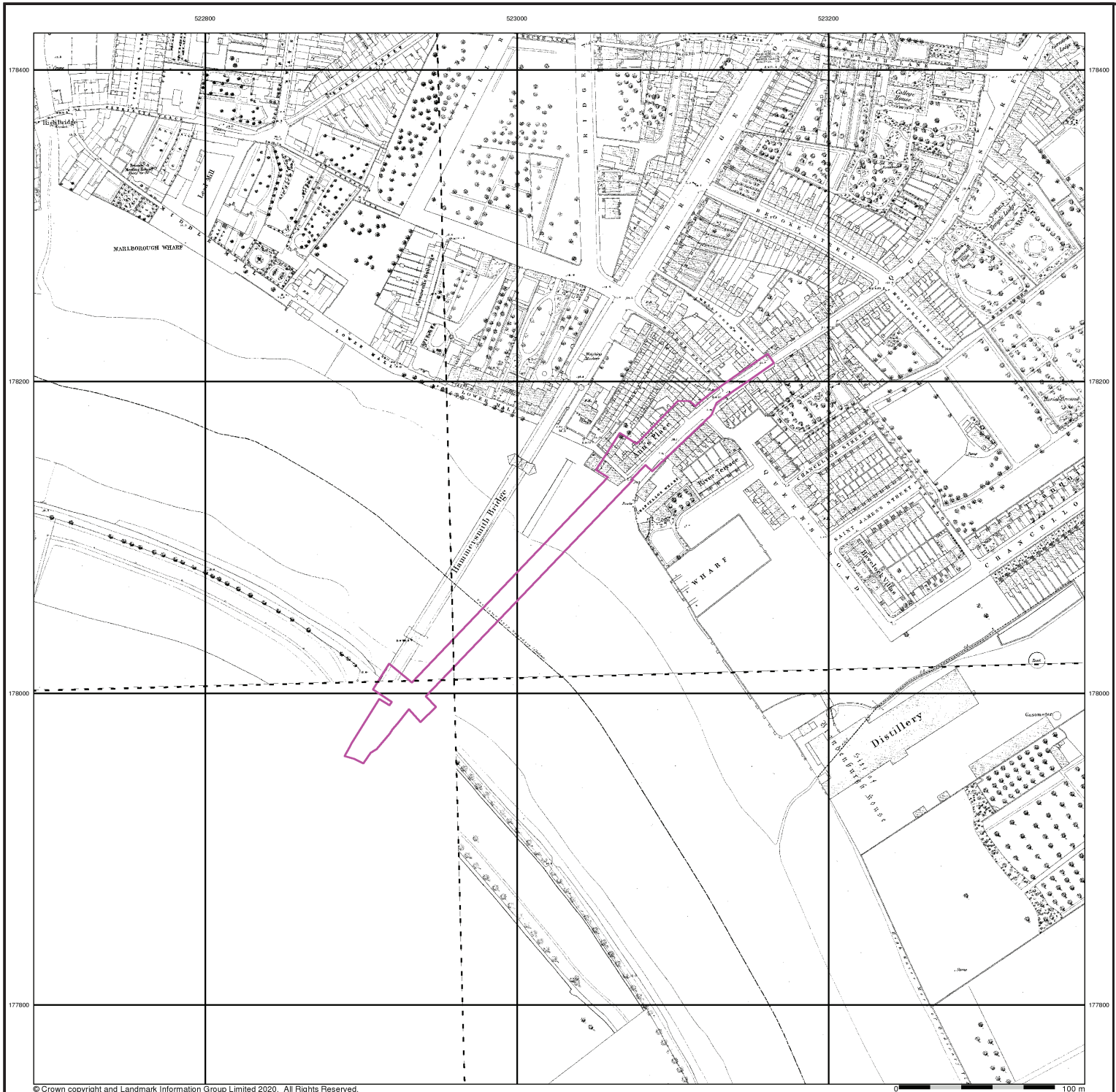

Pell Frischmann

London

Published 1867 - 1870

Source map scale - 1:1,056

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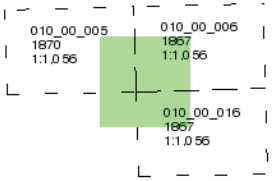
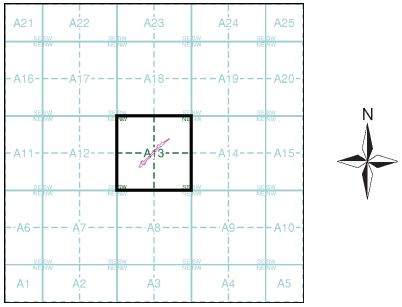
Please note: Due to the partial coverage of Historical Town Plans, it is possible that not all segments within an order will contain mapping. Only the segments that have Town Plan coverage will be generated.

Map Name(s) and Date(s)



Historical Town Plan - Segment A13



Order Details

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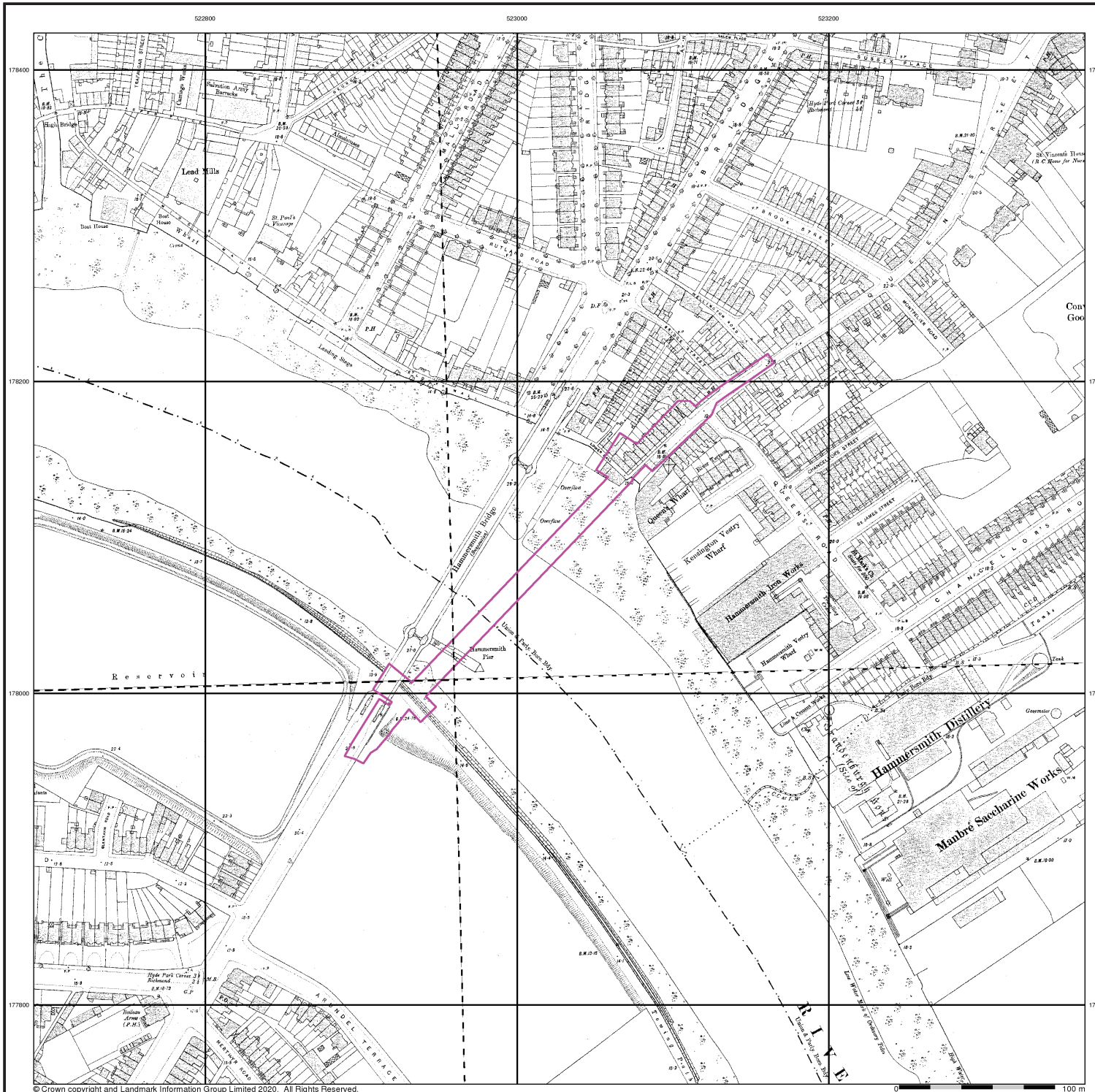
Customer Ref:	102963 HTB JB
National Grid Reference:	523020, 178090
Slice:	A
Site Area (Ha):	0.57
Search Buffer (m):	0

Site Details

Hammersmith Temporary Bridge, Hammersmith, London, W6 9PF

Landmark INFORMATION GROUP

Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk



Pell Frischmann

London

Published 1895

Source map scale - 1:1,056

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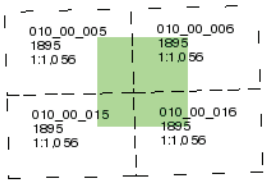

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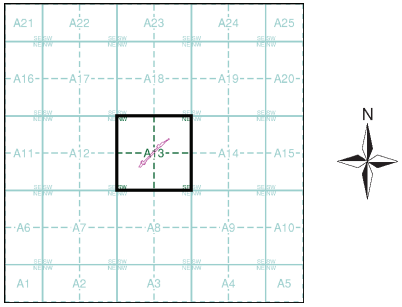

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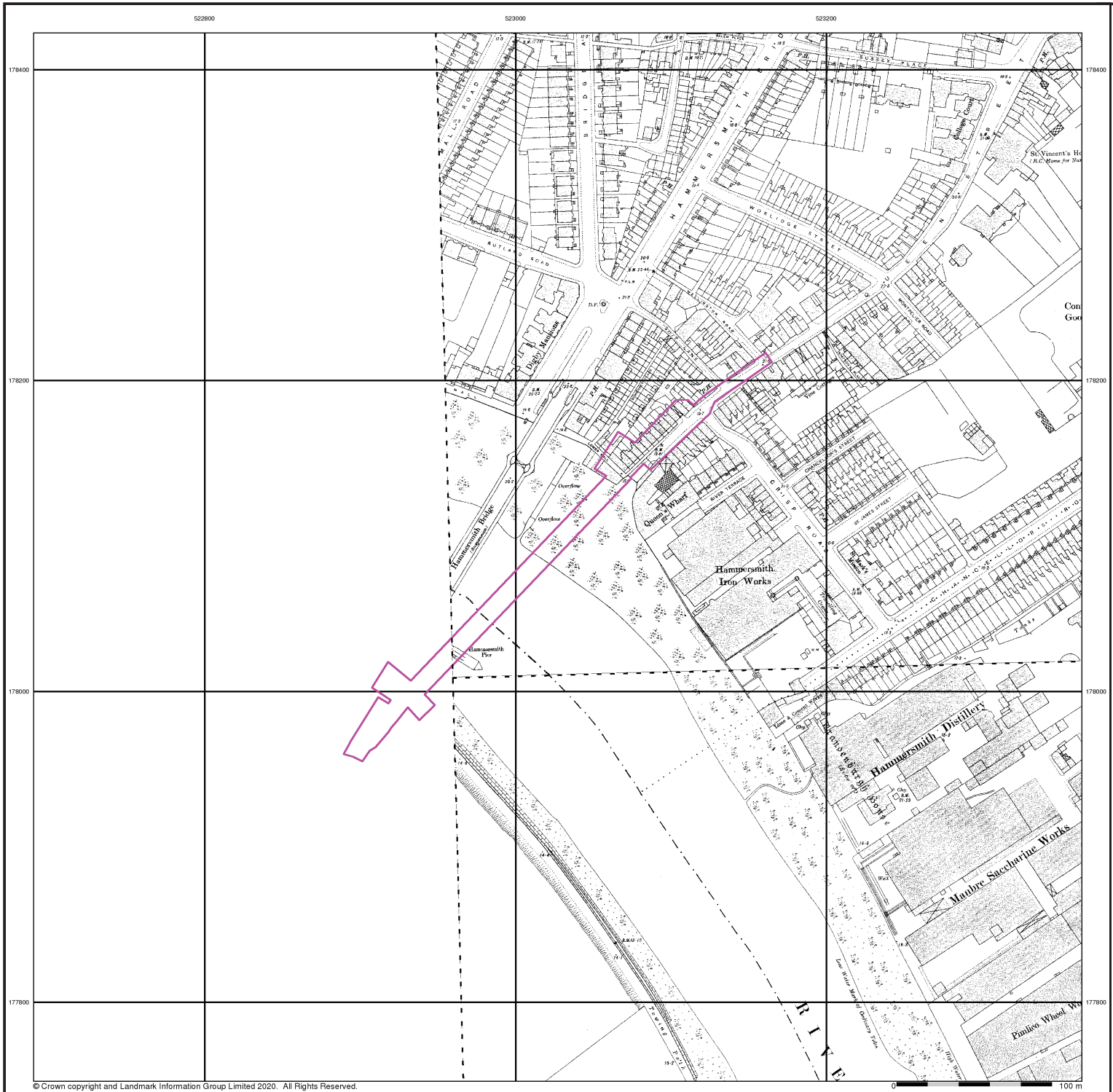

Pell Frischmann

London

Published 1919 - 1921

Source map scale - 1:1,056

The 1:1056 scale of Ordnance Survey mapping was adopted from Ireland in 1848 and was used to survey towns with a population of over 4000, plus county towns of lesser population, in those counties mapped at the six-inch scale in 1841-55. The scale was the largest scale at which London was mapped by the Ordnance Survey and a 'skeleton' survey of the capital, showing little more than streets, street names, frontages and altitudes, was undertaken between 1848 and 1850. The majority of the 1:1056 surveys were later replaced by 1:500 surveys; although almost all the remainder were revised at this scale, sometimes more than once before 1895. The type of detail shown on the 1:1056 scale is broadly similar to that on 1:500; the apparent omission of minor details such as sewer access points and street lights may be as much a reflection of the generally earlier date of these plans, as of the specification of the map.

