1ST LINE DEFENCE

Detailed Unexploded Ordnance (UXO) Risk Assessment

Project Name	Thames Young Mariners, Richmond
Client	Soils Limited
Site Address	Thames Young Mariners, Riverside Dr, Richmond TW10 7RX
Report Reference	DA15987-00
Date	16/09/22
Originator	DB

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Executive Summary

Site Location and Description

The site is located within the London Borough of Richmond upon Thames. Aerial imagery indicates the site predominately comprises a lake connected to the River Thames by a lock. A nature reserve and areas of dense vegetation are located throughout the northern and southern sectors. Within the latter, an educational facility and associated outbuildings are also located. A hardstanding access way connects the facility to River Drive.

The site is bordered to the north and south by Ham Lands nature reserve. East of the site is Riverside Drive with residential and commercial properties situated further east. West of the site is vegetation and a hard-standing access way, with the River Thames extending further west.

The site is approximately centred on the OS grid reference: **TQ 16460 72396**.

Proposed Works

Details of proposed works were not provided by the client during the production of this report

Geology and Bomb Penetration Depth

The British Geological Survey (BGS) map shows the site to be underlain by London Clay Formation - Clay and silt. Sedimentary bedrock formed between 56 and 47.8 million years ago during the Palaeogene period. Superficial deposits include Kempton Park Gravel Member - Sand and gravel.

Site-specific geotechnical information was not available to 1st Line Defence at the time of the production of this report. An assessment of maximum bomb penetration depth can be made once such data becomes available, or by a UXO specialist during on-site support.

It should be noted that the maximum depth that a bomb could reach may vary across a site and will be largely dependent on the specific underlying geological strata and its density.

UXO Risk Assessment

1st Line Defence has assessed that there is an overall **Medium Risk** from German and anti-aircraft unexploded ordnance at the site of proposed works. There is also an assessed **Low - Medium Risk** from Allied unexploded ordnance.

The Risk from German Air Delivered UXO

- During WWII the site was located within the Municipal Borough of Richmond, which sustained an overall moderate-high density of bombing with an average of 96.6 incidents recorded per 1,000 acres (**Annex I**). This is likely owed to the borough's proximity to several viable Luftwaffe targets within the wider area of the site, including the Richmond Water Works, Gas Works and Hawker Hurricane factory, located approximately 2.9km, 3km and 3.2km south of the site respectively (highlighted within Luftwaffe target imagery within **Annex J**).
- Historical OS maps show that during WWII, the site comprised open ground, a body of water, a dock and a sand and gravel works.
- London Bomb Census maps and a local 'Bombs on Richmond 1940-1945' bomb map do not record any incidents on-site. Nonetheless, these sources corroborate in recording a large number of incidents throughout the wider vicinity. This includes two 'sticks' of bombs: one each located to the north and south of the site.
- Incident Records for Richmond corroborates with mapping in reporting bombing across "Ham Fields", fields opposite Eel Pie Island, and the Ham River Grit Company. The latter was situated on-site and was noted within this source as having been subjected to a large amount of incendiary bombing. "Ham Fields", which is noted as the location of five HE bombs and a UXB, was situated throughout the site's northern and southern vicinities.
- 1944 and 1946 WWII-era and post-war imagery do not show any obvious signs of bomb damage, such as cratering or ground clearance, within the structures occupying the gravel and sand works in the south-west of the site. However, it is worth noting that the majority of ground cover across the site comprised a body of water. Given this, it is not possible to accurately identify potential damage across the majority of the site, as typical damage indicators would have been obscured altogether by the waterline.

UXO Risk Assessment

- Access to the majority of the site area is difficult to assess, given that the majority of the site was undeveloped and occupied by a body of water, sites possessing such conditions are generally not considered to have been frequently accessed. The extent to which the on-site grit works would have been accessed/monitored is also difficult to assess and would have likely relied on the vigilance of those using the area.
- In summary, the on-site Ham River Grit Company was noted to have been struck by incendiary bombs on two occasions, while a large number of HE bombs were recorded throughout the wider vicinity which included two 'sticks' of bombs, one of which contained a UXB. While no HE bombs were recorded on-site, it is of concern that this scale of bombing was occurring over a site which was predominately occupied by a body of water. Open bodies of water are concerning because it is generally very unlikely that unexploded bombs falling within such areas would have been recorded or dealt with; they would have left little to no little evidence of their presence, and unless UXO was spotted entering the water it is likely to have been noticed during a raid. Much of the remainder of the site was occupied by open marshy land, which is also considered unconducive towards the observation of UXO given the increased potential for UXB entry holes to be obscured by mud/overgrowth. Therefore, the potential for further incidents to have fallen on/around the site unreported cannot be reduced. For this reason, proactive risk mitigations measures are considered necessary. As such, the site has been assessed as **Medium Risk** from German air delivered ordnance.

  If works are to be undertaken within the body of water, it is advised that 1st Line Defence Ltd be contacted.

The Risk from Allied UXO

- Online sources indicate that a rifle and pistol range was located 300m east of the site during WWII and that there was a Home Guard (HG) presence within the wider area of the site, in areas such as Ham Common and Richmond Park.
- Online sources indicate that there was a HG presence within the wider area of the site in areas such as Ham Common and Richmond Park, located approximately 2km east and 900m southeast of the site. Although details regarding Home Guard activities on Ham Common are limited, sources indicate that by the end of November 1942, 'anti-invasion' exercises were being performed in the area.[1] It is not known what these involved or whether they occurred on-site.
- The aforementioned range was recorded to have trained over 24,000 personnel during WWI and was also requisitioned by the military during WWII. Examples of items of ordnance being discarded or improperly destroyed have been found across the UK and could have taken the form of items being discarded by methods of burying, negligent or accidentally discarding them in the river. Nonetheless, it should be emphasized that there is no conclusive evidence of this occurring within Ham Common. In addition, as there is a distance of 300m between this range and the site, the likelihood of contamination from this source is not considered significant.
- In summary, a rifle range was located in the wider vicinity of the site. This facility was utilized during both world wars and is noted to have trained over 24,000 personnel. Also of note is a local Home Guard presence who were known to have performed 'anti-invasion' exercises. As a result of such activities occurring in the wider vicinity of the site, the risk of contamination from these sources cannot be entirely reduced. However, while these were occurring in the wider area, no conclusive evidence was found to suggest that the site itself was being used for either Home Guard activities or as a disposal area. As a result the potential risk is not considered significant enough for proactive risk mitigation measures to be recommended. Due to these factors, the site is therefore considered to be of **Low-Medium Risk** from historic Allied UXO.

Post-WWII Redevelopment

- Post war, recent aerial imagery shows that the site has been substantially developed, including the infilling of the grit works immediate south of the site and development of an outdoor education facility called *Thames Young Mariners.*
- The risk of UXO remaining is considered to be mitigated at the location of and down to the depth of any post-war redevelopment on site. For example, the risk from deep buried UXO will only have been mitigated within the volumes of any post-war pile foundations or deep excavations for basement levels. The risk will however remain within virgin geology below and amongst these post-war works, down to the maximum bomb penetration depth.

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[1] *http://sussexhistoryforum.co.uk/index.php?topic=7323.0*

Recommended Risk Mitigation Measures

The following risk mitigation measures are recommended to support the proposed works at Thames Young Mariners

All Works

- UXO Risk Management Plan
- Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.

Medium Risk Areas

Open Intrusive Works (trial pits, service pits, open excavations, shallow foundations etc.)

- UXO Specialist On-site Support

Boreholes and Piled Foundations

- Intrusive Magnetometer Survey of all borehole and pile locations/clusters down to maximum bomb penetration depth.

Note – the above risk mitigation measures are not considered necessary for any works taking place at the location of and at the depths of any post-war development present.

Glossary

Abbreviation	Definition
AA	Anti-Aircraft
AFS	Auxiliary Fire Service
AP	Anti-Personnel
ARP	Air Raid Precautions
DA	Delay-action
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
FP	Fire Pot
GM	G Mine (Parachute mine)
HAA	Heavy Anti-Aircraft
HE	High Explosive
IB	Incendiary Bomb
JSEODOC	Joint Services Explosive Ordnance Disposal Operation Centre
LAA	Light Anti-Aircraft
LCC	London County Council
LRRB	Long Range Rocket Bomb (V-2)
LSA	Land Service Ammunition
NFF	National Filling Factory
OB	Oil Bomb
PAC	Pilotless Aircraft (V-1)
PB	Phosphorous Bomb
PM	Parachute Mine
POW	Prisoner Of War
RAF	Royal Air Force
RCAF	Royal Canadian Air Force
RFC	Royal Flying Corps
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SA	Small Arms
SAA	Small Arms Ammunition
SD2	Anti-personnel “Butterfly Bomb”
SIP	Self-Igniting Phosphorous
U/C	Unclassified bomb
UP	Unrotated Projectile (rocket)
USAAF	United States Army Air Force
UX	Unexploded
UXAA	Unexploded Anti-Aircraft
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	Flying Bomb (Doodlebug)
V-2	Long Range Rocket
WAAF	Women’s Auxiliary Air Force
X	Exploded

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1st Line Defence Limited
Detailed Unexploded Ordnance (UXO) Risk Assessment

Site: Thames Young Mariners, Richmond
Client: Soils Limited

1. Introduction

1.1. Background

1st Line Defence has been commissioned by Soils Limited to conduct a Detailed Unexploded Ordnance (UXO) Risk Assessment for the works proposed at Thames Young Mariners, Richmond.
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Buried UXO can present a significant risk to construction works and development projects. The discovery of a suspect device during works can cause considerable disruption to operations as well as cause unwanted delays and expense.

UXO in the UK can originate from three principal sources:

1. Munitions resulting from wartime activities including German bombing in WWI and WWII, long range shelling, and defensive activities.
2. Munitions deposited as a result of military training and exercises.
3. Munitions lost, burnt, buried or otherwise discarded either deliberately, accidentally, or ineffectively.

This report will assess the potential factors that may contribute to the risk of UXO contamination. If an elevated risk is identified at the site, this report will recommend appropriate mitigation measures, in order to reduce the risk to as low as is reasonably practicable. Detailed analysis and evidence will be provided to ensure an understanding of the basis for the assessed risk level and any recommendations.

This report complies with the guidelines outlined in *CIRIA C681*, 'Unexploded Ordnance (UXO) A Guide for the Construction Industry.'

2. Method Statement

2.1. Report Objectives

The aim of this report is to conduct a comprehensive assessment of the potential risk from UXO at Thames Young Mariners. The report will also recommend appropriate site and work-specific risk mitigation measures to reduce the risk from explosive ordnance during the envisaged works to a level that is as low as reasonably practicable.

2.2. Risk Assessment Process

1st Line Defence has undertaken a five-step process for assessing the risk of UXO contamination:

1. The likelihood that the site was contaminated with UXO.
2. The likelihood that UXO remains on the site.
3. The likelihood that UXO may be encountered during the proposed works.
4. The likelihood that UXO may be initiated.
5. The consequences of initiating or encountering UXO.

In order to address the above, 1st Line Defence has taken into consideration the following factors:

- Evidence of WWI and WWII German air delivered bombing as well as the legacy of Allied occupation.
- The nature and conditions of the site during WWII.
- The extent of post-war development and UXO clearance operations on site.
- The scope and nature of the proposed works and the maximum assessed bomb penetration depth.
- The nature of ordnance that may have contaminated the proposed site area.

2.3. Sources of Information

Every reasonable effort has been made to ensure that relevant evidence has been consulted and presented in order to produce a thorough and comprehensible report for the client. To achieve this the following, which includes military records and archive material held in the public domain, have been accessed:

- The National Archives and Richmond Archives.
- Historical mapping datasets.
- Historic England National Monuments Record.
- Relevant information supplied by Soils Limited.
- Available material from 33 Engineer Regiment (EOD) Archive (part of 29 Explosive Ordnance and Disposal and Search Group).
- 1st Line Defence's extensive historical archives, library and UXO geo-datasets.
- Open sources such as published books and internet resources.

3. Background to Bombing Records

3.1. General Considerations of Historical Research

This desktop assessment is based largely upon analysis of historical evidence. Every reasonable effort has been made to locate and present significant and pertinent information. 1st Line Defence cannot be held accountable for any changes to the assessed risk level or risk mitigation measures, based on documentation or other data that may come to light at a later date, or which was not available to 1st Line Defence during the production of this report.

It is often problematic and sometimes impossible to verify the completeness and accuracy of WWII-era records. As a consequence, conclusions as to the exact location and nature of a UXO risk can rarely be quantified and are, to a degree, subjective. To counter this, a range of sources have been consulted, presented and analysed. The same methodology is applied to each report during the risk assessment process. 1st Line Defence cannot be held responsible for any inaccuracies or the incompleteness in available historical information.

3.2. German Bombing Records

During WWII, bombing records were generally gathered locally by the police, Air Raid Precaution (ARP) wardens and military personnel. These records typically contained information such as the date, the location, the amount of damage caused and the types of bombs that had fallen during an air raid. This information was made either through direct observation or post-raid surveys. The Ministry of Home Security Bomb Census Organisation would then receive this information, which was plotted onto maps, charts, and tracing sheets by regional technical officers. The collective record set (regional bomb census mapping and locally gathered incidents records) would then be processed and summarised into reports by the Ministry of Home Security Research and Experiments Branch. The latter were tasked with providing the government 'a complete picture of air raid patterns, types of weapons used and damage caused- in particular to strategic services and installations such as railways, shipyards, factories and public utilities.'[2]

The quality, detail and nature of record keeping could vary considerably between provincial towns, boroughs and cities. No two areas identically collated or recorded data. While some local authorities maintained records with a methodical approach, sources in certain areas can be considerably more vague, dispersed, and narrower in scope. In addition, the immediate priority was mostly focused on assisting casualties and minimising damage at the time. As a result, some records can be incomplete and contradictory. Furthermore, many records were even damaged or destroyed in subsequent air raids. Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are therefore not always reliable. Whereas records of attacks on military or strategic targets were often maintained separately and have not always survived.

3.3. Allied Records

During WWII, considerable areas of land were requisitioned by the War Office for the purpose of defence, training, munitions production and the construction of airfields. Records relating to military features vary and some may remain censored. Within urban environments datasets will be consulted detailing the location of munition production as well as wartime air and land defences. In rural locations it may be possible to obtain plans of military establishments, such as airfields, as well as training logs, record books, plans and personal memoirs. As with bombing records, every reasonable effort will be made to access records of, and ascertain any evidence of, military land use. However, there are occasions where such evidence is not available, as records may not be accessible, have been lost/destroyed, or simply were not kept in the first place.

[2] http://www.nationalarchives.gov.uk/help-with-your-research/research-guides/bomb-census-survey-records-1940-1945/.

4. UK Regulatory Environment and Guidelines

4.1. General

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

4.2. CDM Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) define the responsibilities of parties involved in the construction of temporary or permanent structures.

The CDM 2015 establishes a duty of care extending from clients, principle co-ordinators, designers, and contractors to those working on, or affected by, a project. Those responsible for construction projects may therefore be accountable for the personal or proprietary loss of third parties, if correct health and safety procedure has not been applied.

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

- Provide an appropriate assessment of potential UXO risks at the site (or ensure such an assessment is completed by others).
- 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.

4.3. The 1974 Health and Safety at Work etc. Act

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

4.4. CIRIA C681

In 2009, the Construction Industry Research and Information Association (CIRIA) produced a guide to the risk posed by UXO to the UK construction industry (CIRIA C681). CIRIA is a neutral, independent and not-for-profit body, linking organisations with common interests and facilitating a range of collaborative activities that help improve the industry.

The publication provides the UK construction industry with a defined process for the management of risks associated with UXO from WWI and WWII air bombardment. It is also broadly applicable to the risks from other forms of UXO that might be encountered. It focuses on construction professionals' needs, particularly if there is a suspected item of UXO on site, and covers issues such as what to expect from a UXO specialist. The guidance also helps clients to fulfil their legal duty under CDM 2015 to provide designers and contractors with project specific health and safety information needed to identify hazards and risks associated with the design and construction work. This report conforms to this CIRIA guidance and to the various recommendations for good practice referenced therein. It is recommended that this document is acquired and studied where possible to allow a better understanding of the background to both the risk assessment process and the UXO issue in the UK in general.

4.5. Additional Legislation

In the event of a casualty resulting from the failure of an employer/client to address the risks relating to UXO, the organisation may be criminally liable under the Corporate Manslaughter and Corporate Homicide Act 2007.

5. The Role of Commercial UXO Contractors and The Authorities

5.1. Commercial UXO Specialists

The role of a UXO Specialist (often referred to as UXO Consultant or UXO Contractor) such as 1st Line Defence, is defined in CIRIA C681 as the provision of expert knowledge and guidance to the client on the most appropriate and cost-effective approach to UXO risk management at a site.

The principal role of UXO Specialists is to provide the client with an appropriate assessment of the risk posed by UXO for a specific project, and identify and carry out suitable methodology for the mitigation of any identified risks to reduce them to an acceptable level.

The requirement for a UXO Specialist should ideally be identified in the initial stages of a project, and it is recommended that this occur prior to the start of any detailed design. This will enable the client to budget for expenditure that may be required to address the risks from UXO, and may enable the project team to identify appropriate techniques to eliminate or reduce potential risks through considered design, without the need for UXO specific mitigation measures. The UXO Specialist should have suitable qualifications, levels of competency and insurances.

Please note 1st Line Defence has the capability to provide a complete range of required UXO risk mitigation services, in order to reduce a risk to as low as reasonably practicable. This can involve the provision of both ground investigation, and where appropriate, UXO clearance services.

5.2. The Authorities

The police have a responsibility to co-ordinate the emergency services in the event of an ordnance-related incident at a construction site. Upon inspection they may impose a safety cordon, order an evacuation, and call the military authorities Joint Services Explosive Ordnance Disposal Operation Centre (JSEODOC) to arrange for investigation and/or disposal. Within the Metropolitan Police Operational Area, SO15 EOD will be tasked to any discovery of suspected UXO. The request for Explosive Officer (Expo) support is well understood and practiced by all Metropolitan Boroughs. The requirement for any additional assets will then be coordinated by the Expo if required.

In the absence of a UXO specialist, police officers will usually employ such precautionary safety measures, thereby causing works to cease, and possibly requiring the evacuation of neighbouring businesses and properties.

The priority given to the police request will depend on the EOD teams' judgement of the nature of the UXO risk, the location, people and assets at risk, as well as the availability of resources. The speed of response varies; authorities may respond immediately or in some cases it may take several days for the item of ordnance to be dealt with. Depending on the on-site risk assessment the item of ordnance may be removed from the site and/or destroyed by a controlled explosion.

Following the removal of an item of UXO, the military authorities will only undertake further investigations or clearances in high-risk situations. If there are regular UXO finds on a site the JSEODOC may not treat each occurrence as an emergency and will recommend the construction company puts in place alternative procedures, such as the appointment of a commercial contractor to manage the situation.

6. The Site

6.1. Site Location

The site is located within the London Borough of Richmond upon Thames.

The site is bordered to the north and south by Ham Lands nature reserve. East of the site is Riverside Drive with residential and commercial properties situated further east. West of the site is vegetation and a hard-standing access way, with the River Thames extending further west.

The site is approximately centred on the OS grid reference: **TQ 16460 72396**.

Site location maps are presented in **Annex A**.

6.2. Site Description

Aerial imagery indicates the site predominately comprises a lake connected to the River Thames by a lock. A nature reserve and areas of dense vegetation are located throughout the northern and southern sectors. Within the latter, an educational facility and associated outbuildings are also located. A hardstanding access way connects the facility to River Drive.

A recent aerial photograph and site plan are presented in **Annex B** and **Annex C** respectively.

7. Scope of the Proposed Works

7.1. General

Details of proposed works were not provided by the client during the production of this report.

8. Ground Conditions

8.1. General Geology

The British Geological Survey (BGS) map shows the site to be underlain by London Clay Formation - Clay and silt. Sedimentary bedrock formed between 56 and 47.8 million years ago during the Palaeogene period. Superficial deposits include Kempton Park Gravel Member - Sand and gravel.

8.2. Site Specific Geology

Site-specific geotechnical data was not provided by the client during the production of this report.

