relatively smaller threat. In the UK, the origin of buried UXO can be broadly categorised into three families;

1. **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.

2. **Allied Military Activity:** During WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre of conflict; most notably the US and Canada.
3. **UK Military Activity:** Domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as AA gun and rocket batteries during WWI and WWII.

1.5 UXO DETONATIONS

The effects of a UXO detonation occur extremely quickly and are almost always physically traumatic when personnel are involved. The effects of a detonation are heat, sound, blast and shrapnel. The detonation of a shallow buried 50kg HE bomb would damage masonry up to 16m away and unprotected personnel approximately 70m away. The accepted safety distance for a 500kg WWII HE bomb (with a ~250kg HE fill) is 1,000m.

For a UXO detonation to occur significant stimuli is required; UXO does not spontaneously exploded. WWII-era HE requires a significant quantity of energy to initiate, which is why construction works are particularly vulnerable to UXO. There are three ways in which an item of UXO could initiate:

- **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 cause 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 designed to provide accurate and authoritative information regarding matters of onshore UK risk in the UK.

2.2 SPRC RISK MODEL

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

Sources: For UK and Allied UXO sources can include; military firing ranges, military bases, military storage depots, munitions factories, wartime anti-aircraft weapons usage, etc. There are a number of ways in which enemy action during WWI and WWII could have resulted in UXO contamination. The source that has produced the most enemy UXO contamination is, by far, Luftwaffe air raids during WWII. This source alone has resulted in a variety of UXO (different types of bombs) each posing a specific hazard.

Pathways: For buried UXO, the pathway describes the activity(s) which results in the hazard (UXO) reaching personnel and / or assets. There are a number of pathways (construction methodologies) which require intrusions into the ground and each has the potential to be a UXO pathway. Common pathways are Ground Investigation (SI) works, Site Enabling Works, Various Excavations (soil stripping, levelling, shallow foundations, services, drainage, etc), pile foundations, etc.

Receptors: On construction sites the receptors are either works specific or external and vary in sensitivity. The former includes site personnel, project specific plant and equipment. The latter incorporates the general public, external structures in the vicinity and environmental receptors (atmosphere, soil, flora and fauna).

Consequence: The consequences of an inadvertent UXO detonation event have the potential to be significant, i.e when they affect human receptors (life or limb). Consequences for non-

human receptors can be wide ranging and also significant. However, in real terms the likelihood of detonating UXO is far lower than that of encountering UXO. NB: a UXO find alone can still have substantial financial consequences due to project delay.

2.3 ASSESSMENT STRUCTURE

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

- The risk that the site was contaminated with UXO; site specific history, conflict history and domestic military history.
- The type(s) of UXO that could have contaminated the site and their associated hazards.
- The risk that UXO remains on the site; post-conflict redevelopment / earthworks and military EOD activity.
- Maximum German UXB penetration depth; site specific calculation if required.
- The risk that UXO may be encountered during the proposed works; the extent of the proposed works.
- Risk Rating Assessment; Risk Mapping if required.
- Risk Mitigation Recommendations; if required.

2.4 INFORMATION SOURCES

In order to carry out an informed and accurate risk assessment *BSI* has sought information from a wide range of sources. In preparation for this assessment *BSI's* Research Team has undertaken detailed historical research, including access of original archived records. The following is a general list of information sources that are consulted during the research process:

- The National Archives, London.
- The London Metropolitan Archive.
- Local Archive Centres.
- The Ministry of Defence.
- The Council for British Archaeology.
- Groundsure Mapping Services.
- Historical Aerial Photography (Historic England, Britain From Above, Bluesky).

- Google open source mapping.
- The British Geological Society.
- Open sources; published book, articles, web resources.
- Site specific information supplied by *The Client*.
- *BSI's* library and historical database.
- *BSI's* ex-servicemen employees (including experienced EOD Engineers).

2.5 ALARP PRINCIPLE

The ALARP (as low as reasonably practicable) principle is a risk principle used in the regulation and management of construction industry risks. The term ALARP originated in UK legislation, namely the Health and Safety at Work Act 1974, which states that risks must be averted unless there is a gross disproportion between the costs and benefits of doing so.

The ALARP principle arises from the fact that infinite time, effort and money could be spent attempting to eliminate a risk entirely. It should not be understood as simply a quantitative measure of benefit against detriment. Instead, a best common practice of judgement, balancing risk and societal benefit.

The objective of a *BSI* risk assessment that identifies an elevated UXO risk is to prevent a client unnecessarily spending a grossly disproportionate sum of money reducing that project specific UXO risk. For a risk to be ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

2.6 RISK TOLERANCES

The *BSI* risk assessment process divides UXO risk into two tolerances:

Tolerable: Negligible Risk or Low Risk ratings are tolerable. However, for some sites, where the risk cannot be completely discounted at the Stage 2 risk assessment stage, it would be prudent to employ relatively low cost proactive risk mitigation measures prior to undertaking ground works. For example, a UXO Tool Box briefing to site personnel.

Intolerable: Moderate Risk or High Risk Ratings are intolerable. Therefore, pro-active risk mitigation measures should be employed prior to undertaking and / or during ground works;

magnetometer survey and EOD engineer attendance on site respectively.

2.7 RELIANCE AND LIMITATIONS

This report has been prepared using published information and information provided by *The Client* which were made available at the time of writing only. *BSI* is not liable for any information which has become subsequently available. No third party liability or duty of care is extended. Third parties using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 THE SITE

The Site (centred on the National Grid Ref: SJ 83764 98515) is located in central Manchester, approximately 500m south-west of Manchester Victoria Railway Station. It is bound to the west by Deansgate (road), to the north by St Mary's Gate (road), and to the south and east by neighbouring buildings. The Site (covering approximately 0.12ha) is occupied by Speakers House. The existing building has a net area of 3,754m² (40,408sq. ft) with accommodation arranged over ground, mezzanine, and eight upper floors. The ground floor, circa 1,116m² (12,013sq. ft) is occupied by a variety retail tenants whilst the upper floors are currently used as offices, with an area in excess of 2,638m² (28,395sq. ft). The building does not include a basement level.

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

3.2 THE PROPOSED WORKS

Erection of a 17 storey building comprising office use (Use Class E(g)(i)) and flexible ground floor commercial units (Use Classes E(a),(b),(c) and sui generis 'drinking establishment'), new electricity sub-station, basement cycle parking and rooftop plant enclosure, together with access, servicing and associated works following demolition of the existing building.

FIGURE 3: Proposed Development Plan

4 SITE HISTORY

4.1 INTRODUCTION

Site specific history can be assessed by reviewing historical OS 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 OS MAPPING

Review of OS Mapping			
Period	Map Date	Map Scale	Review
Pre-WWII	1933	1:2,500	FIGURE 4.1: <i>The Site</i> is entirely developed and occupied by several adjoining properties. Like today, <i>The Site</i> is bound to the east and south by buildings and to the west and north by roads.
Post-WWII	1949	1:1,250	FIGURE 4.2: All buildings on <i>Site</i> have been demolished, as have some structures immediately east. A building labelled Ruin bounds <i>The Site</i> to the south-east. NB: such observations are usually indicative of serious bomb damage on early post-war Manchester OS maps. Multiple additional examples of potential bomb damage (clearance and ruins) are visible in the immediate surrounding area.
	1958	1:2,500	An unlabelled line demarcates the southern third of <i>The Site</i> from the northern part. A building has been constructed immediately adjacent to the eastern <i>Site</i> boundary.
	1970	1:1,250	<i>The Site</i> appears as it does today, occupied by one building, comprising several adjoining properties, with open space in the south-east. NB: the northernmost property is labelled Air Terminus.

4.3 AERIAL PHOTOGRAPHY

Review of Aerial Photography		
Period	Photo Date	Review
Pre-WWII	1927	FIGURE 5.1: This oblique view photograph was taken approximately 13 years before WWII. <i>The Site</i> is occupied by a number of multi-storey buildings each with a different roof type and height. Some glazed roofing is visible.
Post-WWII	May 1948	FIGURE 5.2: This oblique view photograph was taken approximately three years after the end of WWII. <i>The Site</i> appears as it does on the OS mapping, completely cleared of all structures. NB: all rubble / debris has been removed from <i>Site</i> also. <i>The Site</i> appears to be level and likely occupied by bare earth / Made Ground, as opposed to vegetation. The OS mapped ruin is visible to the south-east.

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. Research confirms that at the outbreak of WWII *The Site* was occupied by the 'Exchange and Ward Buildings' which comprised shops, a bank and a restaurant with offices above.

5 UXO RISK - GERMAN BOMBING

5.1 WWII BOMBING HISTORY OF THE SITE

5.1.1 Greater Manchester

Greater Manchester was home to a number of vital wartime industries during WWII, many of which were located in Trafford Park. Infrastructure of strategic importance was also present in the form of Manchester Docks. Between 29th July 1940 and 30th July 1942, Greater Manchester experienced 41 air raids, most of which were small in scale, often executed by a solitary bomber.

At least nine raids were carried out during the autumn of 1940, with the first widespread

evening raid on the 28th August and a medium to heavy raid carried out at night on the 1st October. The Luftwaffe then mounted consecutive major attacks on the nights of the 22/23rd and 23/24th December 1940 (the 'Christmas Blitz'). These left large areas of Manchester, Salford and Stretford devastated. NB: a major attack was a Luftwaffe designation for a raid delivering >100 tonnes of HE (in addition to incendiaries) to a target area.