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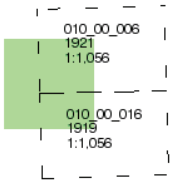

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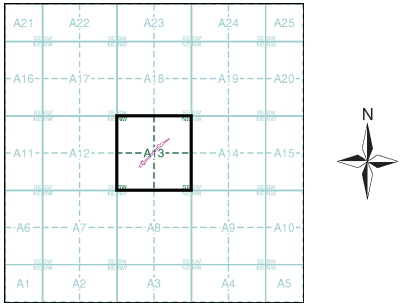

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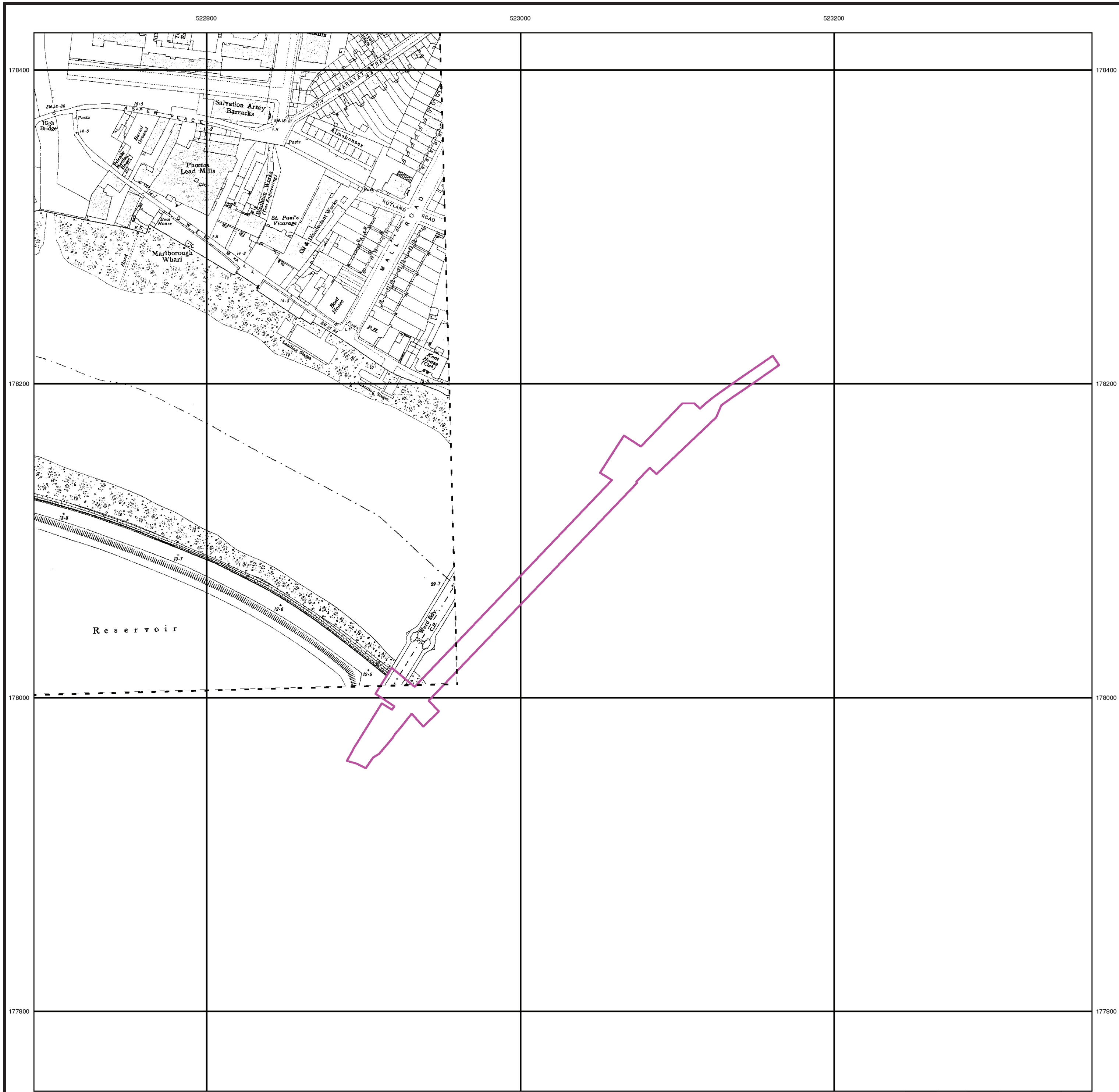

Pell Frischmann

London

Published 1937

Source map scale - 1:1,056

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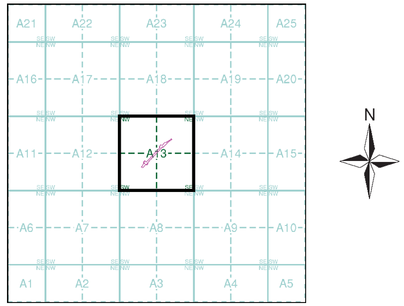
Map Name(s) and Date(s)

010_00_005
1937
1:1,056

Historical Town Plan - Segment A13



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Appendix B
UXO Report

SAFELANE GLOBAL

LEADING THE WAY

Detailed Unexploded Ordnance Risk Assessment

Site: **Hammersmith Bridge Refurbishment**

Client: **Pell Frischmann**

Ref: **8307 RA**

Date: **15th October 2019**

SafeLane Global

Unit 3, The Courtyard, Campus Way, Gillingham Business Park, Gillingham, Kent, ME8 0NZ

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Distribution

Copy No.	Format	Recipient
1	PDF Copy	Pell Frischmann
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Date of Issue: 15th October 2019 Copy no. 1

Originator: PW

This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry.

SafeLane Global

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Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LCC	London County Council
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

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Executive Summary

THE SITE:	
Address	Hammersmith Bridge, London, W6 9DA
OS National Grid Reference	TQ 22971 78089
Details	The site is centred on Hammersmith Bridge, encompassing the entire River Thames crossing area, as well as both embankments and the wider area surrounding the bridge. This area includes several commercial buildings, areas of hardstanding and a large area of open ground in the south-west.
PROPOSED WORKS:	
Proposed works include piling and foundation installation in the River Thames, on the riverbanks and either side of Hammersmith Bridge.	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
Explosive Ordnance Risk Rating	**LOW and MEDIUM zones**
Risk Map	**Annex R**
THREAT OF CONTAMINATION FROM GERMAN AIR-DELIVERED UXO:	

- By the end of WWII, London was the most heavily bombed city in the UK. The Hammersmith area experienced a high bombing density, as confirmed by official statistics. A Luftwaffe Target Map of the surrounding area highlights locations close to the site for possible bombing. As such, the local bombing density was even higher.
- This is confirmed by original bomb census maps which plot at least eight HE bomb strikes on site, with a further 96 within a 300m radius.
- A consolidation of historical sources shows that buildings on site and in the surrounding area suffered varying degrees of bomb damage, many of these buildings were subsequently either redeveloped or cleared.
- Following these bomb strikes on the site; it is likely that rubble and debris would have covered these parts of the site for a time. Consequently, these areas were likely abandoned, increasing the likelihood of subsequent UXO falling on site unnoticed. This is especially pertinent as nearly all air raids on the city occurred at night.
- Had a subsequent UXB fallen within these parts of the site, it will have become immediately obscured within the wreckage / rubble. Note, the entry hole of an SC50 UXB (the most commonly deployed German

HE bombs) could have been as little as 20cm in diameter, and therefore easily obscured in such ground cover. • Had such an incident occurred, the weapon could have eventually come to rest undamaged sections of the site due to the 'J-Curve Effect'. • Within the confines of the river and the reservoir, evidence of a UXB would have been immediately obscured beneath the water line. At the height of hostilities and military activity during WWII, it is highly unlikely that these waters would have been subject to any post-raid checks for UXO. • Furthermore, had a UXB landed within the river itself, any entry hole into sediment will have remained only temporarily, quickly becoming infilled with mobile sediment and obscuring any evidence of its entry.	
MINIMAL THREAT OF UXO CONTAMINATION FROM GERMAN AIR-DELIVERED UXO:	
• The largely undamaged buildings within the south-west and the majority of the north of the site did not appear to suffer any bomb damage, nor does there appear to be any redevelopment consist with locations of bomb strikes. These buildings therefore would have remained in use throughout the war, suggesting that these parts of the site would have been frequently and fully accessed. • Therefore, a subsequent UXB strike to undamaged buildings / areas of hard surfacing on these parts of the site would have been noticed immediately, reported and exhumed at the time.	
THREAT OF CONTAMINATION FROM BRITISH / ALLIED UXO:	
Land Service Ammunition / Small Arms Ammunition	• Two Home Guard battalions were situated within the surrounding area of Hammersmith during WWII; however, the locations of their respective headquarters could not be found. • Although typically HG battalions would take part in training exercises in areas occupied by open countryside, there are several examples of home guard units carrying out invasion training in urban areas. • While the possibility of these being carried out on site cannot be discounted, it is considered unlikely due to the developed nature of the site. • Furthermore, Home Guard battalions are unlikely to have performed training exercises on the reservoir in the south-east or close to commercial buildings in the north of the site. • Note, it is documented in many anecdotal / unofficial sources that Home Guard soldiers often used nearby waterways as quick, easy and untraceable disposal for faulty, surplus or expended munitions (small arms ammunition and land service ammunition). Today, many of these items are found in UK rivers, canals, reservoirs etc. As a result, the possibility that such items may be encountered within the river section of the site cannot be discounted.
Anti-Aircraft Projectiles	• Four HAA batteries were situated within 5km of the site, the nearest of which was located approximately 3.20km south-east. • The site was largely occupied by areas of hard-standing and buildings which sustained severe damage during WWII. It is likely that many of these were abandoned and that areas of rubble or debris would have been present on site for some time. • Other sections of the site, encompassing the river and the reservoir, consisted largely of tidal mud and shallow/deep water.

	• Consequently, it is conceivable that in such locations, the likelihood of a subsequent UX AA shell falling on site unnoticed and the resulting entry hole going unobserved would have been increased.
BOMB PENETRATION ASSESSMENT:	
It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **10-12m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.	
THE LIKELIHOOD THAT UXO REMAINS ON SITE:	

Land:

Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling.

Since WWII, the site has since been significantly redeveloped and repaired. Given the extent of redevelopment to land on both sides of the embankment, and their ongoing use post-war, it is likely that any shallow-buried UXO would have been encountered during shallow excavations and general site use. Consequently, the risk from shallow-buried UXO will have been partially mitigated.

Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated.

The redevelopment of the site at the locations of severe bomb damage is likely to have required some deep foundations/piling. However, the exact location and depth of such works is not known, and therefore we cannot discount that the risk from deeper-buried HE UXB's will not have been mitigated for the majority of the site.

The reservoir was infilled post-WWII, however the details of this operation could not be obtained within the timeframe of this report. The nature and origin of the infill material is unknown, and therefore the possibility that this material was contaminated with UXO cannot be completely discounted. Additionally, the infill was likely placed into the reservoir without sufficient prior clearance operations of the reservoir floor. Consequently, it is assumed that a layer of elevated risk ground lies beneath the infill material within this area.

Marine:

Within the areas of the site occupied by the River Thames, there are two scenarios which could have resulted in UXO remaining onsite post-war:

- **UXO remaining in situ** - whereby UXO remains on the riverbed in the exact location at which it was originally deposited. This is particularly pertinent for larger, air dropped UXBs.
- **UXO penetration into riverbed** – whereby a UXB has fallen into the riverbed, penetrated the material beneath and come to rest at a depth.

Post-war works may have taken place within the river, which could have partly mitigated the risk from UXO on the riverbed. However, whether such works occurred, or the extent of any such works is unknown, and it cannot be discounted that UXO remains buried beneath the extent of any post-war intrusive works. Therefore, the risk of encountering UXO during the proposed works remains unmitigated.

THE RISK THAT ORDNANCE MAY BE INITIATED:

The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation. Drilling of boreholes or similar activities also have the potential to initiate ordnance in this manner, either through impact or vibration.

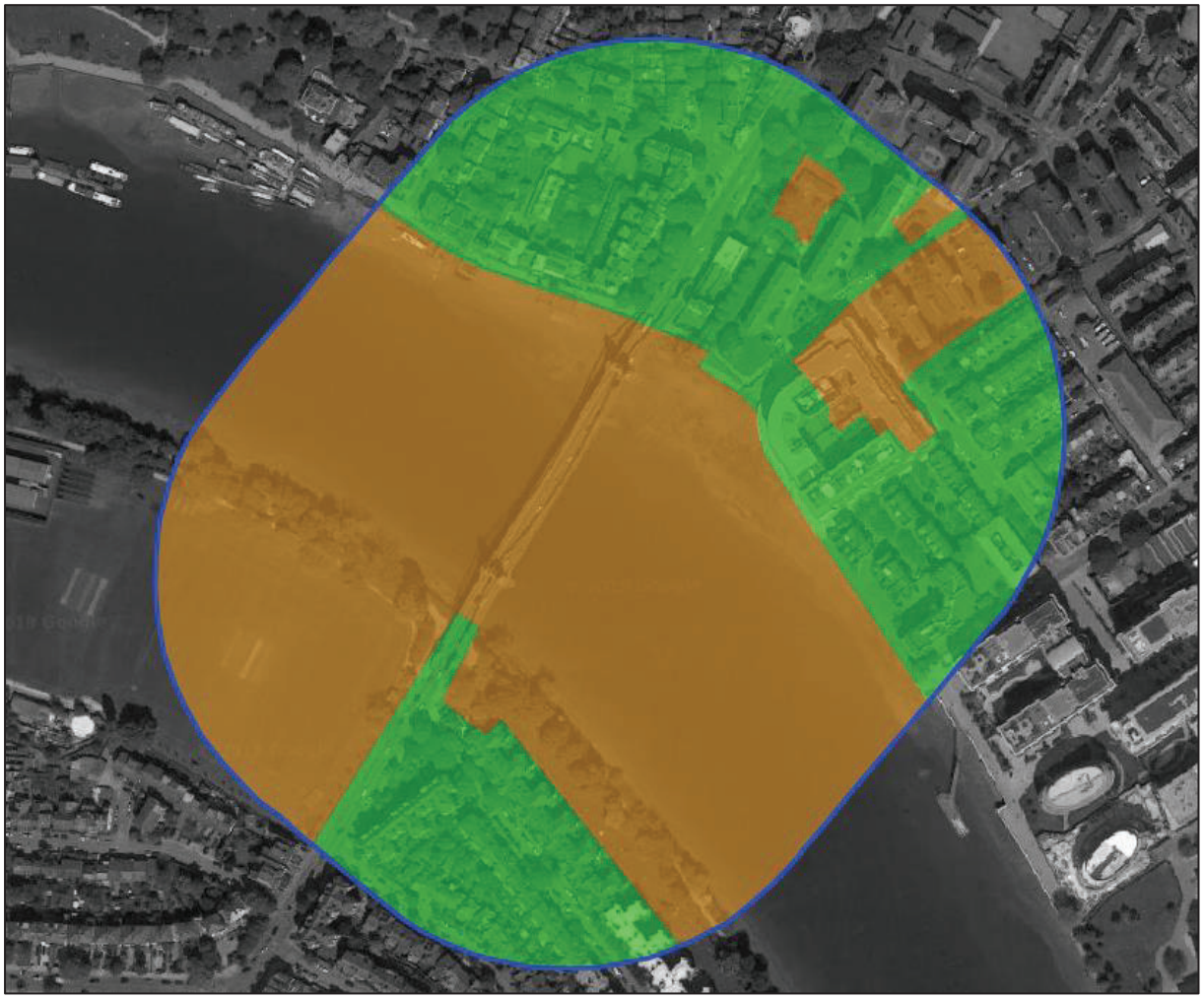
Soil levelling and shallow excavation such as trial pits can pose a similar risk, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.