9. Site History

9.1. Introduction

The purpose of this section is to identify the composition of the site pre and post-WWII. It is important to establish the historical use of the site, as this may indicate the site's relation to potential sources of UXO as well as help with determining factors such as the land use, groundcover, likely frequency of access and signs of bomb damage.

9.2. Ordnance Survey Historical Maps

Relevant historical maps were obtained for this report and are presented in **Annex D.** See below for a summary of the site history shown on acquired mapping.

Pre-WWII		
Date	**Scale**	**Description**
1934 – 1935	1:2500	The site was mostly occupied by a *Dock,* a body of water and open, marsh land. A *Sand & Gravel Works* was situated within the south/south-west of the site. The site was bordered to the north and east by open ground. South of the site was a deep depression, it is not known at this stage whether it was a filled or not and whether it was a gravel pit or water. West of the site was pathway with the *River Thames* situated further west. A *Landing Stage* was situated adjacent to the site.

Post-WWII		
Date	**Scale**	**Description**
1960-1962	1:2500	This mapping edition indicates that significant changes occurred since previous mapping editions, including the expansion of the river occupying the site. The sand and gravel works formally occupying the southern region of the site has been filled and the *Thames Young Mariners Base* has been developed to the east of the dock. In the wider area of the site, open ground borders the north, east and south of the site. The western border of the site is affixed to the bank of the River Thames.

9.3. Pre-WWII Photography of the Site

Pre-WWII aerial photography has been obtained from the Aerofilms collection available from *Britain From Above*. This imagery provides a view of the site in 1927 (**Annex E**). See below for a description:

Title of Photograph	**Comments**
The Ham River Grit Company, Richmond Upon Thames, 1927	This oblique image captured from the southwest is concurrent with the information shown within historical OS mapping (Section 9.2). This image indicates that the majority of the site was occupied by a Lake, marshy ground and a section of the Ham River Grit Company. The deep depression referenced in Section 9.2 situated to the south of the site appears to have been an additional body of water from subsequent spill over from the lake.

10. Introduction to German Air Delivered Ordnance

10.1. General

During WWI and WWII, the UK was subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. The poor accuracy of WWII targeting technology and the nature of bombing techniques often resulted in neighbouring areas to targets sustaining collateral damage.

In addition to raids which concentrated on specific targets, indiscriminate bombing of large areas also took place. This occurred most prominently in the London 'Blitz', though affected many other towns and cities. As discussed in the following sections, a proportion of the bombs dropped on the UK did not detonate as designed. Although extensive efforts were made to locate and deal with these UXBs at the time, many still remain buried and can present a potential risk to construction projects.

The main focus of research for this section of the report will concern German air delivered ordnance dropped during WWII, although WWI bombing will also be considered.

10.2. Generic Types of WWII German Air Delivered Ordnance

To provide an informed assessment of the hazards posed by any items of unexploded ordnance that may remain in situ on site, the table below provides information on the types of German air delivered ordnance most commonly used by the Luftwaffe during WWII. Images and brief summaries of the characteristics of these items of ordnance are listed in **Appendices i-iii**.

Generic Types of WWII German Air Delivered Ordnance		
Type	**Frequency**	**Likelihood of detection**
High Explosive (HE) bombs	In terms of weight of ordnance dropped, HE bombs were the most frequently deployed by the Luftwaffe during WWII.	Although efforts were made to identify the presence of unexploded ordnance following an air raid, often the damage and destruction caused by detonated bombs made observation of UXB entry holes impossible. The entry hole of an unexploded bomb can be as little as 20cm in diameter and was easily overlooked in certain ground conditions (see **Annex F**). Furthermore, ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded smaller bomb. UXBs therefore present the greatest risk to present–day intrusive works.
1kg Incendiary bombs (IB)	In terms of the number of weapons dropped, small IBs were the most numerous. Millions of these were dropped throughout WWII.	IBs had very limited penetration capability and in urban areas would often have been located in post-raid surveys. If they failed to initiate and fell in water, on soft vegetated ground, or bombed rubble, they could easily go unnoticed.
Large Incendiary bombs (IB)	These were not as common as the 1kg IBs, although they were more frequently deployed than PMs and AP bomblets.	If large IBs did penetrate the ground, complete combustion did not always occur and in such cases they could remain a risk to intrusive works.
Aerial or Parachute mines (PM)	These were deployed less frequently than HE and IBs due to size, cost and the difficulty of deployment.	If functioning correctly, PMs would generally have had a slow rate of descent and were very unlikely to have penetrated the ground. Where the parachute failed, mines would have simply shattered on impact if the main charge failed to explode. There have been extreme cases when these items have been found unexploded. However, in these scenarios, the ground was either extremely soft or the munition fell into water.
Anti-personnel (AP) bomblets	These were not commonly used and are generally considered to pose a low risk to most works in the UK.	SD2 bomblets were packed into containers holding between 6 and 108 submunitions. They had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

10.3. Failure Rate of German Air Delivered Ordnance

It has been estimated that 10% of WWII German air delivered HE bombs failed to explode as designed. Reasons for why such weapons might have failed to function as designed include:

- Malfunction of the fuze or gain mechanism (manufacturing fault, sabotage by forced labour or faulty installation).
- Many were fitted with a clockwork mechanism that could become immobilised on impact.
- Failure of the bomber aircraft to arm the bombs due to human error or an equipment defect.
- Jettisoning the bomb before it was armed or from a very low altitude. This most likely occurred if the bomber aircraft was under attack or crashing.

From 1940 to 1945, bomb disposal teams reportedly dealt with a total of 50,000 explosive items of 50kg, over 7,000 anti-aircraft projectiles and 300,000 beach mines. Unexploded ordnance is still regularly encountered across the UK, see press articles in **Annex G**.

10.4. UXB Ground Penetration

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

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

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

10.4.1. The J-Curve Effect Principle

J-curve is the term used to describe the characteristic curve commonly followed by an air delivered bomb dropped from height after it penetrates the ground. Typically, as the bomb is slowed by its passage through underlying soils, its trajectory curves towards the surface. Many UXBs are found with their nose cone pointing upwards as a result of this effect. More importantly, however, is the resulting horizontal offset from the point of entry. This is typically a distance of about one third of the bomb's penetration depth, but can be higher in certain conditions (see **Annex F**).

10.4.2. WWII UXB Ground Penetration Studies

During WWII the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by bomb disposal (BD) teams. Conclusions were drawn predicting the likely average and maximum depths of penetration of different sized bombs in different geological strata.

For example, the largest common German bomb (500kg) had a likely concluded penetration depth of 6m in sand or gravel but 11m in clay. The maximum observed depth for a 500kg bomb was 11.4m and for a 1,000kg bomb 12.8m. Theoretical calculations suggested that significantly greater penetration depths were probable.

10.4.3. Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site of proposed works the following parameters should be used:

- WWII geology – London Clay Formation.
- Impact angle and velocity – 10-15° from vertical and 270 metres per second.
- Bomb mass and configuration – The 500kg SC HE bomb, without retarder units or armour piercing nose (this was the largest of the common bombs used against Britain).

It has not been possible to determine maximum bomb penetration capabilities at this stage due to the limitations of site-specific geotechnical information provided for the purpose of this report. An assessment can be made once further information becomes available or by an UXO Specialist on-site.

10.5. V-Weapons

Hitler's 'V-weapon' campaign began from mid-1944. It used newly developed unmanned cruise missiles and rockets. The V-1, known as the *flying bomb* or *pilotless aircraft*, and the V-2, a long range rocket, were launched from bases in Germany and occupied Europe. A total of 2,419 V-1s and 517 V-2s were recorded in the London Civil Defence region alone.

Although these weapons caused considerable damage, their relatively low numbers allowed accurate records of strikes to be maintained. These records have mostly survived. There is a negligible risk from unexploded V-weapons on land today. Even if the 1,000kg warhead failed to explode, the weapons are so large that they would have been observed and dealt with at the time. Therefore, any V-weapons referenced in this report are referenced not as a viable risk factor, but primarily in order to help account for evidence of damage and clearance reported.

11. Interaction between UXO and the Marine Environment

11.1. General

As a large section of the site comprises a lake that connects to the River Thames, it is beneficial to discuss the ways in which physical conditions can interact with items of UXO present within a marine environment. These can be summarised in three ways.

11.2. Exposure or Penetration into the Riverbed or Shore

The initial resting place and penetration of UXO in the marine environment of the site depends on a large number of factors, including the geology of the riverbed, the presence and thickness of any overlying sediment layers and the residual kinetic energy of the item of UXO and its angle of entry.

The initial position of an item of UXO within a riverbed can be classified as unburied, partially buried or fully buried.

11.3. The Subsequent Burial or Uncovering of UXO

After its initial position within the marine environment an item of UXO may experience burial, due to the vertical deposition of sediments or uncovering, due to the vertical erosion of sediments. Consequently, some items will experience cycles of burial, uncovering and re-burial due to regular trends of erosion deposition. These sediment movements can be the result of both near-field and far-field process and can be formed by gradual ongoing erosion trends or cycles of change dominated by temporal effects, such as seasonal cycles.

12. The Likelihood of Contamination from German Air Delivered UXBs

12.1. World War I

During WWI Britain was targeted and bombed by Zeppelin Airships as well as Gotha and Giant fixed-wing aircraft. The objective of these raids was to unnerve the British public, to destroy strategic targets and to ultimately attempt to coerce Britain's capitulation from the war. A WWI map of air raids and naval bombardments across the UK was consulted, see **Annex H**. This source does not show that the site area sustained any WWI related bombing incidents.

WWI bombs were generally smaller and dropped from a lower altitude than those used in WWII. This resulted in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons there is a limited risk that UXBs passed undiscovered in the urban environment. When combined with the relative infrequency of attacks and an overall low bombing density, the risk from WWI UXBs is considered low and will not be further addressed in this report.

12.2. World War II Bombing of Municipal Borough of Richmond

The Luftwaffe's main objective for the attacks on Britain was to inhibit the country's economic and military capability. To achieve this they targeted airfields, depots, docks, warehouses, wharves, railway lines, factories, and power stations. As the war progressed the Luftwaffe bombing campaign expanded to include the indiscriminate bombing of civilian areas in an attempt to subvert public morale.

During WWII the site was located within the Municipal Borough of Richmond, which sustained an overall moderate-high density of bombing, as represented by bomb density data figures and maps, see **Annex I**. This is likely owed to Richmond and the site's proximity to London, situated on the River Thames. The town of Richmond sustained over 450 bombing incidents with 100 killed, 379 people injured and more made homeless, from 9th September 1940 until March 1945.[3] Furthermore, Richmond and its neighbouring suburb of Kingston were home to several viable Luftwaffe targets aligning the River Thames, including the Richmond Water Works, Gas Works and Hawker Hurricane factory, located approximately 2.9km, 3km and 3.2km south of the site, annotated within **Annex J.**

Records of bombing incidents in the civilian areas of Municipal Borough of Richmond were typically collected by Air Raid Precautions wardens and collated by Civil Defence personnel. Some other organisations, such as port and railway authorities, maintained separate records. Records would be in the form of typed or hand written incident notes, maps and statistics. Bombing data was carefully analysed, not only due to the requirement to identify those parts of the country most needing assistance, but also in an attempt to find patterns in the Germans' bombing strategy in order to predict where future raids might take place.

Records of bombing incidents are presented in the following sections.

[3] *https://www.richmondhistory.org.uk/wordpress/history-of-richmond/richmond-at-war/*

12.3. WWII Home Office Bombing Statistics

The following table summarises the quantity of German air delivered bombs (excluding 1kg incendiaries and anti-personnel bombs) dropped on the Municipal Borough of Richmond between 1940 and 1945.

Record of German Ordnance Dropped on the Municipal Borough of Richmond		
Area Acreage		**4,109**
Weapons	High Explosive bombs (all types)	362
	Parachute mines	4
	Oil bombs	14
	Phosphorus bombs	6
	Fire pots	0
	Pilotless aircraft (V-1)	11
	Long range rockets (V-2)	0
Total		**397**
Number of Items per 1,000 acres		**96.6**

Source: Home Office Statistics
This table does not include UXO found during or after WWII.

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record. Although the risk relating to IBs is lesser than that relating to larger HE bombs, they were similarly designed to inflict damage and injury. Anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. Although Home Office statistics did not record these types of ordnance, both should not be overlooked when assessing the general risk to personnel and equipment.

12.4. London Civil Defence Region Bomb Census Maps

During WWII, the ARP Department within the Research and Experiments Branch of the Ministry of Home Security produced both consolidated and weekly bomb census maps for the London Civil Defence Region, as well as census mapping of V-1 pilotless aircraft. These maps collectively show the approximate locations of bombs, mines and rockets dropped in the region. The site area was checked on each available map sheet. Those showing bomb incidents on and in the immediate vicinity of the site are discussed below and are presented in **Annex K-L**.

Consolidated London Bomb Census Maps – Annex K1	
Date Range	**Comments**
Night Bombing up to 7th October 1940	This map does plot any bombing incidents on site or its immediate vicinity. The closest strike is record approximately 390m northwest of the site area.
7th October 1940 to 6th June 1941	This map does plot any bombing incidents on site or its immediate vicinity. The closest strike is record approximately 670m southeast of the site.

Weekly London Bomb Census Maps – Annex K2-K3	
Date Range	**Comments**
7th - 14th October 1940	An incendiary shower is recorded over the site area dated Tuesday 8th October 1940
14th – 21st October 1940	No HE bomb strikes are recorded within the site area, the closest strike is plotted 670m southeast of the site dated Wednesday 16th October 1940
17th – 24th February 1941	No HE bomb strikes are recorded within the site area, a stick of bombs including an unexploded UXB is plotted approximately 430m north east of the site, dated Wednesday 19th February 1941

V-1 Pilotless Flying Bomb Census Map – Annex L	
Date Range	**Comments**
1944-45	The closest recorded V1 flying bomb was located at Radner Garden. The date of this strike was 19th June 1944

12.5. Bombs on Richmond 1940-1945

A local bomb map produced by Richmond Borough Council was obtained from the Richmond Archives during the production of this report, plotting local bomb incidents. It is worth noting that this map does not include a key and although the red circles plotted across the map are anticipated to be HE bombs, this is not verified. Imagery of this source is presented in **Annex M.**

Bombs on Richmond 1940-1945 – Annex M	
Date Range	**Comments**
1940-1945	This map does not plot any bombing incidents within the site area. The closest incidents are part of a 'stick' of bombs located approximately 300m southeast of the site.

12.6. Richmond Incident Records

Incident records were obtained from Richmond Archives. This record was compiled by local Air Raid Precaution (ARP) personnel and volunteers during the war and contains details such as the date and basic location of Richmond based incidents. A transcript of the relevant written records is presented in the table below. Example imagery of these entries are presented in **Annex N**.

Richmond Incident Records – Annex N	
Date Range	**Comments**
26th September 1940	Fields Opposite Eel Pie Island HE Fields Opposite Eel Pie Island HE
unknown	Ham Fields, five High Explosive/ Unexploded bombs.
1st October 1940	Ham River Grit Company, 20-30 incendiary bombs.
10th October 1940	Ham Field Ham River Grit Company IB.

12.7. Anecdotal references

Online sources were consulted during the production of this report. References were found to the Ham River Grit Company located within the south of the site were available and an extract from this source.[4]

During the Second World War the pits ace said to have been used to store parts of the Mulberry Harbour. Later they were filled with rubble from the bombing. After 1952, when extraction ceased, housing was planned for the area. The area was however designated as Metropolitan Open Land.

An additional source indicates that the aforementioned gravel pits were filled in the late 40s and filled with bomb damaged rubble from central London.[5]

[4] *https://layersoflondon.humap.site/map/records/ham-lands*

[5] Smith, Bamber, *The Rough Guide to Walks in London and Southeast England, 2003*

12.8. WWII-Era Aerial Photography

WWII-era aerial photography for the site area was obtained from the National Monuments Record Office (Historic England). This photography provides a record of the potential composition of the site during the war, as well as its condition immediately following the war (**Annex O, O2**).

WWII-Era Aerial Photography	
Date/Title	**Description**
7th August 1944	This WWII-era vertical image corroborates what is shown within pre-war historical OS mapping, indicating that the majority of the site was occupied by a lake, a dock, smaller structures and the Sand and Gravel Works. As the site was semi-developed, typical signs of bomb damage would include cratering/indentations and circular scaring of the earth. As structures forming the Ham River Grit Company were situated within the south-western region of the site, any damage to this area of the site would be obvious. Bomb damage to structures would generally shows signs of debris and rubble, however none of the aforementioned typical signs of bomb damage are visible across the site within this image. However it is worth noting that a large proportion of the site area within this imagery is obscured by vegetation and a works. Any evidence of UXO within this area of the site would be difficult to spot (such as entry holes which can be as small as 20cm in diameter.) Significantly, a large proportion of the site was occupied by a lake and therefore any evidence of damage indicative of bombing within this area of the site would have been covered by the waterline.
7th July 1946	This image indicates that the dock, gravel, and sand works still occupies the western region of the site. The bounds of the river occupying the majority of the site has changed since the previous image, progressing further south. The jetty within the centre of the site has been cleared and a newer jetty has been developed.

12.9. Abandoned Bombs

A post air-raid survey of buildings, facilities, and installations would have included a search for evidence of bomb entry holes. If evidence of an entry hole was encountered, Bomb Disposal Officer Teams would normally have been requested to attempt to locate, render safe, and dispose of the bomb. Occasionally, evidence of UXBs was discovered but due to a relatively benign position, access problems, or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an 'abandoned bomb'.

Given the inaccuracy of WWII records, and the fact that these bombs were 'abandoned', their locations cannot be considered definitive or the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

1st Line Defence holds no records of officially registered abandoned bombs at or near the site of the proposed works.

12.10. Bomb Disposal Tasks

The information service from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (now part of 29 EOD & Search Group) no longer processes commercial requests for information. It has therefore not been possible to include any updated official information regarding bomb disposal/clearance tasks with regards to this site. A database of known disposal/clearance tasks has been referred to which does not make reference to such instances occurring within the site of proposed works. If any relevant information is received at a later date, Soils Limited will be advised.

12.11. Evaluation of German Air Delivered UXO Records

Factors	Conclusion
Density of Bombing *It is important to consider the bombing density when assessing the possibility that UXBs remain in an area. High bombing density could allow for error in record keeping due to extreme damage caused to the area.*	During WWII the site was located within the Municipal Borough of Richmond, which sustained an overall moderate-high density of bombing with an average of 96.6 incidents recorded pre 1,000 acres see **Annex I**. This is likely owed to Richmond's location within London and the amount of viable Luftwaffe targets within the wider area of the site including the Richmond Water Works, Gas Works and Hawker Hurricane factory, located approximately 2.9km, 3km and 3.2km south of the site, annotated within **Annex J**. London Bomb Census mapping and a local 'Bombs on Richmond 1940-1945' map do not plot any bombing incidents within the site area. However two 'sticks' of bombs were recorded within the former source: one each located in the northern and southern vicinities. The northern 'stick' included a UXB. The latter source also recorded a 'stick' of bombs to the south of the site. Incident Records for Richmond corroborates this, reporting bombing incidents across "Ham Fields", fields opposite Eel Pie Island, and the Ham River Grit Company within the site area. The latter was situated on-site and was noted within this source as having been subjected to a large amount of incendiary bombing. "Ham Fields", which is noted to have been subject to five HE bombs and a UXB, was situated throughout the site's northern and southern vicinities.
Damage *If buildings or structures on a site sustained bomb or fire damage, any resulting rubble and debris could have obscured the entry holes of unexploded bombs dropped during the same or later raids. Similarly, a high explosive bomb strike in an area of open agricultural land will have caused soil disturbance, increasing the risk that a UXB entry hole would be overlooked.*	WWII-era and post WWII aerial imagery do not appear to show any evidence of bomb damage across the site area, however it is worth noting that due to the site's largely undeveloped composition, indications of UXO may be difficult to determine in 1944 and 1946 aerial imagery, especially considering that a UXB entry hole could have been as small as 20cm in diameter and therefore easily obscured. Likewise any bomb strikes falling within the lake are likely to have been totally obscured.
Ground Cover *The nature of the ground cover present during WWII would have a substantial influence on any visual indication that may indicate UXO being present.*	During WWII, a small section of the site was occupied by structures that were part of the Ham River Grit Company. Such conditions are typically considered conducive to the detection of evidence of UXO, as entry holes and unaccounted damage would be easily visible. However, the majority of the site comprised an area of undeveloped, soft ground, gravel pits and a body of water. These types of ground cover are generally considered unconducive to the detection of evidence of UXO, as vegetation/shifting earth may prevent common indicators (such as entry holes which can be as small as 20cm in diameter), being discovered. Additionally, the waterline of the river would have completely obscured any signs of damage/indicators of entry holes.