In total these two attacks involved 441 German bombers dropping 272 tonnes of HE on the first night and 195 tonnes of HE on the second night. Seven conflagrations and 600 smaller fires were reported, the result of tens of thousands of small incendiary bombs. The Christmas Blitz caused the total destruction of >4,000 houses as well as serious damage to a further 12,000. 805 HE bombs were reported across Manchester, Salford, Stretford and Manchester Docks, including 134 UXBs.

During 1941 two further major* raids occurred on the 9th January and 1st June. Although each involved half as many aircraft as the 22nd December 1940 raid, they still delivered a further 208 tonnes of HE bombs and numerous incendiaries onto the city. Three small / medium scale attacks were also mounted during the spring of 1941. *The June 1941 raid actually delivered 97 tonnes of HE, however is close enough to 100 tonnes to be considered within this report as major.

5.1.2 Site Specific History

In addition to the docks and Trafford Park, Manchester city centre was one of the Luftwaffe's primary aiming points for raids on the wider conurbation. Consequently, *The Site* would have been particularly vulnerable to indiscriminate carpet-bombing. Original Luftwaffe target maps of Manchester highlight several facilities within 1km of *The Site*; including Victoria Station, various industrial sites and rail infrastructure.

5.2 BOMBING DECOY SITES:

In mid-1940 the War Office began developing a number of Bombing Decoys with the intention of diverting a proportion of Luftwaffe bombs away from the real civilian and military targets. 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

Some 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. By the end of 1941, airfield decoy sites had received 359 attacks compared with 358 raids carried out against the real airfields and by June 1944 approximately 730 attacks had been recorded on all decoy site types. As *The Site* was located within an urban area during WWII no bombing decoys were installed locally.

5.3 WWII BOMBING RECORDS

5.3.1 Introduction

The Bomb Census was undertaken by the Ministry of Home Security during WWII to try to provide a greater understanding of the effects the Luftwaffe bombing campaign was having upon Britain and to provide intelligence relating to bombing raid patterns, types of munitions used and consequent damage. The Bomb Census was compiled using information recorded by ARP wardens based in every bombed location throughout the UK.

Bombing incidents were reported to ARP wardens who kept a written record for their area of responsibility in the form of individual incident reports. In larger urban areas (mainly cities) these reports were used to compile bomb census / plot maps. ARP bombing records were gathered by the Ministry of Home Security and used to calculate bombing density statistics for every administrative area in the UK.

The detail and quality of information recorded by the Bomb Census was inconsistent for the early stages of the war, however, by 1941 procedures had been standardised. The quality of Bomb Census information also varied greatly depending on where in the UK the records were produced.

5.3.2 ARP Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the County Borough of Manchester, within which *The Site* was located during WWII. It gives a breakdown of the types of large German bombs reported. These figures were sourced from the National Archives, London.

Record of German Air-Delivered Ordnance	
Administrative Area Acreage	27,255
High Explosive Bombs (all types/weights)	712
High Explosive Parachute Mines	18
Flam (Oil) Bombs	17
40kg Phosphorus Incendiary Bombs	0
40kg 'Fire Pot' Incendiary Bombs	0
V1 Flying Bomb	1
V2 Long Range Rocket	0
Total (excluding V-Weapons and 1kg IBs)	737
Bombs Per 1,000 Acres	27

This overall bombing density figure is not high, however that is because the vast majority of the county borough was located far from the central bombing target area. The Luftwaffe's aiming points were positioned at the boundaries of Manchester County Borough, Salford County Borough and Stretford Municipal Borough. Consequently, the weight of the Luftwaffe raids was divided between the bombing figures for these three areas, unlike in most other Blitzed cities.

NB: 1kg / 2kg incendiary bombs (IB) and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are usually not included. Additional information (*Cooper. G, 2018*) states that during the first major air raid alone (22nd December 1940) some 37,000 small IBs were dropped on Manchester.

5.3.3 Manchester Bomb Plot & Damage Map: 1940-1941

BSI has reviewed an original bomb plot and damage map for the wider study area, held at The

University of Manchester. This map was produced by Manchester City Council's Architect's Department (Building Surveyor's Division) during the war and was updated throughout the conflict to reflect all raids on the city. NB: no original legend / key accompanies this map, however a contemporary description does confirm most of the symbols. No symbol for UXBs was identified and any IB strike symbol with a number written within it represents the number of individual IBs falling at that location. A small section of the map covering the study area is presented at **FIGURE 6** and described below.

- No bomb strikes are plotted on / adjacent to *The Site*.
- However, all buildings on and adjacent to *The Site* are identified as totally destroyed, with a date label identifying this damage as occurring during the first major raid (22nd / 23rd December 1940).
- The study area was bombed during at least three separate air raids.
- Two HE parachute mines, five HE bombs, and numerous IBs are plotted within a 400m radius of *The Site*.
- The Salford Borough boundary (140m west of *The Site*) marks the edge of bomb plot map coverage. Therefore, as the 400m radius extends far into Salford Borough, it is considered highly likely that additional bombs fell within 400m of the western *Site* boundary.
- Multiple areas of bomb damage do not have a corresponding bomb strike plotted, indicating that this map is missing multiple bomb strikes.

5.3.4 Manchester ARP Incident Reports

BSI reviewed a log of bombing incidents from the Manchester Emergency Committee's records, held at Trafford Archive. NB: this log only covers the two-night Christmas Blitz. No such records were held for the other raids on the borough. No reference to a bombing incident specifically on *Site* was found, however relevant detail for the local area was found:

Small Luftwaffe pathfinder forces had the job of accurately marking the target with incendiaries. This would create fires that the subsequent main force would aim for. At 19:10hrs on the 22nd December 1940, the pathfinders lit up two areas, one of which was an area between the top of Deansgate and Victoria Station (140m to 480m north of *The Site*).

A ruptured gas main on St Mary's Gate, fuelled the many fires in this area. Within hours, the

Corn Exchange, Royal Exchange, Victoria Buildings (immediately north of *The Site*) were all ablaze. At around a mile long and dead straight, Deansgate's many fires provided an easily recognisable reference point for succeeding waves of bombers. At approximately 22:50hrs, HE bombs were dropped on this area. Although not specifically named, it is considered highly likely that *The Site* was set ablaze during these first few hours.

5.3.5 Abandoned Bombs Register

Evidence of suspected UXB strikes was reported to an ARP warden who in turn reported its location to the local BDU. Occasionally, a combination of factors meant that the BDU had to simply record its location on an Abandoned Bomb Register and leave it buried in situ. The reasons for abandoning a UXB could be; a relatively safe location / position, access problems or a likely extreme depth of burial. Furthermore, BDUs in the most heavily bombed areas were constantly overstretched during WWII and therefore had limited resources available.

The Archive Office of the British Army's 33rd Engineer EOD Regiment holds an Abandoned Bomb Register for Britain, a copy of which BSI has obtained. Considering the inaccuracy of WWII records the locations included in this register cannot be considered definitive, nor the list exhaustive and some of these Abandoned Bombs are known to have been since recovered or discounted. The Department of Communities & Local Government also holds an Abandoned Bomb Register for the UK. No Abandoned Bombs are noted either on or in close proximity to *The Site*.

5.4 LIKELIHOOD OF UXB CONTAMINATION

Several factors govern the likelihood of a UXB actually striking a specific site during WWII. In parts of the UK where detailed bombing records exist it is possible to accurately predict whether any UXBs could have actually contaminated the area of the proposed works. These factors are discussed in the following table:

Density of Bombing	
Number of Air Raids in the Vicinity:	At least three air raids affected the wider study area.
Intensity of these Air Raids:	All bombs dropped locally were part of large scale carpet bombing raids, carried out at night.

Bomb Strike Positions	
Distance between recorded Bomb Strikes and <i>The Site</i> :	HE bombs: 123m east of <i>The Site</i> . 1kg / 2kg IBs: likely on <i>Site</i> .
Alignment of recorded Bomb Strikes:	An aircraft likely flew over <i>The Site</i> whilst dropping its bombload on at least one occasion. The high density of bombing makes it impossible to identify individual bombloads. However, it can be said that subsequent bombers may have flown over <i>The Site</i> whilst dropping their bombloads.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of <i>The Site</i> :	Records of exploded and unexploded HE bombs dropped during the Manchester Blitz give a failure rate of 16.6% (<i>Smith. P, J, C, 2003</i>).
UXBs recorded in close proximity to <i>The Site</i> :	No evidence.

5.5 LIKELIHOOD OF SUBSEQUENT UXB DETECTION

Many factors govern the likelihood of a UXB strike being observed either during its occurrence or subsequently. These are discussed in the following table. NB: it should be noted that assessing the precise conditions that existed on a site >70 years ago can be problematic, especially in urban environments where the number of variables is great.