For works that are not intrusive, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

RECOMMENDED RISK MITIGATION MEASURES:	Low Risk Zone	Medium Risk Zone
Site Specific Explosive Ordnance Safety and Awareness Briefings to all personnel conducting intrusive works	✓	✓
The Provision of Unexploded Ordnance Site Safety Instructions	✓	✓
Explosive Ordnance Disposal (EOD) Engineer presence on site to support shallow intrusive works	✗	✓
Handheld Intrusive Magnetometer Survey of all borehole locations down to the maximum bomb penetration depth	✗	✗
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	✗	✗
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	✗	✓
MARINE ONLY		
Non-Intrusive Magnetometer and Side Scan UXO Survey (Marine)	✗	✓
Intrusive Magnetometer Survey - Down-hole Vallon Probing ahead of Marine Boreholes	✗	✗
Barge-Mounted Intrusive Magnetometer Survey	✗	✗
Seismic Investigation: Further Non-Intrusive Survey over exact locations to identify and mitigate risk.	✗	✓

In making this assessment and recommending these risk mitigation measures, the proposed 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, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.

Risk Map – Annex R



Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph / Current Site Plan

Annex C Pre and Post-WWII OS Maps

Annex D Luftwaffe Target Map

Annex E German Air-Delivered Ordnance

Annex F Recent WWII-era German UXB Finds in the UK

Annex G The J-Curve Effect

Annex H WWII London Bomb Density Map

Annex I London ARP Bomb Census Maps

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Annex N Land Service Ammuniton

Annex O Small Arms Ammunition

Annex P Anti-Aircraft Artillery

Annex Q UXO Press Articles

Annex R Risk Map

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Hammersmith Bridge Refurbishment

2 Introduction

2.1 Background

Pell Frischmann has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of Hammersmith Bridge.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

The most intensive period of bombing over London was the nine months between October 1940 and May 1941 which became known as "The Blitz". During this period, the Luftwaffe attempted to overwhelm Britain's air defences, destroy key industries and infrastructure and break the country's morale ahead of invasion. A total of 18,000 tons of bombs were dropped on London between 1940 and 1945.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

3 Construction Industry Duties and Responsibilities

3.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681).

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

3.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

3.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

3.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

4 The Role of the Authorities and Commercial Contractors

4.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

4.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

5 This Report

5.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

5.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.
- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.

- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

5.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

5.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- London Metropolitan Archives.
- Historic England.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

5.5 Reliability of Historical Records

5.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be

definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

5.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

6 The Site and Scope of Proposed Works

Site Address	Hammersmith Bridge, London, W6 9DA
National Grid Reference Centre Point	TQ 22971 78089
Site Description	The site is centred on Hammersmith Bridge, encompassing the entire River Thames crossing area, as well as both embankments and the wider area surrounding the bridge. This area includes several commercial buildings, areas of hardstanding and a large area of open ground in the south-west.
Proposed Works	Proposed works include piling and foundation installation in the River Thames, on the riverbanks and either side of Hammersmith Bridge.
Maximum Depth of Ground Works	30m bgl.
Site Location Maps and a Recent Aerial Photograph / Current Site Plan are presented in **Annexes A and B.**	

7 Ground Conditions

Data Source		Description
British Geological Survey Borehole	**Borehole Reference**	TQ27NW525
	Location	65m south
	Date	08/07/1987
	Recorded Shallow Geology	• 2.60m of MADE GROUND • 0.80m of CLAY (very soft)

		• 2.40m of SAND (dense) and GRAVEL (fine) • 2.20m of CLAY (firm) • 4.50m of CLAY (stiff)
British Geological Survey Mapping	**Superficial Deposits**	Alluvium – Clay, Silt, Sand and Peat (south and centre). Kempton Park Gravel Member – Sand and Gravel (north).
	Bedrock	London Clay Formation – Clay and Silt.

8 Site History

8.1 Pre-WWII

The following pre-WWII OS map was reviewed.

Date	1916	**Scale**	1:2,500	**Source**	Groundsure Ltd
Observations	• The site encompasses the entirety of *Hammersmith Bridge*, and the surrounding section of the River Thames itself, as well as its northern and southern embankments. • The northern embankment is predominantly occupied by several residential and commercial buildings, fronting sections of *Rutland Road, Bridge, Wellington Road, Crisp Road, Lower Hall, Ship Lane, Chancellors Street* and *St James' Street.* • The south of the site is occupied by residential buildings on *Riverview Gardens* and a section of a *Reservoir.* • Other features demarcated on site include; *Hammersmith Pier, Landing Barge, Landing Stage, Hammersmith Veatry Wharf.* Also, within the sections of the River Thames, the low water mark indicates that part of the site will have been occupied by tidal mud / shingle. • The surrounding area is urban in nature.				
A section of the map showing the site and immediate surrounding area is presented in **Annex C-1**.					

8.2 Post-WWII

The following post-WWII OS map was reviewed.

Date	1951	**Scale**	1:2,500	**Source**	Groundsure Ltd
The following are indicative of serious bomb damage on early post-WWII OS mapping:					
Ruins	✓	One *Ruin* is located in the north of the site, with three more *Ruins* to the north-west of the site.			
Clearance	✓	Several areas of clearance are located both on site and the surrounding area, predominantly north of the embankment, including commercial buildings and the clearance of the Landing Stage.			

Redevelopment	✓	Substantial redevelopment has occurred in the north-east of the site as well as the surrounding area.
Further Observations	• Due to disparity of dates between these two OS maps (~35 years), it cannot be discounted that some instances of redevelopment labelled on site may have in fact occurred before the start of WWII. However, it is likely that a large proportion of the redevelopment labelled was due to bomb damage. • Due to the nature of a large proportion of the site, clearance, ruins and redevelopment will not have been recorded on the bridge itself.	
A section of the map showing the site and immediate surrounding area is presented in **Annex C-2.**		

9 The Threat from Aerial Bombing

9.1 General Bombing History of London

9.1.1 First World War

During WWI, London was targeted and bombed by Zeppelin Airships and by Gotha and Giant fixed-wing aircraft. An estimated 250 tons of ordnance (high explosive and incendiary bombs) was dropped on Greater London, more than half of which fell on the City of London.

A WWI bomb census map for the London area (not annexed) does not record any bomb strikes in close proximity to the site.

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

9.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

As the war progressed, the strategy changed to one of attempting to destroy the morale of the civilian population by the "carpet bombing" of London. The Blitz on London began on 7th September 1940 with concentrated attacks coming to an end in May 1941 as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa'; the invasion of the Soviet Union.

During 1942 and 1943, there were a number of minor raids carried out by small formations of fighter bombers and then between January and May 1944 the Luftwaffe returned to London en masse, for Operation Steinbock. These raids were executed by inexperienced Luftwaffe crews and were less frequent when compared to the original Blitz of 1940/41. Poor navigation and improved defences resulted in unsustainable Luftwaffe losses and many raids were unsuccessful.

Between 1940 and 1945 there were a total of 71 'major' air raids on London. In this period, it is estimated that a total of 190,000 bombs (equivalent to 18,000 tons) were dropped, resulting in the deaths of 29,000 people.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe. Totals of 2,419 V1s and 517 V2s were recorded in the London Civil Defence region.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

A Luftwaffe Target Map, showcasing an area of London in which the site is located, is presented in **Annex D**. Areas close to and encroaching upon the site are labelled on the map, including the West Middlesex Water Works, and may have been considered possible bombing targets. The water works would have been considered a major target as it supplied much of south-west London with water. As such, the site and the surrounding area may have sustained a higher local bombing density.

9.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today. Detailed illustrations of German air-delivered ordnance are presented in **Annex E**.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and

fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.

- Anti-personnel (AP) Bomblets: AP bombs 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.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

9.3 German Air-delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK (see recent press articles, **Annex F**).

9.4 UXB Ground Penetration

9.4.1 General Considerations

The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

9.4.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms^{-1}. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus "offset" from the hole of entry. This "offset" from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. **Annex G** depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.

9.4.3 Second World War Bomb 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, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

9.5 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on both the London Borough of Hammersmith and the London Borough of Barnes between 1940 and 1945:

Record of German Ordnance Dropped		
London Borough	**Hammersmith**	**Barnes**
Area Acreage	2,287	2,519
High Explosive Bombs (all types)	311	240
Parachute Mines	6	3
Oil Bombs	21	15
Phosphorus Bombs	5	15
Fire Pots	0	1
Pilotless Missile (V1)	14	9

Long Range Rocket (V2)	1	3
Total	358	286
Items Per 1,000 Acres	**157**	**114**

Source: Home Office Statistics

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 incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

9.6 WWII London Bomb Density Map

The bombing density map depicts the concentration of bombs that fell on Greater London throughout WWII. The highest densities were recorded around Central and East London along the River Thames.

Site location	Hammersmith & Barnes
Bombing density	High
Bombs per 1000 acres	150-199 100-149
The bombing density map is presented in **Annex H.**	

9.7 Site Specific WWII Bombing Records

9.7.1 London ARP Bomb Census Maps

A review was conducted of The London ARP Bomb Census Maps. Note that all distances given are approximations from the nearest site boundary.

Consolidated Bomb Plots

Date Range	Number of Local Incidents	Weapon	Closest Incident to the Site
Night bombing up to 07/10/1940	25	HE Bombs	120m west
Night bombing 07/10/1940 – 28/07/1941	71	HE Bombs	5 on site
Sections of the Consolidated London ARP Bomb Census Maps, showing bomb strikes on and in the immediate vicinity of the site, are presented in **Annex I-1.**			

Weekly Bomb Plots

Weekly bomb plot maps dated between 7th September 1940 and 18th June 1944 were also reviewed. In addition to the incidents above, the following observations were made:

Date Range	Number of Local Incidents	Weapon	Closest Incident to the Site
07/10/1940 – 14/10/1940	18	HE Bombs	On site – stick aligned with the site
04/11/1940 – 11/11/1940	13	12 x HE Bombs 1 x 1kg IB Shower	Over the north of the site
11/11/1940 – 18/11/1940	1	1kg IB Shower	Over the south of the site
25/11/1940 – 02/12/1940	1	1kg IB Shower	Over the south of the site
03/02/1941 – 10/02/1941	15	14 x HE Bombs 1 x 1kg IB Shower	120m south
10/03/1941 – 17/03/1941	1	HE Bomb	110m north
14/04/1941 – 21/04/1941	13	3 x 1000kg bomb strike 4 x 1kg IB Shower 6 x HE Bombs	On site (in the river)
14/02/1944 – 20/02/1944	3	2 x HE Bomb Strikes 1 x UXB	On site (UXB)
21/02/1944 – 27/02/1944	4	2 x 1800kg bomb strikes 1 x 1000kg bomb strike 1 x 500kg bomb strike	218m east
Sections of the Weekly London ARP Bomb Census Maps, showing bomb strikes on and in the immediate vicinity of the site, are presented in **Annex I-2.**			

9.7.2 London V1 Bomb Census Map

Following the beginning of the V1 campaign in mid-1944, a series of maps showing where these weapons fell was produced for the London Civil Defence region and these were updated as the war progressed.

V1 plotted on site (or in vicinity)	✘
Date	21/08/1944

Distance from site	65m north-east
An extract of the map, showing the site and immediate surrounding area, is presented in **Annex J.**	

9.7.3 LCC Bomb Damage Map

London County Council Bomb Damage Maps were compiled by the Architects Department soon after the bombing of London commenced and were updated throughout the war to document levels of damage that structures sustained.

Damage on site	✓
Further comments	• The LCC bomb damage map covers the majority of the site; however, the south-eastern section is not covered. • The site and the surrounding area suffered varying levels of damage. • Buildings on site sustained damage ranging from *Blast Damage, minor in nature* (Yellow) to *Damage beyond repair* (Purple), predominantly in the north of the site. No damage was recorded on the southern portion of the site. Large areas of clearance (Light Blue and Light Green) are also located across the north-east of the site. • Please note however that bomb damage maps do not record WWII damage to roadways. As such, the bridge itself has not been labelled on the map as sustaining any level of damage. Nonetheless, due to the high bombing density and the fact that bomb strikes have been recorded to have hit the bridge, it is likely that it sustained some level of damage.
A section of the map showing the site and immediate surrounding area is presented in **Annex K.**	

9.7.4 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

ARP written records were reviewed for:	London Borough of Hammersmith	
Source:	National Archives	
Records of bombing on / near the site were found		✓
Date	**Weapon**	**Details**
n/a	50kg HE Bomb	'Penetrated centre of roadway on S end of Hammersmith bridge and fell on to tow-path, slight damage to bridge." This would have occurred on site.

9.7.5 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
20/02/1944	UXB	One UXB was recorded to have been found beneath Hammersmith Bridge on 20th February 1944[1].
20/02/1944	HE Bombs	Bomb strikes were recorded to have hit the reservoir, located within the south-west of the site[2].
03/02/1941	Type Unknown	One bomb was found in a garden at the rear of 20 Lilian Road[3]. Occurred approximately 150m south-west of the site.