Access Frequency *UXO in locations where access was irregular would have a greater chance of passing unnoticed than at those that were regularly occupied. The importance of a site to the war effort is also an important consideration as such sites are likely to have been both frequently visited and subject to post- raid checks for evidence of UXO.*	The north of the site was occupied by densely vegetated ground and a body of water, generally these types of areas were typically not subject to access. There is no evidence to indicate as to why the site would have been an exception. The remaining areas of the site, occupied by the grit company and the dock are likely to have been subject to regular access, if the Ham River Grit Company was in operation during the war. However, it Is difficult to assess level of access to the site, given that observation of signs of UXO within the grit works itself would have been as a result of individual discretion of the local workers.
Bomb Failure Rate	There is no evidence to suggest that the bomb failure rate in the locality of the site would have been dissimilar to the 10% normally used.
Abandoned Bombs	1st Line Defence holds no records of abandoned bombs at or within the site vicinity.
Bombing Decoy sites	1st Line Defence could find no evidence of bombing decoy sites within the site vicinity.
Bomb Disposal Tasks	1st Line Defence could find no evidence of bomb disposal tasks within the site boundary and immediate area.

13. Introduction to Allied Ordnance

13.1. General

Many areas across the UK may be at risk from Allied UXO because of both wartime and peacetime military use. Typical military activities and uses that may have led to a legacy of military UXO at a site include former minefields, home guard positions, anti-aircraft emplacements, training and firing ranges, military camps, as well as weapons manufacture and storage areas.

Although land formerly used by the military was usually subject to clearance before returned to civilian use, items of UXO are sometimes discovered and can present a potential risk to construction projects.

13.2. Land Service Ammunition

The term LSA covers items of ordnance that are propelled, placed, or thrown during land warfare. These items may be filled or charged with explosives, smoke, incendiary, or pyrotechnics and can be divided into five main groups:

Land Service Ammunition	
Item	**Description**
Mortar Rounds	A mortar round is normally nosed-fused and fitted with its own propelling charge. Its flight is stabilised by the use of a fin. They are usually tear-drop shaped (though older variants are parallel sided), with a finned 'spigot tube' screwed or welded to the rear end of the body which houses the propellant charge. Mortars are either High Explosive or Carrier (i.e. smoke, incendiary, or pyrotechnic).
Grenades	A grenade is a short range weapon designed to kill or injure people. It can be hand thrown or fired from a rifle or a grenade launcher. Grenades either contain high explosive or smoke producing pyrotechnic compounds. The common variants have a classic 'pineapple' shape.
Projectiles	A projectile (or shell) is propelled by force, normally from a gun, and continues in motion using its kinetic energy. The gun a projectile is fired from usually determines its size. A projectile contains a fuzing mechanism and a filling. Projectiles can be high explosive, carrier or Shot (a solid projectile).
Rockets	Rockets were commonly designed to destroy heavily armoured military vehicles (anti-tank weapon). The device contains an explosive head (warhead) that can be accelerated using internal propellants to an intended target. Anti-aircraft rocket batteries were also utilised as part of air defence measures.
Landmines	A landmine is designed to be laid on or just below the ground to be exploded by the proximity or contact of a person or vehicle. Landmines were often placed in defensive areas of the UK to obstruct potential invading adversaries.

In the UK unexploded or partially exploded mortars and grenades are the most common items of LSA encountered, as they could be transported and utilised anywhere. They are mostly encountered in areas used for military training and are often found discarded on or near historical military bases. Images of the most commonly found items of LSA are presented in **Appendices v - vii.**

13.3. Small Arms Ammunition

Small Arms Ammunition is being discussed within this report due to the miniature Rifle Range located on Ham Lands nature Reserve during WWII. Detailed of the range will be discussed in the following sections.
The most common type of ordnance encountered on land used by the military are items of Small Arms Ammunition (SAA). SAA refers to the complete round or cartridge designed to be discharged from varying sized hand-held weapons such as rifles, machine guns and pistols. SAA can include bullets, cartridge cases and primers/caps. Example images of the most SAA are presented in **Appendix viii.**

13.4. Defending the UK From Aerial Attack

During WWII the War Office employed a number of defence tactics against the Luftwaffe from bombing major towns, cities, manufacturing areas, ports and airfields. These can be divided into passive and active defences (examples are provided in the table below).

Active Defences	Passive Defences
• Anti-aircraft gun emplacements to engage enemy aircraft. • Fighter aircraft to act as interceptors. • Rockets and missiles were used later during WWII.	• Blackouts and camouflaging to hinder the identification of Luftwaffe targets. • Decoy sites were located away from targets and used dummy buildings and lighting to replicate urban, military, or industrial areas. • Barrage balloons forced enemy aircraft to greater altitudes. • Searchlights were often used to track and divert adversary bomber crews during night raids.

Active defences such as anti-aircraft artillery present a greater risk of UXO contamination than passive defences. Unexploded ordnance resulting from dogfights and fighter interceptors is rarely encountered and difficult to accurately qualify.

13.4.1. Anti-Aircraft Artillery (AAA)

During WWII three main types of gun sites existed: heavy anti-aircraft (HAA), light anti-aircraft (LAA) and 'Z' batteries (ZAA). If the projectiles and rockets fired from these guns failed to explode or strike an aircraft they would descend back to land. The table below provides further information on the operation and ordnance associated with these type of weapons.

Anti-Aircraft Artillery				
Item	**Description**			
HAA	These large calibre guns such as the 3.7" QF (Quick Firing) were used to engage high flying enemy bombers. They often fired large HE projectiles, which were usually initiated by integral fuzes, triggered by impact, area, time delay or a combination of aforementioned mechanisms.			
LAA	These mobile guns were intended to engage fast, low flying aircraft. They were typically rotated between locations on the perimeters of towns and strategically important industrial works. As they could be moved to new positions with relative ease when required, records of their locations are limited. The most numerous of these were the 40mm Bofors gun which could fire up to 120 x 40mm HE projectiles per minute to over 1,800m.			
Variations in HAA and LAA Ammunition	**Gun type**	**Calibre**	**Shell Weight**	**Shell Dimensions**
	3.0 Inch	76mm	7.3kg	76mm x 356mm
	3.7 Inch	94mm	12.7kg	94mm x 438mm
	4.5 Inch	114mm	24.7kg	114mm x 578mm
	40mm	40mm	0.9kg	40mm x 311mm
Z-AA	The three inch unrotated rocket/projectile known as the UP-3 had initially been developed for the Royal Navy. The UP-3 was also used in ground-based single and 128-round launchers known as ''Z'' batteries. The rocket, containing a high explosive warhead was often propelled by cordite.			

The conditions in which anti-aircraft projectiles may have fallen unnoticed within a site area are analogous to those regarding air delivered ordnance. Unexploded anti-aircraft projectiles could essentially have fallen indiscriminately anywhere within range of the guns. The chance of such items being observed, reported and removed during the war depends on factors such as land use, ground cover, damage and frequency of access – the same factors that govern whether evidence of a UXB is likely to have been noted. More information about these factors with regards to this particular site can be found in the German Air Delivered Ordnance section of this report.

Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented at **Appendix iv**.

14. The Likelihood of Contamination from Allied Ordnance

14.1. Introduction

When undertaking construction work within or immediately adjacent to a site with previous and/or current military use, it is often considered likely to contain an elevated risk of contamination from Allied UXO. This assumption of risk is based on the following reasoning:

- The clearance of ordnance from military camps, depots, storage facilities, ranges and training areas were not always effectively managed, or undertaken to equivalent degrees of certainty. In addition, search and detection equipment used over seventy years ago following WWII has proved ineffective both for certain types of UXO and at depths beyond capability.
- In the vast majority of cases, explosive ordnance would have been stored and available for use at military installations. Ordnance ranged from small arms and land service ammunition to weapons components and larger, air delivered items. During periods of heightened activity, ordnance was also frequently lost in transit, particularly between stores and assigned training locations.
- The military generally did not anticipate that their land would be later sold for civilian development, and consequently appropriate ordnance disposal procedure was not always adhered to. It was not uncommon for excess or unwanted ordnance to be buried or burnt within the perimeters of a military establishment as a means of disposal. Records of such practice were rarely kept.

There are several factors that may serve to either affirm, increase, or decrease the level of risk within a site with a history of military usage. Such factors are typically dependent upon the proximity of the proposed area of works to training activities, munition productions and storage, as well as its function across the years.

This section will examine the history of the proposed site and assess to what degree, if any, the site could have become contaminated as a result of the military use of the surrounding area.

14.2. The Ham and Petersham Rifle and Pistol Club.

Available in house records indicate that a rifle range was located approximately 300m east of the site area, within Ham Lands, labelled on **Annex P**. The Rifle Range was founded in 1906 although it is thought it began in 1903. Charles Hanbury-Tracy, the 4th Lord Sudeley was President of the Ham & Petersham Rifle & Pistol Club from 1906. It has six outdoor ranges for archery, air guns, rifles and Black Powder pistols. During WWI it was used for army training and more than 24,000 recruits took their first course in firing there.[6] The Surrey Comet praised the club for its 'invaluable work during the war'. It did so again in WWII and, to this day, still has links with the Ministry of Defence, government and military police, enabling them to use it for training.[7]

[6] *https://hamiswheretheheartis.com/ham-by-topic/leisure/sport/rifle-and-pistol-shooting/*
[7] *https://livinginmagazines.co.uk/the-history-of-ham-petersham-rifle-pistol-club-2/*

14.3. Evaluation of Contamination Risk from Allied UXO

1st Line Defence has considered the following potential sources of Allied ordnance contamination:

Sources of Allied UXO Contamination	Conclusion
Military Camps *Military camps present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training.*	1st Line Defence could find no evidence of a military camp within the site.
Anti-Aircraft Defences *Anti-Aircraft defences were employed across the country. Proximity to anti-aircraft defences increases the chance of encountering AA projectiles.*	1st Line Defence could find no evidence of Anti-Aircraft defences such as a HAA or LAA gun emplacement occupying or bordering the site. The closest HAA was located approximately 4.2km east of the site. Despite this distance the maximum effective range of an AA projectile can be up to 15km. The conditions in which HAA or LAA projectiles may have fallen unnoticed within a site footprint are generally analogous to those regarding German air delivered ordnance.
Home Guard Activity *The Home Guard regularly undertook training and ordnance practice in open areas, as well as burying ordnance as part of anti-invasion defences.*	Online source indicate that there was Home Guard activity in the wider Richmond area. Richmond Home Guard comprised about 140 men divided into 3 platoons who usually trained in Richmond Park (which was closed to the public for the duration) or on Ham Common, located approximately 1.6km east and 900m southeast of the site respectively.[8] Although details regarding Home Guard activities on Ham Common are limited, sources indicate that by the end of November 1942, 'invasion exercises' were being performed in the area.[9] It is not known what these involved or whether they occurred on-site. Evidence of Home Guard activity is often difficult to locate, owing to the ad-hoc nature of Home Guard activity within each local area. Such training was often conducted on a small scale at the discretion of individual commanders and as such was seldom recorded officially.
Defensive Positions *Defensive positions suggest the presence of military activity, which is often indicative of ordnance storage, usage or disposal.*	There is no evidence of any pillbox, emplacement or other defensive features formerly located on or bordering the site footprint.

[8] *https://hamiswheretheheartis.com/ham-by-topic/ham-at-war-wars-national-service/ham-during-the-war-1939-1945/*
[9] *http://sussexhistoryforum.co.uk/index.php?topic=7323.0*

Training or firing ranges *Areas of ordnance training saw historical ordnance usage in large numbers, often with inadequate disposal of expended and live items. The presence of these ranges significantly impact on the risk of encountering items of ordnance in their vicinity.*	No evidence of training or firing ranges could be found within the site itself. Nonetheless, the Ham and Petersham Rifle and Pistol Club firing range was located approximately 300m east of the site, in Ham Lands. Aforementioned online sources indicate that 24,000 troops conducted firing training on the range during WW1 and this usage continued into WWII. The presence and the position of this range increases the risk of military UXO contamination with the site area, Ham Lands or the Lake occupying the centre of the site area due to the possibility of ordnance not being properly disposed of. This could take the form of items being discarded by methods of burying or discarding them in the river. Further anecdotal evidence has been found of examples such as Osterley Park, indicating that military personnel were not often disposed of weapons and ammunition in this manner.
Defensive Minefields *Minefields were placed in strategic areas to defend the country in the event of a German invasion. Minefields were not always cleared with an appropriate level of vigilance.*	There is no evidence of defensive minefields affecting the site.
Ordnance Manufacture *Ordnance manufacture indicates an increased chance that items of ordnance were stored, or disposed of, within a location.*	No information of ordnance being stored, produced, or disposed of within the proposed site could be found.
Military Related Airfields *Military airfields present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training or bombing practice.*	The site was not situated within the perimeters or vicinity of a military airfield.

15. The Likelihood of UXO Contamination Summary

The following table assesses the likelihood that the site was contaminated by items of German air delivered and Allied ordnance. Factors such as the risk of UXO initiation, remaining, and encountering will be discussed later in the report.

UXO Contamination Summary	
Quality of the Historical Record	The research has evaluated pre- and post-WWII Ordnance Survey maps, Luftwaffe reconnaissance imagery, official Home Office bombing statistics, London Census Bomb and V weapon mapping, Bomb Census reports, Richmond incident records, anecdotal and literary sources and post-war aerial imagery. The record set is of generally good quality, pre-war imagery was available to discern the sites pre and post-war conditions, plus, regional and local bomb mapping generally corroborates. However, no fully comprehensive record set exists for Richmond and although the incident records report bombing incidents within the site area, no exact locations were provided, proving problematic for plotting these strikes in relation to the site area. Significantly, at least two incidents recorded within written records were not plotted on regional or local bomb maps.
German Air Delivered Ordnance	• During WWII the site was located within the Municipal Borough of Richmond, which sustained an overall moderate-high density of bombing with an average of 96.6 incidents recorded per 1,000 acres (**Annex I**). This is likely owed to the borough's proximity to several viable Luftwaffe targets within the wider area of the site, including the Richmond Water Works, Gas Works and Hawker Hurricane factory, located approximately 2.9km, 3km and 3.2km south of the site respectively (highlighted within Luftwaffe target imagery within **Annex J**). • Historical OS maps show that during WWII, the site comprised open ground, a body of water, a dock and a sand and gravel works. • London Bomb Census maps and a local 'Bombs on Richmond 1940-1945' bomb map do not record any incidents on-site. Nonetheless, these sources corroborate in recording a large number of incidents throughout the wider vicinity. This includes two 'sticks' of bombs: one each located to the north and south of the site. • Incident Records for Richmond corroborates with mapping in reporting bombing across "Ham Fields", fields opposite Eel Pie Island, and the Ham River Grit Company. The latter was situated on-site and was noted within this source as having been subjected to a large amount of incendiary bombing. "Ham Fields", which is noted as the location of five HE bombs and a UXB, was situated throughout the site's northern and southern vicinities. • 1944 and 1946 WWII-era and post-war imagery do not show any obvious signs of bomb damage, such as cratering or ground clearance, within the structures occupying the gravel and sand works in the south-west of the site. However, it is worth noting that the majority of ground cover across the site comprised a body of water. Given this, it is not possible to accurately identify potential damage across the majority of the site, as typical damage indicators would have been obscured altogether by the waterline. • Access to the majority of the site area is difficult to assess, given that the majority of the site was undeveloped and occupied by a body of water, sites possessing such conditions are generally not considered to have been frequently accessed. The extent to which the on-site grit works would have been accessed/monitored is also difficult to assess and would have likely relied on the vigilance of those using the area. • In summary, the on-site Ham River Grit Company was noted to have been struck by incendiary bombs on two occasions, while a large number of HE bombs were recorded throughout the wider vicinity which included two 'sticks' of bombs, one of which contained a UXB. While no HE bombs were recorded on-site, it is of

	concern that this scale of bombing was occurring over a site which was predominately occupied by a body of water. Open bodies of water are concerning because it is generally very unlikely that unexploded bombs falling within such areas would have been recorded or dealt with; they would have left little to no little evidence of their presence, and unless UXO was spotted entering the water it is likely to have been noticed during a raid. Much of the remainder of the site was occupied by open marshy land, which is also considered unconducive towards the observation of UXO given the increased potential for UXB entry holes to be obscured by mud/overgrowth. Therefore, the potential for further incidents to have fallen on/around the site unreported cannot be reduced. For this reason, proactive risk mitigations measures are considered necessary. As such, the site has been assessed as **Medium Risk** from German air delivered ordnance. *If works are to be undertaken within the body of water, it is advised that 1st Line Defence Ltd be contacted.*
Allied Ordnance	• Online sources indicate that a rifle and pistol range was located 300m east of the site during WWII and that there was a Home Guard (HG) presence within the wider area of the site in areas such as Ham Common and Richmond Park. • Online sources indicate that there was a HG presence within the wider area of the site, in areas such as Ham Common and Richmond Park, located approximately 2km east and 900m southeast of the site. Although details regarding Home Guard activities on Ham Common are limited, sources indicate that by the end of November 1942, 'anti-invasion' exercises were being performed in the area.[10] It is not known what these involved or whether they occurred on-site. • The aforementioned range was recorded to have trained over 24,000 personnel during WWI and was also requisitioned by the military during WWII. Examples of items of ordnance being discarded or improperly destroyed have been found across the UK and could have taken the form of items being discarded by methods of burying, negligent or accidentally discarding them in the river. Nonetheless, it should be emphasized that there is no conclusive evidence of this occurring within Ham Common. In addition, as there is a distance of 300m between this range and the site, the likelihood of contamination from this source is not considered significant. • In summary, a rifle range was located in the wider vicinity of the site. This facility was utilized during both world wars and is noted to have trained over 24,000 personnel. Also of note is a local Home Guard presence how were known to have performed 'anti-invasion' exercises. As a result of such activities occurring in the wider vicinity of the site, the risk of contamination from these sources cannot be entirely reduced. However, while these were occurring in the wider area, no conclusive evidence was found to suggest that the site itself was being used for either Home Guard activities or as a disposal area. As a result the potential risk is not considered significant enough for proactive risk mitigation measures to be recommended. Due to these factors, the site is therefore considered to be of **Low-Medium Risk** from historic Allied UXO.

[10] *http://sussexhistoryforum.co.uk/index.php?topic=7323.0*

16. The Likelihood that UXO Remains

16.1. Introduction

It is important to consider the extent to which any explosive ordnance clearance (EOC) activities or extensive ground works have occurred on site. This may indicate previous ordnance contamination or reduce the risk that ordnance remains undiscovered.

16.2. UXO Clearance

1st Line Defence has found no evidence in the public domain or within internal records that any official ordnance clearance operations have taken place on site. Note however that we have not received confirmation of this fact from the 33 EOD Regiment Archive (now part of 29 EOD & Search Group). It should also be noted that in addition to 29 EOD & Search Group archival information, 1st Line Defence also do not currently have access to data that may be relevant including 5131(BD)SQN Archive, SD Training Technical Advisory Section (TAS) and MACA Records (bomb disposal callouts).

If such information is available at a later date, it is recommended that it be reviewed as it will assist with understanding both levels and types of contamination likely to be present, and may indicate risk reduction in certain areas.

16.3. Post-War Redevelopment

Post war, recent aerial imagery shows that the site has been substantially developed, including the infilling of the grit works immediate south of the site and development of an outdoor education facility called *Thames Young Mariners*.

The risk of UXO remaining is considered to be mitigated at the location of and down to the depth of any post-war redevelopment on site. For example, the risk from deep buried UXO will only have been mitigated within the volumes of any post-war pile foundations or deep excavations for basement levels. The risk will however remain within virgin geology below and amongst these post-war works, down to the maximum bomb penetration depth.

