21.2244/CB/KJH
17 February 2022

Mark Costello
Concert Limited

ABELLIO BUS GARAGE, NORTH HYDE GARDENS: UNEXPLODED ORDNANCE SURVEY

Introduction
Paragon was instructed by Concert Ltd to inspect an anomaly identified during an Unexploded Ordnance (UXO) spot-check of a borehole as part of a previous Ground Investigation by Paragon on a site referred to as Abellio Bus Garage, North Hyde Gardens, Hayes, UB3 4QQ (Figure 1, Appendix 1).

Paragon previously completed a Detailed Stage 2 UXO Risk Assessment and a Phase 2 Ground Investigation (Ref: 21.1177/CB/NW. Dated: Nov 2021) at the above site. The UXO Risk Assessment (presented in Appendix 3) concluded that UXO posed a moderate risk to the proposed works and therefore a UXO engineer was present throughout the drilling. As part of the ground investigation, the UXO engineer identified an anomaly in the Made Ground during the UXO clearance of borehole WS04. Paragon subsequently terminated the borehole and recommended that the area was further investigated under the supervision of a UXO engineer to assess the source of the anomaly. The location of the anomaly is shown in Figure 2 (Appendix 1).

This investigation solely relates to the area immediately surrounding WS04.

Fieldwork
The fieldwork was carried out on two days. The utility clearance was completed on 26 January 2022 and the excavation was completed on 1 February 2022. Photographs taken during the works are presented in Appendix 2. Paragon supervised a utility clearance survey in the location of WS04 on 26 January 2022. The area surveyed was approximately 5m^2, and no services were identified in the excavation area. A clearance sheet is presented in Appendix 5.

Brimstone Site Investigation Ltd (hereafter referred to as Brimstone) was commissioned by Paragon to undertake the excavation works. The UXO engineer from Brimstone supervised the excavation of an area of approximately 2m^2. The excavation was carried out by removing 0.20m scrapes of soil using a toothless bucket. The UXO engineer continuously scanned the excavation and arisings at each layer using a magnetometer to identify UXO.

The Harlequin Building
65 Southwark Street
London, SE1 0HR

t: +44 (0)207 125 0112
f: +44 (0)207 125 0113

e: info@paragonbc.co.uk
w: paragonbc.co.uk

The pit was excavated to a depth of 1.00m below ground level (bgl) where the original anomaly was encountered. However, the magnetometer presented a signal that indicated that the anomaly was at a deeper depth. As such, the excavation was extended. The UXO engineer confirmed the source of the signal to be a piece of metal wire rope located at a depth of 1.20m below ground level (bgl). The rope was found to extend across the length of the base of the trial pit running west to east. The pit was terminated at 1.30m and the pit was backfilled with the arisings. The UXO Clearance certificate from Brimstone UXO is provided in Appendix 4.

Ground Conditions

The geology encountered generally comprised Made Ground, which was described as a brown sandy gravel of mixed lithology including brick, concrete and limestone, with occasional fragments of metal wiring, plastic and glass. No visual or olfactory signs of contamination were identified and groundwater was not encountered. The trial pit log is presented in Table 1 below.

Table 1: Ground Conditions

Depth (m)	Strata Description
0.00 – 0.20	Macadam.
0.20 – 0.50	MADE GROUND. Light brown slightly silty SAND and GRAVEL. Sand is fine to coarse. Gravel is fine to medium subangular to subrounded of limestone, concrete and brick.
0.50 – 0.55	Black geotextile.
0.55 – 0.70	MADE GROUND. Light brown, slightly silty sandy GRAVEL. Sand is fine to coarse. Gravel is fine to coarse, subangular to subrounded of limestone, concrete and brick, with occasional metal wire fragments.
0.70 – 1.10	MADE GROUND. Soft, light brown gravely CLAY. Gravel is fine to coarse, subangular to subrounded of limestone, concrete and brick, with occasional metal wire fragments.
1.10 – 1.20	Concrete slab.
1.20 – 1.30	MADE GROUND. Light brown slightly silty sandy GRAVEL. Sand is fine to coarse. Gravel is fine to coarse, subangular to subrounded of limestone, concrete and brick.
1.25	A steel wire rope (4.5cm thick) was found at 1.25m running west to east across the base of the pit.
1.30	End of trial pit

Summary
The investigation was completed to inspect an anomaly identified during a UXO spot clearance of a borehole completed as part of a previous phase of ground investigation. This investigation confirmed the source of the anomaly to be a length of metal wire rope at 1.25m bgl and not an item of UXO.

Whilst the investigation has confirmed the absence of UXO in the location of WS04 to a depth of 1.25m bgl (where the original anomaly was identified), the Made Ground may extend to deeper. Furthermore, whilst the Abellio site has been classified as having a moderate risk of UXO, there is the potential for UXO to remain elsewhere. As such, the potential for UXO to be present in areas not investigated cannot be discounted. Therefore, during future works it is recommended that a UXO site briefing is completed prior to ground works and if required, a UXO supervisor is present during excavations.

We hope the above meets your requirements, but please do not hesitate to contact the undersigned if you have any questions.

Yours Sincerely

On behalf of Paragon.

Charlie Bruinvels BSc MSc. C.WEM CEnv
Associate Director
Paragon
M: 07730 096894
E: charliebruinvels@paragonbc.co.uk

Encs: Appendix 1 – Figures
Appendix 2 – Photographs
Appendix 3 – Stage 2 Detailed UXO Risk Assessment
Appendix 4 – UXO Clearance Letter
Appendix 5 – Service Clearance Certificate
Appendix 6 – Extent of Survey Limitations

APPENDIX 1: FIGURES

building & project consultants

paragon

Paragon Building Consultancy
65 Southwark Street
London
SE1 0HR
0207125 0112
www.paragonbc.co.uk

Key

WS04

Project

212244 Hayes, Abellio

Figure 2

WS04 Plan

Date

02.02.2022

building & project consultants

paragon

Paragon Building Consultancy
The Harlequin Building 65
Southwark Street London SE1
0HR 0207125 0112
www.paragonbc.co.uk

Site Location
Development Area
Abellio Boundary

Project

212244 Hayes, Abellio

Figure 1

Site Location Plan

Date

02.02.2022

APPENDIX 2: PHOTOGRAPHS

01: Service clearance markings and excavator over WS04.

02: 2m box marked for UXO assessment at WS04.

03: The Trial pit exposing granular Made Ground and geotextile membrane.

04: Metallic finds within the trial pit.

05: Source of reading at the base of the pit. Circled in red.

06: Post-con backfilled trial pit.

APPENDIX 3: STAGE 2 DETAILED UXO RISK ASSESSMENT

STAGE 2 DETAILED UXO RISK ASSESSMENT

Report Reference: DRA-19-1105

INTEGRITY • PROFESSIONALISM • KNOWLEDGE

STAGE 2 DETAILED UXO RISK ASSESSMENT:

Bulls Bridge Industrial Estate, Hayes

Prepared For:

Paragon Building Consultancy Limited

Brimstone Site Investigation

1-3 Manor Road
Chatham
Kent
ME4 6AE

Phone: 0207 117 2492
Web: www.brimstoneuxo.com

REPORT REF: DRA-19-1105 | Revision: 1		
Prepared by:	O. Brown	02/07/2019
Reviewed by:	C. Bull	03/07/2019
Release Authorised by:	A. Florence	03/07/2019
Report Issue Date:		**03/07/2019**

EXECUTIVE SUMMARY

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

THE SITE: The Site (centred on National Grid Ref: TQ 10438 79306) is located within the London Borough of Hillingdon, approximately 440m east of Hayes & Harlington Railway Station. It is bound to the south-east by the Grand Union Canal, to the north by a railway line, and to the east by North Hyde Gardens (road).

The Site occupies part of the post-WWII constructed Bulls Bridge Industrial Estate. It encompasses four separate properties comprising commercial warehouse type and / or office buildings, car parking, loading bays and soft landscaping, all served by North Hyde Gardens. Significant areas of dense vegetation exist along the eastern Site boundary and fronting the canal. Yeading Brook (stream) passes through the eastern extent of The Site and a raised highway flyover (A312) passes through the north-eastern part of The Site.

THE PROPOSED WORKS: The proposed development is to comprise the demolition of the existing buildings and construction of new commercial units with associated offices, lorry docks, access and car parks. NB: The Client expects shallow foundations to be required. Prior to this, an SI will be carried out. The investigation will comprise 10 windowless boreholes to 5m bgl, six mechanically-excavated trial pits to 3m bgl and 10 hand-excavated trial pits to 1m bgl.

UXO RISK ASSESSMENT:

German UXO:

- London was the most frequently and heavily bombed British city during WWII. Although Hayes was positioned >15km from central London, high altitude, night time bombing tactics resulted in inaccurate overspill bombing of the wider study area. Original bombing statistics confirm that The Site occupied an area of moderate bombing density.
- A collection of original London bomb plot maps covering the entire German bombing campaign was reviewed. These confirm that the wider study area was bombed on at least eight separate occasions, resulting in 29 large 'iron' bombs and one Parachute Mine within a 500m radius of The Site. One 'iron' bomb strike is plotted within The Site boundary, near the canal, in the western half.
- Analysis of the maps confirms that a German aircraft flew over The Site whilst dropping bombs in the vicinity on at least two occasions, possibly more. This raises the possibility of a UXB being released over The Site.
- No 1kg / 2kg IB strikes were recorded over The Site during the vast majority of WWII, however the possibility cannot be discounted that such bombs fell on Site during the first month of the 1940 Blitz, for which no records are available.