9.7.6 WWII-era RAF Aerial Photography

The following WWII-era photography of the site was reviewed.

Source	Historic England	Image Type	Aerial	Quality	Small-scale Mixed Quality
Date	29/01/1947 + 18/05/1948				
Observations	• The site appears to be as shown in post-WWII OS mapping, comprising the bridge, its surroundings and the section of the river. • Evidence of bomb damage and clearance appears to be present both on site and within the wider area, predominantly to the north-east of the site. This is consistent with evidence seen in both bomb damage maps as well as the location of bomb strikes. • Note however, the small-scale of the photograph means an accurate assessment of bomb damage to the remaining buildings cannot be made. • Ground conditions on site appear to consist largely of cleared ground at the location of previous buildings, as well as water in the reservoir in the south-west of the site. The centre of the site is largely occupied by the River Thames and its associated embankments. • It is possible that earlier in the war, the area within the site that sustained damage may have been occupied by quantities of rubble and debris due to bomb damage to the site. Had a subsequent UXB then fallen here it will have become immediately obscured within the wreckage. • Evidence of any UXB landing within the river or reservoir will have been immediately obscured beneath the waterline, therefore invisible within photography.				

[1] *http://www.barnes-history.org.uk/Bombmap/mappage.html*

[2] *http://www.barnes-history.org.uk/Bombmap/mappage.html*

[3] *Ibid.*

This image is presented in **Annex L.**

9.7.7 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 were 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, nor 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.

SafeLane Global holds records of officially registered abandoned bombs at or near the site.	✘
Additional comments:	• No abandoned bombs were recorded to have been found close to the site. • One bomb of an unknown size was recovered in the River Thames approximately 25 yds from the bank, located 1.71km south-west of the site. The exact date of recovery however is unknown.

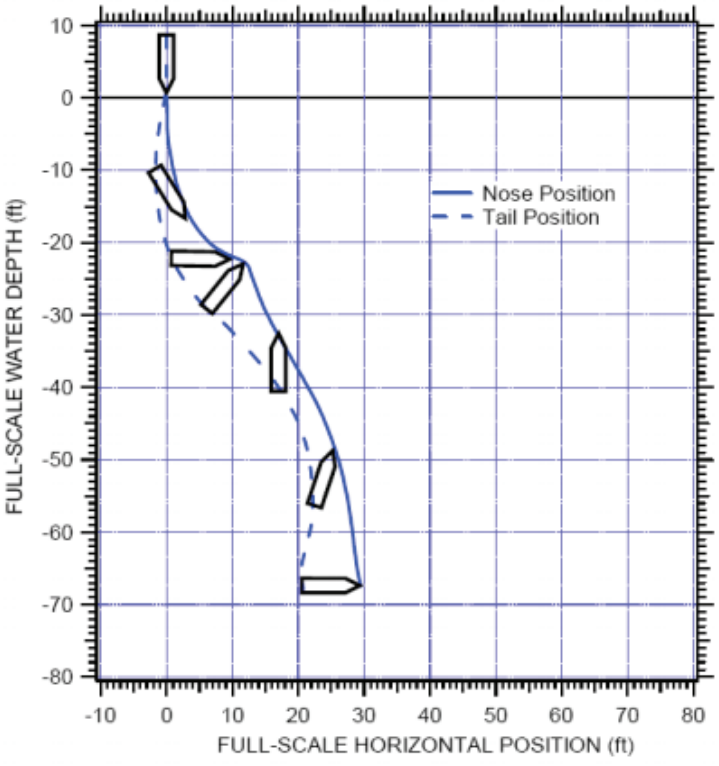
9.8 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 2.60m of MADE GROUND, 0.80m of CLAY (very soft), 2.40m of SAND (dense) and GRAVEL (fine), 6.70m of CLAY.
- Impact Angle and Velocity – 80-90^0 from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **10-12m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Within the section of the site occupied by river, the lowest possible water depth above the locations of the proposed works during WWII will also be considered.



For any part of the site located below the water mark of the lowest water level, calculating a maximum bomb penetration assessment is more problematic as the water column produces a decelerating effect that is not easily calculated.

Penetration into riverbed by bombs with a standard tangent Ogive nosecone is not well predicted as the bomb will deviate from its original path. The velocity at which a bomb is travelling becomes irrelevant in water deeper than several metres because the water has such a decelerating effect that a bomb will essentially "float" down to the seabed, however not necessarily in a vertical orientation; see graph (left) - plotting the trajectory of an American MK-84 (925kg) HE bomb with no tail section into water at an entry velocity of 296m/s.[4]

By approximately 6m water depth the bomb has become fully horizontal and therefore has lost most of its ability to significantly penetrate the seabed.

Note, that this 925kg bomb is approximately twice the weight of the 500kg bomb used above. This means that the bomb used in this American experiment struck the water with more force than the vast majority of those deployed over the UK during WWII.

Therefore, where the water depth above the study area exceeds approximately 4m, a 500kg UXB striking the water surface is unlikely to have had the required kinetic energy to achieve complete burial beneath the riverbed.

Further research confirms the following key features:

- Ignoring surface tension there will be an immediate loss of inertia due to rapid energy losses; sound, wave, splash, bubble formation and cavitation.
- The drag force rapidly decelerates the bomb. If there is sufficient water depth then acceleration will become 0m/s2 and the terminal velocity in water will be achieved; 11m/s.
- Once the terminal velocity in water is reached the bomb impacts the riverbed as a free-fall penetrator.

Analysis of the air-water-soil regime is complex and difficult to measure. The current model assumes that 5m of water column is required in order to achieve the terminal velocity of a German WWII HE UXB

[4] *P. Gefken, Underwater Bomb Trajectory Prediction for Stand-off Assault (Mine/IED) Breaching Weapon Fuse Improvement (SOABWFI), 2006*

in water. Impacts at this speed will cause a riverbed sediment penetration of 2.3m, assuming a bearing capacity of 75kPa.[5]

However, a large section of the site comprised a water filled reservoir, which has subsequently been infilled during the post-war period. Therefore, in addition to the above the below parameters also need to be considered:

- Water level in the reservoir at time of impact. Water will have an attenuating effect on the velocity of the bomb and if sufficiently deep may reduce its impact velocity sufficiently that it will not penetrate the reservoir bed.
- Penetration into the reservoir bed by bombs with a standard tangent Ogive nosecone is not well predicted as the bomb will deviate from its original path. The velocity at which a bomb is travelling becomes irrelevant in water deeper than several metres because the water has such a decelerating effect.[6]

9.9 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in *Section 8.7*, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

9.9.1 Density of Bombing Assessment:

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

Density of Bombing Assessment	
Based on wartime records or secondary source information, what was the bombing density over the site?	High
Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✓
Were any HE bomb strikes recorded on site?	✓

[5] *Department of The US Army., TM 5-855-1 Fundamentals of Protective Design for Conventional Weapons, 1986*

[6] *P. Gefken, Underwater Bomb Trajectory Prediction for Stand-off Assault (Mine/IED) Breaching Weapon Fuse Improvement (SOABWFI), 2006*

What is the distance between the site boundary and the closest recorded large bomb strike?	On site x 8
How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	104
Were any nearby sticks of large bombs recorded in line with the site?	✓
Were any 1kg incendiary bomb showers recorded over the site?	✓
Additional comments:	n/a

9.9.2 Bomb Damage Assessment:

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

Bomb Damage Assessment	
A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✓
Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✗
Buildings on site were seriously damaged by a V1 and / or V2 strike.	✗
Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a
Additional comments:	n/a

9.9.3 Frequency of Access Assessment:

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

Frequency of Access Assessment	
The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✓
The site was exclusively or partially developed during WWII.	✓
Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓
The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓
The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗
The site was occupied by a school during WWII.	✗
Part of the site is likely to have been subject to post-raid searches for UXO.	See additional comments
Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✓
The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓

The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✘
The site was occupied by a graveyard which would have experienced limited access.	✘
The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✘
The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✘
The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✘
Additional comments:	• It is considered likely that any serious WWII-era damage to Hammersmith Bridge would have been noticed immediately and subsequently repaired. As such, the risk of encountering UXO on the bridge itself is considered unlikely. • However, access to the river itself will have been sporadic, with possibly no access at all to the riverbed. As a result, a UXB landing in the river and coming to rest on the riverbed is unlikely to have been observed. This is especially pertinent as most air raids over the city occurred during the night, where visibility over the river will have been very impaired. • This scenario can also be ascribed to the reservoir.

9.9.4 Ground Cover Assessment:

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

Ground Cover Assessment

The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	Possibly
The site was occupied by dense, inaccessible vegetation during WWII.	Possibly
The site may have been susceptible to waterlogged conditions during WWII.	✓
The site was occupied by (possibly) unmaintained grass field during WWII.	✗
The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓
The site was occupied by tidal mud or marshland during WWII.	✓
The site was occupied by railway tracks crossing soft ground during WWII.	✗
The site was occupied by stockpiled material during WWII.	✗
The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓
A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✓
The site was occupied by well-maintained, manicured lawn during WWII.	✗
Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓
Additional comments:	• A large proportion of the site comprised the river and a reservoir during WWII. A UXB strike to these locations will have left little to no evidence. • Additionally, when the River Thames was at its lower water mark, part of the study area will have been occupied by tidal mud. A UXB entry hole within the river bank mud on site (revealed at low tide) is unlikely to have persisted, the next high tide filling in the hole with water and sediment. • Furthermore, even if evidence of a UXB was observed, it is unlikely to have been reported due to its insignificant position.

9.9.5 Bomb Failure Rate Assessment:

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

Bomb Failure Rate Assessment	
Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗
Additional comments:	n/a

10 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✗
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Military Fortifications and Coastal Defences	✗
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

10.1 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several recent HG UXO finds (see **Annex M**).

Home Guard Activity		
Nearest HG Battalion to the site.	6th and 7th County of London Battalions – Hammersmith	
Site Specific Details:	• Two Home Guard battalions were situated within the surrounding area of Hammersmith during WWII; however, the locations of their respective headquarters could not be found. • Although typically HG battalions would take part in training exercises in areas occupied by open countryside, there are several examples of home guard units carrying out invasion training in urban areas. • While the possibility of these being carried out on site cannot be discounted, it is considered unlikely due to the developed nature of the site. • Furthermore, Home Guard battalions are unlikely to have performed training exercises on the reservoir in the south-east or close to commercial buildings in the north of the site. • Note, it is documented in many anecdotal / unofficial sources that Home Guard soldiers often used nearby waterways as quick, easy and untraceable disposal for faulty, surplus or expended munitions (small arms ammunition and land service ammunition). Today, many of these items are found in UK rivers, canals, reservoirs etc. As a result, the possibility that such items may be encountered within the river section of the site cannot be discounted.	
There is evidence to suggest an elevated risk of land service / small arms ammunition contamination on site.		✓

10.2 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing

to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

Anti-Aircraft Gun Batteries	
Number of HAA batteries within 5km of the site.	4
Additional Comments:	• The nearest was located approximately 3.20km south-east. • The site was largely occupied by areas of hard-standing and buildings which sustained severe damage during WWII. It is likely that many of these were abandoned and that areas of rubble or debris would have been present on site for some time. • Other sections of the site, encompassing the river and the reservoir, consisted largely of tidal mud and shallow/deep water. • Consequently, it is conceivable that in such locations, the likelihood of a subsequent UX AA shell falling on site unnoticed and the resulting entry hole going unobserved would have been increased.
There is evidence to suggest an elevated risk of unexploded AA shells contamination on site.	✓

10.3 The Threat Posed by Allied Unexploded Ordnance

10.3.1 Land Service Ammunition (LSA)

10.3.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK and therefore the possibility cannot be discounted that they were stores on site. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases. Examples of Grenades, Mortars and Home Guard weapons are presented in **Annex N**.

10.3.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They

are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

10.3.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

10.3.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury. Images of SAA are presented in **Annex O**.

10.3.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Pictures of AAA projectiles are presented in **Annex P**. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg

4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

11 Ordnance Clearance and Post-WWII Ground Works

11.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

11.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Records were found to indicate that Army EOD tasks have taken place on / in the vicinity of the site.	✘
Further Comments:	n/a
Records of recent local ordnance finds were found.	✓

Further Comments:	• A WWII shell was removed from the River Thames, north of Putney Bridge in April 2017[7]. This was found approx. 2.6km south-east of the site.
	• Although the following were not found in the vicinity of the site, the following finds were discovered in the River Thames within the past few years:
	  ○ A WWII bomb was found in the river near the runway of London City Airport in 2018[8].
	  ○ Another bomb was found within the same month in Grays to the east of London on the banks of the River Thames[9].
	  ○ A bomb was found in 2017 close to the Houses of Parliament in the River Thames[10].

[7] *https://www.bbc.co.uk/news/uk-england-39472672*

[8] *https://www.theguardian.com/uk-news/2018/feb/12/london-city-airport-closed-after-wwii-bomb-found-in-thames*

[9] *https://talkradio.co.uk/news/another-unexploded-wwii-bomb-discovered-near-river-thames-18021324004*

[10] *https://www.theguardian.com/uk-news/2017/jan/20/unexploded-wwii-second-world-war-bomb-pulled-river-thames*

	○ Another bomb found in the River Thames in 2019 by a magnet fisherman[11]. ○ A WWII grenade found on the banks of the Thames was safely detonated in June 2015[12]. ○ In 2010, an UX WWII hand grenade was found on the Thames foreshore in Fulham[13].
SafeLane Global have encountered UXO in the local area.	✘
Further Comments:	n/a

11.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII.	✓
Further details:	• The bridge on site, barring routine maintenance work, has remained largely the same as pre-WWII conditions. However, the portions of the site located on the northern and southern sides of the embankments have undergone substantial redevelopment since the end of WWII. • In 1968, the buildings on the river associated with the West Middlesex Waterworks were demolished and the area was cleared to create a public park. The reservoir was subsequently infilled. The nature and origin of this infill material is not known, however could have comprised contaminated material. Also, any items of UXO left on the floor of the reservoir basin is unlikely to have been removed prior to infill operations. • The majority of the redevelopment occurred toward the north of the bridge, with many areas having been cleared and redeveloped for new buildings. • It is possible that redevelopment on buildings north of the bridge may have mitigated the risk of encountering UXO beneath those buildings. However, this would depend to what depths the redevelopment went to.