17. The Likelihood of UXO Encounter

17.1. Introduction

For UXO to pose a risk at a site, there should be a means by which any potential UXO might be encountered on that site.

The likelihood of encountering UXO on the site of proposed works would depend on various factors, such as the type of UXO that might be present and the intrusive works planned on site. In most cases, UXO is more likely to be present below surface (buried) than on surface.

In general, the greater the extent and depth of intrusive works, the greater the risk of encountering. The most likely scenarios under which items of UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations.

Generally speaking, the risk of encountering any type of UXO will be minimal for any works planned within the footprint and down to the depth of post-war foundations and excavations.

17.2. Encountering Air Delivered Ordnance

Since an air delivered bomb may come to rest at any depth between just below ground level and its maximum penetration depth, there is a chance that such an item (if present) could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level as well as at depth.

17.3. Land Service/Small Arms Ammunition Encounter

Items of LSA and SAA are mostly encountered in areas previously used for military training. Such items could have been lost, burnt, buried or discarded during being in use by the military. Due to this, LSA are most likely to be encountered at relatively shallow depths – generally in the top 1m below ground level. Therefore, such items are most likely to be encountered during open excavation works. In some cases, there is the potential that LSA or SAA may be present on the surface of the ground – especially in areas with active military use or were recently in use by the MoD.

18. The Likelihood of UXO Initiation

18.1. Introduction

UXO does not spontaneously explode. Older UXO devices will require an external event/energy to create the conditions for detonation to occur. The likelihood that a device will function can depend on a number of factors including the type of weaponry, its age and the amount of energy it is struck with.

18.2. Initiating Air Delivered Ordnance

Unexploded bombs do not spontaneously explode. All high explosive filling requires significant energy to create the conditions for detonation to occur.

In recent decades, there have been a number of incidents in Europe where Allied UXBs have detonated, and incidents where fatalities have resulted. There have been several hypotheses as to the reason why the issue is more prevalent in mainland Europe – reasons could include the significantly greater number of bombs dropped by the Allied forces on occupied Europe, the preferred use by the Allies of mechanical rather than electrical fuzes, and perhaps just good fortune. The risk from UXO in the UK is also being treated very seriously in many sectors of the construction industry, and proactive risk mitigation efforts will also have affected the lack of detonations in the UK.

There are certain construction activities which make initiation more likely, and several potential initiation mechanisms must be considered:

UXB Initiation	
Direct Impact	Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g. from piling or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Such violent action can cause the bomb to detonate.
Re- starting the Clock	A small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion would have taken place within the fuze mechanism over the last 70+ years that would prevent clockwork mechanisms from functioning. Nevertheless, it was reported that the clockwork fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-start.
Friction Impact	The most likely scenario resulting in the detonation of a UXB is friction impact initiating the shock-sensitive fuze explosive. The combined effects of seasonal changes in temperature and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive which could detonate the main charge.

18.3. Land Service /Small Arms Ammunition Initiation

Items of LSA generally do not become inert or lose their effectiveness with age. Time can cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays, or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

If left alone, an item of LSA will pose little/no risk of initiation. Therefore, if it is not planned to undertake construction/intrusive works at the site, the risk of initiation of any LSA that may be present would be negligible. Similarly, those accessing a contaminated area would be at minimal risk if they do not interfere with any UXO present on the ground. Clearly for many end uses, however, the presence of UXO anywhere on a site would not be acceptable as it could not be guaranteed that the items will not be handled, struck or otherwise affected, increasing the likelihood of initiation.

Items of SAA are much less likely to detonate than LSA or UXBs, but can be accidentally initiated by striking the casing, coming into contact with fire, or being tampered with/dismantled. It is likely that the detonation of an item of SAA would result in a small explosion, as the pressure would not be contained within a barrel. Detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

19. Consequences of Initiation/Encounter

19.1. Introduction

The repercussions of the inadvertent detonation of UXO during intrusive ground works, or if an item or ordnance is interfered with or disturbed, are potentially profound, both in terms of human and financial cost. A serious risk to life and limb, damage to plant and total site shutdown during follow-up investigations are potential outcomes. However, if appropriate risk mitigation measures are put in place, the chances of initiating an item of UXO during ground works is comparatively low.

The consequences of encountering UXO can be particularly notable in the case of high-profile sites (such as airports and train stations) where it is necessary to evacuate the public from the surrounding area. A site may be closed for anything from a few hours to a week with potentially significant cost in lost time. It should be noted that even the discovery of suspected or possible item of UXO during intrusive works (if handled solely through the authorities), may also involve significant loss of production.

19.2. Consequences of Detonation

When considering the potential consequences of a detonation, it is necessary to identify the significant receptors that may be affected. The receptors that may potentially be at risk from a UXO detonation on a construction site will vary depending on the site specific conditions but can be summarised as follows:

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

20. 1st Line Defence Risk Assessment

20.1. Risk Assessment Stages

Taking into account the quality of the historical evidence, the assessment of the overall risk from unexploded ordnance is based on the following five considerations:

1. That the site was contaminated with unexploded ordnance.
2. That unexploded ordnance remains on site.
3. That such items will be encountered during the proposed works.
4. That ordnance may be initiated by the works operations.
5. The consequences of encountering or initiating ordnance.

20.2. Assessed Risk Level

1st Line Defence has assessed that there is an overall **Medium Risk** from German and anti-aircraft unexploded ordnance at the site of proposed works. There is also an assessed **Low- Medium Risk** from Allied unexploded ordnance.

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German Unexploded HE Bombs			✓	
German 1kg Incendiary Bombs			✓	
Anti-Aircraft Artillery Projectiles			✓	
Allied Land Service and Small Arms Ammunition		✓		

This report has been undertaken with due diligence, and all reasonable care has been taken to access and analyse relevant historical information. By necessity, when dealing historical evidence, and when making assessments of UXO risk, various assumptions have to be made which we have discussed and justified throughout this report. Our reports take a common-sense and practical approach to the assessment of risk, and we strive to be reasonable and pragmatic in our conclusions.

It should however be stressed that if any suspect items are encountered during the proposed works, 1st Line Defence should be contacted for advice/assistance, and to re-assess the risk where necessary. The mitigation measures outlined in the next section are recommended as a minimum precaution to alert ground personnel to the history of the site, what to look out for, and what measures to take in the event that a suspect item is encountered. It should also be noted that the conclusions of this report are based on the scope of works outlined in the 'Proposed Works' section of this report. Should the scope of works change or additional works be proposed, 1st Line Defence should be contacted to re-evaluate the risk.

21. Proposed Risk Mitigation Methodology

21.1. General

The following risk mitigation measures are recommended to support the proposed works at Thames Young Mariners, Richmond

Type of Work	Recommended Mitigation Measure
All Works	• **UXO Risk Management Plan** It is recommended that a site-specific plan for the management of UXO risk be written for this site. This plan should be kept on site and be referred to in the event that a suspect item of UXO is encountered at any stage of the project. It should detail the steps to be taken in the event of such a discovery, considering elements such as communication, raising the alarm, nominated responsible persons etc. Contact 1st Line Defence for help/more information. • **Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.** As a minimum precaution, all personnel working on the site should be briefed on the basic identification of UXO and what to do in the event of encountering a suspect item. This should in the first instance be undertaken by a UXO Specialist. Posters and information on the risk of UXO can be held in the site office for reference.
Shallow Intrusive Works/Open Excavations	• **Unexploded Ordnance (UXO) Specialist Presence on Site to support shallow intrusive works** When on site the role of the UXO Specialist would include: • Monitoring works using visual recognition and instrumentation, including immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by the ground workers on site. • Providing UXO awareness briefings to any uninformed staff and advise staff of the need to modify working practices to take account of the ordnance risk. • To aid incident management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard.
Borehole/Piles	• **Intrusive Magnetometer Survey of all borehole and pile locations down to a maximum bomb penetration depth:** 1st Line Defence can deploy a range of intrusive magnetometer techniques to clear pile locations. The appropriate technique is influenced by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed.

In making this assessment and recommending these risk mitigation measures, if known, the works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified or additional intrusive engineering works be considered, 1st Line Defence should be consulted to see if a re-assessment of the risk or mitigation recommendations is necessary.

1st Line Defence Limited **16/09/22**

This Report has been produced in compliance with the Construction Industry Research and Information Association (CIRIA) C681 guidelines for the writing of Detailed UXO Risk Assessments.

Bibliography

- Bates, H. E., *Flying Bombs over England*, Frogletts Publications Ltd., 1994
- Clarke, N. J., *Adolf Hitler's Holiday Snaps: German Aerial Reconnaissance Photography of London and the Home Counties 1939 – 1943*, N. J. Clarke Publications., 1996
- Clarke, N. J., *Adolf Hitler's Holiday Snaps: German Aerial Reconnaissance Photography of Southern England 1939 – 1943*, N. J. Clarke Publications., 1995
- Clarke, N. J., *Adolf's British Holiday Snaps: Luftwaffe Aerial Reconnaissance Photographs of England, Scotland and Wales*, Fonthill Media Ltd., 2012
- Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, Methuen., 2001
- Fegan, T., *The 'Baby Killers': German Air raids on Britain in the First World War*, Leo Cooper Ltd., 2002
- Fleischer, W., *German Air-Dropped Weapons to 1945,* Midland Publishing., 2004
- Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, Channel 4 Books., 2001
- Morris, J., *German Air Raids on Britain: 1914 – 1918*, The Naval & Military Press., 1993
- Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, Purnell Book Services Ltd., 1977
- Ramsey, W., *The Blitz Then and Now, Volume 1*, Battle of Britain Prints International Ltd., 1987
- Ramsey, W., *The Blitz Then and Now, Volume 2*, Battle of Britain Prints International Ltd., 1988
- Ramsey, W., *The Blitz Then and Now, Volume 3*, Battle of Britain Prints International Ltd., 1990
- Scofield, J., *Modern Military Matters*., Council for British Archaeology., 2004
- Stone, K., et al., *Unexploded Ordnance (UXO) A Guide For The Construction Industry (C681)*., CIRIA, 2009
- Whiting, C., *Britain Under Fire: The Bombing of Britain's Cities 1940-1945*, Pen & Sword Books Ltd., 1999

This report has been prepared by 1st Line Defence Limited with all reasonable care and skill. The report contains historical data and information from third party sources. 1st Line Defence Limited has sought to verify the accuracy and comprehensiveness of this information where possible but cannot be held accountable for any inherent errors. Furthermore, whilst every reasonable effort has been made to locate and access all relevant historical information, 1st Line Defence cannot be held responsible for any changes to risk level or mitigation recommendations resulting from documentation or other information which may come to light at a later date.

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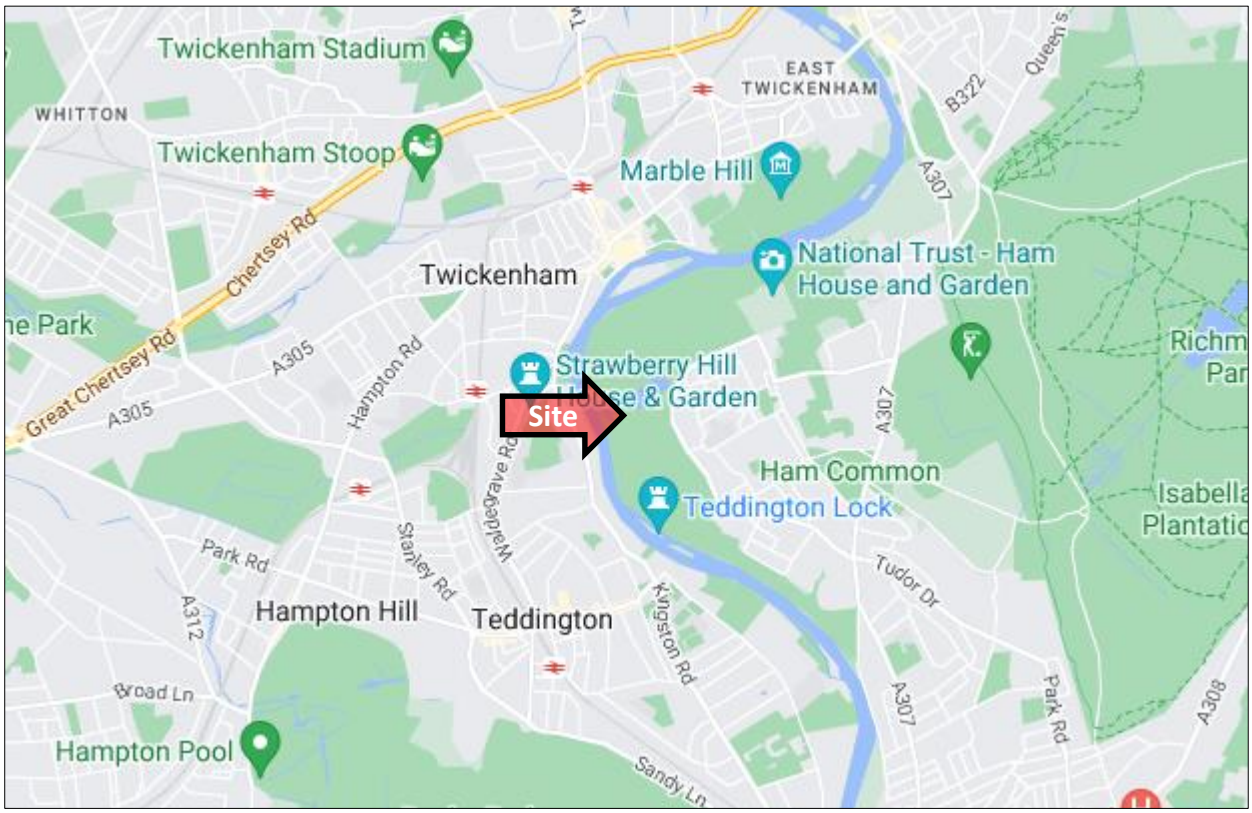
Site Location Maps

Annex: **A**



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Client: **Soils Limited**

Approximate site boundary

N

Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: Google Maps

Recent Aerial Photography

Annex: **B**

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Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: Google Earth ™ Mapping Services

Client Provided Site Plan

Annex: **C**

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Approximate site boundary

N

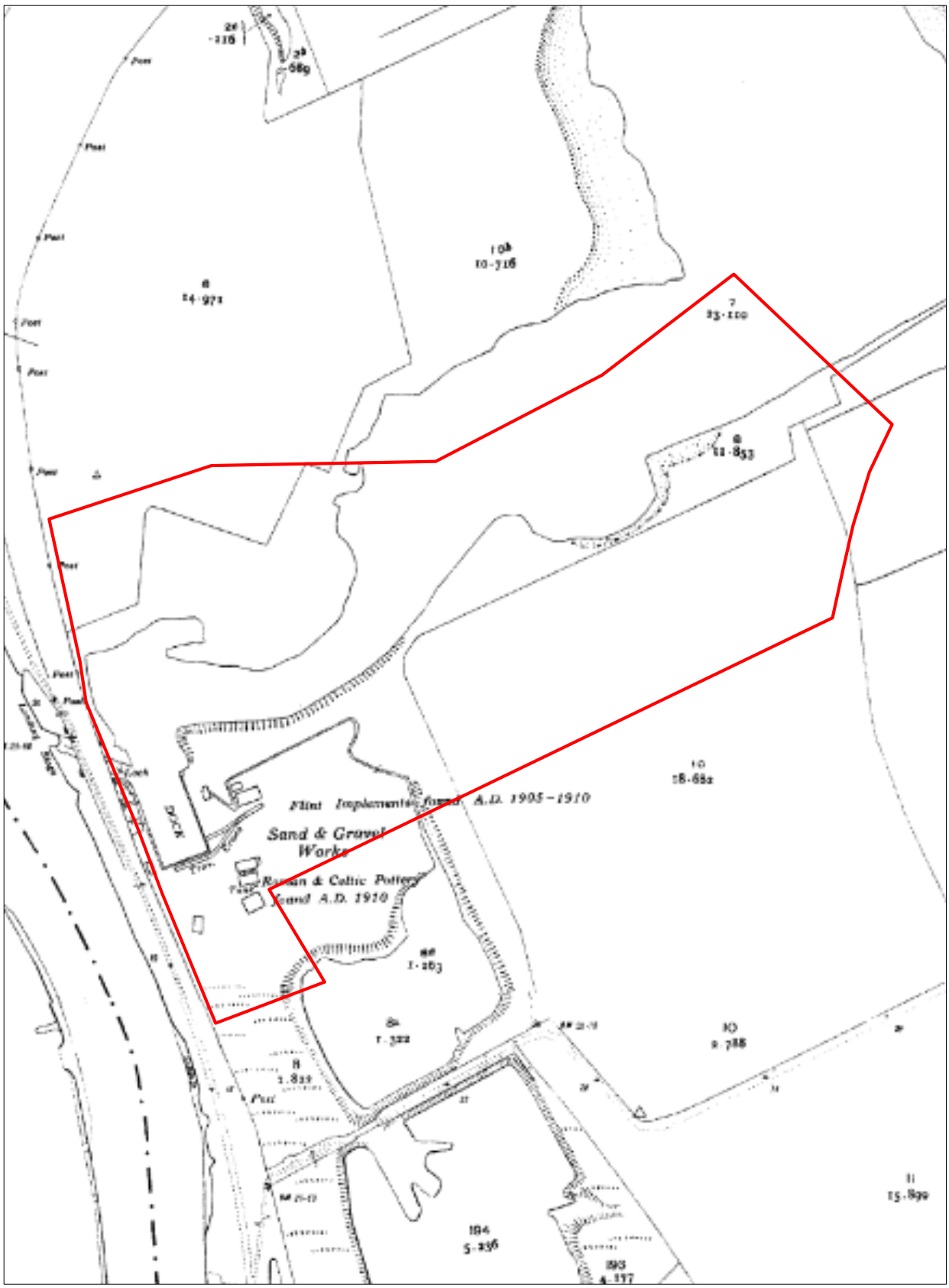
Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: Soils Limited

Pre-WWII 1934 – 1935 1:2500 Historical Map

Annex: D1



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Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