- Historical aerial photography shows that the southern portion of The Site was occupied by unmaintained grass / scrubland, with denser and / or taller vegetation in the east, suggesting this area was likely neglected for significant periods. A UXB entry hole to such ground cover could have easily been overlooked. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured entry hole.

After a time, environmental conditions would cause the hole to collapse and in-fill, erasing evidence of the UXO strike.

- A stream and possibly a large pond existed in this area during WWII. Any UXB striking water would have been immediately lost beneath the waterline, leaving no evidence of its incidence.
- The northern portion of The Site was occupied by a railway creosote works, comprising one large structure (near the northern Site boundary), timber storage areas and railway tracks. This vital facility did not sustain any significant bomb damage and would likely have remained in operation throughout the conflict. Consequently, this developed part of The Site will have been frequently accessed, likely on a daily basis and specific searches for delayed action bombs or UXBs were probably carried out, following each local air raid. As a result, there is a lower likelihood of a UXB entry hole going unreported within this part of The Site.
- Any UXB strike to undamaged structures, hardstanding, stacked timber, railway tracks or railway cars would have caused obvious damage or resulted in a persistent, easily recognisable entry hole which would have been reported and dealt with at the time.

British / Allied UXO:

- 20 permanent HAA batteries were constructed within a 15km radius of The Site immediately prior to WWII. Furthermore, Great West Aerodrome may have been defended by some LAA guns and these would have been within range of The Site also. Luftwaffe activity was frequent over the wider area and therefore, for the same reasons as above, an unexploded AA shell could have remained undetected (shallow buried) within undeveloped parts of The Site.
- Although no specific evidence of WWII Home Guard activity on Site has been located, the possibility cannot be discounted that the unused open ground on Site was requisitioned temporarily. Alternatively, armed Home Guard soldiers could conceivably have accessed The Site whilst on patrol. Any such activity on Site would raise the risk of associated UXO contamination; chiefly the common practice of unauthorised disposal (burial) of surplus ammunition.

The Likelihood of UXO Encounter:

- Prior to the post-war levelling works on Site, there does not appear to have been any development or redevelopment. Therefore, any buried UXO within the southern central part of The Site is unlikely to have been disturbed and will have been simply buried to a deeper depth prior to construction of the power station. However, if the construction of the power station required deep ground works (beyond the maximum depth pf the fill material), any deeper buried German HE UXBs could have been encountered and removed.
- The lack of deep high-volume excavations within much of The Site post-war, confirms that any deep buried German HE UXB would likely remain in-situ. A shallower buried German HE UXB could also conceivably remain within undisturbed soil, in between existing strip shallow excavations.
- Within the footprints of the power station and the subsequent (existing) commercial buildings, there is a lower likelihood of any small items of UXO (British AA shells and German 1kg / 2kg IBs) remaining, as these shallow buried devices would likely have been encountered and removed.
- No proposed Site plan showing the footprints of the proposed buildings was available at the time of writing. However, it is understood that the foundations will likely be shallow. If future excavations penetrate below WWII-era ground level within the southern part of The Site where post-war Made Ground exists, there will be an elevated likelihood of a UXO encounter. NB: the origin of the post-war fill material is not known however is unlikely to be UXO contaminated. There is a low likelihood of UXO contamination and / or UXO remaining within the northern part of The Site and consequently, a low likelihood of UXO encounter.
- NB: experience shows that heavy UXBs can also reside at surprisingly shallow depths and therefore could also be encountered during shallow excavations, just below WWII-era ground level.

RECOMMENDED RISK MITIGATION MEASURE: Brimstone has identified an elevated UXO risk within part of The Site. The measures detailed below are recommended to mitigate the UXO risk on Site to ALARP level. A UXO encounter cannot be completely ruled out during ground works within the Low Risk zone and therefore it would be considered prudent to employ the minimum mitigation measure here also.

Risk Mitigation Measure	Recommended For?
UXO Safety Awareness Briefings	Prior to all intrusive works within both Risk Zones
EOD Engineer - On Site Supervision	Open excavations within the ***MODERATE RISK*** zone only
Intrusive Magnetometer Probe Survey (if required)	Any pile locations within the ***MODERATE RISK*** zone only

RISK MAP:

Former Power Station - Approximate footprint

LOW UXO RISK ZONE
Low likelihood of German or British UXO remaining.

MODERATE UXO RISK ZONE
Elevated likelihood of British UXO remaining.
Elevated likelihood of German HE UXB remaining.

CONTENTS

FIGURES

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

Paragon Building Consultancy Limited, referred to hereon in as *The Client*, has commissioned Brimstone Site Investigation, referred to hereon in as *BSI*, to carry out a Stage 2 Detailed Unexploded Ordnance (UXO) Risk Assessment of the proposed intrusive ground works at the Bulls Bridge Industrial Estate, Hayes site, referred to hereon in as *The Site*.

1.2 LEGISLATION

1.2.1 Introduction

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

1.2.2 Construction (Design & Management) Regulations 2015

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

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

1.2.3 The Health and Safety at Work Act 1974

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

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

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

1.3 UXO - THE ROLE OF COMMERCIAL CONTRACTORS AND THE AUTHORITIES

1.3.1 Commercial Contractors

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

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

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

1.3.2 UK Authorities

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

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

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

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

1.4 UXO RISK IN THE UK

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

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

1. ***Enemy Action:*** - During WWI and WWII the air forces of Germany, and to a lesser extent Italy, bombed targets throughout the UK. The German Navy bombarded several

coastal targets in eastern England during WWI and then in WWII German long range artillery on the French coast bombarded parts of Kent.

2. ***Allied Military Activity:*** During WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre of conflict; most notably the US and Canada.

3. ***UK Military Activity:*** Domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as AA gun and rocket batteries during WWI and WWII.

1.5 UXO DETONATIONS

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

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

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

2 ASSESSMENT METHODOLOGY

2.1 INTRODUCTION

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is designed to provide accurate and authoritative information regarding matters of onshore UK risk in the UK.

2.2 SPRC RISK MODEL

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

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

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

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

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

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

2.3 ASSESSMENT STRUCTURE

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

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

2.4 INFORMATION SOURCES

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

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

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

2.5 ALARP PRINCIPLE

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

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

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

2.6 RISK TOLERANCES

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

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

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

magnetometer survey and EOD engineer attendance on site respectively.

2.7 RELIANCE AND LIMITATIONS

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

3 THE PROJECT

3.1 THE SITE

The Site (centred on National Grid Ref: TQ 10438 79306) is located within the London Borough of Hillingdon, approximately 440m east of Hayes & Harlington Railway Station. It is bound to the south-east by the Grand Union Canal, to the north by a railway line, and to the east by North Hyde Gardens (road).

The Site occupies part of the post-WWII constructed Bulls Bridge Industrial Estate. It encompasses four separate properties comprising commercial warehouse type and / or office buildings, car parking, loading bays and soft landscaping, all served by North Hyde Gardens. Significant areas of dense vegetation exist along the eastern *Site* boundary and fronting the canal. Yeading Brook (stream) passes through the eastern extent of *The Site* and a raised highway flyover (A312) passes through the north-eastern part of *The Site.*

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

3.2 THE PROPOSED WORKS

The proposed development is to comprise the demolition of the existing buildings and construction of new commercial units with associated offices, lorry docks, access and car parks. NB: *The Client* expects shallow foundations to be required.

Prior to this, an SI will be carried out. The investigation will comprise 10 windowless boreholes to 5m bgl, six mechanically-excavated trial pits to 3m bgl and 10 hand-excavated trial pits to

1m bgl.

FIGURE 3: Proposed SI Plan

4 SITE HISTORY

4.1 INTRODUCTION

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

4.2 OS MAPPING

Review of OS Mapping			
Period	**Map Date**	**Map Scale**	**Review**
WWI	**1914**	**1:2,500**	The majority of *The Site* is occupied by two fields. The north-western part of *The Site* encroaches into a Creosoting Works (comprising railway sidings, open ground and some small structures). A railway line passes through and parallel to the northern *Site* boundary. It serves the Creosoting Works. Yeading Brook is present on *Site*. The southern extent of *The Site* is occupied by open ground with an earth embankment marked.
Pre-WWII	**1934/35**	**1:2,500**	***FIGURE 4:*** The two fields on *Site* are no longer demarcated. A large, elongated building (and some smaller ancillary structures) labelled Creosoting Works have been constructed at a central northern position on *Site*. The Works is served by several new railway tracks. The vast majority of *The Site* remains undeveloped. Earth embankments pass through *The Site* from west to east and within the north-eastern corner. These indicate significant changes in level on *Site*. The southern corner of *The Site* is now shown to be occupied by rough grassland. A Towing Path is labelled within / along the south-western *Site* boundary.