[11] *https://www.bbc.co.uk/news/uk-england-beds-bucks-herts-48002685*

[12] *https://www.standard.co.uk/news/london/watch-the-moment-police-blow-up-wwii-grenade-found-by-mudlarker-beside-the-thames-10319679.html*

[13] *https://www.mylondon.news/news/local-news/unexploded-hand-grenade-found-foreshore-5998981*

12 The Overall Unexploded Ordnance Risk Assessment

12.1 General Considerations

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:

- That the site was contaminated with unexploded ordnance
- That UXO remains on site
- That such items could be encountered during any intrusive works
- That ordnance may be activated by the works operations
- The consequences of encountering or initiating ordnance

12.2 The Likelihood that the Site was Contaminated with Unexploded Ordnance

The below is a generalised table of factors used to determine the level of UXO risk on a site. Note that additional site-specific information can increase UXO risk beyond these criteria:

Low Risk	Medium Risk	High Risk
German Air Dropped Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
Allied Ordnance		
No evidence of Allied military activity on or near the site.	Evidence of military activity on or near the site. This can include Home Guard activities, ground defence structures, munitions factories or military sites such as airfields.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

For the reasons discussed in *Section 8 and 9* SafeLane Global believes that there is an elevated likelihood that UXO contaminated the study area. This is based on the following:

GERMAN AIR-DELIVERED UXO	
Elevated Threat	
• By the end of WWII, London was the most heavily bombed city in the UK. The Hammersmith area experienced a high bombing density, as confirmed by official statistics. A Luftwaffe Target Map of the surrounding area highlights locations close to the site for possible bombing. As such, the local bombing density was even higher. • This is confirmed by original bomb census maps which plot at least eight HE bomb strikes on site, with a further 96 within a 300m radius. • A consolidation of historical sources shows that buildings on site and in the surrounding area suffered varying degrees of bomb damage, many of these buildings were subsequently either redeveloped or cleared. • Following these bomb strikes on the site; it is likely that rubble and debris would have covered these parts of the site for a time. Consequently, these areas were likely abandoned, increasing the likelihood of subsequent UXO falling on site unnoticed. This is especially pertinent as nearly all air raids on the city occurred at night. • Had a subsequent UXB fallen within these parts of the site, it will have become immediately obscured within the wreckage / rubble. Note, the entry hole of an SC50 UXB (the most commonly deployed German HE bombs) could have been as little as 20cm in diameter, and therefore easily obscured in such ground cover. • Had such an incident occurred, the weapon could have eventually come to rest undamaged sections of the site due to the 'J-Curve Effect'. • Within the confines of the river and the reservoir, evidence of a UXB would have been immediately obscured beneath the water line. At the height of hostilities and military activity during WWII, it is highly unlikely that these waters would have been subject to any post-raid checks for UXO. • Furthermore, had a UXB landed within the river itself, any entry hole into sediment will have remained only temporarily, quickly becoming infilled with mobile sediment and obscuring any evidence of its entry.	
Minimal Threat	
• The largely undamaged buildings within the south-west and the majority of the north of the site did not appear to suffer any bomb damage, nor does there appear to be any redevelopment consist with locations of bomb strikes. These buildings therefore would have remained in use throughout the war, suggesting that these parts of the site would have been frequently and fully accessed. • Therefore, a subsequent UXB strike to undamaged buildings / areas of hard surfacing on these parts of the site would have been noticed immediately, reported and exhumed at the time.	
BRITISH / ALLIED UXO	
Land Service Ammunition / Small Arms Ammunition	• Two Home Guard battalions were situated within the surrounding area of Hammersmith during WWII; however, the locations of their respective headquarters could not be found.

	• Although typically HG battalions would take part in training exercises in areas occupied by open countryside, there are several examples of home guard units carrying out invasion training in urban areas. • While the possibility of these being carried out on site cannot be discounted, it is considered unlikely due to the developed nature of the site. • Furthermore, Home Guard battalions are unlikely to have performed training exercises on the reservoir in the south-east or close to commercial buildings in the north of the site. • Note, it is documented in many anecdotal / unofficial sources that Home Guard soldiers often used nearby waterways as quick, easy and untraceable disposal for faulty, surplus or expended munitions (small arms ammunition and land service ammunition). Today, many of these items are found in UK rivers, canals, reservoirs etc. As a result, the possibility that such items may be encountered within the river section of the site cannot be discounted.
Anti-Aircraft Projectiles	• Four HAA batteries were situated within 5km of the site, the nearest of which was located approximately 3.20km south-east. • The site was largely occupied by areas of hard-standing and buildings which sustained severe damage during WWII. It is likely that many of these were abandoned and that areas of rubble or debris would have been present on site for some time. • Other sections of the site, encompassing the river and the reservoir, consisted largely of tidal mud and shallow/deep water. • Consequently, it is conceivable that in such locations, the likelihood of a subsequent UX AA shell falling on site unnoticed and the resulting entry hole going unobserved would have been increased.

12.3 The Likelihood that Unexploded Ordnance Remains on Site

12.3.1 Land:

Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling.

Since WWII, the site has since been significantly redeveloped and repaired. Given the extent of redevelopment to land on both sides of the embankment, and their ongoing use post-war, it is likely that any shallow-buried UXO would have been encountered during shallow excavations and general site use. Consequently, the risk from shallow-buried UXO will have been partially mitigated.

Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated.

The redevelopment of the site at the locations of severe bomb damage is likely to have required some deep foundations/piling. However, the exact location and depth of such works is not known, and therefore we cannot discount that the risk from deeper-buried HE UXB's will not have been mitigated for the majority of the site.

The reservoir was infilled post-WWII, however the details of this operation could not be obtained within the timeframe of this report. The nature and origin of the infill material is unknown, and therefore the possibility that this material was contaminated with UXO cannot be completely discounted. Additionally, the infill was likely placed into the reservoir without sufficient prior clearance operations of the reservoir floor. Consequently, it is assumed that a layer of elevated risk ground lies beneath the infill material within this area.

12.3.2 Marine:

Within the areas of the site occupied by the River Thames, there are two scenarios which could have resulted in UXO remaining onsite post-war:

- **UXO remaining in situ** - whereby UXO remains on the riverbed in the exact location at which it was originally deposited. This is particularly pertinent for larger, air dropped UXBs.
- **UXO penetration into riverbed** – whereby a UXB has fallen into the riverbed, penetrated the material beneath and come to rest at a depth.

Post-war works may have taken place within the river, which could have partly mitigated the risk from UXO on the riverbed. However, whether such works occurred, or the extent of any such works is unknown, and it cannot be discounted that UXO remains buried beneath the extent of any post-war intrusive works. Therefore, the risk of encountering UXO during the proposed works remains unmitigated.

12.4 The Likelihood that Ordnance may be Encountered during the Works

The most likely scenarios under which a 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.

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

If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.

12.5 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed 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.

12.5.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

- Direct impact onto the main body of the bomb: Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
- Re-starting the clock timer in the fuze: Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-commence.
- Induction of a static charge, causing a current in an electric fuze: The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism over the last 60 years such that the fuze circuit could not be activated.
- Friction impact initiating the (shock-sensitive) fuze explosive: This is the most likely scenario resulting in the bomb detonating.

12.5.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation. Drilling of boreholes or similar activities also have the potential to initiate ordnance in this manner, either through impact or vibration.

Soil levelling and shallow excavation such as trial pits can pose a similar risk, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.

For works that are not intrusive, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

12.6 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first

action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

Annex Q-1 details UXB incidents where intrusive works have caused UXBs to detonate, resulting in death or injury and damage to plant. Whilst these recent incidents occurred internationally, there is still reason to believe that such incidents are possible in the UK without the implementation of suitable risk mitigation measures. **Annex Q-2** details incidents on construction sites in the UK, at which delays, site shut-downs, evacuations and disruptions have occurred.

12.7 SafeLane Global's Assessment

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be heterogeneous and can therefore be divided into areas of **Low** and **Medium** risk.

Low Risk:

- Undamaged buildings and hardstanding (inclusive of Hammersmith Bridge itself)

	Level of Risk		
Type of Ordnance	**Low**	**Medium**	**High**
German High Explosive Bombs	✓		
German 1kg Incendiary Bombs	✓		
Allied Anti-Aircraft Shells	✓		
British / Allied Small Arms and Land Service Ammunition	✓		

Medium Risk:

- Areas occupied by the River Thames, tidal mud or the reservoir during WWII (inclusive of the area beneath Hammersmith Bridge)
- Areas of open ground during WWII
- Buffer area to account for the J-Curve Effect

	Level of Risk		
Type of Ordnance	**Low**	**Medium**	**High**
German High Explosive Bombs		✓	
German 1kg Incendiary Bombs		✓	
Allied Anti-Aircraft Shells		✓	
British / Allied Small Arms and Land Service Ammunition	✓		

13 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site:

Scope-Specific Recommended Risk Mitigation Measures	Low Risk Zone	Med Risk Zone
Site Specific Explosive Ordnance Safety and Awareness Briefings to all personnel conducting intrusive works A specialised briefing is always advisable when there is a possibility of explosive ordnance contamination. It is an essential component of the Health & Safety Plan for the site and conforms to requirements of CDM Regulations 2015. All personnel working on the site should be instructed on the identification of UXB, actions to be taken to alert site management and to keep people and equipment away from the hazard.	✓	✓
The Provision of Unexploded Ordnance Site Safety Instructions These written instructions contain information detailing actions to be taken in the event that unexploded ordnance is discovered. They are to be retained on site and will both assist in making a preliminary assessment of a suspect object and provide guidance on the immediate steps to be taken in the event that ordnance is believed to have been found.	✓	✓
Explosive Ordnance Disposal (EOD) Engineer presence on site to support shallow intrusive works When on site the role of the EOD Engineer would include; monitoring works using visual recognition and instrumentation and immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by the ground workers on site; providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and advise staff of the need to modify working practices to take account of the ordnance risk, and finally to aid Incident Management which would involve liaison with the local authorities and Police should ordnance be identified and present an explosive hazard.	✗	✓
Handheld Intrusive Magnetometer Survey of all borehole locations down to the maximum bomb penetration depth As part of the EOD Engineer presence on site, SafeLane Global Ltd can deploy intrusive magnetometry techniques to provide staged clearance ahead of all the borehole locations.	✗	✗
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only) This survey is carried out using caesium vapour magnetometers linked to a data logger. Data is interpreted using advanced proprietary software which is capable of modelling the magnetic anomalies for mass, depth and location, thus providing information which can be used to locate discrete buried objects that may be ordnance. The system will typically locate buried ordnance to a depth of up to 4m for a 50kg bomb (the smallest HE bomb used by the Luftwaffe) and deeper for larger bombs. Additionally, the survey will locate any buried services with a magnetic signature, will indicate areas of gross magnetic "contamination" (which may indicate unknown underground obstructions) and provide information on archaeological features	✗	✗

Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed 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. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.	✘	✓
MARINE		
Non-Intrusive Magnetometer and Side Scan UXO Survey A Magnetometer and high-resolution Side Scan Survey should be conducted over the proposed works area to identify any ferrous anomalies (potential UXO), This will also identify areas clear of ferrous anomalies that may be used for the placement of piled foundations. The Side Scan Survey also allows for the identification of non-ferrous surface obstructions which may hamper the proposed works, to aid planning and design.	✘	✓
Intrusive Magnetometer Survey - Down-hole Vallon Probing ahead of Marine Boreholes A down-hole Vallon magnetometer is lowered to the estuary bed first to scan a radius for ferrous anomalies. Provided the river bed is clear, boreholing is conducted to 1m. Nonferrous sleeving must be used with the Vallon lowered down the sleeve to clear the next metre ahead of the borehole. This sequence is repeated until bomb penetration depth is reached, then boreholing can continue unrestricted. Sleeving would be expected to extend from the JU Barge deck to river bed to ensure drill bit relocates the borehole each time it is withdrawn.	✘	✘
Barge-Mounted Intrusive Magnetometer Survey Magnetometer surveys of discrete pile locations in the dock basin are accomplished by the use of a TFG drill rig mounted on a jack up barge with a moon pool over each pile position. Where the use of a moon pool is not feasible due to the proximity of the pile location to other structures, a gantry can be constructed over the side of the barge to allow for drilling and safe access to the rig. A TFG survey can then be conducted to depth to prove whether a position is clear of ferrous anomalies.	✘	✘
Seismic Investigation: Further Non-Intrusive Survey over exact locations to identify and mitigate risk (as an alternative to above two measures) . This method will enable the gathering of detailed target information on individual targets giving the ability to produce true 3D seismic volumes of the upper tens of metres of sediment and imaging buried structures and objects with 3D decametric resolution allowing accurate UXO risk decision making to be made. This process is quick and requires no intrusive works unless an item of UXO is identified. In addition, this process would provide details of any other obstructions that may affect piling operations. In recent projects, SafeLane has reduced potential obstructions affecting piling works from an anticipated 10% to 0.01%.	✘	✓
In making this assessment and recommending these risk mitigation measures, the proposed 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, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.		