Historic Site Access
A UXB falling on a site which was frequently accessed would have had a greater chance of being observed during its descent or subsequently. In frequently bombed residential areas, ARP Wardens carried out post-raid searches for UXBs. The importance of a site or facility is an important consideration. Many factories, gas works, power stations, docks, etc had teams of Fire Watchers tasked with extinguishing 1kg IBs and reporting UXBs.
The entire <i>Site</i> was developed and would have seen access on a daily basis at the outbreak of war. The lack of any open ground on <i>Site</i> indicates that specific searches for delayed action bombs / UXBs would have been unnecessary. Once the buildings on <i>Site</i> sustained bomb damage, the entire <i>Site</i> would have been abandoned until the ruins could be cleared, likely during the latter war years or (more likely) immediately post-war. As all local air raids occurred during the hours of darkness, there is a higher likelihood that a subsequent UXB fall on <i>Site</i> could have occurred unobserved. No evidence of fire watchers specifically assigned to the Exchange and Ward Buildings on <i>Site</i> was found. However, it is known that following the Christmas Blitz, the city's Civil Defence authority put into place the 'Fire Watchers Order', as the previous scheme had been inadequate. Therefore, it is

possible that Fire Watchers were not active in the study area between the 22nd and 24th December 1940.

Bomb Damage

A type of WWII specific ground cover, substantial bomb damage to a site will have resulted in conditions that would make the identification of a subsequent UXB strike extremely difficult.

A HE bomb striking soft ground will have thrown up a large quantity of soil, as well as producing a crater. If this ground disturbance was not immediately repaired, any subsequent UXB strike could have been overlooked.

The buildings on *Site* sustained significant damage at the beginning of the first of the four major raids on the city. Although the condition of *The Site* by the end of the first major raid is not known, it is considered likely that it was gutted by fire, down to ground floor level.

Therefore, it can be said that for the majority of the bombing campaign, *The Site* was in a state of ruin. Any subsequent UXB strike here would not have created obvious evidence of its incidence. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small UXB entry hole, easily obscured within bomb site wreckage.

An undated historic photograph showing part of *The Site* is displayed at **FIGURE 7**. This image shows some ruins remaining approximately 20m east of *The Site* boundary, confirming that this photograph was taken at some point between 1942 and 1946. The visible part of *The Site* is occupied by some wreckage as well as rubble which appears to descend into a depression just east of *The Site*. This likely confirms the presence of a collapsed basement level. Alternatively it could be evidence of a subsequent HE bomb strike causing a crater within the ruins on *Site*.

Ground Cover Type

The type of ground cover at a site during WWII is significant as differing types will have had differing effects on the visual evidence of a UXB entry hole. Evidence of a UXB strike to manmade structures and hard-standing will have been long lasting and easily identifiable.

A UXB strike to dense vegetation or very soft ground (marshland) could have easily been overlooked. In the extreme, a UXB landing in a body of water would have been immediately obscured from view and is highly unlikely to have been accurately reported and therefore recovered.

Any HE UXB strike to the undamaged streets / pavements bounding *The Site* to the west and north would have created a clean, recognisable entry hole which would have been reported at the time and then dealt with by the local BDU. It is therefore considered unlikely that a HE UXB strike here could have come to rest within *The Site* boundary due to the J-Curve Effect.

5.6 BOMBING DURING WWI

During 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 first raid on the Capital took place on the 31st May 1915.

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.

A WWI air raids plot map of Britain and collection of written records of air raids were reviewed. These confirm that Manchester did not experience any bombing during WWI. Consequently, there is no risk associated with WWI German UXO.

5.7 WWII GERMAN MUNITIONS

5.7.1 Bombs Dropped on the UK

The Luftwaffe deployed a wide variety of ordnance against the UK during WWII. The design and specific usage of the various air-delivered munitions differs greatly. Some bombs achieved significant ground penetration and are therefore more likely to remain buried in the ground today. The design of each weapon allows an informed assessment of the hazards posed by a UXB. Data sheets on those bombs most likely to be encountered today are included at **APPENDIX 2**. Descriptions of the various families of bombs are presented below:

NB: the Italian Air Force's CAI participated in air raids against targets in Essex and Kent during the Battle of Britain in 1940. However, the CAI was a small force, dropping a fraction of the ordnance that the Luftwaffe deployed.

- **HE Bombs - Moderate charge / weight ratio:** The most common type of HE bombs dropped were the SC (general purpose) and SD (semi-armour piercing) series of bombs. The charge / weight ratios were between 30% and 50% allowing for penetration through multiple floors / basements of buildings and fragmentation of the thick steel shell to create an anti-personnel shrapnel hazard. The most common weights were 50kg, 250kg and

500kg. Although six additional models between 1,000kg and 2,500kg were also deployed, ~70% of HE bombs dropped on the UK were of the 50kg type.

- **HE Bombs - High charge / weight ratio:** Blast Bombs, Parachute Mines or Land Mines had thin steel walls allowing for larger HE charges which detonated above ground, producing a far greater blast effect than general purpose bombs. These large weapons were parachute retarded with a ~40 mph rate of descent resulting in very limited or no ground penetration, depending on the ground cover. Therefore, it is highly unlikely that any unexploded blast bombs remain buried underground in the UK today.
- **HE Bombs - Low charge / weight ratio:** The PC series of bombs (500kg and 1,000kg) were armour piercing bombs used against heavily fortified defences and deep buried, reinforced bunkers, as such they were not commonly used over the UK. Charge / weight ratios were approximately 15%.
- **Small Incendiary Bombs - sub-munitions:** The B1E (1kg) and B2E (2kg) series of sub-munitions were the most commonly dropped bomb of all types. Up to 620 x 1kg incendiaries could be packed into the largest 'AB' series cluster bomb canisters, which opened at a pre-determined height scattering the incendiaries over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. The longer 2kg model incorporated an additional HE hazard, in the form of a small anti-tampering charge with a delay fuse. Over 100,000 were dropped on London alone during the Blitz.
- **Large Incendiary Bombs - Thick skinned:** The Brand C50 A had a thick steel body similar to an SC 50 but contained a mixture of incendiary liquids and Phosphorus. The C50 B was the same size but incorporated mostly White Phosphorus as its fill. The Sprengbrand C50 Firepot bomb also had an SC 50 shell but contained both Thermite incendiary containers (Firepots) and a small HE charge.
- **Large Incendiary Bombs - Thin skinned:** The Flam 250 and Flam 500 (Oil bomb) models had thin steel bodies enabling them to break up on impact and spread their oil incendiary mixture across the ground. As such they are unlikely to remain buried today. Furthermore, their unreliability resulted in them being withdrawn from frontline use by January 1941.
- **Anti-Personnel Bombs:** The SD2 'Butterfly' bomb was a 2kg sub-munition dropped on

several British cities and towns. It contained 225grams of Amatol however, had no ground penetration ability and therefore any unexploded SD2s would have been recovered during WWII, unless they fell into water.

- **V1 Flying Bombs and V2 Long Range Rockets:** In the final year of WWII Germany began using pilotless weapons against England, launched from sites in occupied Europe. Both V Weapons had 1,000kg HE warheads however, were thin-skinned constructions and therefore any that failed to detonate would have broken up on impact, resulting in a large debris field of incontrovertible evidence. As such, there is no risk from unexploded V Weapons today. Thousands landed in south-east England causing widespread damage in London especially.

5.7.2 Bomb Failures

Original War Office statistics record a daily average of 84 large German UXBs (not including 1kg and 2kg sub-munitions) dropped on civilian targets throughout Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these were Delayed Action (time delay fuses) bombs and therefore exploded sometime later, with the remainder being unintentional UXBs.

By the end of WWII empirical evidence indicated a (generally accepted) 10% failure rate for German HE bombs dropped on the UK as whole. However, it should be noted that this estimate is based on BDU figures collected during the war and therefore will not have taken account of the unknown numbers of UXBs that went unreported, i.e the German UXBs that are found every year by the construction industry. UXBs occur for one of the following four reasons:

- Failure of the aircraft's crew to properly arm the bombs (charging the electrical condensers) due to human error or equipment defect.
- Failure of the clockwork mechanism in the fuses of Delayed Action bombs.
- Jettisoning the bomb from a very low altitude. Most likely if the bomber was under attack or crashing.
- Fuse malfunction due to a fault during the manufacturing process. This could be the result of accidental faulty installation or sabotage by POWs put to work in German factories.

5.8 WWII UXB GROUND PENETRATION

5.8.1 Introduction

During WWII the Research & Experiments Department of the Ministry of Home Security was tasked with analysing the varying penetration depths achieved by the Luftwaffe's HE bombs. The Army's Bomb Disposal Headquarters provided details of 1,304 UXB clearance tasks carried out on bombs which had penetrated undeveloped land (soil). In addition, the Research & Experiments Department carried out their own tests; 24 bombs were dropped into Chalk, under controlled conditions.

Records held at the National Archive include the results of this analysis. Once a pattern was ascertained from the 1,304 datasets, each bomb weight was amplified to produce a table of anticipated bomb penetration depths (below), including both average maximums and probable maximums.

Bomb weight (kg)	SANDSTONE		SAND		GRAVEL		CHALK		CLAY	
	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)
50	2.7	6.0	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1
250	4.6	10.3	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	5.8	13.1	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.3	16.4	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

As the 1,304 datasets involved broadly homogenous geologies, the penetration depths given above are likely to be different for situations where a bomb firstly penetrates through superficial deposits or made ground and then through bedrock, as would be the case for many locations in the UK which were bombed. Furthermore, some locations in the UK are underlain by geology not included in the table above and therefore informed calculations of bomb penetration cannot be made.

In both cases, the above WWII-era data should be coupled with knowledge of the strength of various rock types to make inferences on likely maximum bomb penetration depths. To calculate a maximum bomb penetration depth for a specific site, one must use a number of assumptions based on the most likely WWII German bombing scenario:

- **UXB Impact Velocity:** The majority of German HE bombs dropped over the UK resulted

from mass carpet bombing raids. These attacks were carried out at altitudes in excess of 5,000m which would have resulted in a 500kg HE UXB impacting the ground at an approximate velocity of 260m/s.