Post-WWII	**1959**	**1:10,560**	No changes on *Site* observed. A small structure on *Site,* previously labelled Tanks, has been demolished. A Creosoting Works building encroaching into the eastern *Site* boundary has been demolished. Such observations on post-WWII London OS maps can be indicative of WWII bomb damage. However, as this map was produced approximately 14 year after WWII, these clearance areas could be unrelated to WWII.
	1963	**1:1,250**	A large Pond is present within the central southern parts of *The Site*. A new section of railway line has been laid within the western half of *The Site*. Some additional small ancillary buildings (associated with the main Works building) have been constructed on *Site*. A new earth embankment has appeared in the centre of *The Site.*
	1972/79	**1:1,250**	All the Creosoting Works buildings on *Site* have been demolished.
	1985	**1:10,000**	A small Power Station has been constructed on *Site.* It comprises four main rectangular buildings surrounding a central courtyard occupied by a single chimney. Three smaller buildings are positioned to the west end of the courtyard. The whole facility is served by an access road.

4.3 AERIAL PHOTOGRAPHY

Review of Aerial Photography		
Period	**Photo Date**	**Review**
Pre-WWII	**1930s**	***FIGURE 5.1:*** These two photographs show *The Site* from the south-west. The 1932 image confirms that the north-western part of *The Site* was at a higher level than the southern area. *The Site* was largely occupied by rough grassland with areas of denser vegetation (bushes and trees) in the east. The 1935 image records the main works building on *Site*; a single storey structure. At the eastern end of this structure is a timber storage area. The visible open ground on *Site* is unmaintained.

Post-WWII	**May 1946**	***FIGURE 5.2:*** This low resolution photograph was taken approximately one and a half years after the end of WWII. *The Site* appears as it does on the historic OS mapping. The main Works building on *Site* appears to remain, although any moderate to minor bomb damage at this low resolution and small scale may not be visible. No obvious German bomb craters are visible on *Site* or in the immediate surrounding area. NB: some bomb craters only persisted temporarily during WWII, particularly on arable (worked) land. They were often in-filled / repaired prior to the available aerial photography. Just to the south-west of the main building is a second timber storage area, represented here by squares of white and paler grey. NB: the main timber storage area is visible immediately east of *The Site*. Large areas of dense bushes / mature trees are visible along and within the eastern *Site* extent.
	***circa* 1948**	***FIGURE 5.3:*** This image confirms that the main Works building has the same footprint as the pre-war structure and has likely survived the bombing campaign intact. The post-war mapped Pond (within the southern part of *The Site*) could be visible here as a darker area.
	Sep 1999	*The Site* appears as it does today.

4.4 ADDITIONAL SITE-SPECIFIC HISTORY

Some sites will have been historically occupied by landmarks or significant buildings and in such cases specific written histories are occasionally available in the public domain. Research confirms that *The Site* was part occupied by Hayes Railway Sleeper Works during WWII. It was brought into operation by the Great Western Railway in 1935. For treating wooden sleepers, the facility used >1.5 million gallons of creosote each year and its yard could store >750,000 sleepers.

5 UXO RISK - GERMAN BOMBING

5.1 WWII BOMBING HISTORY OF THE SITE

5.1.1 General WWII History

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

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

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

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

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

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

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

5.1.2 Site Specific History

Although Hayes was positioned >15km from central London, where the Luftwaffe aimed the majority of its raids, high altitude, night time tactics resulted in inaccurate overspill bombing of the wider study area.

A large but incomplete collection of Luftwaffe target reconnaissance photographs of Britain was searched. No images highlighting facilities as bombing targets in the study area were included.

Southall Gas Works (approximately 800m to the north-east) would have been an easily identifiable target. Gasometers were frequently attacked by the Luftwaffe as secondary or opportunistic targets during WWII. Great West Aerodrome (Heathrow Airport) was only intermittently used by the RAF during WWII, however this airfield (approximately 2.8km south-west of *The Site*) would still have been easily identifiable from the air as a viable bombing target.

5.2 BOMBING DECOY SITES:

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

- A system of lighting to simulate an urban area or a military airfield's runway
- Deliberately started fires to simulate a previously bombed target

- Dummy buildings and vehicles to simulate a military facility

Some 792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. By the end of 1941, airfield decoy sites had received 359 attacks compared with 358 raids carried out against the real airfields and by June 1944 approximately 730 attacks had been recorded on all decoy site types. As *The Site* was located within an urban area during WWII no bombing decoys were installed locally. The closest was sited >5km to the south-west.

5.3 WWII BOMBING RECORDS

5.3.1 Introduction

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

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

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

5.3.2 ARP Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Urban District of Hayes & Harlington and the Municipal Borough of Southall. The boundary of these two areas passed through *The Site* historically. The figures for the Municipal Borough of

Heston & Isleworth have also been included as boundary of this area ran adjacent to and parallel to the southern *Site* boundary.

It gives a breakdown of the types of large German bombs reported. These figures were sourced from the National Archives, London. NB: 1kg / 2kg incendiary bombs (IB) and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are usually not included.

Record of German Air-Delivered Ordnance			
Administrative Area	**H&H UD**	**S MB**	**H&I MB**
Administrative Area Acreage	**5,160**	**2,606**	**7,219**
High Explosive Bombs (all types/weights)	189	123	344
High Explosive Parachute Mines	2	1	4
Flam (Oil) Bombs	8	2	15
40kg Phosphorus Incendiary Bombs	0	1	24
40kg 'Fire Pot' Incendiary Bombs	0	0	0
V1 Flying Bomb	6	7	16
V2 Long Range Rocket	2	0	2
Total (excluding V-Weapons and 1kg IBs)	199	127	387
Bombs Per 1,000 Acres	**38.5**	**48.7**	**53.6**

5.3.3 London Bomb Census Maps

BSI has reviewed a collection of original consolidated and weekly London Bomb Census Maps for the wider study area, held at the National Archives. The two consolidated plot maps only record large 'iron' bomb strikes, not 1kg / 2kg IB showers. No weekly plot maps are available for the first month of the Blitz and therefore no record of 1kg / 2kg IBs is available between 7th September and 7th October 1940. The small scale of these maps makes accurate plotting difficult and therefore the locations of bomb strike symbols should not be considered truly accurate.

Those maps that record bombing incidents in and around *The Site* are presented at ***FIGURE 6*** and described below.

- Approximately 29 large 'iron' bombs and one Parachute Mine are plotted within a 500m radius of *The Site* boundary.
- The wider study area was bombed during at least eight separate air raids.
- One 'iron' bomb is plotted within *The Site* boundary, near the canal, approximately 50m south-west of the main Works building.
- The weekly plot maps do not record any 1kg / 2kg IB showers over or near *The Site*.
- The second weekly map (14/10/40 - 20/10/40) was missing from the collection.
- Four bombs plotted on the second consolidated plot map are not replicated within the collection of weekly plot maps. NB: these strikes likely occurred between the 14/10/40 and 20/10/40.
- One bomb plotted in the collection of weekly plot maps is not replicated on the second consolidated plot map.

Hillingdon Local Studies Archive was contacted, however this local record office does not hold a bomb plot map of the Urban District of Hayes & Harlington or the Municipal Borough of Southall.

5.3.4 V Weapons

BSI has reviewed a collection of original consolidated V1 Bomb Plot Maps for the whole of Greater London, held at the National Archives. *BSI* has also reviewed a modern plot map of all V2 Rocket incidents, based on a complete collection of original written reports sourced from the London County Council.

Neither map plots a V Weapon strike within *The Site* boundary or within a significant distance. The closest V1 strike is plotted approximately 300m to the north and the nearest V2 strike is plotted >1km to the north.

5.3.5 Abandoned Bombs Register

Evidence of suspected UXB strikes was reported to an ARP warden who in turn reported its location to the local BDU. Occasionally, a combination of factors meant that the BDU had to simply record its location on an Abandoned Bomb Register and leave it buried in situ. The reasons for abandoning a UXB could be; a relatively safe location / position, access problems

or a likely extreme depth of burial. Furthermore, BDUs in the most heavily bombed areas were constantly overstretched during WWII and therefore had limited resources available.

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

5.3.6 WWII Middlesex War Damage Map

A collection of war damage maps covering the former county of Middlesex is held at the London Metropolitan Archive. The Engineer and Surveyor's Department of Middlesex County Council was responsible for assessing each damaged building and grading the damage. The results were hand painted in different colours onto 1916 (updated to 1940) OS maps, at a scale of 25 inches to one mile. However, the mapping sheet (No. XV.09) that covers *The Site* ismissing from the collection.

5.4 LIKELIHOOD OF UXB CONTAMINATION

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

Density of Bombing	
Number of Air Raids in the Vicinity:	Eight air raids affected the wider study area.
Intensity of these Air Raids:	Most bombs dropped locally were part of large scale carpet bombing raids (many of which were carried out at night).
Bomb Strike Positions	
Closest Bomb Strikes to *The Site*:	'iron' HE bombs: one strike on *Site*. 1kg / 2kg IBs: not known.