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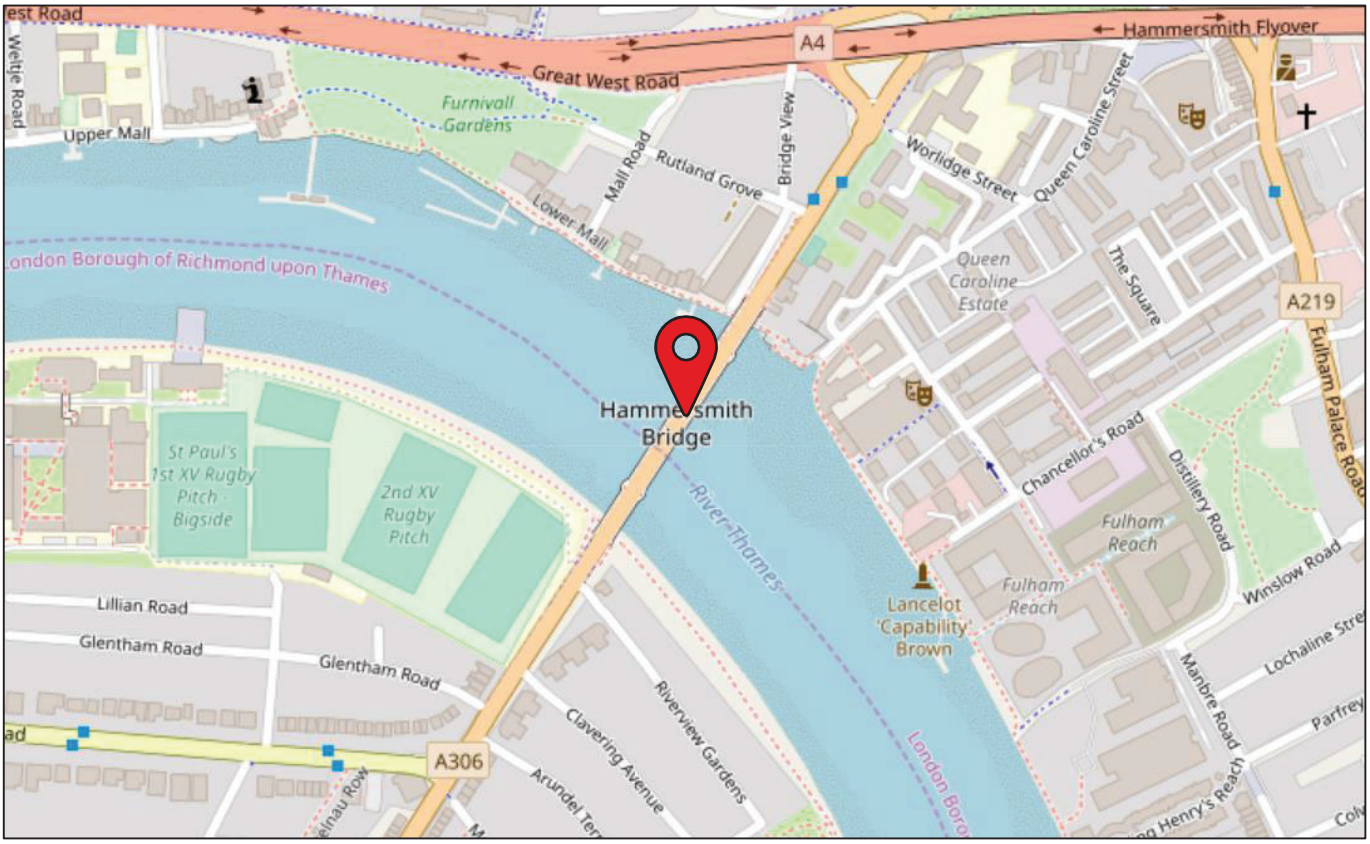

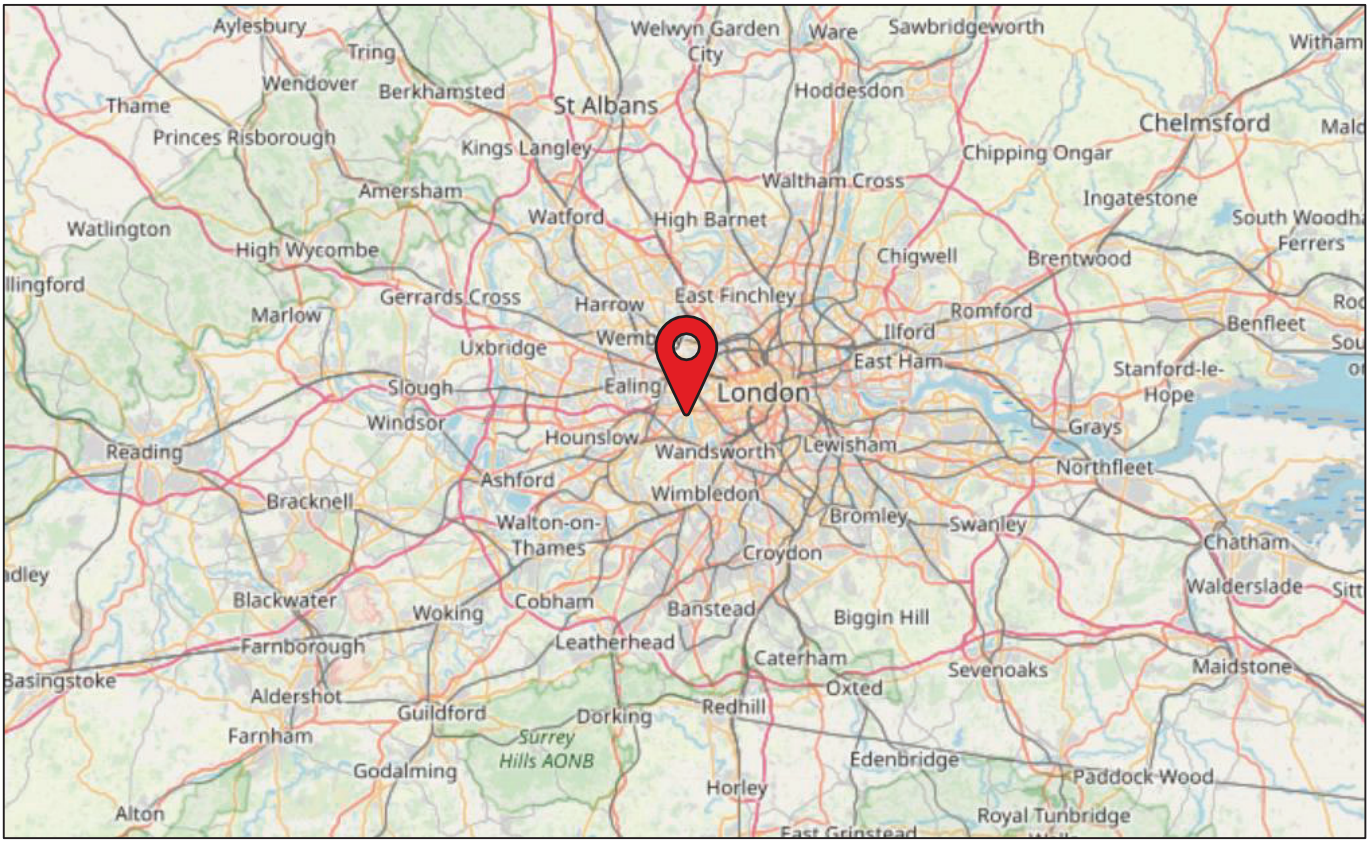

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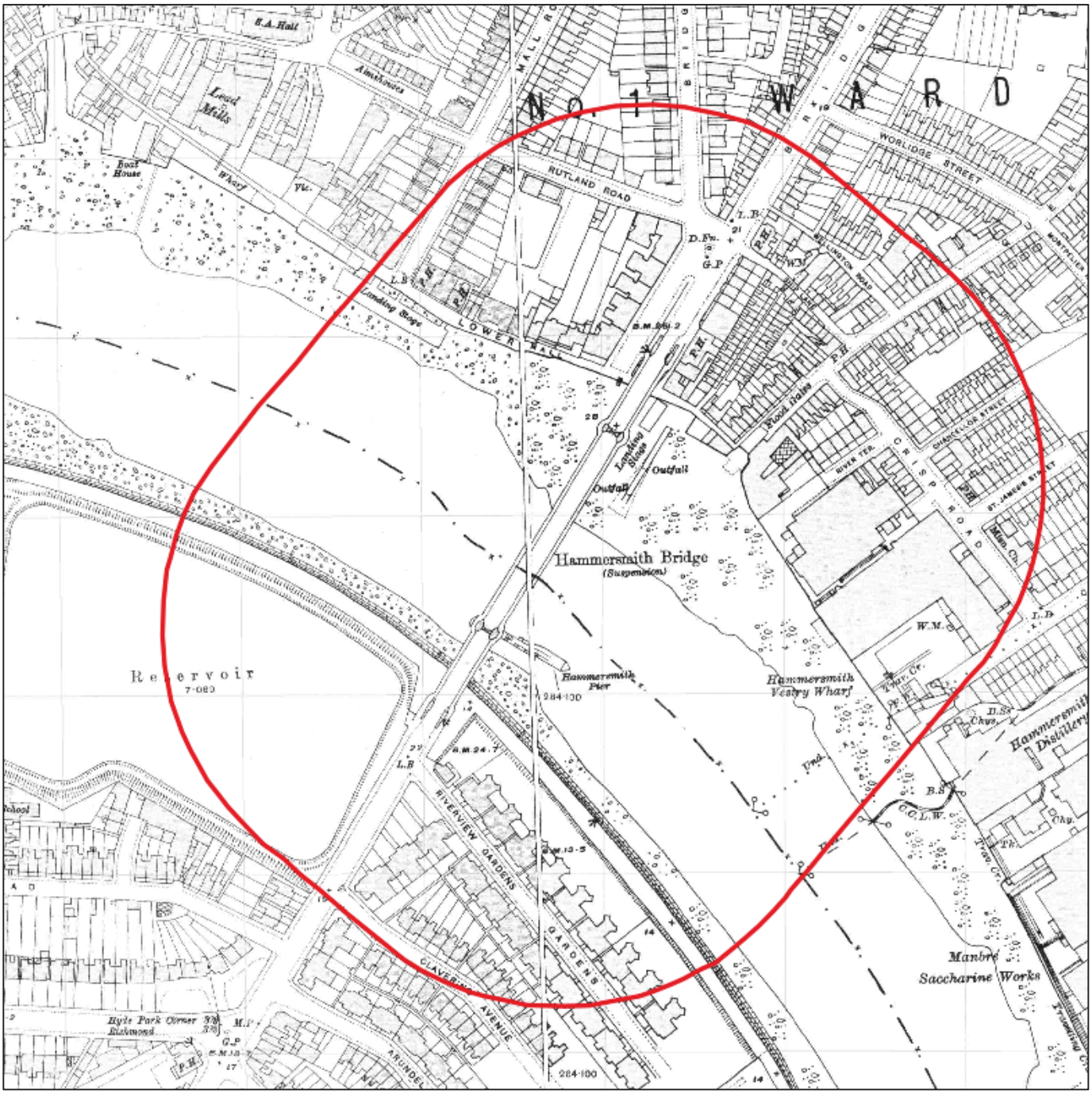
Approximate site boundary

Google Earth™ Mapping Services / Pell Frischmann

N



Approximate site boundary

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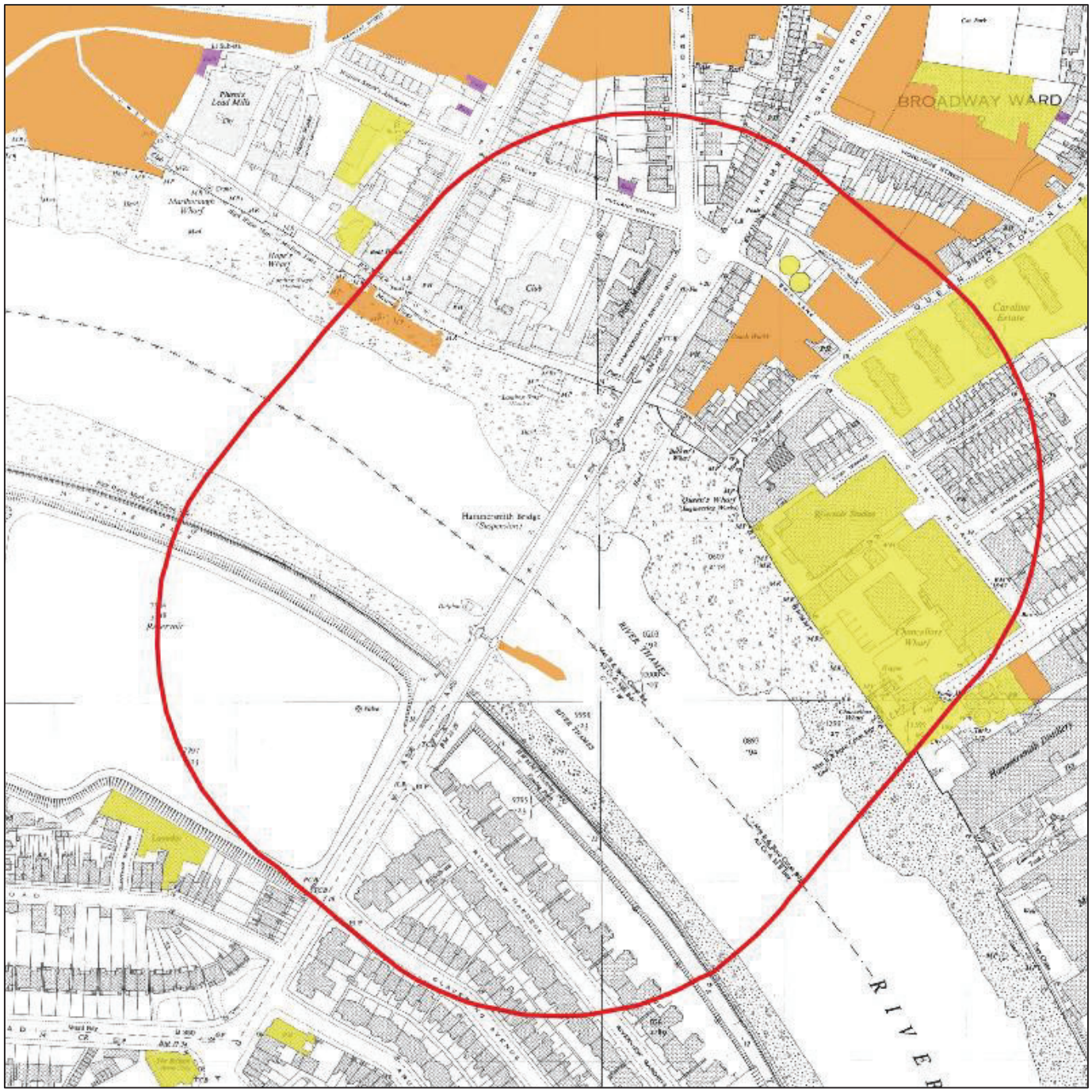


- Approximate site boundary
- Clearance
- Redevelopment
- Ruins

SAFELANE GLOBAL

Luftwaffe Target Map – 1st October 1940

Annex D

Hammersmith Bridge Refurbishment

Pell Frischmann

8307 RA

N

Approximate site boundary

Possible Luftwaffe Targets

N.J. Clarke, Adolf's British Holiday Snaps

Most Commonly Deployed German HE Bombs

SC 50

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)

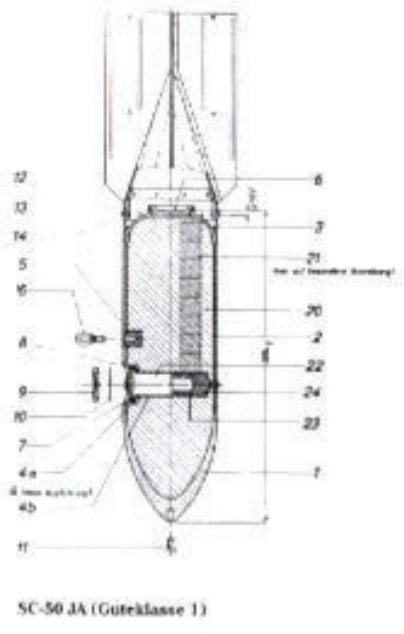
Body Diameter: 200mm (7.87in)

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.