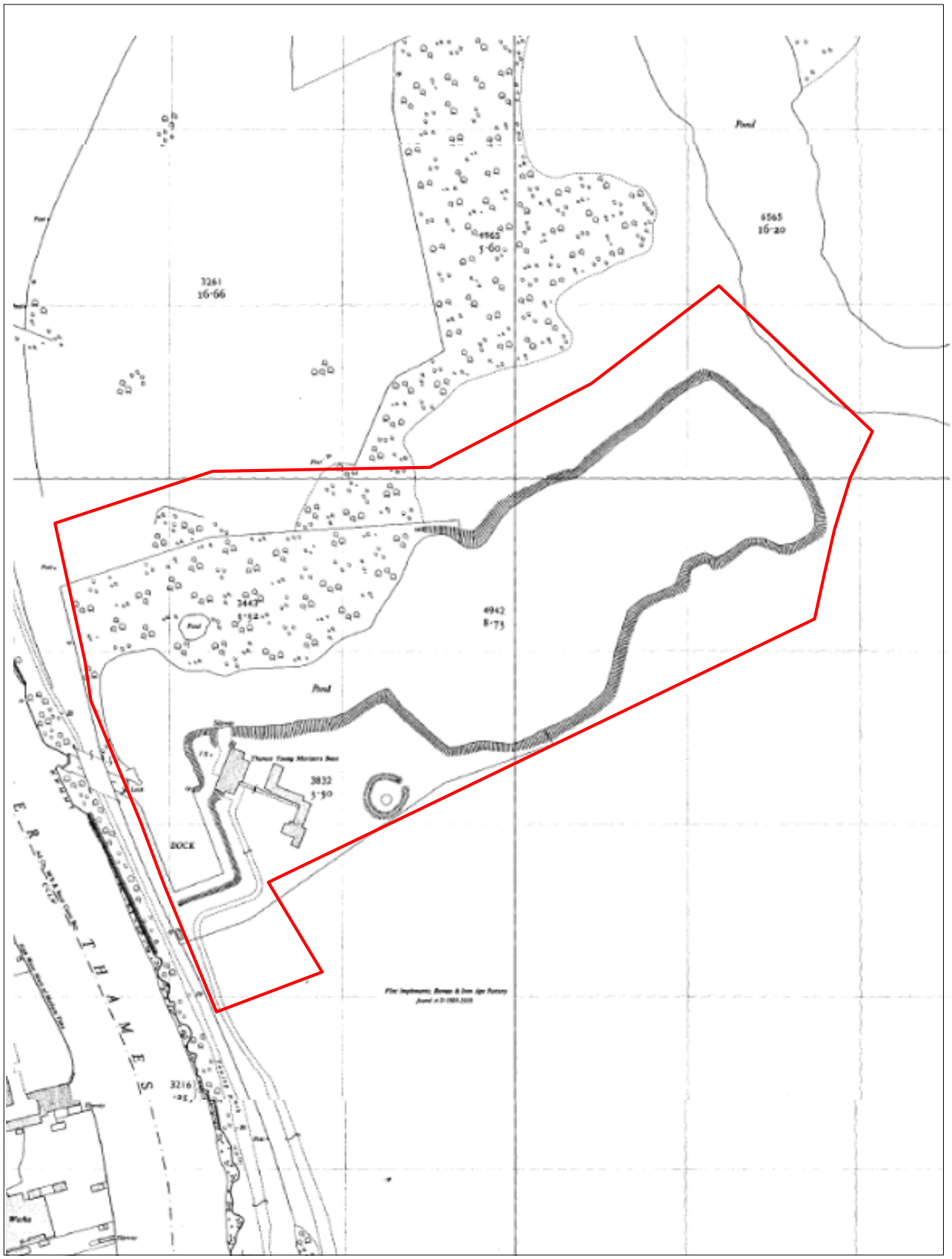
Source: Landmark Maps

Approximate site boundary

N

Post-WWII 1960-1962 1:2500 Historical Map

Annex: D2



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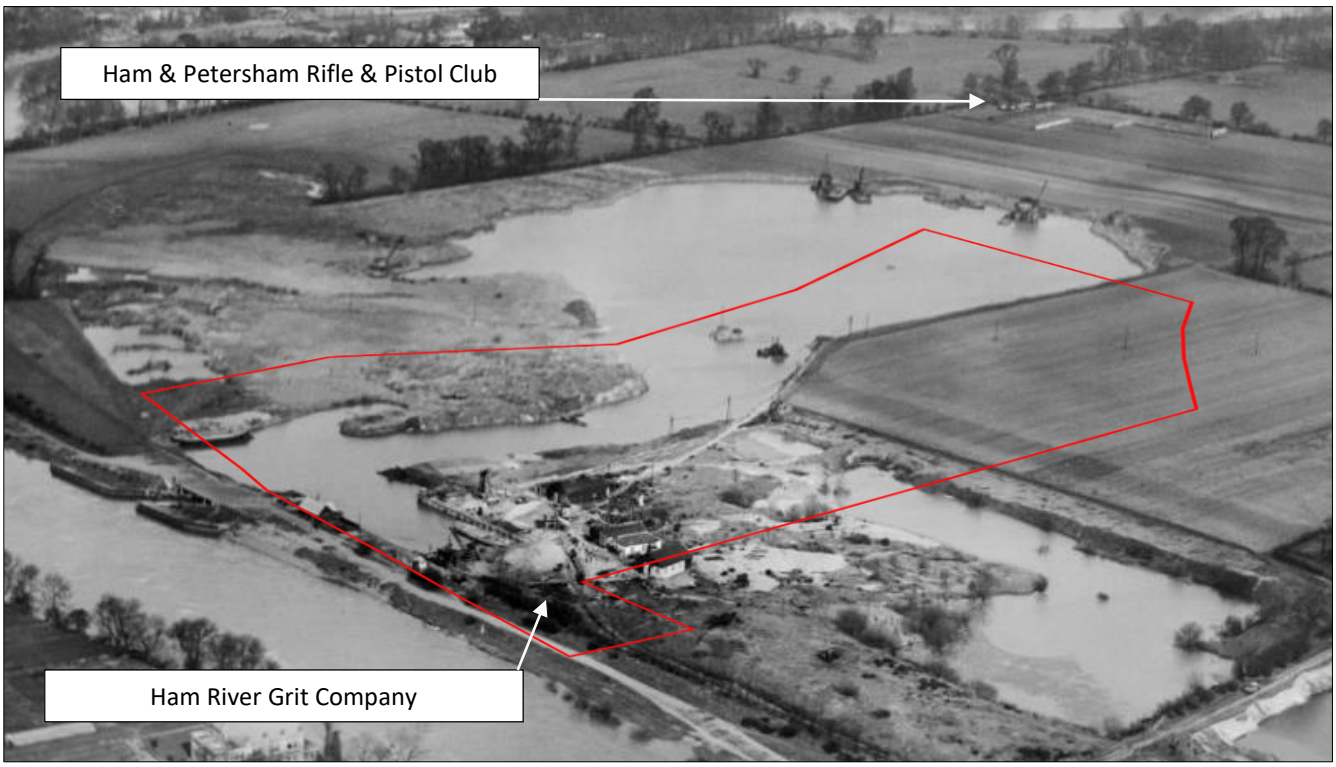
Source: Landmark Maps

Approximate site boundary

N

The Ham River Grit Company, Richmond Upon Thames, 1927



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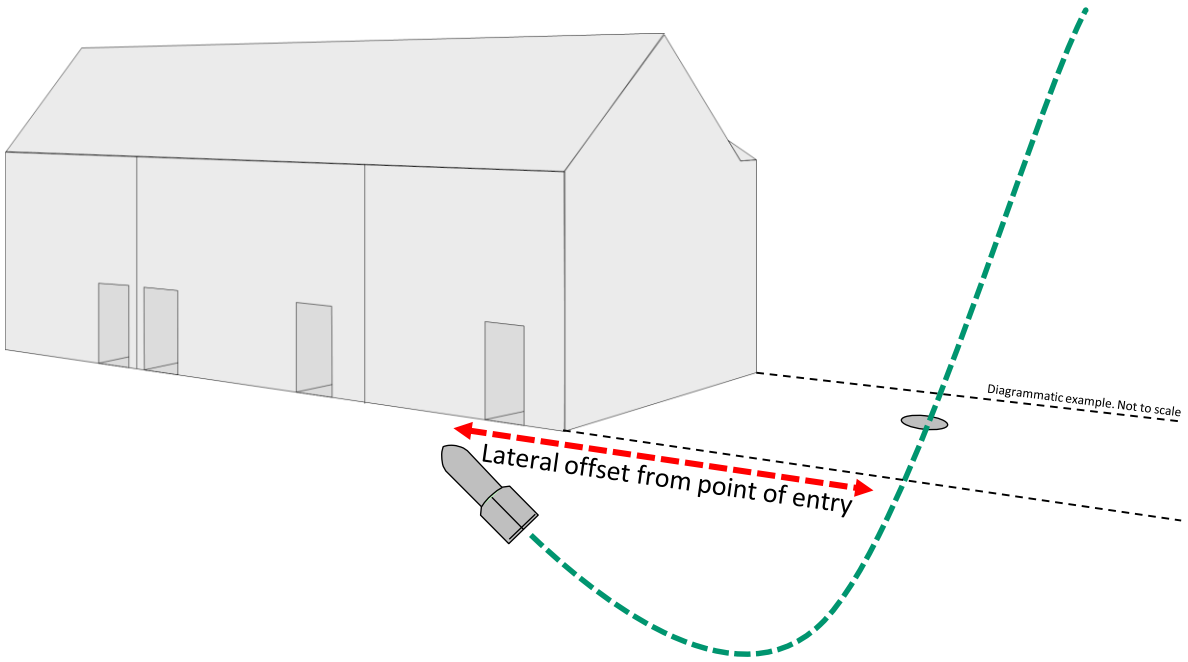
Approximate site boundary

Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: EPW017370 Britain from Above

Example of UXO Entry Hole / The 'J-curve' Effect Principle



Top: J-curve Effect - Due to angle of entry, unexploded bombs would often end their trajectory at a lateral offset from point of entry, often ending up beneath adjacent extant structures/sites. The photograph above shows 250kg bomb found in Bermondsey pointing upwards, demonstrating 'J-curve'

One of the most common scenarios for UXO going unnoticed was when a UXB fell into a 'bomb site' (such as the area shown **Top Left**), the entry hole of the bomb obscured by any debris and rubble present. Note that the entry hole of a 50kg UXB could be as little as 20cm in diameter (**Left**).

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Project:	**Thames Young Mariners, Richmond**		
Ref:	**DA15987-00**	Source:	Various sources

BBC NEWS

Bermondsey bomb: World War Two device safely removed

An unexploded World War Two bomb found in south London has been driven away safely under police and Army escort.

The 500lb (250kg) device was found on a building site in Grange Walk, Bermondsey on Monday.

March 2015

BBC NEWS

Bethnal Green WW2 bomb: Experts remove unexploded device

An unexploded World War Two bomb that prompted the evacuation of 700 people in east London has been made safe and removed by the military.

Families spent the night in a school hall after the 500lb bomb was found in the basement of a building site on Temple Street, in Bethnal Green, on Monday afternoon.

A 200m (650ft) exclusion zone was set up around the device.

August 2016

BBC NEWS

Bath WW2 bomb scare: Device defused, police say

A 500lb World War Two bomb found on the site of a former school in Bath has been defused and made safe.

The discovery of the bomb on Thursday **led to the evacuation of hundreds of homes** and many road closures in the Lansdown area of the city.

A cordon around the site was lifted on Friday evening, more than 24 hours after residents were asked to leave their homes.

May 2016

BBC NEWS

London City Airport reopens after WW2 bomb moved

London City Airport has reopened after an unexploded 500kg World War Two bomb was safely moved from the area.

The device was discovered at the King George V Dock on Sunday during planned work at the east London airport.

All flights were cancelled on Monday after an exclusion zone was put in place, **with the closure affecting up to 16,000 passengers and nearby residents being evacuated from their homes.**

May 2015

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Source: BBC News

Examples of Unexpected Detonation of WWII Bombs

Annex: **G2**

BASF has confirmed that an explosive device, most likely a World War II-era bomb, caused the blast that left one person injured Tuesday at a plant construction site in Germany.

The explosion was reported at BASF's Ludwigshafen toluene diisocyanate (TDI) plant, which recently broke ground for a 300,000 metric tons per year TDI production plant and other construction to expand its facilities.

BASF Provides Some Details

Responding to a request from *PaintSquare News* for more information on Wednesday (Feb. 27), BASF's manager of media relations and corporate communications Europe, Ursula von Stetten, wrote in an email, "So here [are] the facts: The detonation took place at 10:00 a.m. One person was injured; the injury is not serious. He will be kept in the hospital for some days.

"Cause of the detonation was an explosive device, presumably a bomb deriving from the Second World War. The device detonated when grounding work was done. No details on [a] delay [are] available. At the moment, the exact circumstances of the incident are [being] evaluated."

1st March 2013

SPIEGEL ONLINE

Blast Kills One

World War II Bomb Explodes on German Motorway

A highway construction worker in Germany accidentally struck an unexploded World War II bomb, causing an explosion which killed him and wrecked several passing cars.

A World War II bomb has exploded during construction work on a German highway, killing one worker and injuring several motorists who were driving past, police said.

The worker had been cutting through the road surface near the south-western town of Aschaffenburg when his machine struck the bomb and triggered it. Police said they weren't sure yet what type of bomb it was. "The explosion seems to have been too small for it to have been an aircraft bomb," a police spokesman said.

23rd October 2006

WWII bomb injures 17 at Hattingen construction site

Seventeen people were injured on Friday when a construction crew unwittingly detonated a buried World War II-era bomb in Hattingen.

An excavator apparently drove over a 250-kilogramme (550 pound) American bomb, damaging surrounding buildings. Most of the injured suffered auditory trauma from the blast, and the excavator operator suffered injuries to his hands, police in the German state of North Rhine-Westphalia said.

"The hole was astoundingly small for such a large bomb full of so many explosives," Armin Gebhard, head of the Arnsberg department for military ordnance removal, told The Local. "But of course it damaged all the surrounding buildings too. We are really happy it wasn't worse."

19th September 2013

BBC NEWS

World War II bomb kills three in Germany

A special commission is investigating the causes of the explosion, while prosecutors are considering whether the team leader should face charges of manslaughter through culpable negligence, the BBC's Oana Lungescu reports from Berlin.

The blast happened an hour before the defusing operation was due to start.

Officials said the three men who died were experienced sappers, or combat engineers, who over 20 years had defused up to 700 bombs.

More than 7,000 people were immediately evacuated when the 500kg bomb was found. Several schools, a kindergarten and local companies remain closed.

2nd June 2010

June 2006

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Ref: **DA15987-00**

Source: Various news sources

Unexploded Second World War bomb discovered under Somerset footpath

By Western Daily Press | Posted: January 21, 2014

The unexploded bomb was found in Somerset

Comments (0)

An unexploded bomb dropped in Britain during the Second World War has finally been discovered – underneath a popular footpath in Somerset.

Unexploded WW2 bomb found at Kenfig Pool, Bridgend

23 August 2014 Last updated at 15:01

Dean Smith believes the shell was made in Germany

Bomb experts have been called to a south Wales nature reserve after an unexploded World War Two shell was discovered by a walker in Bridgend.

Dean Smith, 38, of Pyle, was walking near Kenfig Pool on Saturday when he saw a fin sticking out of the sand.

He reached down to pick it up, but ending up falling and landed with the 2ft-long (0.6m) bomb on top of him.

The site has been cordoned off by police and the Royal Logistics Corps will carry out a controlled explosion.

Related Stories

'Panic' as dog nearly thrown grenade

WW2 bomb found at wind farm exploded

WWII bomb found in kitchen cupboard

Mortar thought to be from WWII found on Oshawa's Camp-X grounds

August 24, 2016 | 5:42 am

What is believed to be a World War II mortar has been discovered in south Oshawa. A man out in Intrepid Park, the site of the Camp-X Second World War training grounds, discovered the round with his metal detector on Tuesday evening. Durham police are held the scene overnight awaiting military officials from Trenton to come and properly detonate the mortar.

Unexploded bomb found in farmer's field

17 May 2010

A live Second World War mortar shell was blown up by Army experts after a farmer found it in his field.

The discovery was made in the field alongside the A20 between Folkestone and Dover.

The mortar shell, which was around a foot long and 3in in diameter, was around 50ft from the main road.

The farmer alerted police and PC Trevor Moody and PCSO Michelle Brady went to the field.

PC Moody contacted the Army who sent in a bomb disposal unit.

An Army officer confirmed the live shell was from the Second World War and was packed with high explosives.

They moved it a safe distance away from the A20 and carried out a controlled explosion.

PC Moody said: "Given that we live in an area that saw much action during the Second World War, it is not uncommon for us to be alerted about unexploded bombs."

The incident was on Thursday.

Click here for more news from Kent.

Royal Navy bomb disposal experts remove a World War Two shell discovered in a nature reserve

- A World War Two bomb was discovered in a Plymouth nature reserve
- Amateur metal detector found the shell and partially dug it up
- Royal Navy experts carried the explosive away before disposing of it

By VALERIE EDWARDS FOR MAILONLINE
PUBLISHED: 01:29, 13 January 2016 | **UPDATED:** 09:51, 13 January 2016

Share 338 shares 10 View comments

A World War Two bomb was reportedly found at Efford Nature Reserve in Plymouth after a member of the public was metal detecting and partially dug it up.

The Royal Navy Bomb Disposal team was called in to remove the bomb and police have closed off Military Lane, with the possibility of Military Road also being closed.

Police were called at around 1.30pm yesterday after what appeared to be a shell was discovered and partially dug up near Military Lane, Efford.

Holiday beach cordoned off after landslip sends more than a THOUSAND Second World War bombs and rockets tumbling onto the sands

- Bad weather led to ground movement which exposed the huge arsenal at Mappleton, East Riding
- A dog walker stumbled across the deadly find on Saturday and 15 controlled explosions were carried out
- Rockets, mortar bombs and 25-pounder bombs were recovered after they were fired into the cliffs by RAF aircraft during the war
- Most of the devices were dummy rounds used for bombing practice but contain enough explosives to cause terrible injuries

© Jonathan Pow

Bomb Beach Alley: Rockets were found after a landslide on Mappleton beach in 2012

Army bomb disposal team called to Blacksole Bridge in Herne Bay

by Aidan Barlow abarlow@thekmgroup.co.uk 08 July 2015

It was like a scene from Dad's Army when Army bomb disposal experts found wartime explosives made by the Home Guard in makeshift bottles.

A team was called to the Blacksole Bridge in Herne Bay after the wartime bombs were found.

The team from the Royal Logistics Corps set up a 30 metre exclusion zone for pedestrians around the railway embankment after the suspected homemade phosphorous bombs were found.

The scene at Blacksole Bridge after wartime explosives were found in the railway cutting

Tweet

Published by Huw Oxburgh

Posted: 03/06/14

Updated: 03/06/14

Unexploded bomb found in Axminster

Update: The bomb disposal unit has made the device safe and the road has re-opened.

Six homes have been evacuated today after the discovery of an unexploded device in Axminster.

A Royal Navy bomb disposal team have been called to the scene after a 'historic German device' was discovered in a garden.

Police have set up a 20m cordon around the garden in Alexandra Road and evacuated homes in the surrounding area as a precaution.

Storms and floods unearth unexploded wartime bombs

By Claire Marshall
BBC environment correspondent

There has been a dramatic increase in the number of wartime bombs unearthed because of the winter storms and flooding.

Bomb disposal teams in the South West have dealt with double the number of unexploded ordnance than in the same period last year.

Since mid December, the Royal Navy's Southern Dive Unit has recovered or disposed of 244 items of ordnance.

During the same period last year, they dealt with just 108 items.

The storms have uncovered a lethal past

Almost 70 years after the end of WWII, one legacy of that conflict continues to turn up on beaches and harbours around Britain.

Unexploded shells, bombs and mines continue to be discovered every year, and the Royal Navy's Southern Dive Unit is tasked with making these devices safe.

Its area of responsibility stretches for some 2,250km (1,400 miles). It begins from the highwater mark in Hull and proceeds seaward to the territorial limit, and then runs clockwise around the British Isles - including the Isle of Wight, Channel Islands, and Isles of Scilly - to finish in Liverpool.

Related Stories

Ancient trees revealed by storms

Land Service Ammunition (LSA) resulting from historic military activity is commonly encountered across the UK by the public and construction industry alike. Such finds are much more common in rural areas than in urban environments, and can often be anticipated in areas such as former RAF stations or ranges. However, many such items are encountered entirely by surprise where the landowner or developer has no knowledge of any previous military use of the land.

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Ref: **DA15987-00**

Source: Various news sources

Suspected unexploded WW2 bomb closes Richmond Bridge

richmondandtwickenhamtimes.co.uk/news/16109344.Suspected_unexploded_WW2_bomb_closes_Richmond_Bridge/

An "unexploded WW2 bomb" was reported to be found near Richmond Bridge today (March 22).

Police originally thought it was an unexploded shell, but later found it was a "piece of fencing".

A spokeswoman for the Met Police said the situation was "made safe" at 2pm.

She said: "Police in Richmond have dealt with a suspected item of WW2 ordnance.

"Officers were called at 1.14pm on Thursday, March 22, to the embankment near Richmond Bridge.

"An item, that was believed to be a WW2 shell, had been found.