Alignment of recorded Bomb Strikes:	It is possible to identify most (eight) local bomb-sticks (individual bomb loads) on the London Bomb Census maps. Six are not aligned with *The Site*, one is generally aligned with the very western extent of *The Site* and one more is ambiguous. The lack of some weekly bomb plot mapping means that this analysis cannot be performed for two or more air raids affecting the study area, one of which resulted in a bomb strike on *Site*. It can be said that German aircraft flew over *The Site* whilst dropping bombs in the vicinity on at least two occasions.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of *The Site*:	No evidence.
UXBs recorded in close proximity to *The Site*:	650m east of *The Site.*

5.5 LIKELIHOOD OF SUBSEQUENT UXB DETECTION

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

Historic Site Access
A UXB falling on a site which was frequently accessed would have had a greater chance of being observed during its descent or subsequently. In frequently bombed residential areas, ARP Wardens carried out post-raid searches for UXBs. The importance of a site or facility is an important consideration. Many factories, gas works, power stations, docks, etc had teams of Fire Watchers tasked with extinguishing 1kg IBs and reporting UXBs.
The sparsely populated nature of the immediate surrounding area during WWII suggests it is possible that a UXB dropping within *The Site* boundary could have done so unnoticed, especially during one of the night time raids over Hayes. Much of *The Site* will likely have been neglected for significant periods as it was undeveloped and had no apparent use. Any unobserved UXB landing here could have remained undetected for a significant period of time. The Works did not sustain any significant bomb damage during WWII and therefore, as a vital wartime industry, is highly likely to have remained in operation throughout the conflict. Consequently, this developed part of *The Site* will have been frequently accessed, likely on a daily basis.

The main creosote Works building and its associated railway tracks would likely have been subject to specific searches for delayed action bombs or UXBs immediately following each of the air raids that affected the study area. At the very least, it is considered unlikely that any railway cars would have ridden the railway sidings on *Site* without them having already been checked for damage / buckling.

As a result, there is a lower likelihood of a UXB entry hole going unreported within the northern developed part of *The Site* and in amongst the timber storage areas.

Bomb Damage
A type of WWII specific ground cover, substantial bomb damage to a site will have resulted in conditions that would make the identification of a subsequent UXB strike extremely difficult. A HE bomb striking soft ground will have thrown up a large quantity of soil, as well as producing a crater. If this ground disturbance was not immediately repaired, any subsequent UXB strike could have been overlooked.
A HE bomb strike is plotted within open ground on *Site*. As such, a crater and associated soil debris likely existed here for a time. Any subsequent unobserved UXB strike to this location could have easily remained undetected, its entry hole obscured in the unmade soil.

Ground Cover Type
The type of ground cover at a site during WWII is significant as differing types will have had differing effects on the visual evidence of a UXB entry hole. Evidence of a UXB strike to manmade structures and hard-standing will have been long lasting and easily identifiable. A UXB strike to dense vegetation or very soft ground (marshland) could have easily been overlooked. In the extreme, a UXB landing in a body of water would have been immediately obscured from view and is highly unlikely to have been accurately reported and therefore recovered.
It is not possible to confirm the exact ground conditions on *Site* during the WWII bombing campaign, however aerial photography indicates that most of *The Site* was unmaintained grass / scrubland, with denser and / or taller vegetation in the east. A UXB entry hole to such ground cover could have easily been overlooked. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured entry hole. After a time, environmental conditions would cause the hole to collapse and in-fill, erasing evidence of the UXO strike. A stream was, and a pond may, have been present on *Site* during WWII. Any UXB strike to a body of water would have been immediately lost beneath the waterline, leaving no evidence of its incidence. Even if the UXB was observed, the difficulties in retrieving a large UXB buried several metres below a body of water could have resulted in its abandonment. A HE UXB strike to undamaged structures, hardstanding, railway tracks or railway cars would have caused obvious damage or resulted in a persistent easily recognisable entry hole which would have been reported and dealt with at the time by the local BDU.

5.6 BOMBING DURING WWI

During WWI, an estimated 9,000 German bombs were dropped on London, Eastern England

and South-Eastern England during some 51 Zeppelin airship raids and 52 fixed-wing aircraft raids. London suffered the worst of the bombing with an estimated 250 tonnes of HE and incendiary bombs recorded across the Capital, over half of which fell on the City of London district. The first raid on the Capital took place on the 31st May 1915.

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

A small-scale WWI bomb plot map of London and accompanying written reports of bombing incidents were reviewed. No bomb strikes were identified in the wider study area, the closest incident appears to have occurred in Brentford, >7km to the east. The risk posed by German WWI UXBs is therefore considered to be negligible.

5.7 WWII GERMAN MUNITIONS

5.7.1 Bombs Dropped on the UK

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

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

- ***HE Bombs*** - ***Moderate charge / weight ratio:*** The most common type of HE bombs

dropped were the SC (general purpose) and SD (semi-armour piercing) series of bombs. The charge / weight ratios were between 30% and 50% allowing for penetration through multiple floors / basements of buildings and fragmentation of the thick steel shell to create an AP shrapnel hazard. The most common weights were 50kg, 250kg and 500kg. Although six additional models between 1,000kg and 2,500kg were also deployed, ~70% of HE bombs dropped on the UK were of the 50kg type.

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

had thin steel bodies enabling them to break up on impact and spread their oil incendiary mixture across the ground. As such they are unlikely to remain buried today. Furthermore, their unreliability resulted in them being withdrawn from frontline use by January 1941.

- ***Anti-Personnel (AP) Bombs***: The SD2 'Butterfly' bomb was a 2kg sub-munition dropped on several British cities and towns. It contained 225grams of Amatol however, had no ground penetration ability and therefore any unexploded SD2s would have been recovered during WWII, unless they fell into water.
- ***V1 Flying Bombs and V2 Long Range Rockets:*** In the final year of WWII Germany began using pilotless weapons against England, launched from sites in occupied Europe. Both V Weapons had 1,000kg HE warheads however, were thin-skinned constructions and therefore any that failed to detonate would have broken up on impact, resulting in a large debris field of incontrovertible evidence. As such, there is no risk from unexploded V Weapons today. Thousands landed in south-east England causing widespread damage in London especially.

5.7.2 Bomb Failures

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

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

- Failure of the aircraft's crew to properly arm the bombs (charging the electrical condensers) due to human error or equipment defect.
- Failure of the clockwork mechanism in the fuses of Delayed Action bombs.

- Jettisoning the bomb from a very low altitude. Most likely if the bomber was under attack or crashing.
- Fuse malfunction due to a fault during the manufacturing process. This could be the result of accidental faulty installation or sabotage by POWs put to work in German factories.

5.8 WWII UXB GROUND PENETRATION

5.8.1 Introduction

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

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

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

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

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

- ***UXB Impact Velocity:*** The majority of German HE bombs dropped over the UK resulted from mass carpet bombing raids. These attacks were carried out at altitudes in excess of 5,000m which would have resulted in a 500kg HE UXB impacting the ground at an approximate velocity of 260m/s.
- ***UXB Impact Angle:*** Luftwaffe high altitude bombing resulted in strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.
- ***Bomb Design:*** Some larger German bombs were occasionally fitted with "Kopfrings"; a metal ring, triangular in cross section, fitted around the nose of the bomb to limit ground penetration. It must be assumed that no such retarder units were fitted to the bomb.

5.8.2 The 'J-Curve' Effect

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

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

5.8.1 Site Specific Geology

WWII-era Site Geology		
British Geological Survey (BGS) 1:50,000 scale Mapping:	***Superficial Deposits:*** Lynch Hill Gravel Member (Sand and Gravel) under most of *The Site*. Alluvium (Clay, Silt, Sand and Gravel) associated with Yeading Brook. Langley Silt Member (Clay and Silt) at the north-western extent.	***Bedrock:*** London Clay Formation (Clay, Silt and Sand)
Previous SI Data:	A recent SI report (dated 2018) was provided by *The Client.* A historic BGS borehole log for *The Site* was also reviewed. The encountered sequence on *Site:* A variable thickness of Made Ground (up to 5.6m bgl), overlying sandy clayey Gravel / gravelly Sand to a maximum proven depth of 6.0m bgl, overlying Clay (London Clay) to the base of the boreholes at a maximum proven depth of 15.4m bgl.	

5.8.2 Site Specific Maximum Bomb Penetration Depth

During WWII the Luftwaffe dropped many different types of HE bomb. The SC (general purpose) series was by far the most numerous and of this series, the SC 500 model (weighing 500kg) was the largest of the most commonly deployed and therefore this will be used as the benchmark weapon for the Maximum Bomb Penetration Depth assessment.

The presence of two differing natural deposits (superficial and bedrock) under *The Site,* makes calculating an accurate maximum bomb penetration depth difficult. NB: the empirical 1940s evidence appears to record UXBs travelling through geology of only one type. Each lithology will have had a differing decelerating effect on a HE UXB, both individually and in combination, thereby complicating the estimation of burial depth.

Taking into account the above-mentioned factors, it has been assessed that a 500kg HE bomb would have had a maximum bomb penetration depth of ***10m*** below WWII ground level and the average depth of HE UXBs would be approximately ***6m*** below WWII ground level.

The presence of differing levels on *Site* during WWII and the apparent raising of part of *The Site* post-war indicates that a buried HE UXB would likely reside at a deeper depth today, within the part of *The Site* to the south of the OS mapped earth embankment. The height

difference in the levels during WWII is not known.

Theoretically penetration depths could be greater if the UXB was larger, however, War Office statistics confirm that between October 1940 and May 1941 the majority of HE UXBs (>90%) were either 50kg or 250kg, with the 500kg bombs making up most of the remaining 10%.

6 UXO RISK - BRITISH / ALLIED MILITARY ACTIVITY

6.1 POTENTIAL SOURCES OF UXO

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

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

6.2 INTRODUCTION

Research has not located any evidence of British or Allied army, RAF or Royal Navy activity specifically on *Site*, however this does not necessarily mean that no such activity occurred historically. The most likely potential source of UXO contamination on *Site* is WWII AA fire, however WWII Home Guard activity provides a second potential source of UXO contamination.