50kg bomb, London Docklands

50kg bomb, minus tail section



SC 250

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.

250kg bomb, Hawkinge

SC250 attached to undercarriage of Messerschmitt Bf109

SafeLane Global and various historical sources

1kg Incendiary Bomb

Bomb weight: 1.0 and 1.3kg (2.2 and 2.87lb)

Filling: 680gm (1.3lb) Thermite

Fuze type: Impact fuze

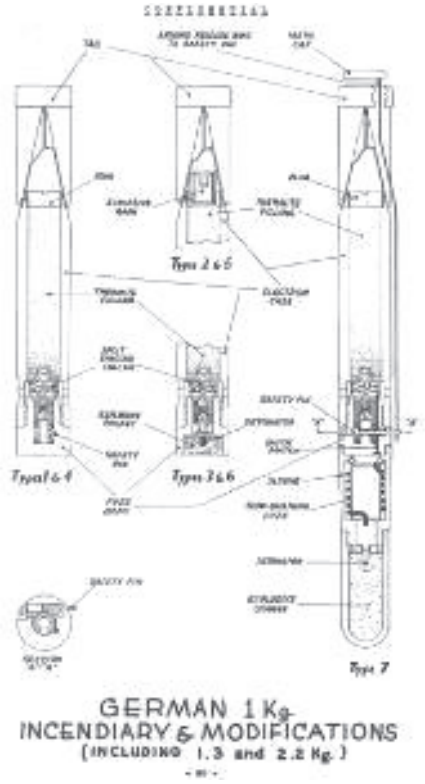
Bomb dimensions: 350 x 50mm (13.8 x 1.97in)

Body diameter: 50mm (1.97in)

Use: As incendiary – dropped in clusters against towns and industrial complexes

Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes fitted with high explosive charge

1. Ordinary scaffold pipe
2. 1kg incendiary bomb
3. Incendiary bomb recently found on site in UK



1kg German Incendiary Bomb next to a 30cm ruler

SafeLane Global and various historical sources

EveningStandard.

Pictured: Unexploded World War II bomb found in Brondesbury Park

EveningStandard.

Bomb disposal expert reveals dramatic details of how huge WW2 bomb found in Thames was detonated

BBC NEWS

Kingston University campus evacuated over 'WW2 bomb'

The Telegraph

Giant WWII bomb dug up by builders in London

Mail Online

Hundreds of people evacuated after a massive WWII bomb was found in the grounds of a Bath school face a weekend away from their homes

Top Left: 500lb UXB found in Brondesbury Park, London – March 2017.
Bottom Left: UXB discovered in the Thames near the Houses of Parliament – February 2017.
Top Right: The discovery of a 250kg UXB near Kingston University resulted in the closure of the University and nearby homes – May 2019
Middle Right: A 400m cordon was established after a 1,000lb UXB was found in Grange Walk, Bermondsey – March 2015
Bottom Right: 500lb UXB discovered in Lansdown, Bath – May 2016

Various News Sources

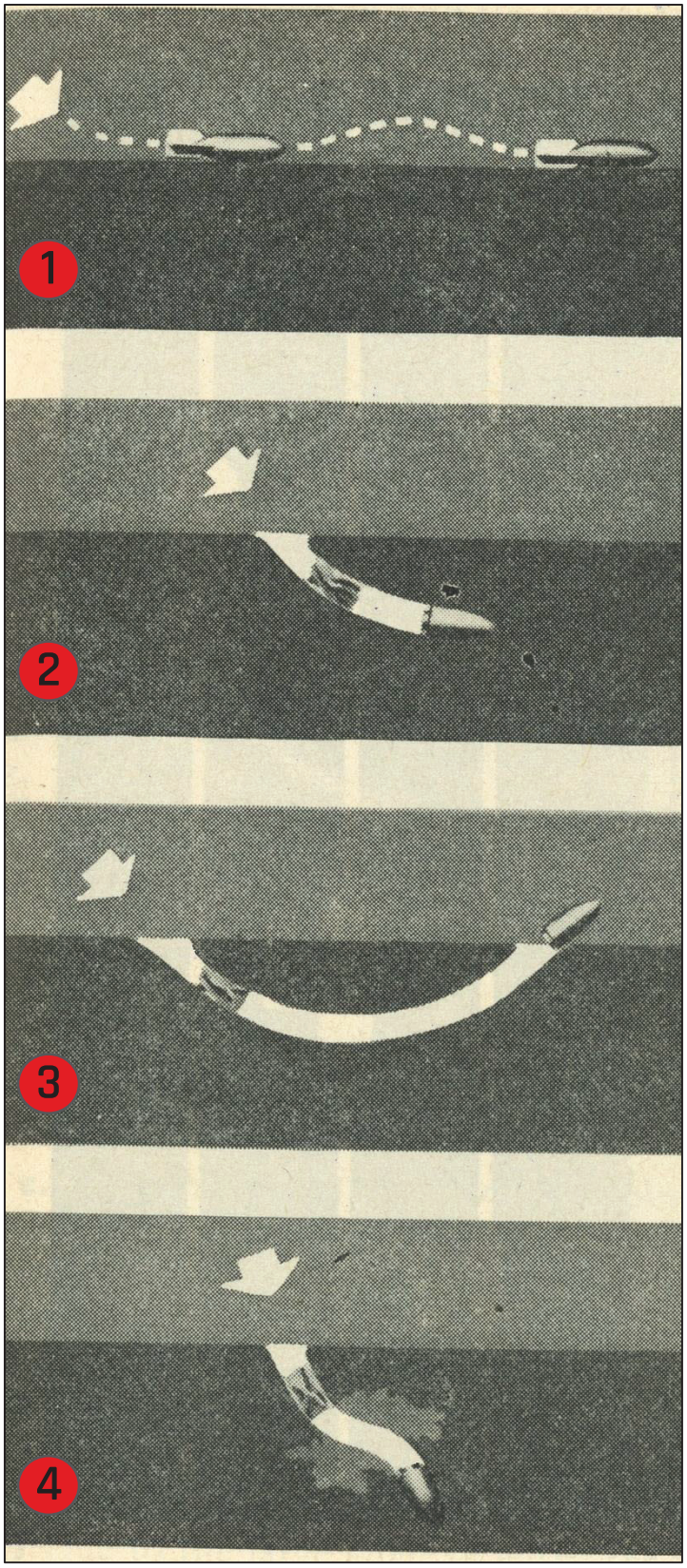
Path of UXB in soft ground

1. **Ricochet resulting from low level attack:** UXB stays perpendicular to ground and rests at surface.

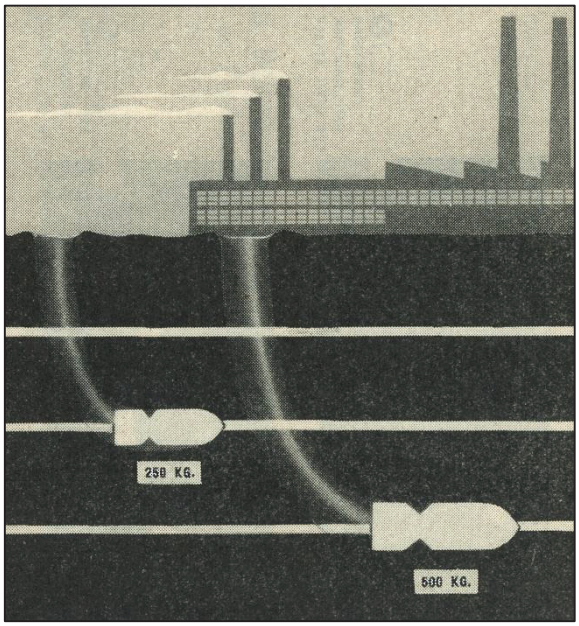
2. **Buried UXB with J-Curve:** Bomb curves horizontally and rests perpendicular to surface.

3. **UXB returning to surface due to J-Curve:** Bomb points towards surface but may remain partially or completely below ground level.

4. **UXB deflected by buried objects:** Results in unpredictable path and unusual shaft.



Below: UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.



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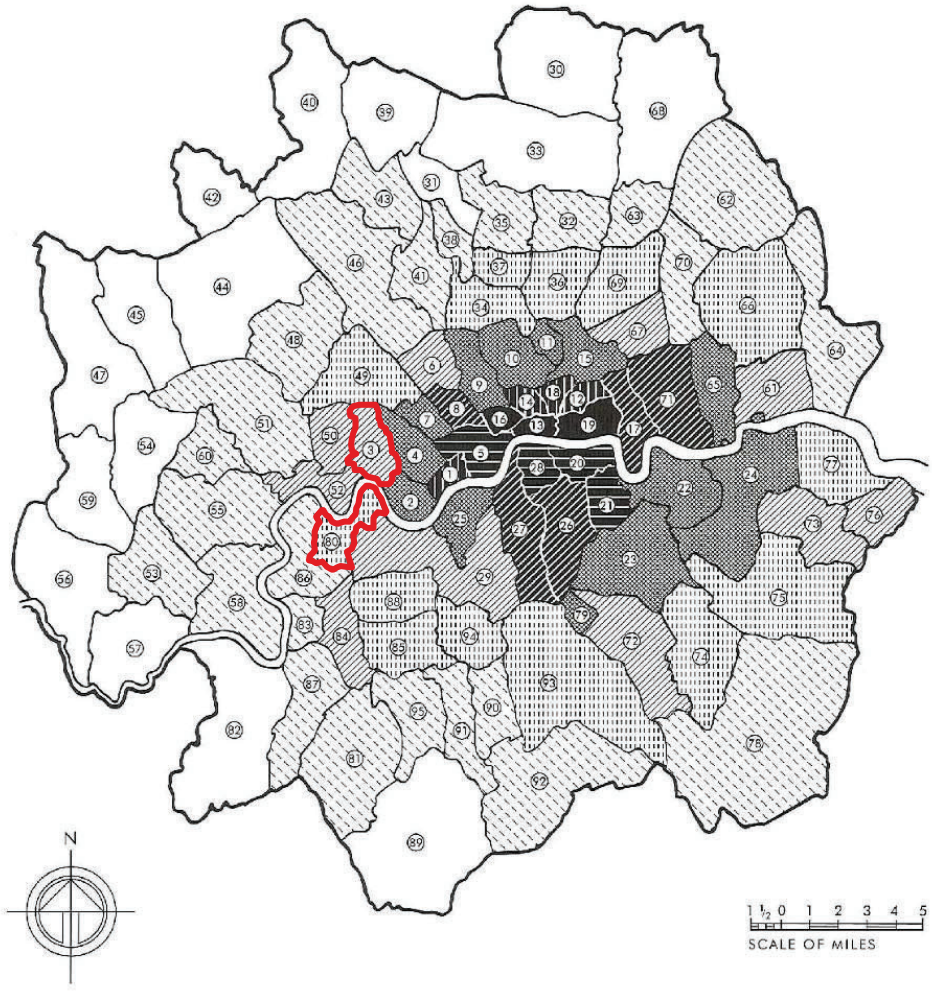

No. OF BOMBS PER 1,000 ACRES

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	60 Southall and Norwood	83 Kingston on Thames
13 City of London	37 Wood Green	61 Barking	84 Malden and Coombe
14 Finsbury	38 Friern Barnet	62 Chigwell	85 Merton and Morden
15 Hackney	39 Potters Bar	63 Chingford	86 Richmond
16 Holborn	40 Elstree	64 Dagenham	87 Surbiton
17 Poplar	41 Finchley	65 East Ham	88 Wimbledon
18 Shoreditch	42 Bushey	66 Ilford	89 Banstead
19 Stepney	43 Barnet U.D.	67 Leyton	90 Beddington and Wallington
20 Bermondsey	44 Harrow	68 Waltham Holy Cross	91 Carshalton
21 Deptford	45 Ruislip and Northwood	69 Walthamstow	92 Coulsdon and Purley
22 Greenwich	46 Hendon	70 Wanstead and Woodford	93 Croydon
23 Lewisham	47 Uxbridge	71 West Ham	94 Mitcham
24 Woolwich	48 Wembley		95 Sutton and Cheam

The density of bombing across the London Region from 1939 to 1945 produced by the Research and Experiments Dept of the Ministry of Home Security. The site is located within the WWII-era London Boroughs of both Hammersmith and Barnes which sustained 150 - 199 bombs and 100 – 149 bombs respectively per 1,000 acres.