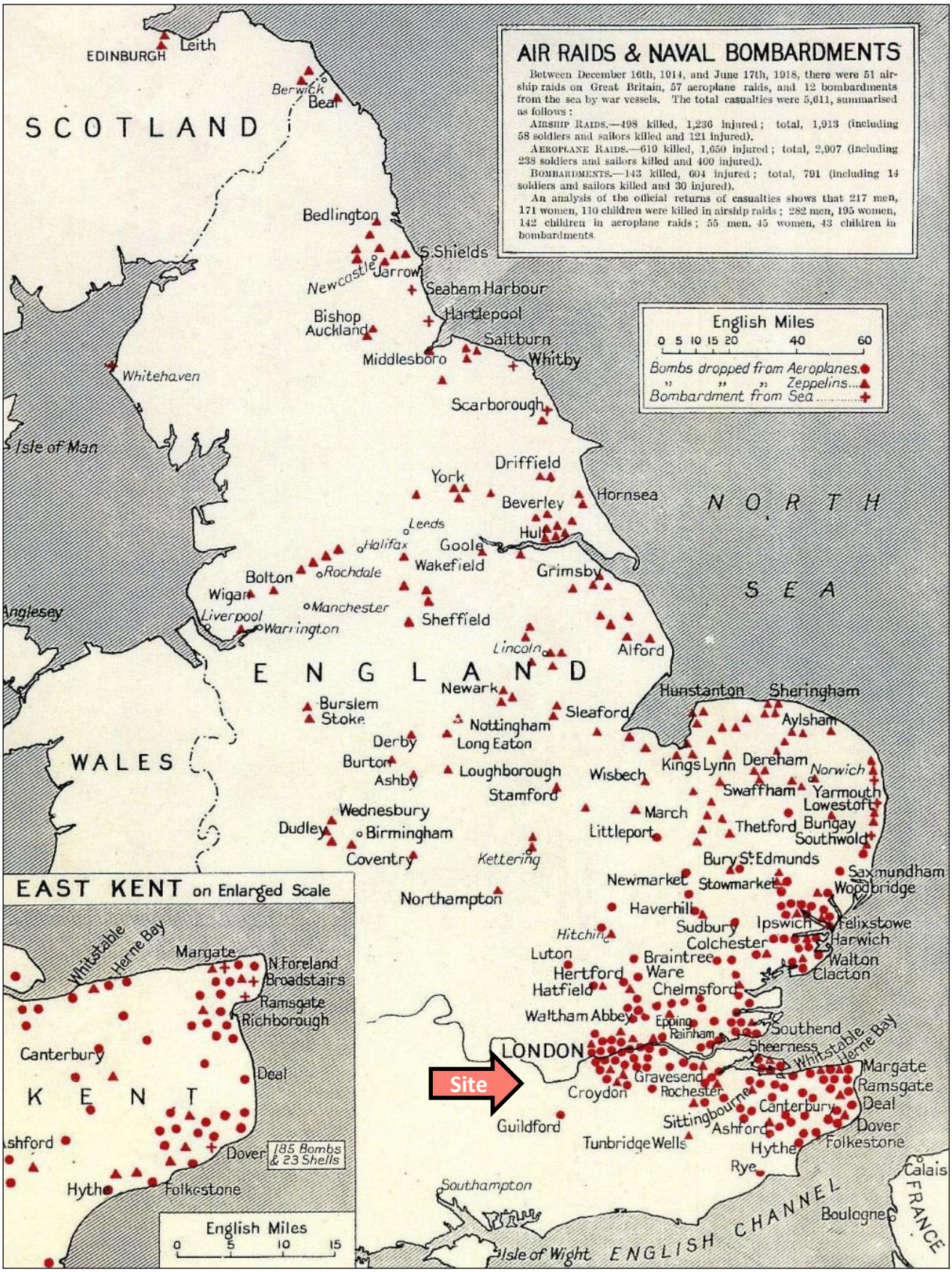
"London Ambulance Service and London Fire Brigade have attended as a precaution.

"Local road closures were in place while emergency services dealt.

"The item was assessed and found not to be an explosive object."

WWI Map of Air Raids and Naval Bombardments

Annex: **H**



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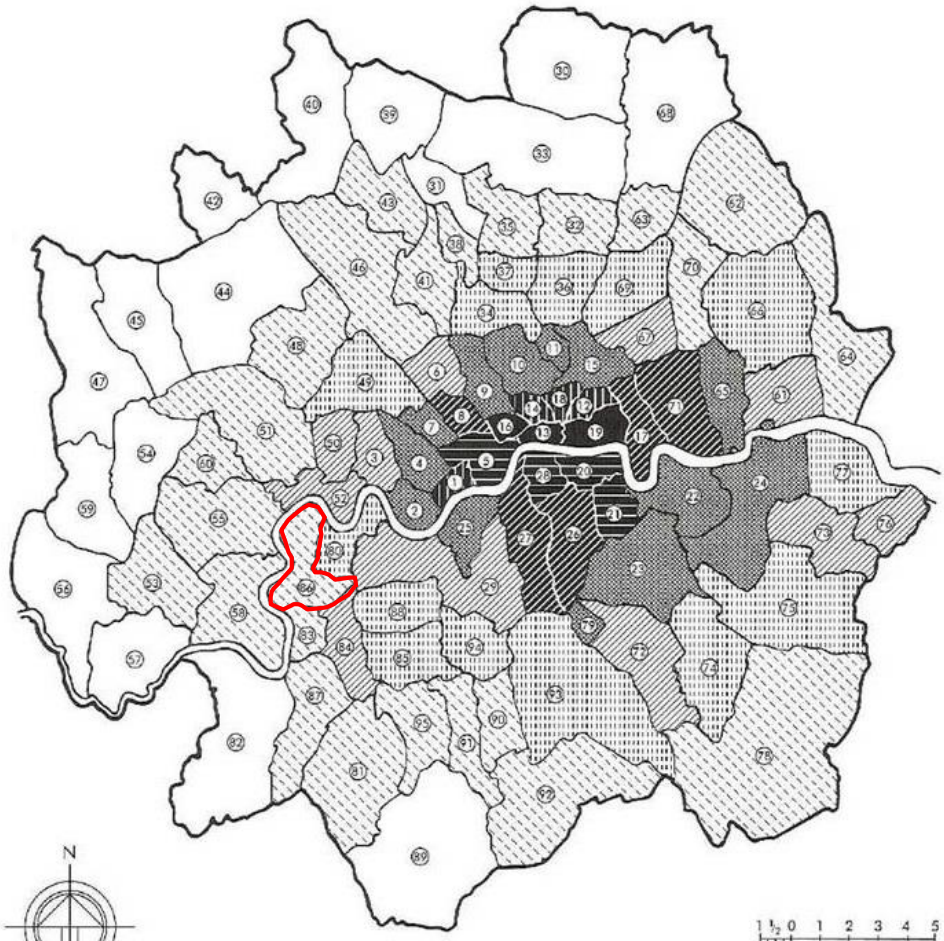
Source: J. Morris, *German Air Raids on Britain*

London WWII Bomb Density Map

Annex: I



No. OF BOMBS PER 1,000 ACRES

OVER 600	300 – 399	100 – 149
500 – 599	200 – 299	50 – 99
400 – 499	150 – 199	UNDER 50

1	Chelsea	25	Battersea	49	Willesden	72	Beckenham
2	Fulham	26	Camberwell	50	Acton	73	Bexley
3	Hammersmith	27	Lambeth	51	Ealing	74	Bromley
4	Kensington	28	Southwark	52	Brentford and Chiswick	75	Chislehurst and Sidcup
5	Westminster	29	Wandsworth	53	Feltham	76	Crayford
6	Hampstead	30	Cheshunt	54	Hayes and Harlington	77	Erith
7	Paddington	31	East Barnet	55	Heston and Isleworth	78	Orpington
8	St. Marylebone	32	Edmonton	56	Staines	79	Penge
9	St. Pancras	33	Enfield	57	Sunbury	80	Barnes
10	Islington	34	Hornsey	58	Twickenham	81	Epsom and Ewell
11	Stoke Newington	35	Southgate	59	Yiewsley and West Drayton	82	Esher
12	Bethnal Green	36	Tottenham			83	Kingston on Thames
13	City of London	37	Wood Green	60	Southall and Norwood	84	Malden and Coombe
14	Finsbury	38	Friern Barnet	61	Barking	85	Merton and Morden
15	Hackney	39	Potters Bar	62	Chigwell	86	Richmond
16	Holborn	40	Elstree	63	Chingford	87	Surbiton
17	Poplar	41	Finchley	64	Dagenham	88	Wimbledon
18	Shoreditch	42	Bushey	65	East Ham	89	Banstead
19	Stepney	43	Barnet U.D.	66	Ilford	90	Beddington and Wallington
20	Bermondsey	44	Harrow	67	Leyton	91	Carshalton
21	Deptford	45	Ruislip and Northwood	68	Waltham Holy Cross	92	Coulsdon and Purley
22	Greenwich	46	Hendon	69	Walthamstow	93	Croydon
23	Lewisham	47	Uxbridge	70	Wanstead and Woodford	94	Mitcham
24	Woolwich	48	Wembley	71	West Ham	95	Sutton and Cheam

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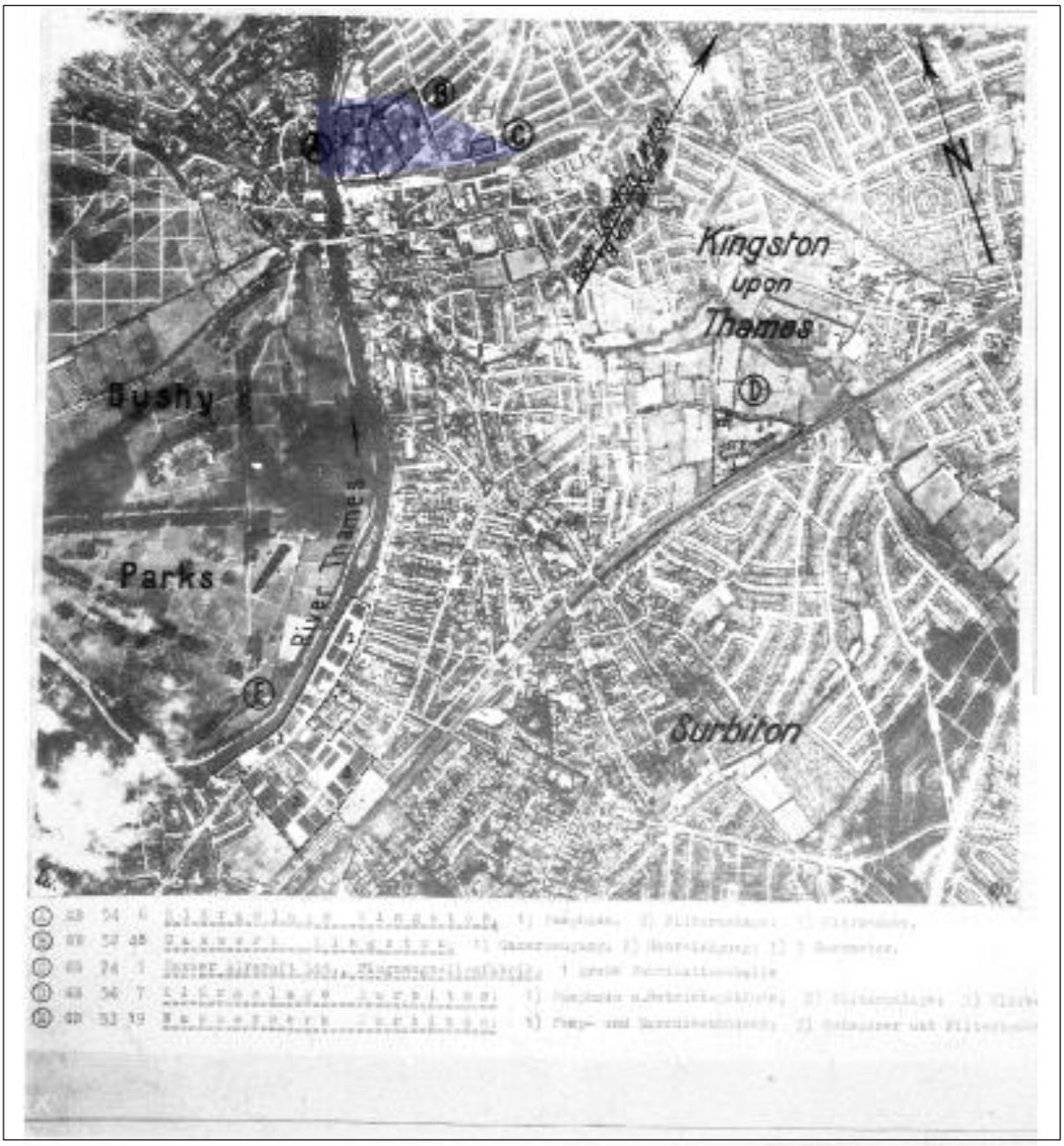
Ref: **DA15987-00**

Source: The London Metropolitan Archives

Luftwaffe Photograph, 12th August 1940



LONDON – KINGSTON – SURBITON
12TH. AUGUST 1940
Hawker Aircraft factory, waterworks
TN 1662

The site area is situated approximately 2km north of this image.

Luftwaffe Photograph, 1st October 1940

LONDON – KINGSTON
2ND. SEPTEMBER 1940
TN 2502
COMMENT
Hampton Court Gardens are in the bottom left of the photograph.

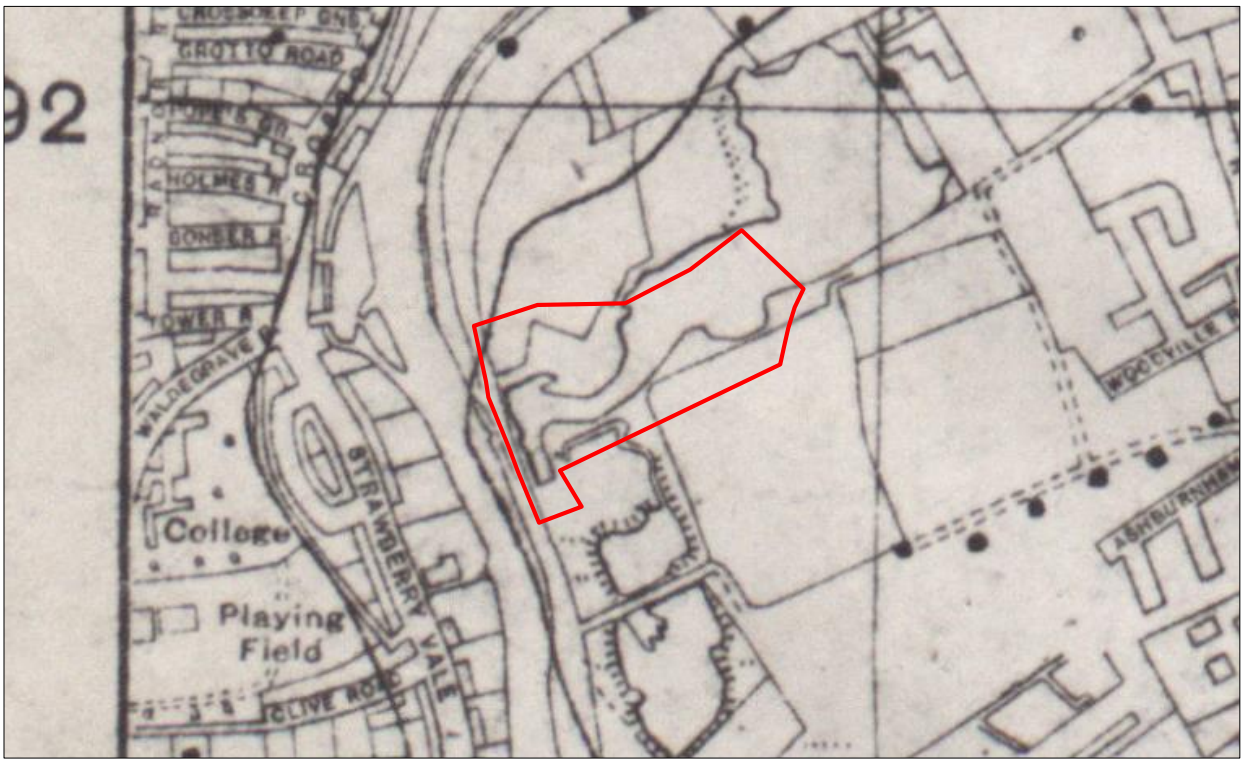
The site area is situated approximately 1.8km north of this image.

Consolidated London Bomb Census Mapping

Annex: **K1**

Night Bombing up to 7th October 1940

Night Bombing - 7th October 1940 to 28th July 1941



Recorded bomb strike

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Client: **Soils Limited**

Approximate site boundary

Project: **Thames Young Mariners, Richmond**

N

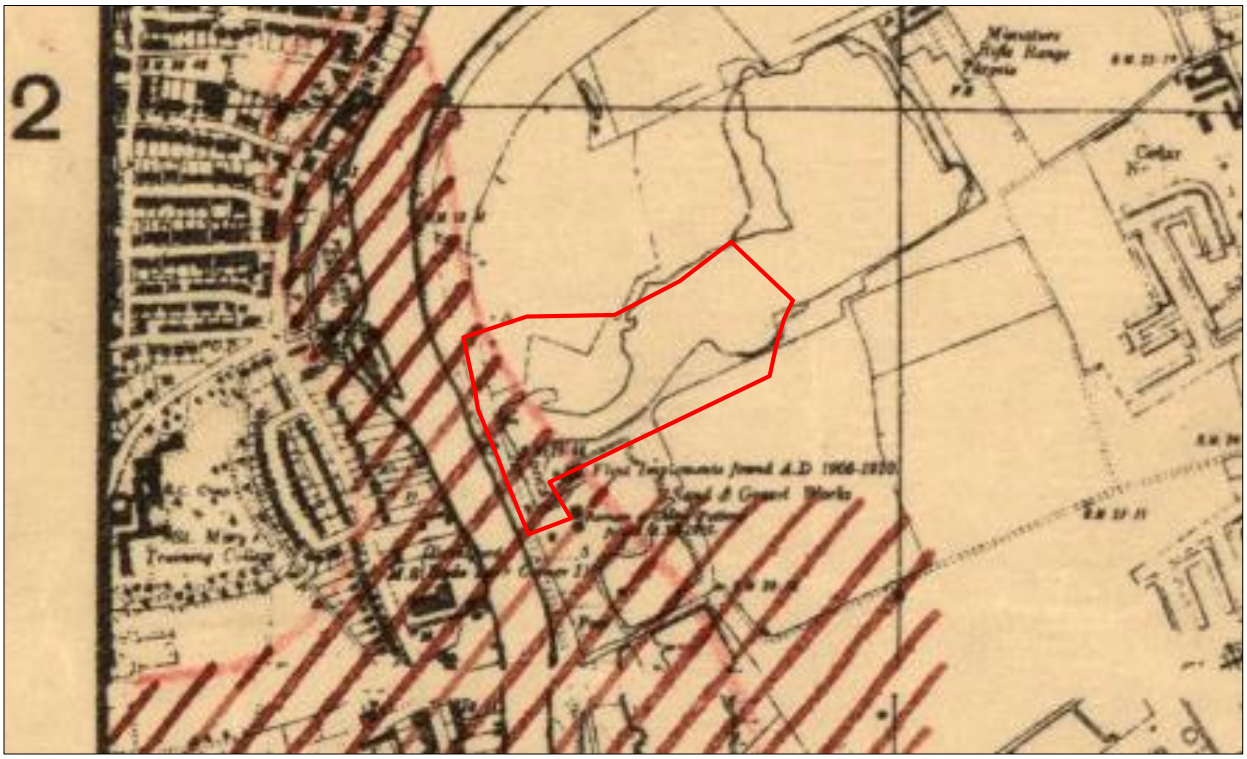
Ref: **DA15987-00**

Source: The National Archives, Kew

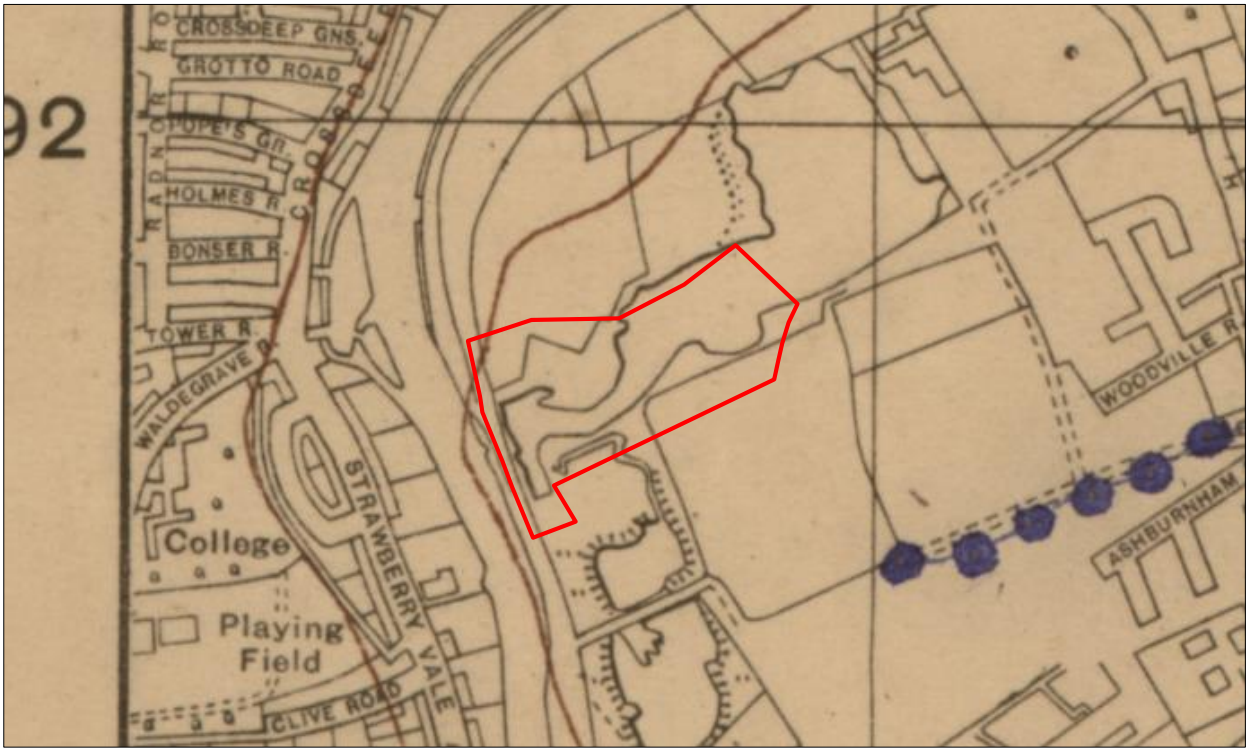
Weekly London Bomb Census Mapping

Annex: **K2**

7th -14th October 1940



14th – 21st October 1940



Recorded HE bomb strike

Recorded UXB strike

Recorded incendiary bomb shower

Recorded oil bomb strike

Key to weekly map symbol colours

Monday - Brown	Friday - Green
Tuesday - Vermilion	Saturday - Violet
Wednesday - Blue	Sunday - Yellow
Thursday - Black	