6.3 WWII HOME GUARD ACTIVITY

The Home Guard, originally the Local Defence Volunteers, was formed in the summer of 1940. It was a volunteer force comprising men who were either too young, too old, or in reserved occupations (those jobs vital to the war effort). Battalions were established in most urban areas and some large organisations (such as railway networks) created their own platoons.

Their main purpose was to bolster regular Army units in the event of German invasion. By the end of June 1940, over one million had signed up. Initially, only shotguns, old hunting rifles, bayonets, knives and an array of improvised weapons were available, however by mid WWII, conventional weapons were available and some were even designed specifically for the Home Guard; such as SIP grenades (Molotov Cocktails) and the Northover anti-tank Projector. Furthermore, ammunition in very short supply during 1940 became more readily available.

Home Guard units had a variety of responsibilities; road patrols, manning Observation Posts at commanding points, reporting on enemy airborne landings, delaying the enemy at specified road-blocks, and organising mobile fighting patrols to harry the enemy.

The 4th Middlesex Battalion (Harlington) or 10th Middlesex Battalion (Southall) would have been responsible for the study area during WWII. Although no specific evidence of Home Guard activity on *Site* has been identified, it is known that troops often carried out training and manoeuvres on unused open ground, sometimes within close proximity to civilian life. Official records of day to day activity were rarely kept by the Home Guard and therefore any present-day evidence of their activities is usually only anecdotal.

As much of *The Site* was undeveloped and had no apparent use during WWII, it is conceivable that this land was temporarily requisitioned for Home Guard use which could have included, as an ad-hoc weapons range. Even if this did not occur, it is still possible that armed Home Guard soldiers accessed *The Site* whilst on patrol.

Recent UXO finds confirm that Home Guard soldiers purposefully buried caches of ammunition in tactical locations to be used in the event of a German invasion. However, such activity is more likely to have occurred within the defended coastal areas, far from *The Site*.

Other recent WWII land service and small arms ammunition finds in the England indicate an ill disciplined 'out of sight out of mind' culture in the armed forces during WWII. It would appear that faulty or partially spent ammunition was sometimes simply discarded in seemingly random locations, becoming buried over time. Similarly, there are many examples of surplus (boxed) ammunition simply buried as a hassle-free means of disposal, likely when the Home Guard was disbanded in 1944. Such a scenario on *Site* can therefore not be completely discounted, although is considered unlikely.

6.4 WWII ANTI-AIRCRAFT BATTERIES

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

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

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

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

   The 40mm Bofors gun could fire 120 x HE shells / minute to a ceiling of 1,800m. Each

shell was designed to self-destruct if it didn't strike an aircraft, however, inevitably some failed and fell back to earth.

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

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

Unlike bombs which were designed to strike the ground nose first, AA shells and rockets were not designed to hit the ground and therefore unexploded AA munitions do not necessarily land nose first. This coupled with the lower mass of AA UXO resulted in shallower ground penetration depths. Although, in very soft conditions, unexploded WWII AA munitions were observed to penetrate to >1.5m bgl.

20 permanent HAA batteries were constructed within a 15km radius of *The Site* immediately prior to WWII. Great West Aerodrome may have been defended by some LAA guns during WWII and these would have been within range of *The Site*. Luftwaffe activity was frequent over the wider area and therefore, as *The Site* was mainly soft ground, it is quite possible that an unexploded AA shell could have landed on *Site*, become shallow buried and remained there undetected.

6.5 LAND SERVICE AMMUNITION (LSA)

6.5.1 General

Land Service Ammunition (LSA) is a broad military term relating to a wide variety of weapons primarily deployed for land use. NB: Similar weapons (particularly artillery guns) were also

deployed on naval platforms historically. LSA encompasses those types of ammunition that can be placed, thrown or propelled and as such is broken down into five main munitions families; Grenades, mortar bombs, artillery projectiles, anti-tank rockets and landmines.

The former three (detailed below) were produced / deployed in the greatest numbers historically and therefore are more likely to be encountered on UK sites today.

Anti-tank rockets were portable infantry weapons, however saw only limited service in the latter years of WWII. As such, the US made Bazooka and British made PIAT were deployed in relatively small numbers.

Landmines (both anti-personnel and anti-tank) were used by the British Army to fortify English beaches against an anticipated German invasion during WWII. However, as expected, each minefield was well documented and subsequently cleared during the 1940s.

Like German UXBs, LSA does not lose its effectiveness with age. Decades of burial can cause ammunition to become less stable and more sensitive. The potentially fragile state of expended, yet unexploded LSA, coupled with the relatively shallow burial state of such items, makes for a particularly hazardous scenario as LSA is more likely to be encountered and tampered with by unqualified personnel.

Data sheets on the most likely types to be encountered today and / or the most hazardous are included at ***APPENDIX 4***.

6.5.2 Grenades

A grenade is a short-range infantry weapon, essentially a small bomb, typically thrown by hand or launched from rifles or dedicated grenade launchers. A wide variety of grenades have been deployed in the UK historically, the most common being explosive (fragmentation or blast / concussion) grenades designed to detonate after impact or after a set amount of time.

They are divided into two categories; HE and Carrier (chiefly smoke for signalling and white phosphorus). Grenades were designed for both anti-personnel and anti-tank roles.

The Mills Bomb was the first modern fragmentation grenade produced for the British Army,

and was used in the WWI trenches from 1915. Updated Mills models were the mainstay of the Army throughout WWII and into the post-war period.

The striker of a Grenade (found buried on site today) may either be in contact with the detonator or still be retained by a spring under tension. As a result, any shock or vibration may cause it to function.

6.5.3 Mortars

A mortar is a simple infantry weapon that fires a projectile (mortar bomb) in a high-arcing ballistic trajectory, at low velocity, to a relatively short range. It is a compact, easily transportable weapons system used by British and Allied armies since WWI, when the British Stokes Trench Mortar became the first truly portable infantry mortar.

During WWII British mortars had a rate of fire of 30 bombs per minute with ranges in excess of 2km. The 2" and 3" mortars were the most common types used by the British Army.

Ammunition for mortars generally comes in two main varieties: fin-stabilized and spin-stabilized. Examples of the former have short fins on their posterior portion, which control the path of the bomb in flight. Spin-stabilized mortar bombs rotate as they travel along and leave the mortar tube, which stabilizes them in much the same way as a rifle bullet. Both types of bomb come in a variety of types; high explosive, smoke, parachute illumination, inert practice.

The mortar bomb is almost always nose fused with the tail piece comprising a 'spigot tube' (housing the propellant charge) screwed or welded to the rear end of the main body. A mortar relies on a striker hitting a detonator for explosion to occur. Like grenades, the striker of an expended but unexploded mortar bomb may now be in a very fragile state, after decades exposed to environmental conditions.

6.5.4 Artillery Projectiles

Anti-tank guns and Howitzers have been in use with the British Army for over a hundred years. The former ranged from the Ordnance QF 2 Pounder (40mm) to the Ordnance QF 17 Pounder (76mm) in calibre. The latter ranged from the Ordnance QF 25 Pounder (87.6mm) to the BL 60 Pounder (127mm).

A wide variety of artillery projectiles have been deployed in the UK historically, by British and Allied Armies. In general, projectiles fall into two categories; Shot and Shell. The former are inert; solid metal projectiles containing no hazardous element, whereas the latter are hollow (like bombs), containing a variety of potentially hazardous fills.

Solid shot falls into four categories, mainly for gun proofing and target practice, however as they are inert they are relatively irrelevant with regards to present day UXO risk. Historically, there were three types of WWII-era British artillery shell:

- ***Bursting Type*** - The filling (or part of it) caused the shell to burst. The most common filling was HE where the shell caused damage to material by the force of the burst or to personnel and aircraft by fragmentation of the shell casing producing shrapnel. NB: bursting shells were also used with chemical fillings.
- ***Shrapnel Type*** - These usually burst in the air and projected their 'payload' forwards acting like a shotgun. The usual payload was shrapnel bullets however Thermite 'pots' were used during WWI. By the start of WWII shrapnel shells were obsolete for field artillery.
- ***Carrier Type*** - These also burst in the air, however ejected their payload backwards after blowing the base plate off the shell. The most common fills used were smoke, star and flare shells. The latter two being designed to illuminate an area or target. Smoke shells were used to produce smoke screens and used various fillings (the common being white Phosphorus).

  Artillery projectiles were always painted, this protected the steel from rust but was also used to indicate the nature of the ammunition. The basic body colours for artillery were; Yellow (HE), Light Green (smoke), Black (Flare / Star) and Grey (chemical).

Most artillery shells have a similar appearance and therefore the 3.7” AA shell shown in *Appendix 3* is a good example of a WWII-era artillery projectile.

NB: artillery shell fuses found on their own do not represent a significant hazard. A fuse from an unspent shell will only contain a very small quantity of gunpowder in the detonator.

6.6 20MM AUTOCANNON AMMUNITION

During WWII, a number of RAF and USAAF fighters were fitted with 20mm autocannons; manufactured by the Swiss company Oerlikon and the French company Hispano-Suiza. These weapons were also used by UK based Army and Navy units in the LAA role. An autocannon is essentially a larger calibre machine gun utilising fused (not solid shot) ammunition.