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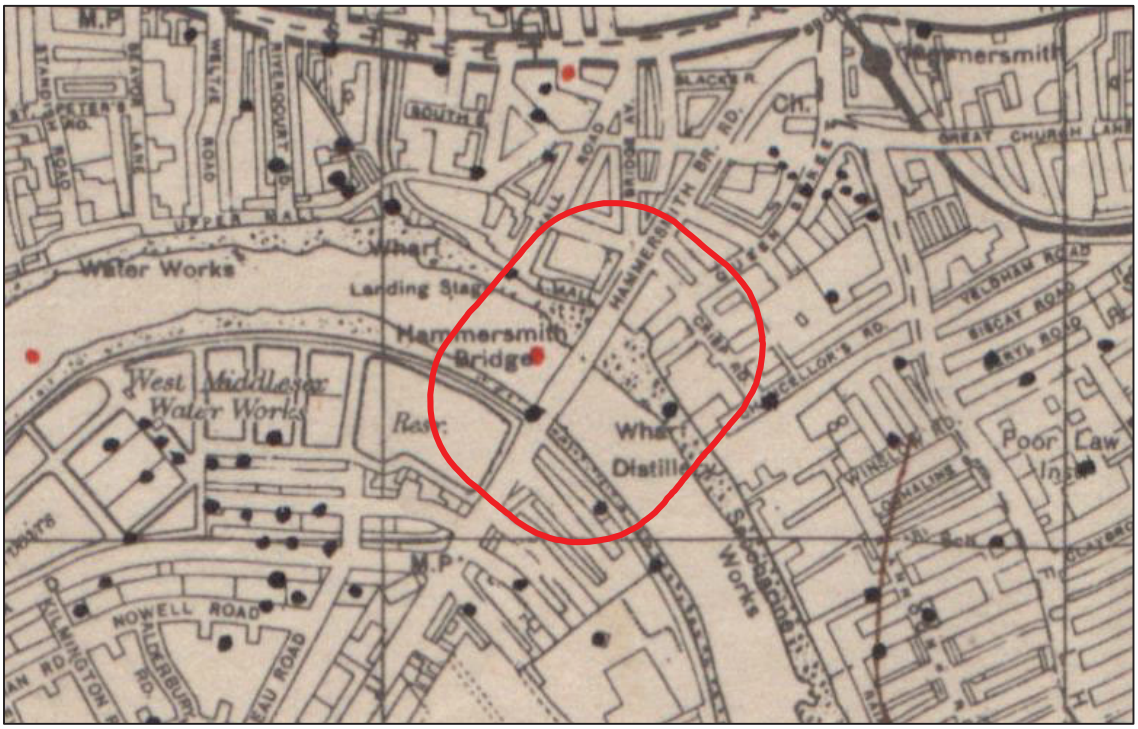
Night bombing up to 7th October 1940



Night bombing between 7th October 1940 and 28th July 1941

Approximate site boundary

HE bomb strike

National Archives

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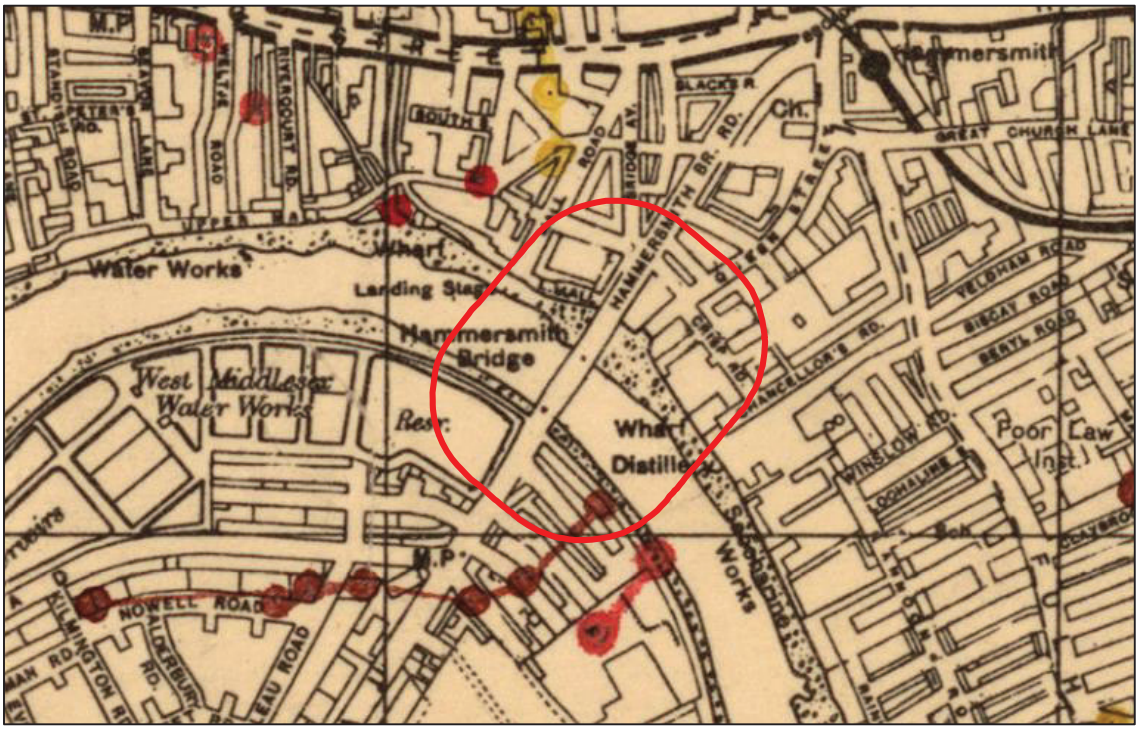


07/10/1940 – 14/10/1940

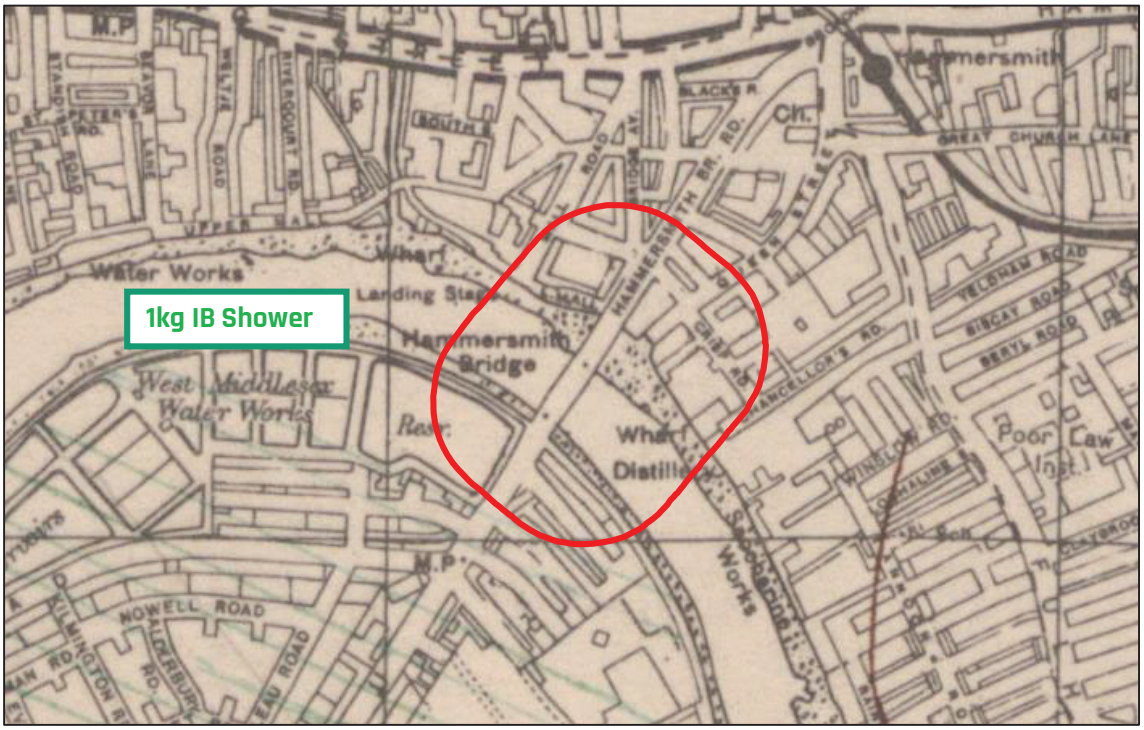
04/11/1940 – 11/11/1940

Approximate site boundary

HE bomb strike

N

11/11/1940 – 18/11/1940



25/11/1940 – 02/12/1940

Approximate site boundary

N

03/02/1941 – 10/02/1941

10/03/1941 – 17/03/1941

Approximate site boundary

HE bomb strike

National Archives

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14/04/1941 – 21/04/1941

14/02/1944 – 20/02/1944

Approximate site boundary
HE bomb strike
1000kg bomb strike
UXB strike

National Archives

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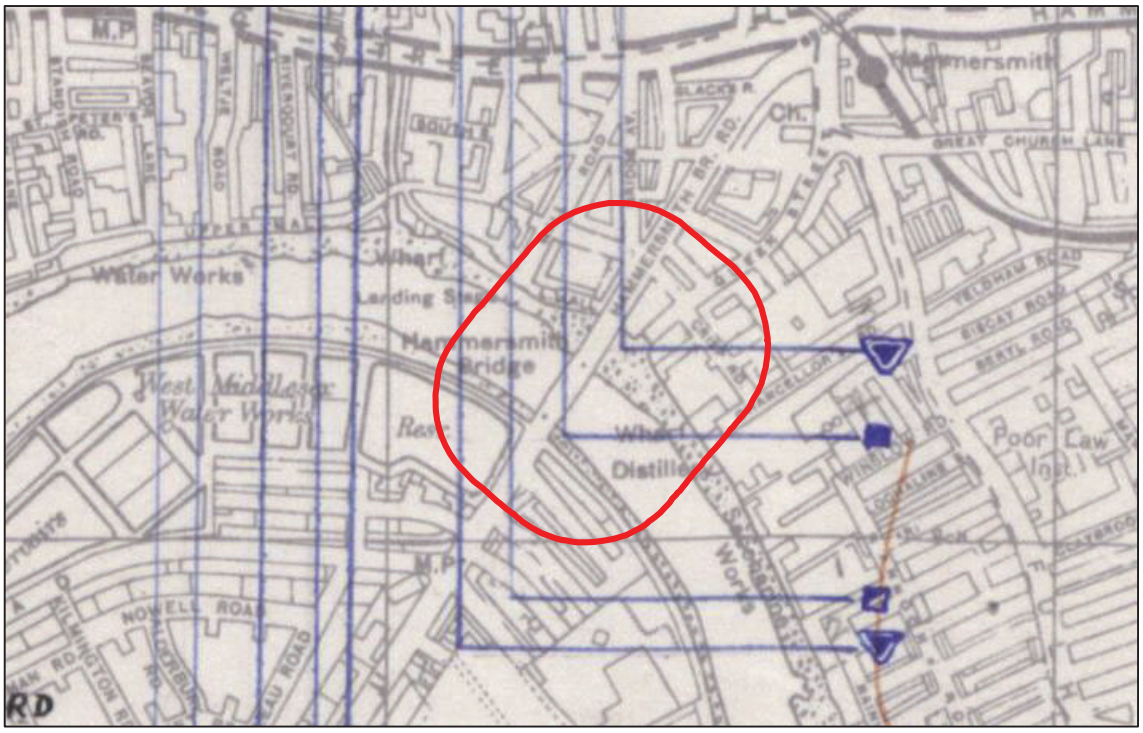

21/02/1944 – 27/02/1944

Approximate site boundary
1000kg bomb strike
1800kg bomb strike
500kg bomb strike

SAFELANE GLOBAL

London V1 Bomb Census Map

Annex J

Hammersmith Bridge Refurbishment

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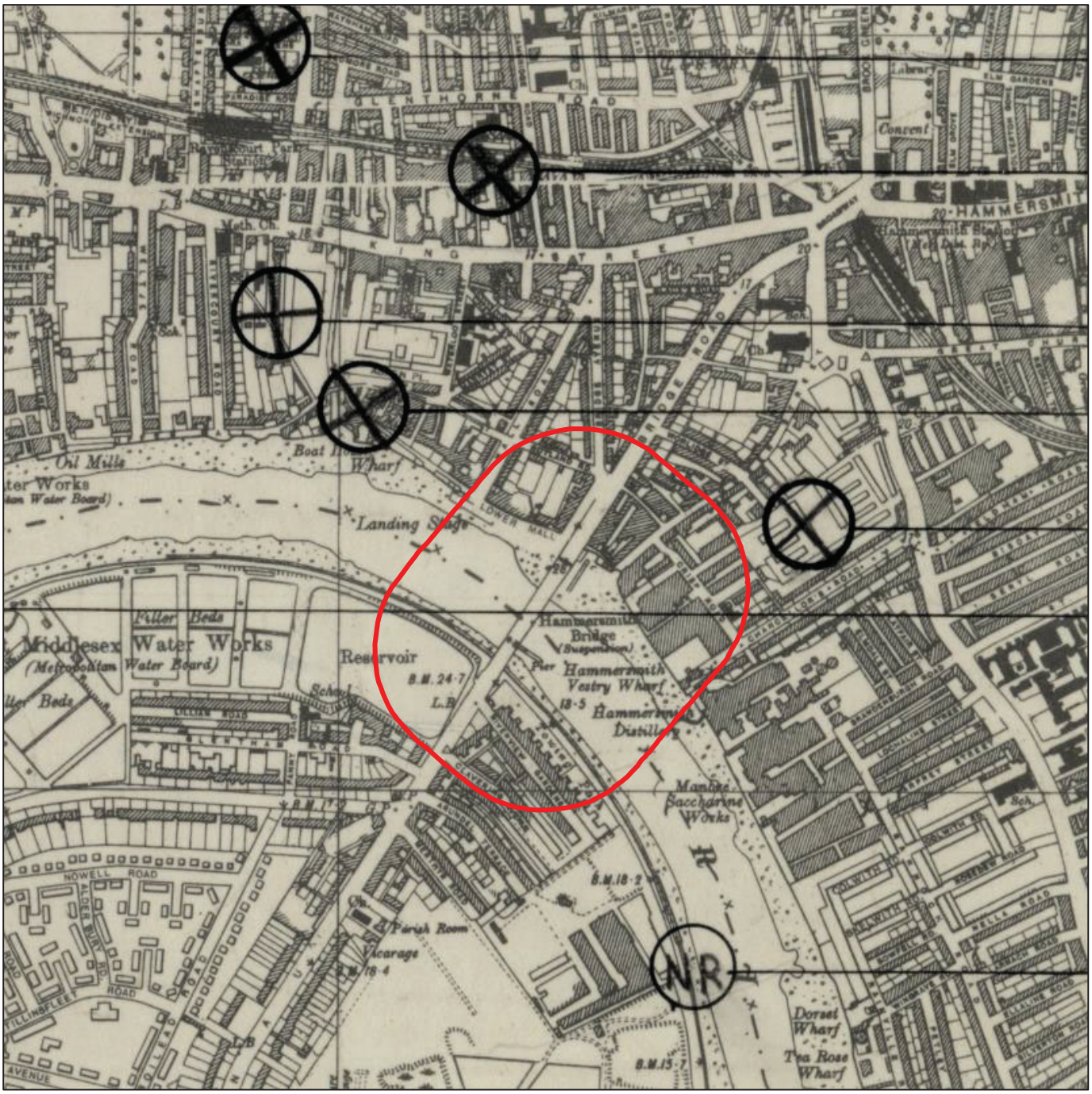

Approximate site boundary

V1 strike

National Archives