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Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: The National Archives, Kew

Approximate site boundary

N

Weekly London Bomb Census Mapping

Annex: **K3**

17th – 24th February 1941

Recorded HE bomb strike

Recorded UXB strike

Recorded incendiary bomb shower

Recorded oil bomb strike

Key to weekly map symbol colours

Monday - Brown
Tuesday - Vermilion
Wednesday - Blue
Thursday - Black
Friday - Green
Saturday - Violet
Sunday - Yellow

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Tel: +44 (0)1992 245 020

Client: **Soils Limited**

Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

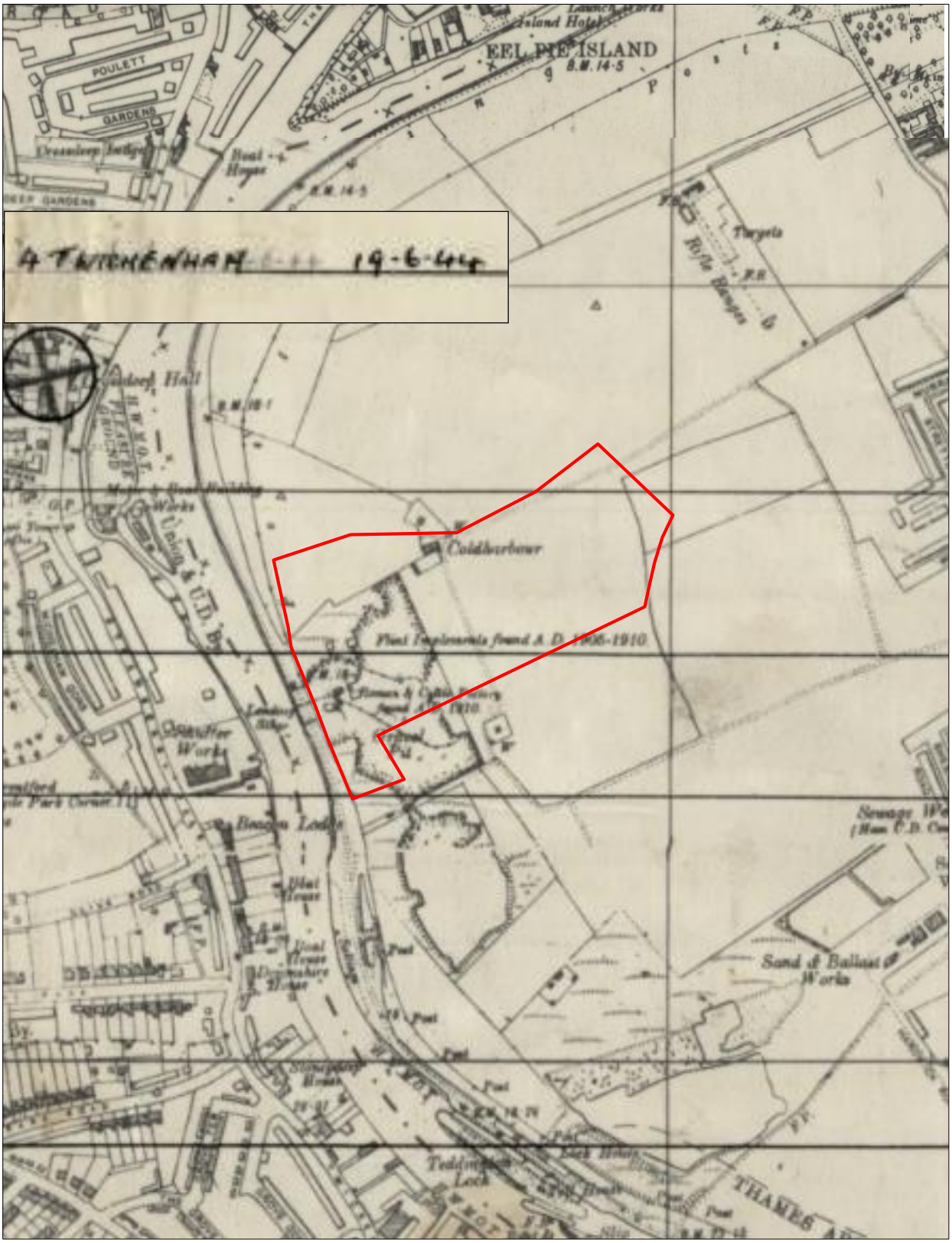
Source: The National Archives, Kew

Approximate site boundary

N

London V-1 Flying Bomb Map

Annex: **L**



V-1 Flying Bomb

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Client: **Soils Limited**

Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: The National Archives, Kew

Approximate site boundary

N

Bombs on Richmond 1940-1945

Annex: **M**

HE bomb

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Client: **Soils Limited**

Approximate site boundary

N

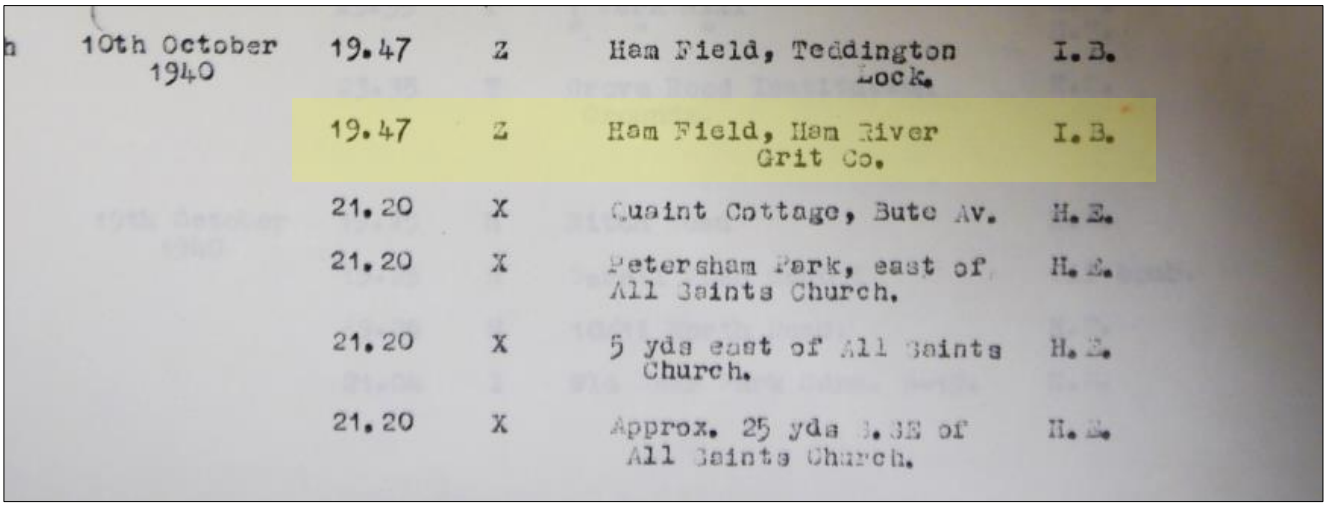
Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: Richmond Archives

Date of strikes unknown

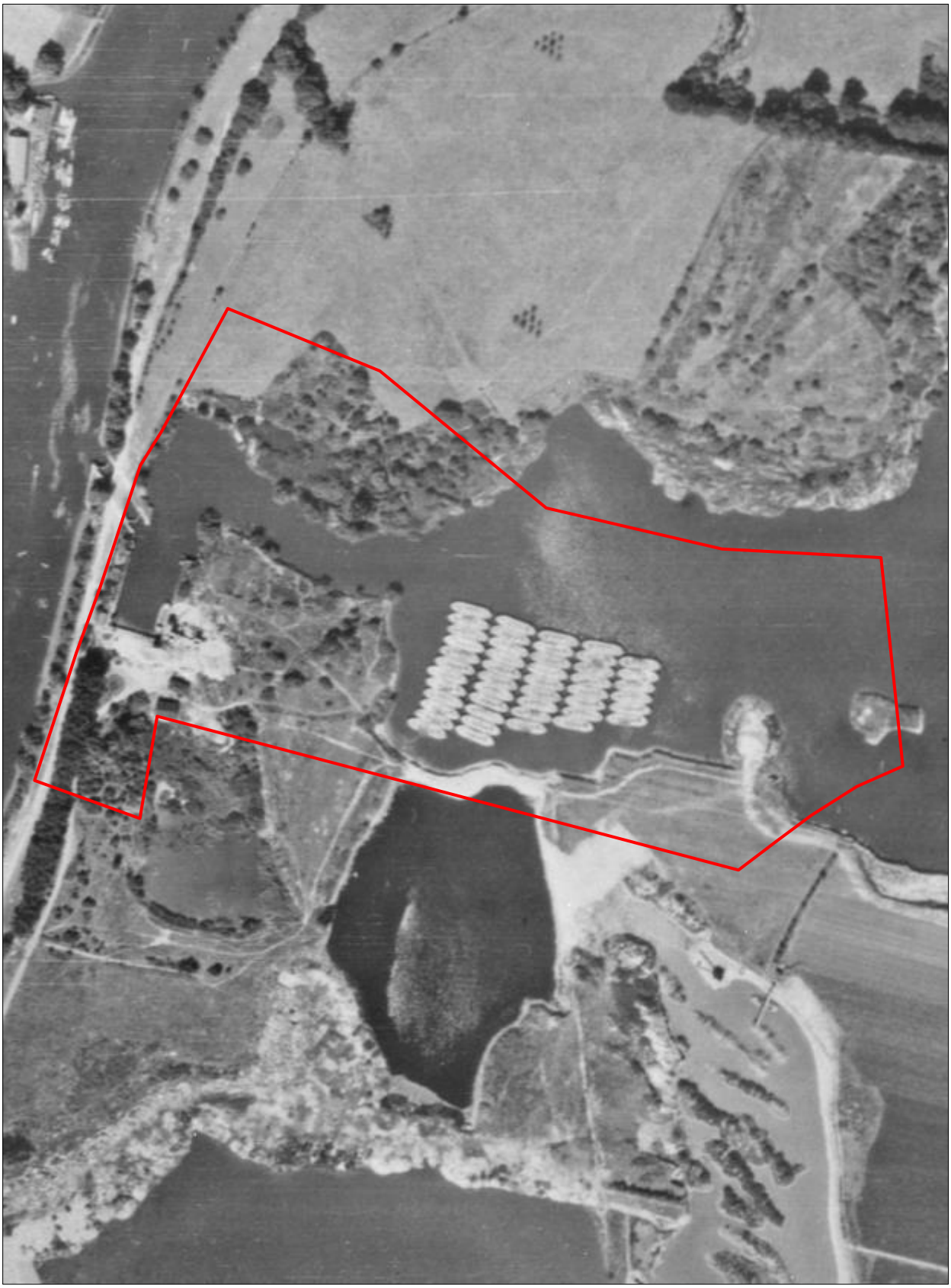
	04.00	A	Fair Ground, Kew Bridge.	H.E.
	04.00	C	250/252 Kew Road.	Incendiary.
	04.20	Z	Ham Fields.	H.E./UXB. H.E./UXB. H.E./UXB. H.E./UXB. H.E./UXB.
	05.25	B	6 Westhall Road.	H.E.
26th September, 1940	02.15	Z	Fields opposite Sel Pie Island.	H.E.
	02.15.'	Z	Fields opposite Sel Pie Island.	H.E.
	02.15	X	Douglas House, Petersham	H.E.
	02.15	X	Petersham Road, Roadway.	H.E.
	03.00	Z	Ham Common	Incendiary
	03.00	Y	Mulberry Cottage Budbrook Gardens.	Incendiary.
	03.00		Budbrook Cottages.	Incendiary
	03.00	E	139 Sandycombe Road.	Mine
1st October, 1940.	02.40	X	Towpath, River Lane.	Oil Bomb.
	02.40	J	St.Pauls Church, Raleigh Road.	H.E.
	02.40	Z	Ham River Grit Co.	20-30 Indend'
	02.40	E	South Ave. Sandycombe Road.	Incendiary
	02.40	Z	Ham House Garden.	H.E.
	02.40		Richmond Park.	H.E. H.E.
	03.55	Z	Langham House, Lawrence Hall and surrounds.	Dread Basket Incendiary.
	03.55	Z	Eckett & Ellis Yard Ham Common.	Incendiary.
	03.55	Z	12 Arlington Road, Ham.	H.E. H.E.
	03.55	Z	Ham Common.	15-20 Incend'



h	10th October 1940	19.47	Z	Ham Field, Teddington Lock. I.B.
		19.47	Z	Ham Field, Ham River Grit Co. I.B.
		21.20	X	Quaint Cottage, Bute Av. H.E.
		21.20	X	Petersham Park, east of All Saints Church. H.E.
		21.20	X	5 yds east of All Saints Church. H.E.
		21.20	X	Approx. 25 yds S.SE of All Saints Church. H.E.

RAF Aerial Photography 7th August 1944

Annex: **O1**



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Approximate site boundary

Project: **Thames Young Mariners, Richmond**

Ref: **DA15987-00**

Source: National Monuments Record Office (Historic England)

RAF Aerial Photography 7th July 1946

Annex: **O2**

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Ref: **DA15987-00**

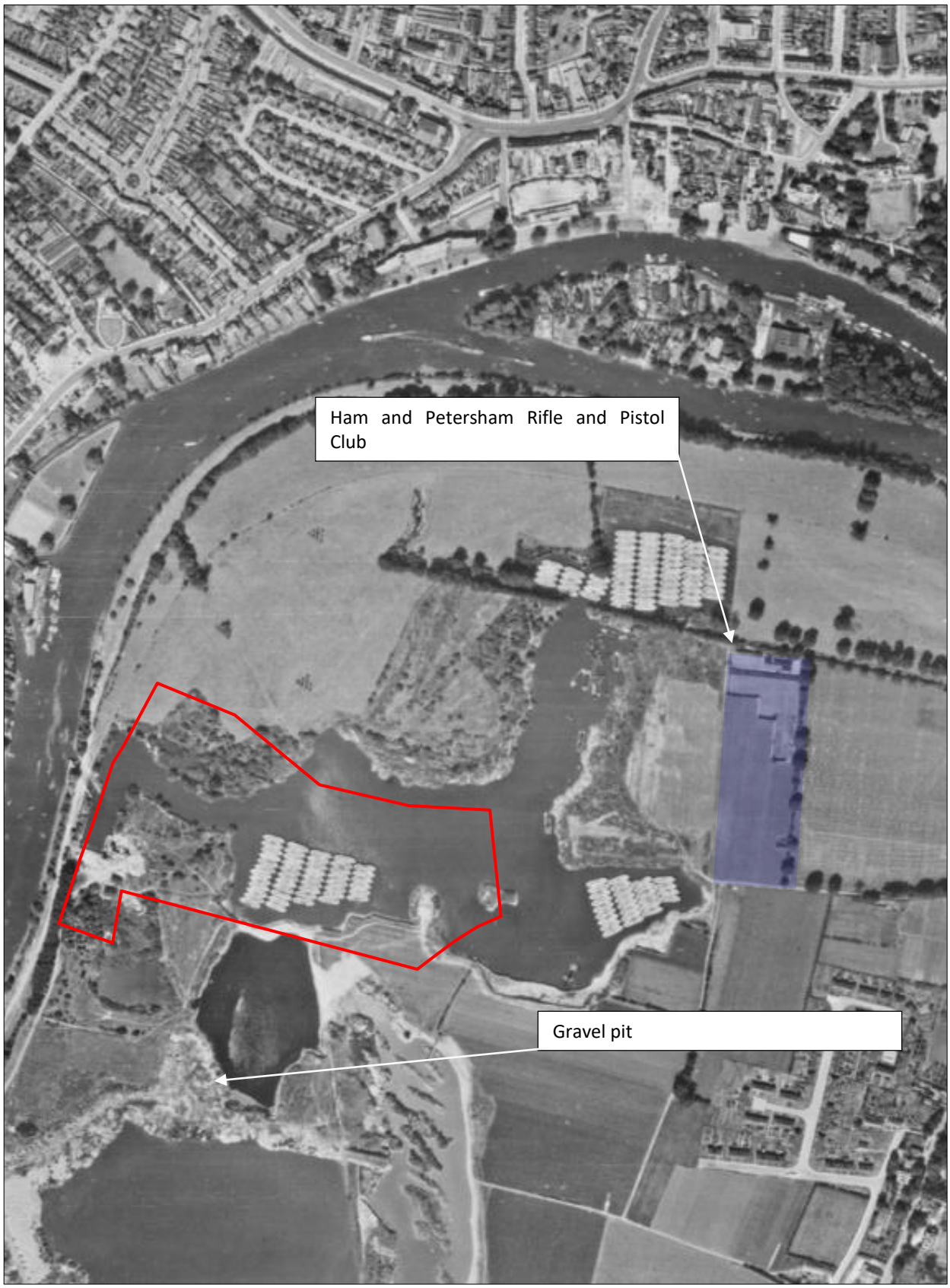
Source: National Monuments Record Office (Historic England)

Approximate site boundary

N

RAF Aerial Photography 7th August 1944/ Allied Overlay

Annex: **P**



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Client: **Soils Limited**

Approximate site boundary

Project: **Thames Young Mariners, Richmond**

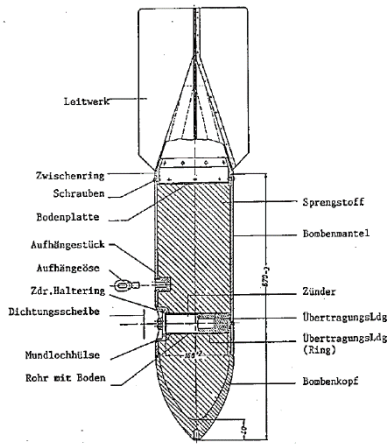
Ref: **DA15987-00**

Source: National Monuments Record Office (Historic England)

Examples of German Bombs - HE

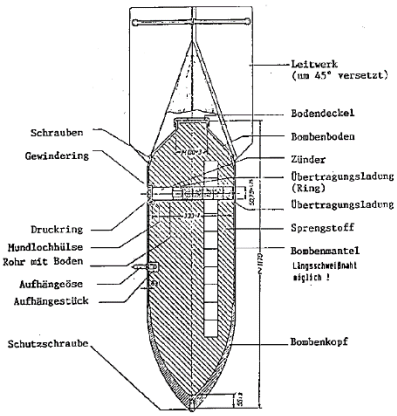
SC 50kg

Bomb Weight	40-54kg (110-119lb)
Explosive Weight	c25kg (55lb)
Fuze Type	Impact fuze/electro-mechanical time delay fuze
Bomb Dimensions	1,090 x 280mm (42.9 x 11.0in)
Body Diameter	200mm (7.87in)
Use	Against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to three stories.
Remarks	The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.