Although cannon ammunition looks very similar to SAA, some projectiles incorporate a small, simple impact fuse and an approximately 4gram HE and / or incendiary fill. Although small, when compared with artillery shells, each bursting charge still has the potential to cause serious injury.

During WWII, Hispano-Suiza and Oerlikon produced a variety of 20mm ammunition types; High Explosive, High Explosive Incendiary, Armour-Piercing, Armour Piercing Incendiary, Target Practice (inert), Target Practice Tracer (inert). Each type was distinguished by the painted colour of the projectile head and colours varied between the two manufactures.

On some projectiles, the tracer became a self-destruct mechanism, detonating the bullet if no impact occurred after five seconds. This resulted in the potential for less collateral damage and far less unexploded 20mm rounds falling back to earth.

A data sheet on 20mm ammunition is included at ***APPENDIX 5***.

6.7 SMALL ARMS AMMUNITION (SAA)

Small arms ammunition is primarily cartridge-based, solid shot ammunition with a calibre <20mm. It covers ammunition used for side arms, rifles and light to heavy machine guns. Each 'round' of ammunition comprises a cartridge case, solid shot projectile (bullet), propellant and primer.

The most common types of SAA to be encountered in the UK are 0.303” calibre (the standard British and Commonwealth military cartridge from 1889 until the 1950s), 0.30” calibre (the standard American cartridge used during WWII) and 0.5” calibre (used by machine guns deployed on USAAF bombers based in Britain during WWII).

As solid shot, spent SAA rounds do not pose a hazard. Unspent rounds comprise a small propellant charge within the cartridge, however SAA is generally stable and relatively safe to handle. NB: Unspent rounds can function if subjected to high heat, such as fire. Any detonation however would not be contained within a barrel and would only result in local, minor overpressure.

7 UXO RISK MITIGATING CIRCUMSTANCES

7.1 INTRODUCTION

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

7.2 EXPLOSIVE ORDNANCE CLEARANCE TASKS

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

BSI has access to a database of historic EOC tasks carried out by the British Army's Royal Engineer EOD unit; the 29th Regiment. NB: this database is only complete up until the early 2000s and therefore does not include recent EOC tasks. No such database for the RAF and Royal Navy EOD units is easily accessible. A search of this database has not resulted in any Army EOC tasks in the vicinity of *The Site*.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. However, no UXO incidents in the vicinity of *The Site* were found.

7.3 GROUND WORKS

During the 1970s, Bulls Bridge (gas-turbine) Power Station was constructed within the centre

of *The Site*. The station was mothballed in the 1980s and then demolished. A photograph of this facility shows the main buildings at approximately two to four storeys in height and a very tall, wide chimney at its centre. A cylindrical gas storage tank and ancillary structure immediately south-east are also present. This facility would likely have required substantial sub-surface ground works and possibly piled foundations.

The photograph and OS mapping also confirm that a quantity of fill material will have been brought onto *Site* to raise the southern area up to the same level as that of the north, where the main creosote Works building once stood. This is substantiated by *The Client* provided SI report which records 4-5m of Made Ground in this area and generally thinner Made Ground in the north.

The existing commercial buildings on *Site* represent the second phase of post-WWII redevelopment. The foundation types of these buildings are not known, however are unlikely to be deep piled and it is considered unlikely that any basement levels will have been constructed on *Site*. NB: much of the power station footprint has experienced two phases of post-war redevelopment.

Some of *The Site* is occupied by dense vegetation or soft landscaping and therefore is unlikely to have experienced any significant post-war ground disturbance.

7.4 DEDUCTIONS

Prior to the post-war levelling works on *Site*, there does not appear to have been any development or redevelopment. Therefore, any buried UXO within the southern central part of *The Site* is unlikely to have been disturbed and will have been simply buried to a deeper depth prior to construction of the power station. However, if the construction of the power station required deep ground works (beyond the maximum depth pf the fill material), any deeper buried German HE UXBs could have been encountered and removed.

The lack of deep high-volume excavations within much of *The Site* post-war, confirms that any deep buried German HE UXB would likely remain in-situ. A shallower buried German HE UXB could also conceivably remain within undisturbed soil, in between existing strip shallow excavations.

Within the footprints of the power station and the subsequent (existing) commercial buildings, there is a lower likelihood of any small items of UXO (British AA shells and German 1kg / 2kg IBs) remaining, as these shallow buried devices would likely have been encountered and removed.

8 CONCLUSION

8.1 ACCURACY OF THE HISTORICAL RECORDS

Occasionally, the accuracy of some historical records can be proven to be poor, when compared with other records. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the vicinity of a study area. A review of the records gathered for this assessment has highlighted an inconsistency. One of the consolidated bomb plot maps does not record an 'iron' bomb strike which is plotted on a weekly bomb plot. However, this does not significantly affect the assessment of UXO risk on *Site*.

8.2 THE RISK OF UXO CONTAMINATION ON SITE

8.2.1 Key Findings - German UXO Risk

- London was the most frequently and heavily bombed British city during WWII. Although Hayes was positioned >15km from central London, high altitude, night time bombing tactics resulted in inaccurate overspill bombing of the wider study area. Original bombing statistics confirm that *The Site* occupied an area of moderate bombing density.
- A collection of original London bomb plot maps covering the entire German bombing campaign was reviewed. These confirm that the wider study area was bombed on at least eight separate occasions, resulting in 29 large 'iron' bombs and one Parachute Mine within a 500m radius of *The Site.* One 'iron' bomb strike is plotted within *The Site* boundary, near the canal, in the western half.
- Analysis of the maps confirms that a German aircraft flew over *The Site* whilst dropping bombs in the vicinity on at least two occasions, possibly more. This raises the possibility of a UXB being released over *The Site*.
- No 1kg / 2kg IB strikes were recorded over *The Site* during the vast majority of WWII, however the possibility cannot be discounted that such bombs fell on *Site* during the first

month of the 1940 Blitz, for which no records are available.

- Most, if not all bombs dropped locally were part of large scale carpet bombing raids, mostly carried out at night. In addition, the wider study area was sparsely populated during WWII and most of *The Site* was undeveloped, with no apparent occupancy / use. This increases the chances of a UXB fall on *Site* occurring unobserved.
- Historical aerial photography shows that the southern portion of *The Site* was occupied by unmaintained grass / scrubland, with denser and / or taller vegetation in the east, suggesting this area was likely neglected for significant periods. A UXB entry hole to such ground cover could have easily been overlooked. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured entry hole. After a time, environmental conditions would cause the hole to collapse and in-fill, erasing evidence of the UXO strike.
- A stream and possibly a large pond existed in this area during WWII. Any UXB striking water would have been immediately lost beneath the waterline, leaving no evidence of its incidence.
- The northern portion of *The Site* was occupied by a railway creosote works, comprising one large structure (near the northern *Site* boundary), timber storage areas and railway tracks. This vital facility did not sustain any significant bomb damage and would likely have remained in operation throughout the conflict. Consequently, this developed part of *The Site* will have been frequently accessed, likely on a daily basis and specific searches for delayed action bombs or UXBs were probably carried out, following each local air raid. As a result, there is a lower likelihood of a UXB entry hole going unreported within this part of *The Site*.
- Any UXB strike to undamaged structures, hardstanding, stacked timber, railway tracks or railway cars would have caused obvious damage or resulted in a persistent, easily recognisable entry hole which would have been reported and dealt with at the time.

8.2.2 Key Findings - British UXO Risk

- 20 permanent HAA batteries were constructed within a 15km radius of *The Site* immediately prior to WWII. Furthermore, Great West Aerodrome may have been defended by some LAA guns and these would have been within range of *The Site* also.

Luftwaffe activity was frequent over the wider area and therefore, for the same reasons as above, an unexploded AA shell could have remained undetected (shallow buried) within undeveloped parts of *The Site*.

- Although no specific evidence of WWII Home Guard activity on *Site* has been located, the possibility cannot be discounted that the unused open ground on *Site* was requisitioned temporarily. Alternatively, armed Home Guard soldiers could conceivably have accessed *The Site* whilst on patrol. Any such activity on *Site* would raise the risk of associated UXO contamination; chiefly the common practice of unauthorised disposal (burial) of surplus ammunition.

8.3 SITE SPECIFIC UXO HAZARDS

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

UXO Type	NEQ (NEQ Range)	Likely Burial Depth	Hazard Posed
WWII German General Purpose HE Bombs	25kg - 220kg (most commonly deployed bomb weights)	Likely deep burial (>3m)	**HIGH RISK**
WWII British Heavy Anti-Aircraft Shells	1.1kg - 1.7kg	Shallow burial (<1.5m)	**MODERATE-HIGH RISK**
WWII British Land Service Ammunition	<2kg	Shallow burial (<1.5m)	
WWII German 2kg Incendiary / HE Bombs	680g incendiary hazard + ~500g explosive hazard	Shallow burial (<1.5m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (<1.5m)	**MODERATE RISK**
WWII British Light Anti-Aircraft Shells	4g - 70g	Very shallow burial (<1m)	**LOW-MODERATE RISK**

8.4 THE LIKELIHOOD OF UXO ENCOUNTER

8.4.1 Introduction

This report assesses the risk of UXO in relation to the proposed works, not simply the risk that UXO remains buried on site. The likelihood of UXO encounter during intrusive ground works will vary depending on the type of UXO and the type of construction methods employed during the project. Naturally, the greater the number, volume and depth of intrusions, the greater the likelihood of UXO being encountered, assuming UXO resides on site.