- **UXB Impact Angle:** Luftwaffe high altitude bombing resulted in 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 limit ground penetration. It must be assumed that no such retarder units were fitted to the bomb.

5.8.2 The ‘J-Curve’ Effect

During WWII, BDUs reported that most deep buried German HE UXBs were found to be in a horizontal or up-turned orientation. This observation confirmed the presence of the J-Curve Effect. As a HE bomb penetrates the ground, slightly offset from the vertical, its trajectory through the underlying geology curves towards the surface.

This phenomenon can be significant to a risk assessment as the J-Curve Effect results in a horizontal offset from the point of UXB entry. This is typically a distance of about one third of the bomb’s penetration depth. In the extreme, a low altitude attack resulting in a low angle UXB strike could produce even greater horizontal offset, up to 15m.

5.8.3 Site Specific Geology

WWII-era Site Geology		
British Geological Survey 1:50,000 scale Mapping:	Superficial Deposits: Glaciofluvial Sheet Deposits (Sand and Gravel)	Bedrock: Chester Pebble Beds Formation (Sandstone)
Previous SI Data:	No SI data was provided by <i>The Client</i> and no historic BGS borehole logs are available for <i>The Site</i>. The closest log (through the same mapped geology as <i>The Site</i>) is approximately 30m south-west of <i>The Site</i>. It encountered: - Made Ground generally comprising Tarmacadam, Cobblestone and Hardcore to 0.9m bgl - Clay, Silt, Sand and Gravel to 7.8m bgl - Medium grained Sandstone to 15.0m bgl (end of the borehole)	

5.8.4 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 Maximum Bomb Penetration Depth assessment.

The WWII-era ground conditions beneath *The Site* will have included a thickness of Made Ground and two different natural soil types (superficial and bedrock). Therefore, it has not been possible to accurately calculate a maximum bomb penetration depth based on wartime data. NB: the empirical 1940s evidence appears to record UXBs travelling through geology of only one type. Each lithology will have had a differing decelerating effect on a HE UXB, both individually and in combination, thereby complicating the estimation of burial depth. In addition, as the on-*Site* thickness of the Glaciofluvial Sheet deposit is not known and a basement collapse could have occurred during the Blitz, estimating *Site* specific bomb penetration depths is further hindered.

Taking into account the above-mentioned factors, it has been assessed that a 500kg HE bomb would have had a maximum bomb penetration depth of **10m** below WWII ground level and the average depth of HE UXBs would be approximately **5m** below WWII ground level.

NB: Theoretically penetration depths could be greater if the UXB was larger, however, 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%.

6 UXO RISK - BRITISH / ALLIED MILITARY ACTIVITY

6.1 SOURCES OF UXO

The table below lists all the modern and historical facilities and activities that could have potentially resulted in localised British / Allied UXO contamination in the UK. Those which are relevant to *The Site* have been discussed in the subsequent section(s).

POTENTIAL UXO SOURCE	DOES THE SOURCE HAVE THE POTENTIAL TO AFFECT THE SITE IN QUESTION?
Existing or historic Army or RAF Training Areas / Ranges	✗
Existing or historic Military Bases and Other Installations	✗
Existing or historic Munitions or Explosives Factories	✗
Existing or historic Military Storage Depots	✗
Existing or historic Military Defensive Fortifications	✗
Sites requisitioned by the military during conflict	✗
WWII Pipe Mined Locations and Beach Minefields	✗
WWII Home Guard activity	✗
WWII Light and / or Heavy Anti-Aircraft Fire	✓

6.2 ANTI-AIRCRAFT BATTERIES

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 some 7,000 UX 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**.

1. **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.

2. **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.

3. **Z (Rocket) Batteries** - A Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotating 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 nose first, AA shells and rockets were not designed to hit the ground and therefore unexploded AA munitions do not necessarily land nose first. This coupled with the lower mass of UXO resulted in shallower ground penetration depths. Although, in very soft conditions, unexploded WWII AA munitions were observed to penetrate to >1.5m bgl.

31 HAA static batteries were established within a 15km radius of *The Site*. No evidence of LAA batteries within range of *The Site* was found. The frequency and intensity of Luftwaffe air raids over Greater Manchester suggests these batteries would have expended a large quantity of AA ammunition. Any unexploded AA shell striking the ruins on *Site* could have easily gone unnoticed and unreported. NB: a Home Guard Z Battery was established in Alexandra Park

during July 1942, however no AA rockets were ever fired in anger over the city.

7 UXO RISK MITIGATING CIRCUMSTANCES

7.1 INTRODUCTION

Subsequent works on a UXO contaminated site could have resulted in the partial or complete removal of this UXO risk. Various construction works or earthworks could have uncovered UXO which would then have been reported and removed by the authorities. Alternatively, a site may have been subject to a military Explosive Ordnance Clearance (EOC) task, involving surveying, subsequent target investigation and removal.

7.2 EXPLOSIVE ORDNANCE CLEARANCE TASKS

The British Army, RAF and Royal Navy all have EOD units that are responsible for carrying out UXO clearance on their own bases and training areas. UXO found on civilian land is dealt with by whichever EOD unit is local and available.

BSI has access to a database of historic EOC tasks carried out by the British Army's Royal Engineer EOD unit; the 29th Regiment. NB: 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 an 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 evidence of recent UXO finds within the immediate vicinity was found. The closest recent UXO find occurred in October 2018 when an old tank gun shell was found on a building site, approximately 700m south-west of *The Site*. It is not clear how such an item came to be buried under a city centre site.

7.3 GROUND WORKS

Research has confirmed that Speakers House was built on *Site* in 1963. This represents the only phase of post-war redevelopment. The building will have required deep piled foundations.

The alignments of two tunnels pass immediately adjacent to *The Site*. One is only rumoured to exist, however the other was constructed post-WWII. Neither are likely to have disturbed the ground beneath *The Site*.

7.4 DEDUCTIONS

Any small items of UXO (AA shells and 1kg / 2kg IBs) hidden within the WWII-era rubble on *Site* will likely have been removed when the ruins were cleared and all material removed from *The Site* immediately post-war.

During the 1960s, the pile foundations will have partly mitigated the risk from German HE UXBs remaining on *Site*. However, it is quite possible that a deep buried HE UXB could still remain in-situ, occupying undisturbed earth in between individual piles.

8 CONCLUSION

8.1 ACCURACY OF THE HISTORICAL RECORDS

Occasionally, the accuracy of some historical records can be proven to be poor, when compared with other records. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the vicinity of a study area. A review of the records gathered for this assessment has highlighted a significant inconsistency.

The bomb plot / damage map shows several areas of damage with no corresponding bomb strike. Previous research has highlighted missing HE bombs on this map and therefore the possibility cannot be discounted that additional unplotted HE bombs fell within the vicinity of *The Site*. NB: during the chaos of each major raid, examples of human error in record keeping would have increased.

In addition, there is a nine strike discrepancy in the number of parachute mines recorded in Manchester Borough between the Ministry of Home Security records and those included within a local history publication (*Smith. P, J, C, 2003*). This further highlights the difficulties in wartime ARP record keeping.

8.2 THE RISK OF UXO CONTAMINATION ON SITE

8.2.1 Key Findings - German UXO Risk

- Greater Manchester was the 11th most heavily bombed British conurbation during WWII. Like today, *The Site* occupied a city central location during the Blitz with confirmed Luftwaffe bombing targets in the vicinity. Consequently, it experienced a high bombing density, the result of four major raids (defined as >100 tonnes of HE bombs dropped) and some medium scale attacks.
- A bomb plot and damage map covering all air raids on the city was analysed, as were individual incident reports covering the two heaviest attacks. These confirm that the study area was affected by three major air raids resulting in at least two HE parachute mines, five HE bombs, and numerous IBs within a 400m radius of *The Site*. NB: this map does not record Salford Borough (which occupied part of the 400m radius to the west of *The Site*) and therefore multiple additional bombs likely occurred within the vicinity.
- The high density of bombing makes it impossible to identify individual bombload alignments in relation to *The Site*, however it can be said that an aircraft likely flew over *The Site* whilst dropping their bombloads.
- Records of exploded and unexploded HE bombs dropped during the Manchester Blitz give a failure rate of 16.6%; a significantly higher figure than the widely accepted 10% average for Britain as a whole.
- At the commencement of the Blitz, *The Site* was entirely occupied by multi-storey commercial buildings. A comparison of the historical records confirms that all these buildings sustained damage beyond repair, the result of a large fire caused by IBs during the first few hours of the first major raid on the city.
- *The Site* would have been immediately abandoned until the ruins could be cleared, likely post-war. As the following raids occurred during the hours of darkness, there is a higher likelihood that any subsequent UXB fall on *Site* occurred unobserved. NB: during the first two major raids, the performance of voluntary fire watchers has been shown to be inadequate.
- For the majority of the Luftwaffe bombing campaign, *The Site* would have been in a state of ruin with photographic evidence indicating that a basement level on *Site* probably

suffered collapse. Any subsequent HE UXB strike would not have created any obvious evidence of its incidence. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small entry hole, easily obscured within bomb site wreckage.