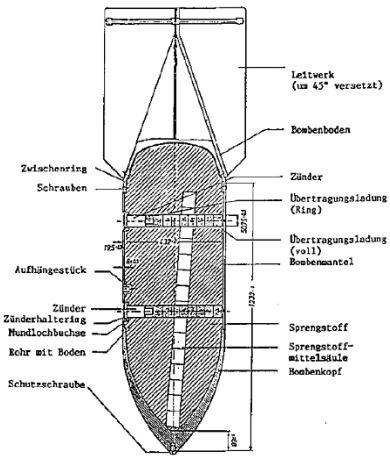
SC 250kg

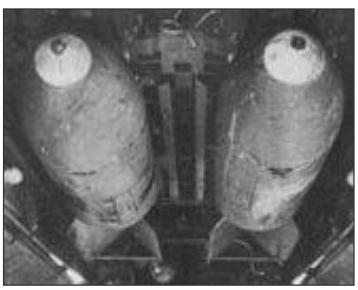
Bomb Weight	245-256kg (540-564lb)
Explosive Weight	125-130kg (276-287lb)
Fuze Type	Electrical impact/mechanical time delay fuze.
Bomb Dimensions	1640 x 512mm (64.57 x 20.16in)
Body Diameter	368mm (14.5in)
Use	Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.
Remarks	It could be carried by almost all German bomber aircraft, and was used to notable effect by the Junkers Ju-87 Stuka (Sturzkampfflugzeug or dive-bomber).



SC 500kg

Bomb Weight	480-520kg (1,058-1,146lb)
Explosive Weight	250-260kg (551-573lb)
Fuze Type	Electrical impact/mechanical time delay fuze.
Bomb Dimensions	1957 x 640mm (77 x 25.2in)
Body Diameter	470mm (18.5in)
Use	Against fixed airfield installations, hangars, assembly halls, flyovers, underpasses, high-rise buildings and below-ground installations.
Remarks	40/60 or 50/50 Amatol TNT, trialene. Bombs recovered with Trialen filling have cylindrical paper wrapped pellets 1-15/16 in. in length and diameter forming





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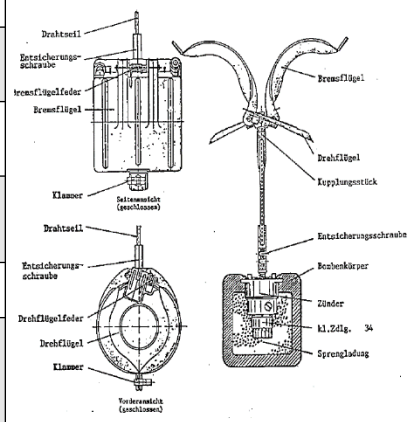
Source: Various sources

Examples of German Bombs - HE, AP and Parachute Mines

SD2 Butterfly Bomb

Bomb Weight	2kg (4.41lb)
Explosive Weight	7.5oz (212.6 grams) of TNT surrounded by a layer of bituminous composition.
Fuze Type	41 fuze (time) , 67 fuze (clockwork time delay) or 70 fuze (anti-handling device)
Bomb Dimensions	Length 240 mm Width 140 mm Height 310 mm
Body Diameter	3in (7.62 cm) diameter, 3.1in (7.874) long
Use	It was designed as an anti-personnel/fragmentation weapon. They were delivered by air, being dropped in containers that opened at a predetermined height, thus scattering the bombs.
Remarks	The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

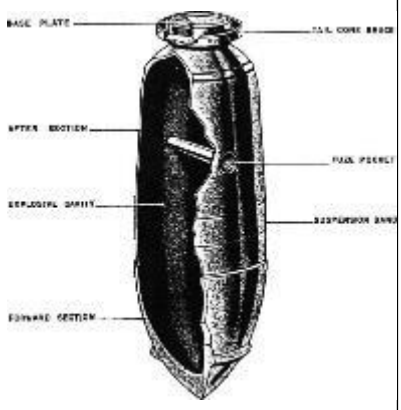


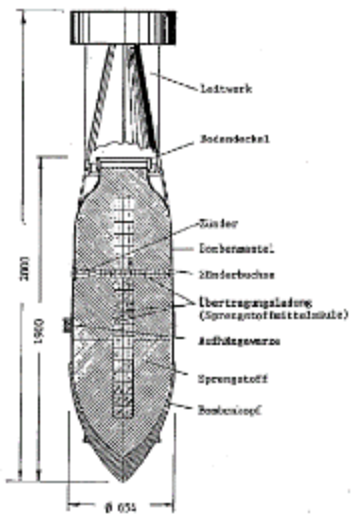
Parachute Mine (Luftmine B / LMB)

Bomb Weight	987.017kg (2176lb)
Explosive Weight	125-130kg (276-287lb)
Fuze Type	Impact/ Time delay / hydrostatic pressure fuze
Bomb Dimensions	1640 x 512mm (64.57 x 20.16in)
Body Diameter	368mm (14.5in)
Use	Against civilian, military and industrial targets. Designed to detonate above ground level to maximise damage to a wider area.
Remarks	Parachute Mines were normally carried by HE 115 (Naval operations), HE 111 and JU 88 aircraft types. Deployed a parachute when dropped in order to control its descent.

SC 1000kg

Bomb Weight	996-1061kg (1,058-1,146lb)
Explosive Weight	530-620kg (551-573lb)
Fuze Type	Electrical impact/mechanical time delay fuze.
Filling	Mixture of 40% amatol and 60% TNT, but when used as an anti-shipping bomb it was filled with Trialen 105, a mixture of 15% RDX, 70% TNT and 15% aluminium powder.
Bomb Dimensions	2800 x 654mm (77 x 25.2in)
Body Diameter	654mm (18.5in)
Use	SC type bombs are General Purpose Bombs used primarily for general demolition work. Constructed of parallel walls with comparatively heavy noses. They are usually of three piece welded construction





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Project: **Thames Young Mariners, Richmond**

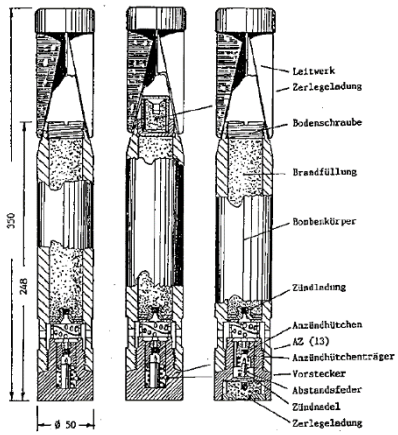
Ref: **DA15987-00**

Source: Various sources

Examples of German Bombs - Incendiary

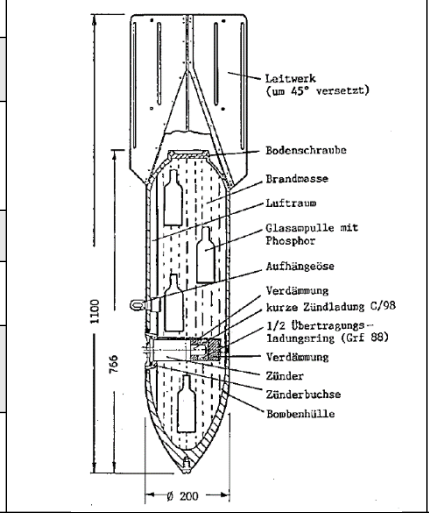
1kg Incendiary Bomb

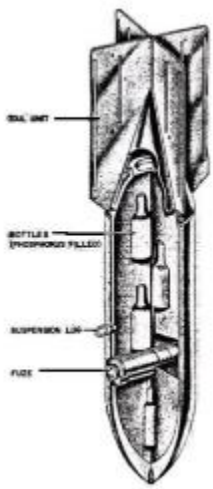
Bomb Weight	1.0 and 1.3kg (2.2 and 2.87lb)
Explosive Weight	680gm (1.3lb) Thermite
Fuze Type	Impact fuze
Bomb Dimensions	350 x 50mm (13.8 x 1.97in)
Body Diameter	50mm (1.97in)
Use	As incendiary – dropped in clusters against towns and industrial complexes
Remarks	Magnesium alloy case. Sometimes fitted with high explosive charge. The body is a cylindrical alloy casting threaded internally at the nose to receive the fuze holder and fuze.



C50 A Incendiary Bomb

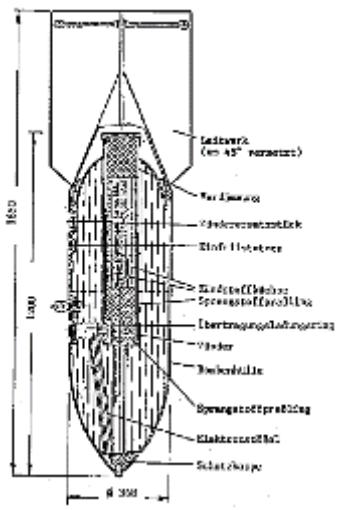
Bomb Weight	c41kg (90.4lb)
Explosive Weight	0.03kg (0.066lb)
Incendiary Filling	12kg (25.5lb) liquid filling with phosphor igniters in glass phials. Benzine 85%; Phosphorus 4%; Pure Rubber 10%
Fuze Type	Electrical impact fuze
Bomb Dimensions	1,100 x 280mm (43.2 x 8in)
Use	Against all targets where an incendiary effect is to be expected
Remarks	Early fill was a phosphorous/carbon disulphide incendiary mixture





Flam C-250 Oil Bomb

Bomb Weight	125kg (276lb)
Explosive Weight	1kg (2.2lb)
Fuze Type	Super-fast electrical impact fuze
Filling	Mixture of 30% petrol and 70% crude oil
Bomb Dimensions	1,650 x 512.2mm (65 x 20.2in)
Body Diameter	368mm (14.5in)
Use	Often used for surprise attacks on living targets, against troop barracks and industrial installations. Thin casing – not designed for ground penetration



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Examples of Anti-Aircraft Projectiles

QF 3.7 Inch WWII Anti-Aircraft Projectile

Projectile Weight	28lb (12.6 kg)
Explosive Weight	2.52lbs
Fuze Type	Mechanical Time Fuze
Dimensions	3.7in x 14.7in (94mm x 360mm)
Rate of Fire	10 to 20 rounds per minute
Use	High Explosive Anti-Aircraft projectile. 4.5in projectiles were also used in this role.
Ceiling	30,000ft to 59,000ft

40mm Bofors Projectile

Projectile Weight	1.96lb (0.86kg)
Explosive Weight	300g (0.6lb)
Fuze Type	Proximity and Mechanical Time Fuze
Rate of Fire	120 rounds per minute
Projectile Dimensions	40mm x 310mm (1.6in x 12.2in)
Ceiling	23,000ft (7000m)

Unrotated Projectile (UP) – Z Battery

Projectile Weight	84lb (24.5kg)
Warhead Weight	4.28lb (1.94kg)
Warhead	Aerial Mine with a No. 700 / 720 fuze
Filling	High Explosive
Dimensions	1930mm x 82.6mm (76 x 3.25in)
Use	As a short range rocket-firing anti-aircraft weapon developed for the Royal Navy. It was used extensively by British ships during the early days of World War II. The UP was also used in ground-based single and 128-round launchers known as Z Batteries.

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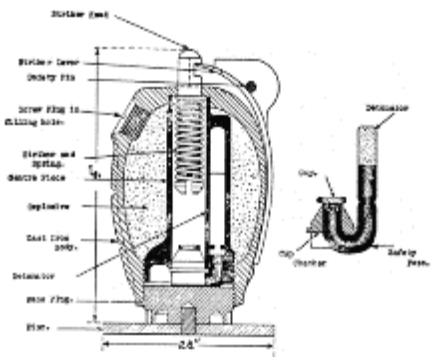
Examples of LSA - Grenades

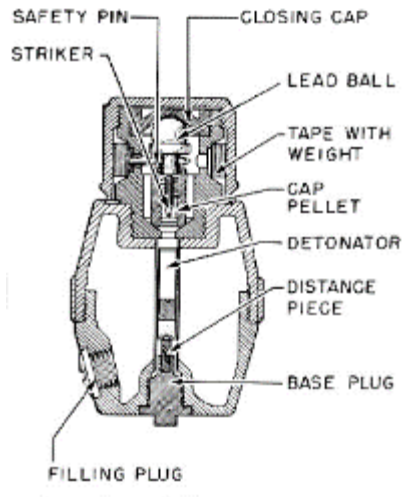
No. 36 'Mills' Grenade

Weight	760g filled (1ib 6oz)
Explosive Weight	71g (2.5 oz) Baratol filling.
Fuze Type	4 second delay hand-throwing fuze
Dimensions	95 x 61mm (3.7 x 2.4in)
Use	Fragmentation explosive at approx. 30m range 100m range of damage.
Remarks	First introduced in 1915 its classic grooved 'pineapple' design was designed to provide uniform fragmentation. Approx. over 70million were produced.



No. 69 Grenade

Weight	383g (0.81b)
Explosive Weight	93g (3.25 oz) of either Amatol, Baratol or Lyddite
Fuze Type	'All-ways' Fuze. Compromised of a safety cap, a weighted streamer attached to a steel ball bearing and a safety bolt designed to detonate from any point of impact.
Dimensions	114 x 60mm (4.5 x 2 .4 in)
Use	A blast grenade for use as an offensive weapon.
Remarks	Introduced December 1940 and made from the plastic Bakelite as opposed to conventional metals. Detection is difficult due to this low metal content.



L2 Grenade

Weight	454g (16 oz)
Explosive Weight	164g. (16 oz)
Fuze Type	Time Friction Fuze
Dimensions	Approx. 99 x 57 mm (3.9 x 2.2 in)
Use	A widely used anti-personnel grenade, a version of the American M26. Variants still see use in the present day.
Remarks	The L2 series also came as a Practice (L3) grenade and a Drill (L4) Grenade. The Drill variant, with a non-functional fuze and no filing, is visible on the far right.

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Source: Various sources

Examples of LSA - Mortars

Typical 2 Inch High Explosive Mortar

Weight	1.02kg (2.25lb)
Maximum Range	460m (500yards)
Filling	200g RDX/TNT
Dimensions	51 x 290mm (2in x 11.4 in)
Fuze Type	An impact fuze which detonates the fuze booster charge and in turn the high explosive charge.
Use	A small, portable mortar introduced into the British army in 1938. It had greater range and firepower over hand and rifle grenades, and was used to attack targets behind cover with high explosive rounds.
Remarks	Detonation causes the mortars bomb body to shatter producing optimum fragmentation and blast effect at the target.

Typical 3 inch Smoke Mortar

Weight	4.5kg (9lb 14oz)
Maximum Range	2515m (2,750 yards)
Filling	White phosphorus & smoke fill (also came in Explosive & Illuminating models)
Bomb Dimensions	490 x 76mm (19.3in x 3in)
Fuze Type	An impact fuze which initiates a bursting charge. This ruptures the mortar bomb 's body and disperses the phosphorus filler
Use	As a screening devices for unit movement or to impair enemy field of vision.
Remarks	This mortars long cylindrical body and tail sometimes causes it to be misrecognised as a German incendiary bomb.

ML 4.2 inch Mortar

Weight	9kg (19lb 13oz)
Maximum Range	3,750m (4,100 yards)
Filling	High explosive, smoke (white phosphorous or Titanium Tetrachloride) or chemical
Bomb Dimensions	500 x 105 mm (19 in x 4 in)
Fuze Type	Sensitive fuze with HE bursting charge.
Use	A widely used heavy motor which first saw use in 1942 and saw usage throughout the post-war period.
Remarks	Different markings denoted different filings. See image to the right.

L to R: HE, Smoke, Chemical, Smoke BE.

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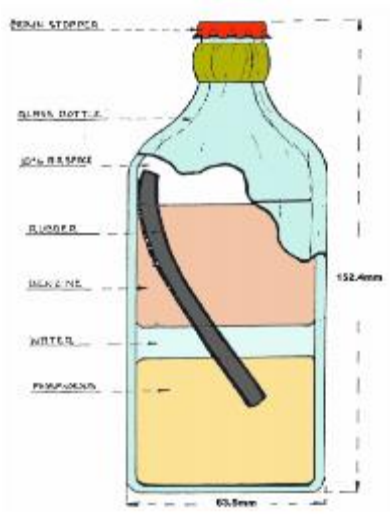
Source: Various sources

Examples of LSA - Home Guard Ordnance

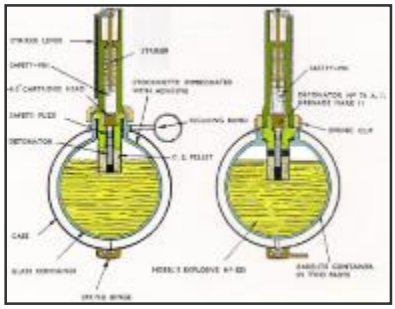
Self Igniting Phosphorous (SIP) Grenades

Weight	Various
Filling	White Phosphorous and Benzene
Design	The filling was contained in a pint sized glass bottle with water and a strip of rubber. Over time the rubber dissolved to create a sticky which would self ignite when the bottle broke.
Use	Originally intended as an anti-tank incendiary weapon deployed by hand. Designed to be produced cheaply without consuming materials needed to produce armaments on the front line.
Remarks	The Home Guard hid caches of these grenades during the war for use in the event of an invasion. Not all locations were officially recorded and some caches were lost. Occasionally discovered today. In all cases, the grenades are still found to be dangerous.



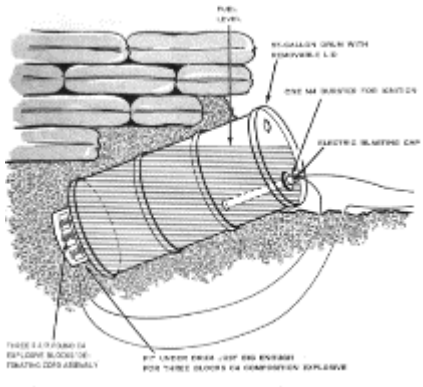
No. 74 Grenade (Sticky Bomb)

Weight	Approx. 1.1kg (2ib 4oz)
Filling	Approx. 600g Nobel's No.283 (Nitro-glycerine)
Design	A glass ball on the end of a Bakelite (plastic) handle. The inside of the ball would contain the explosive filling and the outside a very sticky adhesive coating.
Use	An anti-tank grenade primarily issued to the home guard. It required the user to come in very close proximity with the target and smash the glass explosive container against it.
Remarks	One of a number of weapons developed for use as an *ad hoc* solution to the lack of sufficient anti-tank guns in the aftermath of the Dunkirk evacuation amid fear of German invasion.



Flame Fougasse Bomb

Weight	Various
Filling	Initially a mixture of 40% petrol and 60% gas. Ammonal provided the propellant charge.
Design	Usually constructed from a 40-galleon drum dug into a roadside and camouflaged.
Use	As an improvised anti-tank bomb. When triggered the Fougasse could project a beam of burning sticky fuel in a fixed direction from up to 3m (10ft) wide and 27m (30yards) long.
Remarks	A highly unorthodox weapon designed by the Petroleum warfare department to address a critical lack of weapons in 1940. 50,000 are estimated to have been distributed around the UK.



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Examples of Small Arms Ammunition

Cannon Ammunition

Rifle Ammunition

Buried and Decayed Ammunition

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