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

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

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

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

8.4.2 German UXBs

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

- ***Tip and Run:*** When enemy aircraft had to take evasive action to escape RAF fighter interception and / or AA defences, they often dropped their bomb loads from a reduced height, potentially resulting in extreme J-Curve Effect.
- ***Deflection:*** The shape of German HE bomb nosecones meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hard-standing, roads, etc.
- ***Aircraft Crash Site:*** If an aircraft was unable to dump its bomb load before impacting the ground, due to mechanical fault, any externally fitted bombs could have become buried on impact.

German 1kg / 2kg incendiaries were cylindrical and approximately 50mm in diameter. They had tailfins, which meant they landed nose first, which in soft ground could result in full penetration of the bomb below the surface. Therefore, such items are usually found close to the surface.

8.4.3 British / Allied UXO

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

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

8.4.4 Deductions

No proposed *Site* plan showing the footprints of the proposed buildings was available at the time of writing. However, it is understood that the foundations will likely be shallow. If future excavations penetrate below WWII-era ground level within the southern part of *The Site* where post-war Made Ground exists, there will be an elevated likelihood of a UXO encounter. NB: the origin of the post-war fill material is not known however is unlikely to be UXO

contaminated. There is a low likelihood of UXO contamination and / or UXO remaining within the northern part of *The Site* and consequently, a low likelihood of UXO encounter.

NB: experience shows that heavy UXBs can also reside at much shallower depths than expected (see ***APPENDIX 1***) and therefore could also be encountered during shallow excavations, just below WWII-era ground level.

8.5 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating *The Site*, remaining on *Site* up to the present day and being encountered during the proposed works, inform the overall risk rating. The UXO risk on *Site* varies; **Low** and **Moderate** Risk Zones have been identified. These are illustrated on a Risk Map displayed at ***FIGURE 7***.

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

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

NB: post-war deposited Made Ground within the Moderate Risk Zone is Low UXO Risk.

9 RISK MITIGATION RECOMMENDATIONS

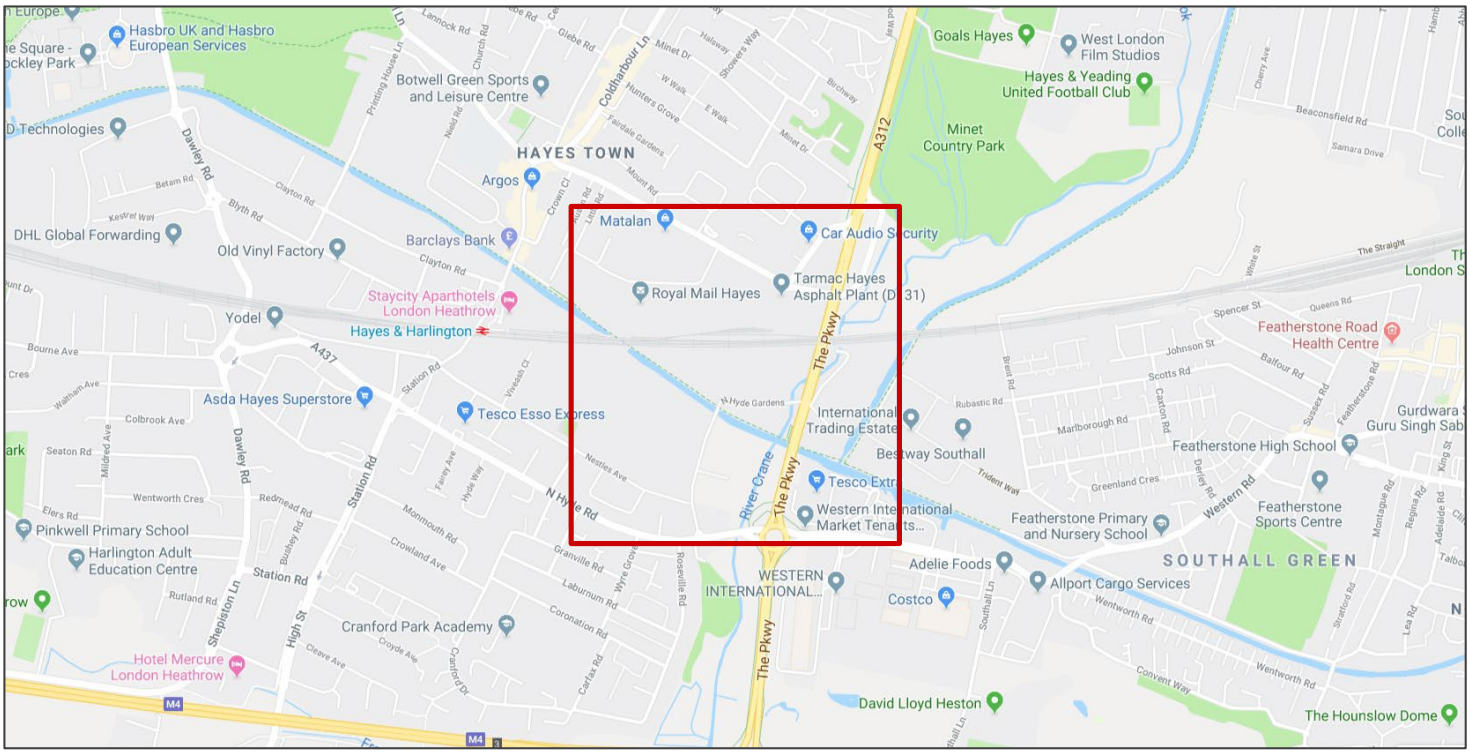
BSI has identified an elevated UXO risk across part of *The Site.* The measures detailed below are recommended to mitigate the UXO risk to ALARP level. A UXO encounter cannot be completely ruled out during ground works within the Low Risk zone and therefore it would be considered prudent to employ the minimum mitigation measure here also.

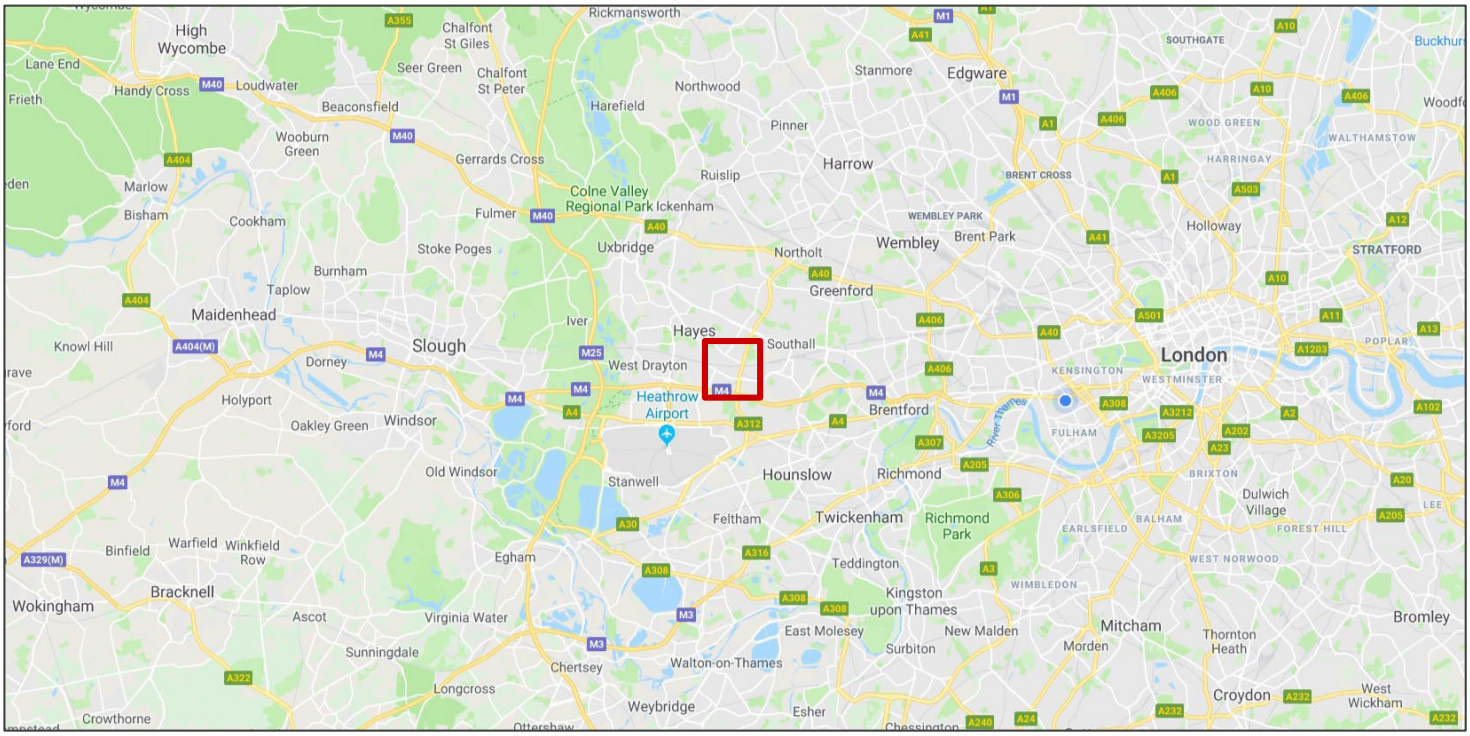
Risk Mitigation Measure	Recommended For?
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Ahead of all intrusive works, within areas of: **LOW RISK** **MODERATE RISK**
EOD Engineer - On Site Supervision: Watching brief of shallow excavations. Portable magnetometer instruments for clearing ground ahead of shallow excavations and SI boreholes (where / when appropriate). Positive identification of suspicious (non UXO) objects. Liaison during confirmed UXO incidents. Provision of additional UXO Safety Awareness Briefings.	Excavations within areas of: **MODERATE RISK**
Intrusive Magnetometer Probe Survey (if required): A range of intrusive magnetometer methodologies can be deployed to survey the ground (down to the maximum bomb penetration depth) prior to deep intrusive works; pile foundations. The appropriate technique is governed by a number of factors, the most important being the site-specific ground conditions.	Any pile foundations within areas of: **MODERATE RISK**