8.2.2 Key Findings - British UXO Risk

- 31 HAA gun batteries were within range of *The Site* during WWII. The frequency and intensity of Luftwaffe air raids over the wider area suggests these batteries would have expended a vast quantity of AA ammunition. For the same reasons as above, any unexploded unobserved AA shell strike to the ruins would have likely gone unreported. However, such a strike is unlikely to have penetrated undisturbed earth below.
- No evidence of, or likelihood of, historic British / Allied military activity on or use of *The Site* has been found. Consequently, the risk from associated UXO is considered to be low.

8.3 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)	Likely deep burial (>3m)	HIGH RISK
WWII British Heavy Anti-Aircraft Shells	1.1kg - 1.7kg	Shallow burial (<1.5m)	MODERATE-HIGH RISK
WWII British Land Service Ammunition	<2kg	Shallow burial (<1.5m)	
WWII German 2kg Incendiary / HE Bombs	680g incendiary hazard + ~500g explosive hazard	Shallow burial (<1.5m)	
WWII German 1kg Incendiary Bombs	680g (incendiary, not explosive hazard)	Shallow burial (<1.5m)	MODERATE RISK
WWII British Light Anti-Aircraft Shells	4g - 70g	Very shallow burial (<1m)	LOW-MODERATE RISK

8.4 THE LIKELIHOOD OF UXO ENCOUNTER

8.4.1 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. Naturally, the greater the number, volume and depth of intrusions, the greater the likelihood of UXO being encountered, assuming UXO resides on site.

Within an area of elevated UXO contamination risk (delineated at ground level), 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 / 2kg 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.

8.4.2 German UXBs

Although most German HE 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 interception and / 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 HE bomb nosecones meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hard-standing, roads, etc.
- **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 tailfins, which meant they landed end first, which in soft ground resulted in full penetration of the bomb below the surface. Therefore, such items are usually found close to the surface.

8.4.3 British / Allied UXO

The nature of British / Allied military activity involving LSA / 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, unless any post contamination fill material has raised the ground level, effectively burying the UXO even deeper.

Domestic military LSA and SAA contamination will either be the result of expending dud ammunition (shells) 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.

8.4.4 Deductions

An elevated likelihood of German UXO remaining up to the present day has been identified across the entire *Site*. The likelihood of a UXB encounter has been partly reduced as a result of post-war ground works. However, all intrusions within undisturbed virgin WWII-era soil will be exposed to a potential HE UXB encounter. NB: piling is the engineering activity most at risk of initiating a German UXB at depth, due to the forces involved and the 'blind' nature of the

intrusion.

8.5 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating *The Site*, remaining on *Site* up to the present day and being encountered during the proposed works, inform the overall risk rating. There is a **Moderate Risk** to the proposed works.

RISK TABLE: MODERATE RISK				
UXO TYPE (ASSOCIATED HAZARD)	LIKELIHOOD OF UXO CONTAMINATION	LIKELIHOOD OF UXO REMAINING	LIKELIHOOD OF ENCOUNTER	OVERALL RISK RATING
WWII German General Purpose HE Bombs	MODERATE-HIGH	MODERATE	MODERATE-HIGH	MODERATE RISK
WWII British Heavy Anti-Aircraft Shells	MODERATE	LOW	LOW	LOW RISK
WWII British Land Service Ammunition	LOW	LOW	LOW	
WWII German 2kg Incendiary / HE Bombs	HIGH	LOW	LOW	
WWII German 1kg Incendiary Bombs	HIGH	LOW	LOW	
WWII British Light Anti-Aircraft Shells	LOW	LOW	LOW	

9 RISK MITIGATION RECOMMENDATIONS

BSI has identified an elevated UXO risk on *Site*. The measures detailed below are recommended to mitigate the UXO risk to ALARP level.

Risk Mitigation Measure	Recommended For?
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.	Ahead of all intrusive works.
EOD Engineer - On Site Supervision: Watching brief for open excavations within Made Ground. Portable magnetometer instruments for clearing ground ahead of shallow excavations and SI boreholes (where / when appropriate). Positive identification of suspicious (non UXO) objects. Liaison during confirmed UXO incidents. Provision of additional UXO Safety Awareness Briefings.	Open excavations within areas of: MODERATE RISK
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.	All pile positions within areas of: MODERATE RISK

FIGURES: 1 - 7



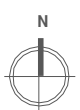
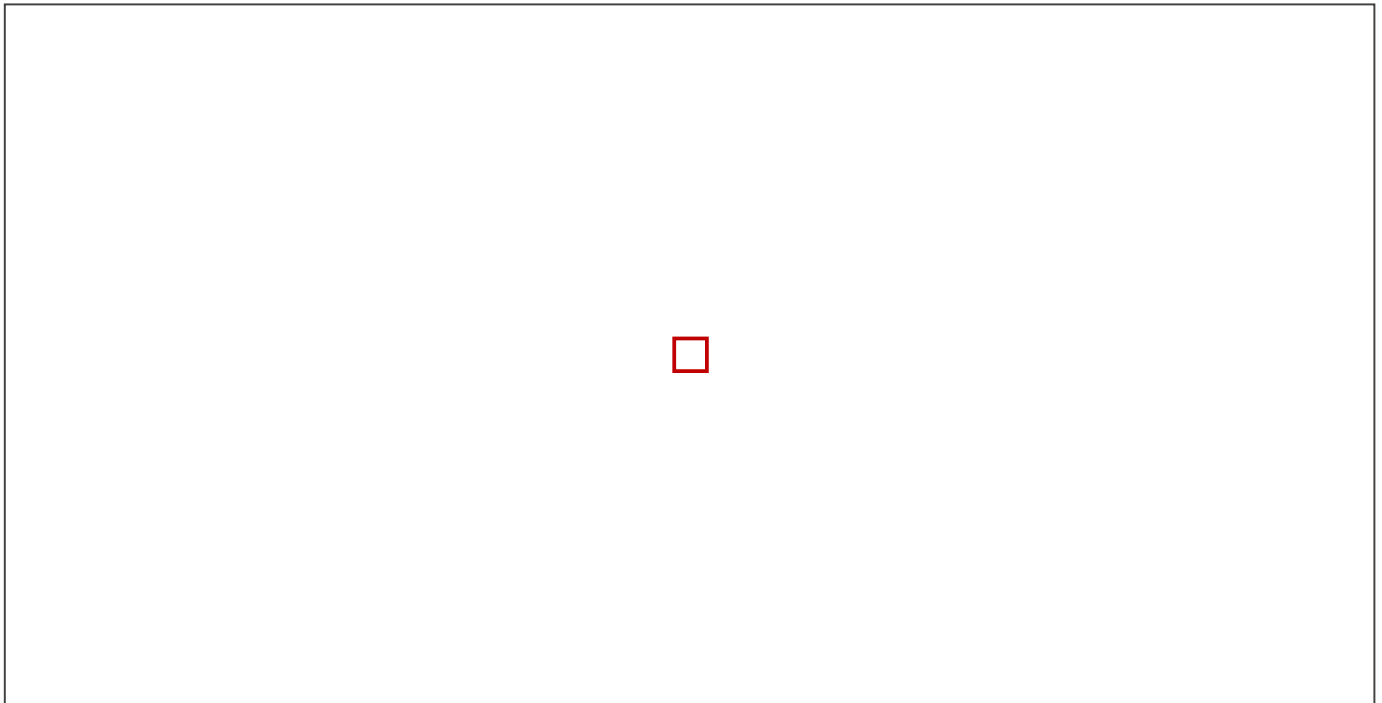
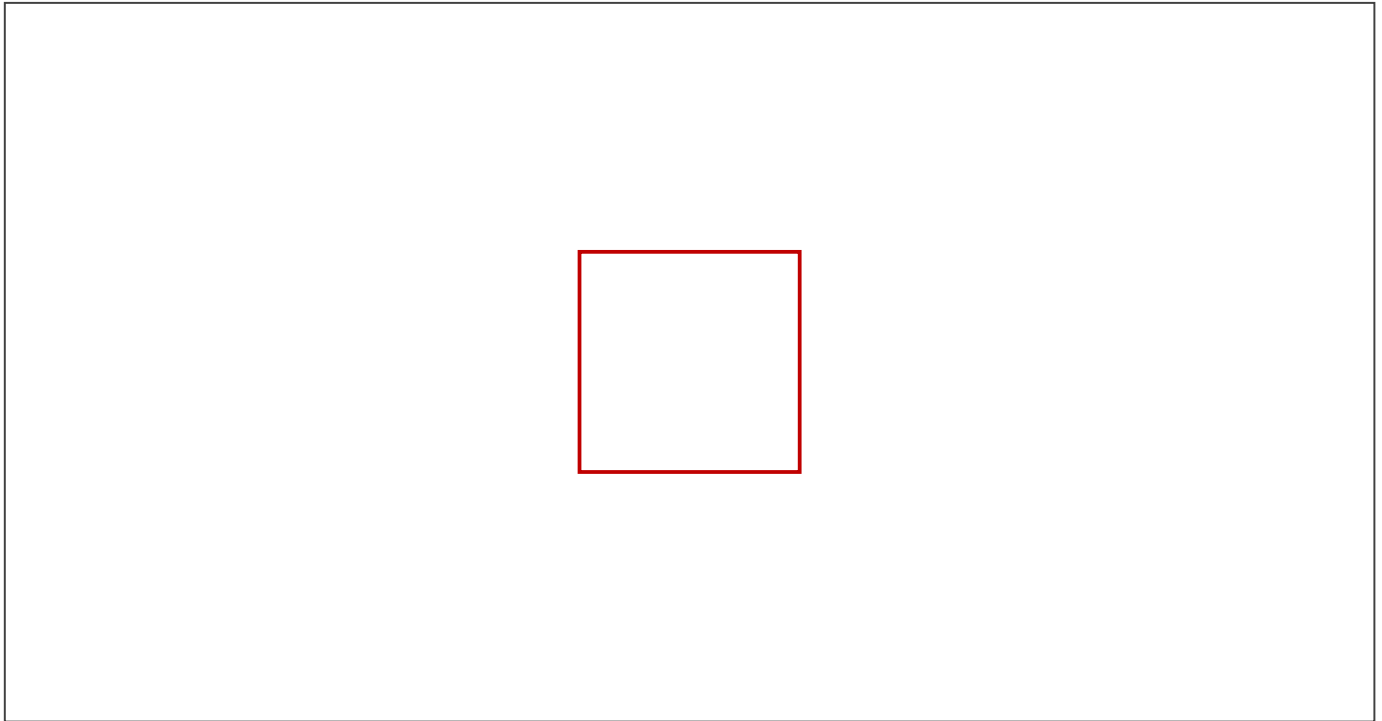
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Title:

SITE LOCATION MAPS

FIGURE: 1



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General Site Location

Info Source:

Google (open-source)

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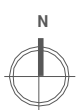
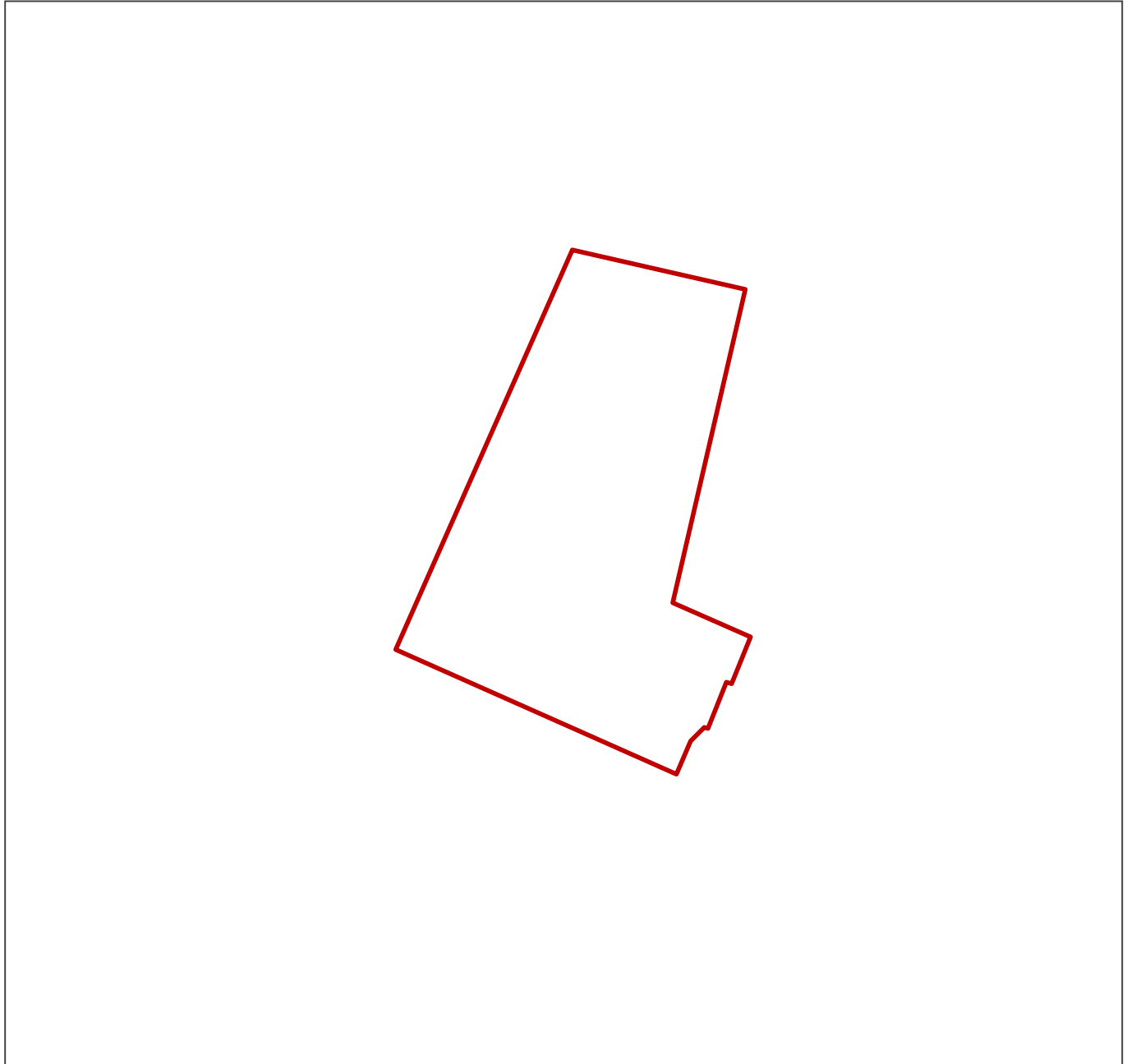
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RECENT AERIAL PHOTOGRAPH

FIGURE: 2

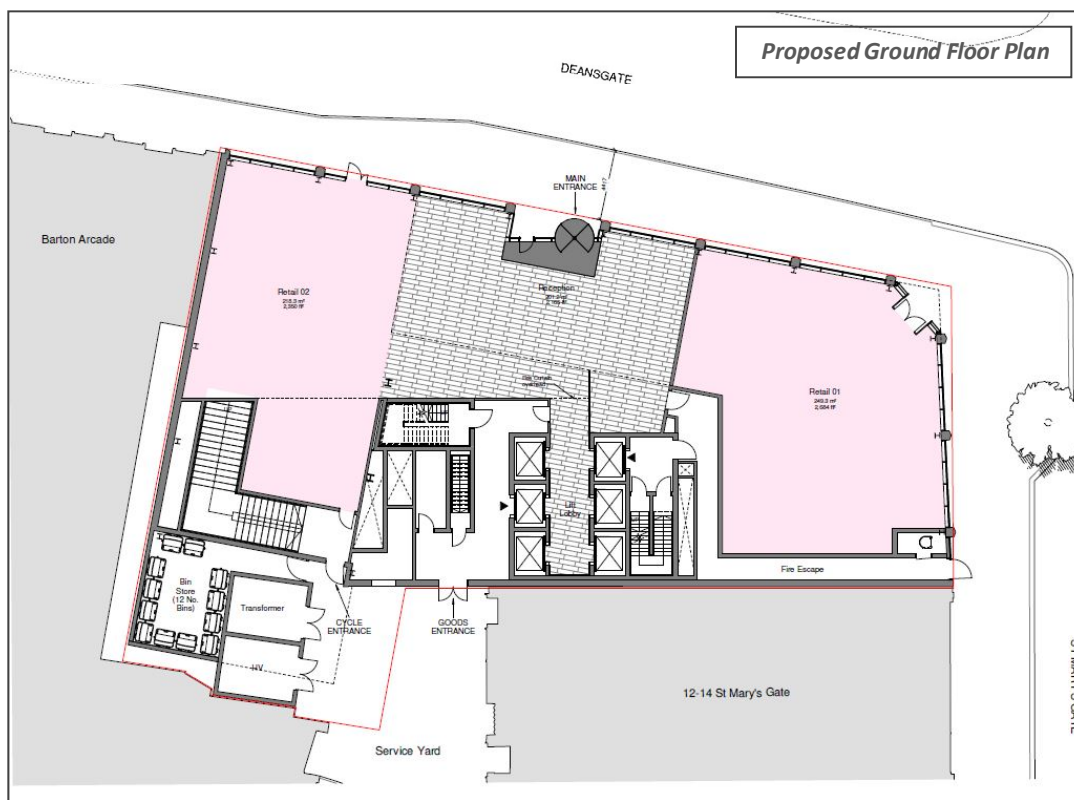


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Report Ref:	DRA-19-1118	
 Approx. Site Boundary	Info Source:	Google (open-source)

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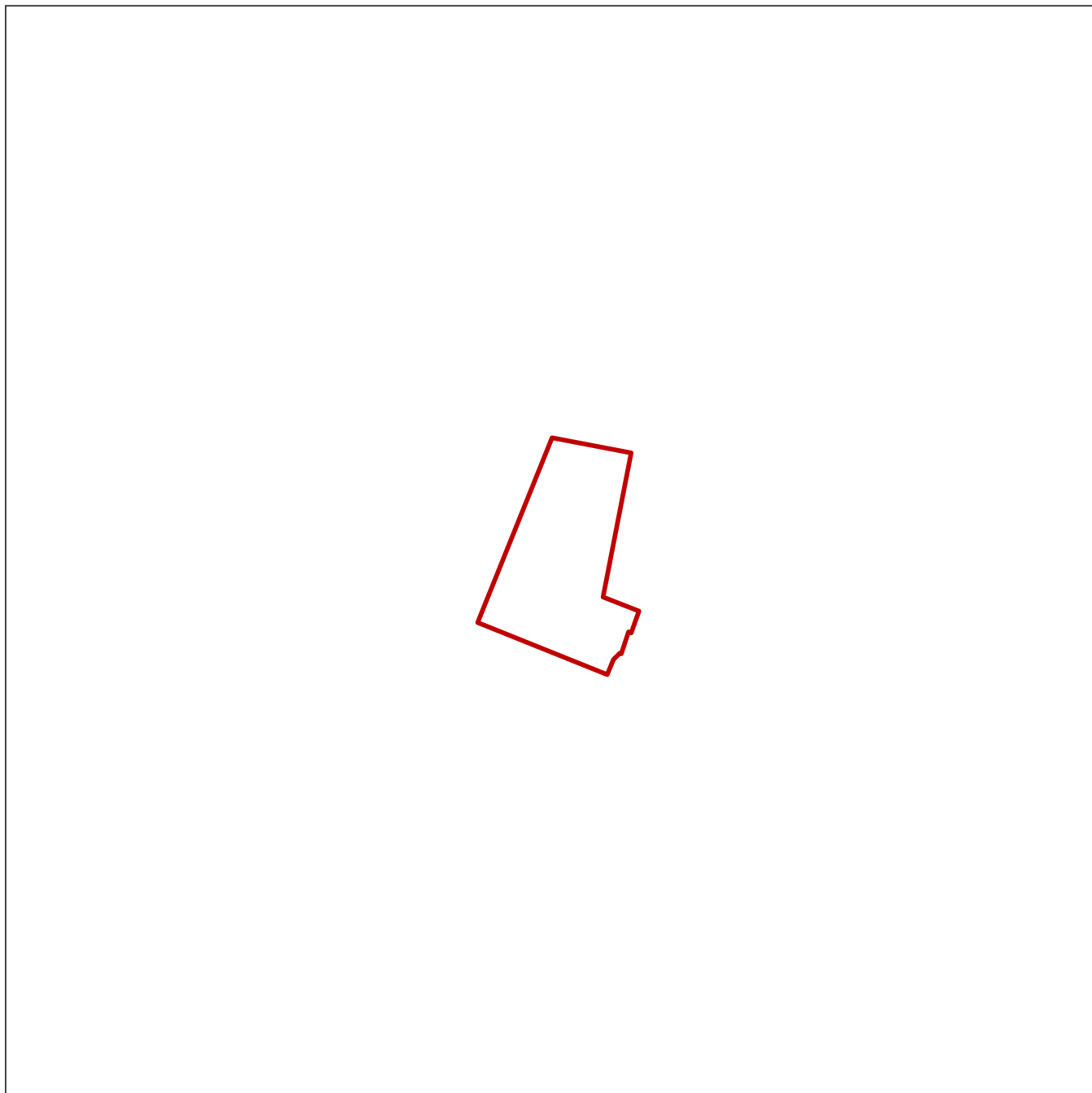
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Title:

HISTORICAL OS MAPPING - 1933

FIGURE: 4.1



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Approx. Site Boundary

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Groundsure

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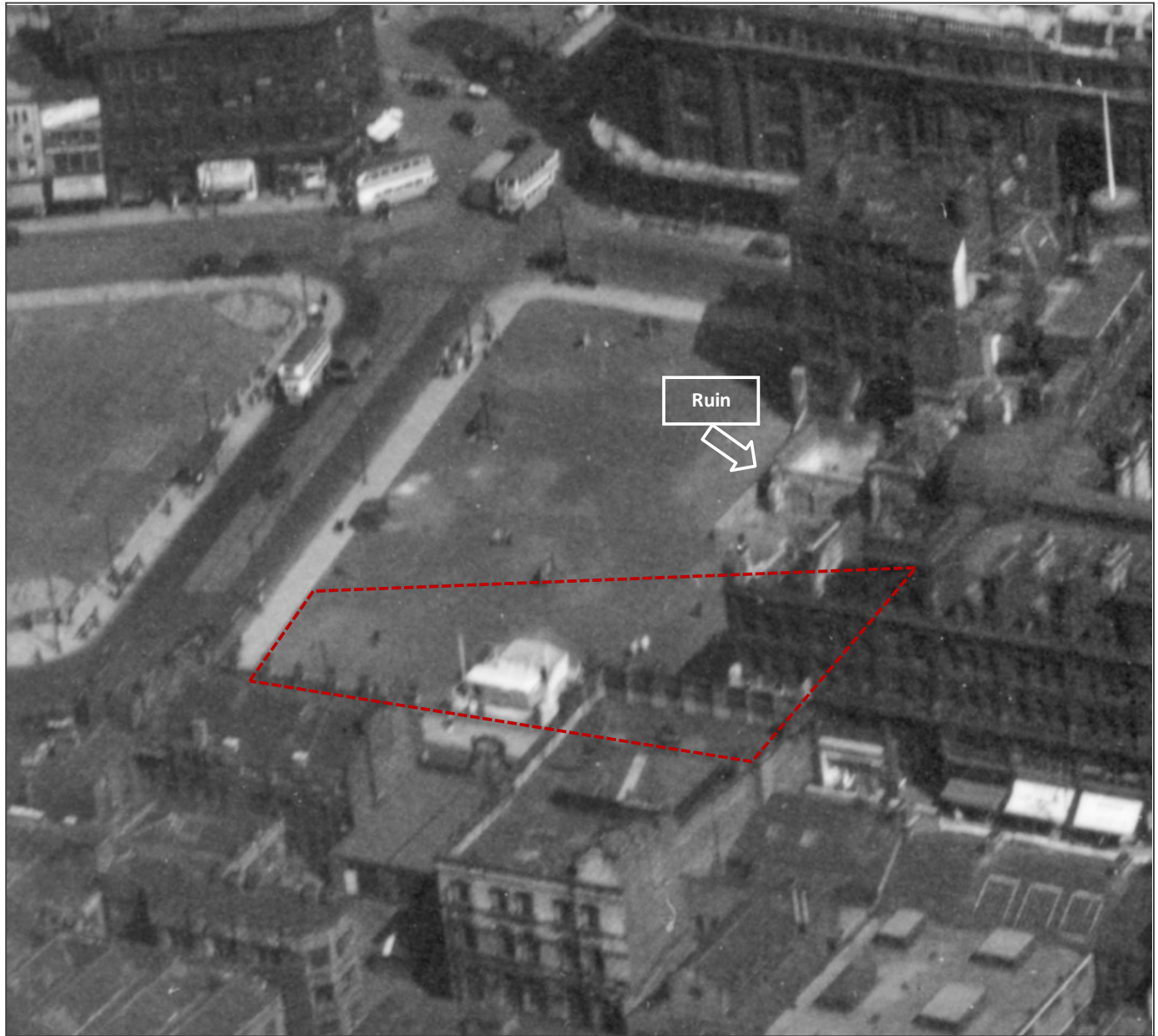

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Notes:
Each bomb strike's date of fall has been identified by coloured circles; blue (22/12/40), orange (23/12/40), and purple (01/06/41).

Some areas of damage have been labelled with a date. These have also been highlighted accordingly.

Several bomb strikes are undated.

Multiple areas of structural damage do not have a corresponding bomb strike.

- HE bomb
- HE parachute mine
- Incendiary bomb
- Damage
- Total destruction



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Title:

WWII BOMB DAMAGE PHOTOGRAPHY

FIGURE: 7



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--- General Site Location

Info Source:

Imperial War Museum

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APPENDICES: 1 - 5



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Recent German UXB Finds in the UK + Historical Analysis

- **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.*
- **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.*
- **19th January 2017** - An SD50 (semi-armour piercing 50kg HE bomb) was dredged from the Thames during barge dredging works near Westminster Bridge, London.
- **12th May 2016** - A 500kg HE bomb was found buried just 1m below the playground of the former Royal High Junior School in Bath. *Historical Analysis: The UXB landed in a plot of neglected, unmaintained vegetation in between the school gym and main school building.*
- **23rd September 2015** - A 1,000kg HE bomb was encountered by a mechanical excavator on a building site in Paradise Street, Coventry. *Historical Analysis: the UXB landed in a large residential back garden occupied by dense vegetation. A two storey building was built on top of the UXB post-WWII.*
- **10th August 2015** - A 250kg HE bomb was found immediately beneath a basement floor during refurbishment works in Temple Street, Bethnal Green (London). *Historical Analysis: The UXB struck a house that had been damaged beyond repair during a previous air raid. The existing house was then built on top of UXB post-WWII.*
- **21st May 2015** - An SC50 (general purpose 50kg HE bomb) was found during deep excavations at a construction site in Wembley, London. *Historical Analysis: UXB landed in a large residential back garden.*
- **23rd March 2015** - A 250kg HE bomb was found during deep excavations at a building site in Grange Walk, Bermondsey (London). *Historical Analysis: inconclusive - reported UXB position is likely inaccurate.*

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).

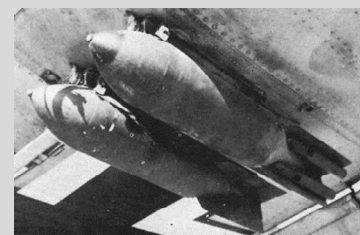
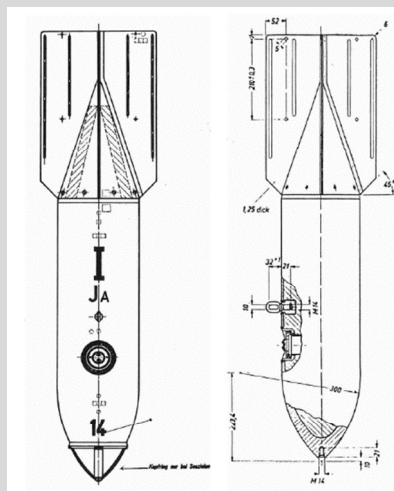
Initiation of WWII Allied Bombs

- **6th January 2014** - Mechanical excavator stuck a WWII bomb in Euskirchen (Germany) causing it to explode, killing the operator and injuring 13 more, two critically. The explosion was so large it damaged buildings 400m away.
- **1st March 2013** - During piling at a construction site in Ludwigshafen (Germany) a small buried WWII bomb exploded, injuring one worker.
- **2nd June 2010** - A British 500kg bomb detonated whilst being defused, killing three EOD engineers in Goettingen, Germany. The bomb was found as builders dug the foundations for a new sports hall. Several houses had their fronts blown off by the blast.
- **19th September 2008** - Seventeen people were injured and buildings were damaged when an excavator apparently drove over and set off a 250kg American bomb at a construction site in Hattingen, Germany.
- **23rd October 2006** - A construction worker breaking up tarmac at the side of a highway near the south-western German town of Aschaffenburg was killed when his machine struck and detonated a WWII bomb. In addition, the blast injured several motorists who were driving past.
- **2006** - A piling rig and dump truck were destroyed when a piling rig struck an Allied bomb on a construction site in Austria.
- **2003** - In the Austrian city of Salzburg, two people were killed while attempting to defuse a 250kg Allied bomb.
- **1994** - At a central Berlin construction site a piling rig struck a large WWII Allied bomb. 3 were killed and 14 more were injured. Dozens of cars in a 250m radius were wrecked, the top 10 floors of neighbouring office building collapsed and human remains were found 100m away.
- **1990** - In Wetzlar (Germany) two EOD engineers were blown up as they removed the detonator of an allied WWII UXB.

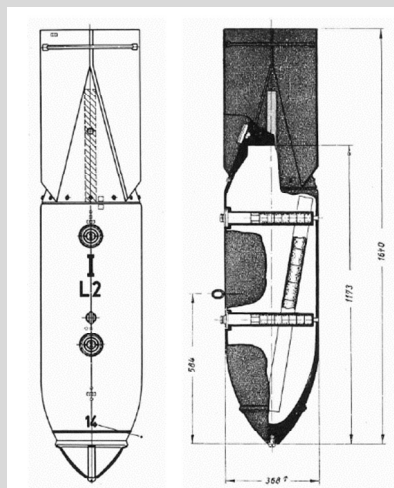
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	Info Source:		Various	

SC 50

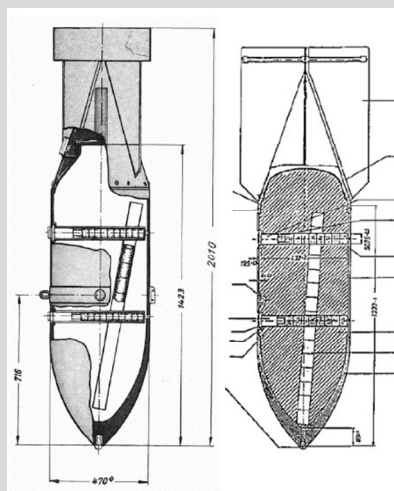
Bomb Weight: 40-54kg (110-119lb)
Explosive Weight: 25kg (55lb)
Filling: TNT, Amatol or Trialen
Charge/Weight Ratio: 46%
Fuse Type: Electrical impact fuse or mechanical delayed action fuse
Body Dimensions: 1,100mm length x 200mm diameter
Appearance: Bomb body and tail painted grey/green with a yellow 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.



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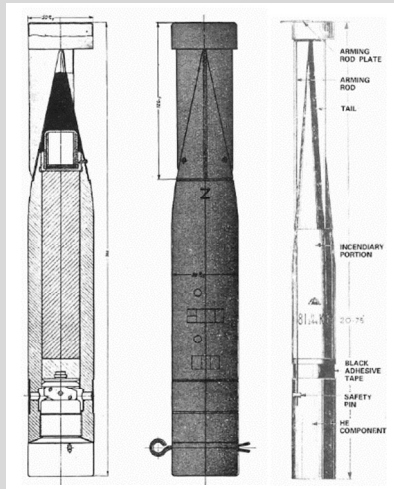
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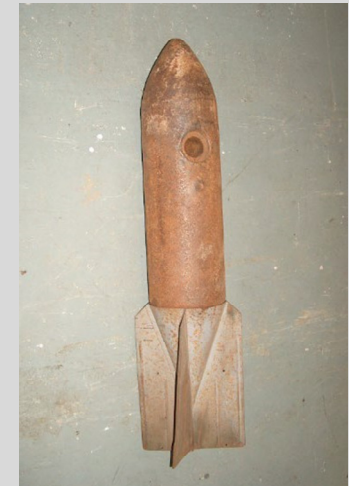
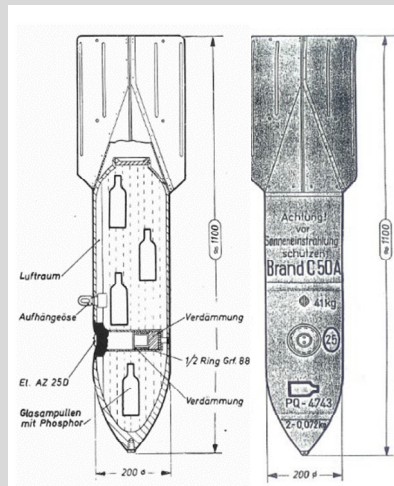
B-1E Sub-Munition

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.



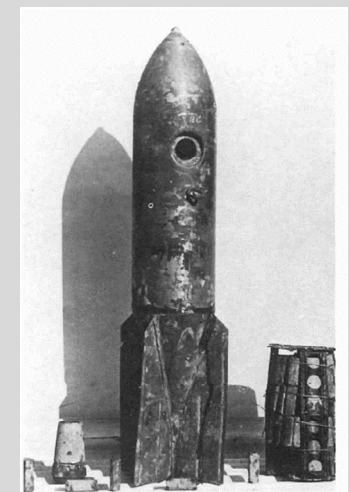
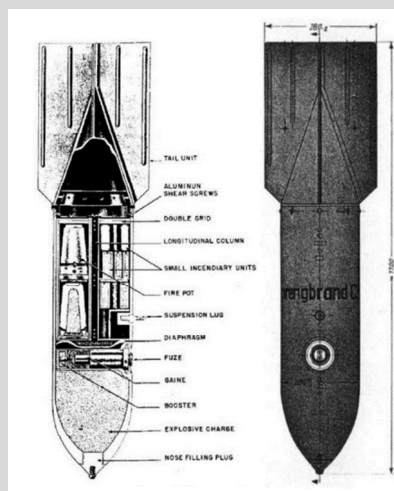
Brand C50

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 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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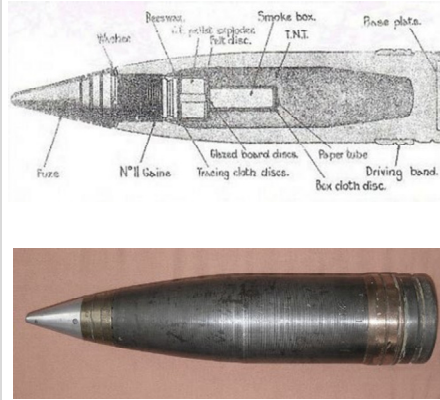
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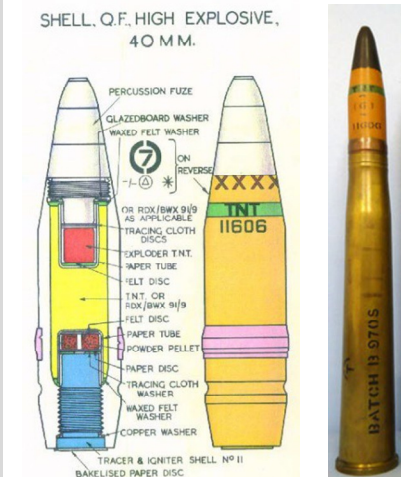
HAA Battery - 3.7" QF Shell

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.



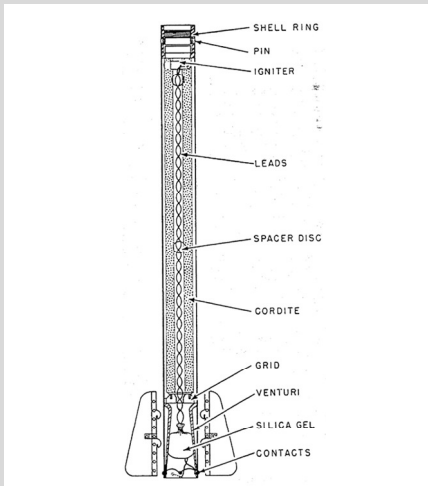
LAA Battery - 40mm Bofors Shell

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

39 Deansgate, Manchester

Client:

Kames Property Income Fund

Report Ref:

DRA-19-1118

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

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Title:		GLOSSARY	APPENDIX: 4
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			
	Project	39 Deansgate, Manchester	
	Client:	Kames Property Income Fund	
	Report Ref:	DRA-19-1118	
		Info Source:	n/a
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Title:	BIBLIOGRAPHY	APPENDIX: 5
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