FIGURES: 1 - 7

BRIMSTONE
SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	SITE LOCATION MAPS	FIGURE: 1





N	Project	Bulls Bridge Industrial Estate, Hayes
	Client:	Paragon Building Consultancy Limited
	Report Ref:	DRA-19-1105
	General Site Location	Info Source: Google (open-source)

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

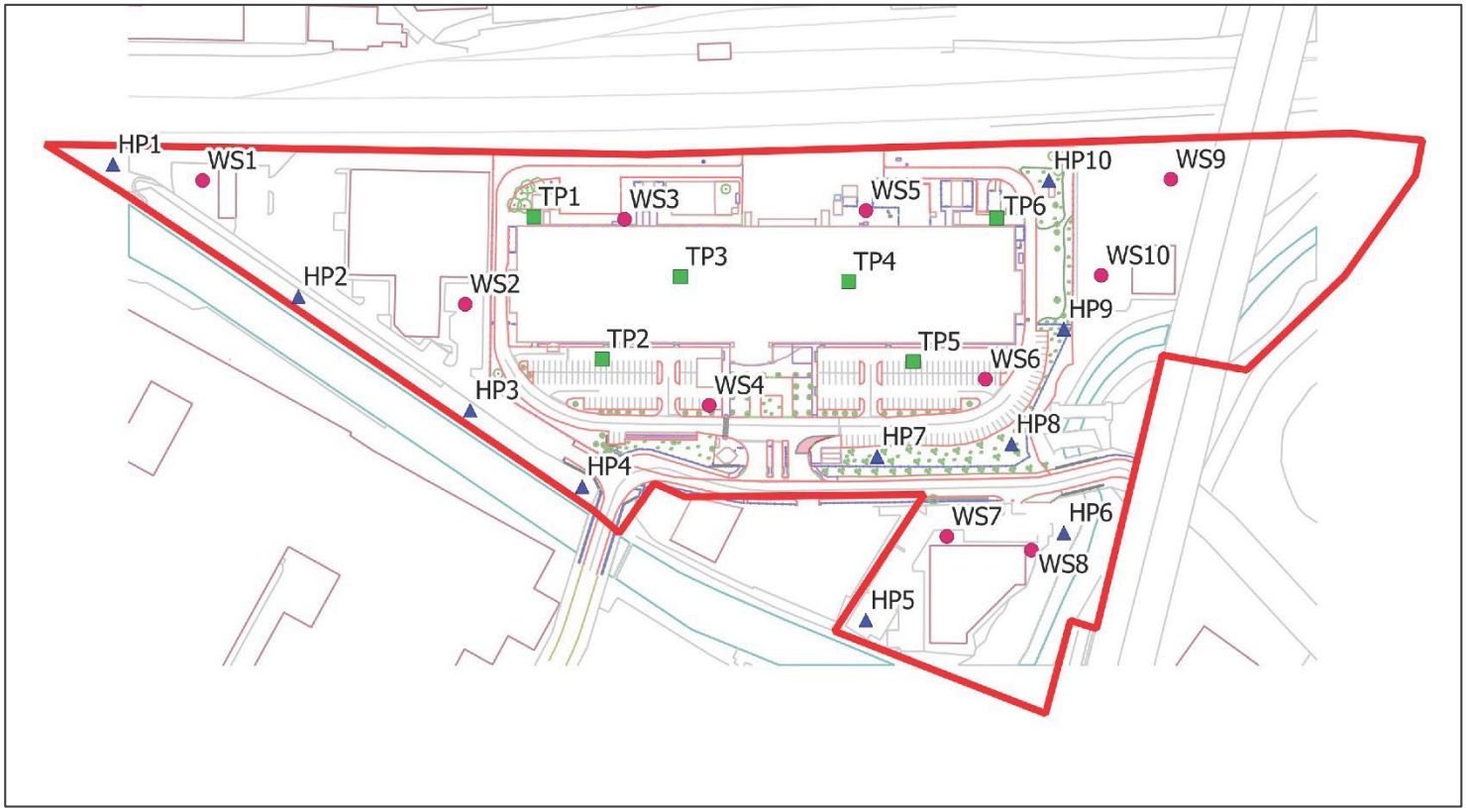
Title:	RECENT AERIAL PHOTOGRAPH	FIGURE: 2

N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: Google (open-source)

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	PROPOSED SI PLAN	FIGURE: 3

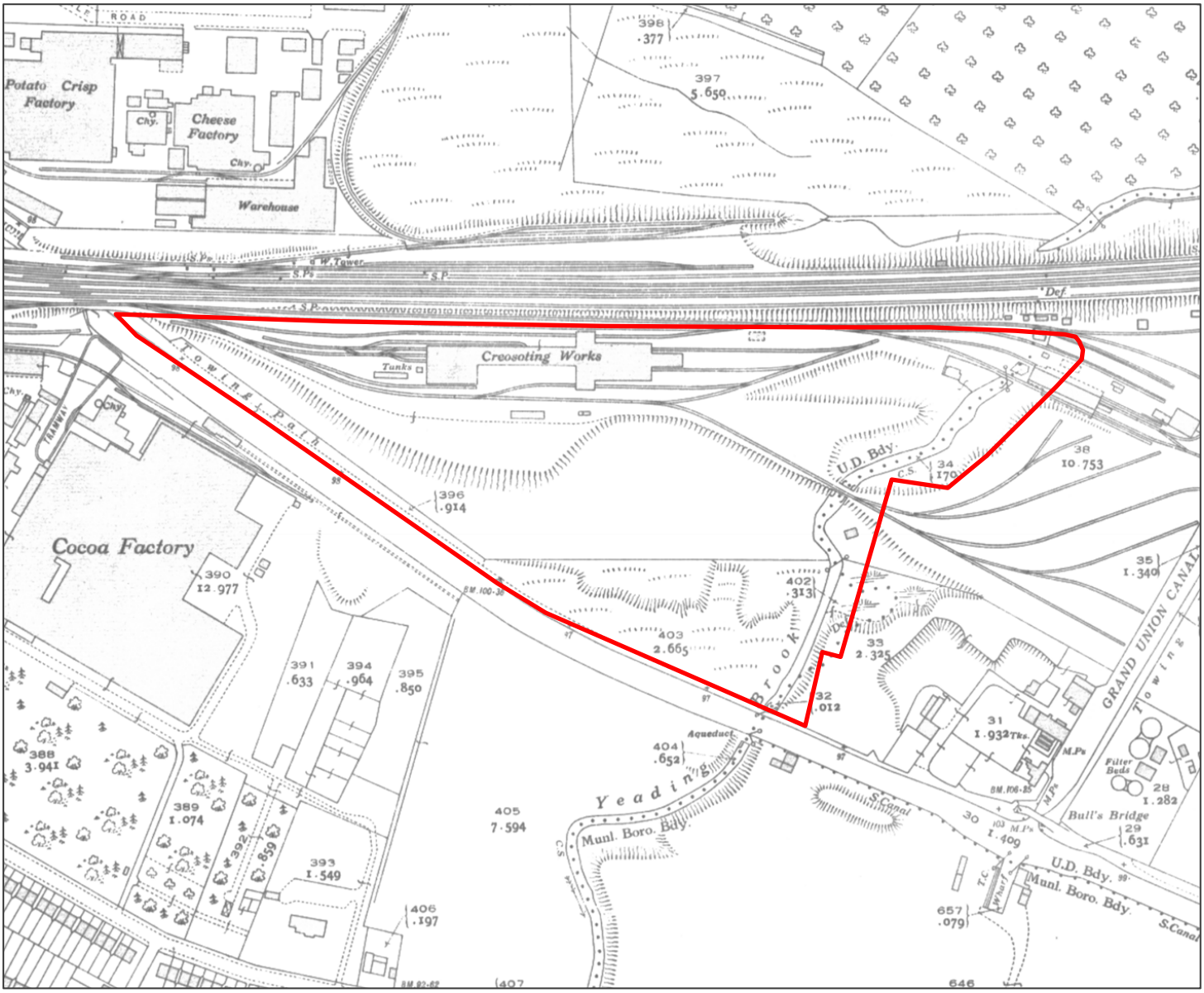


N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Site Boundary	Info Source: Paragon Building Consultancy Limited

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

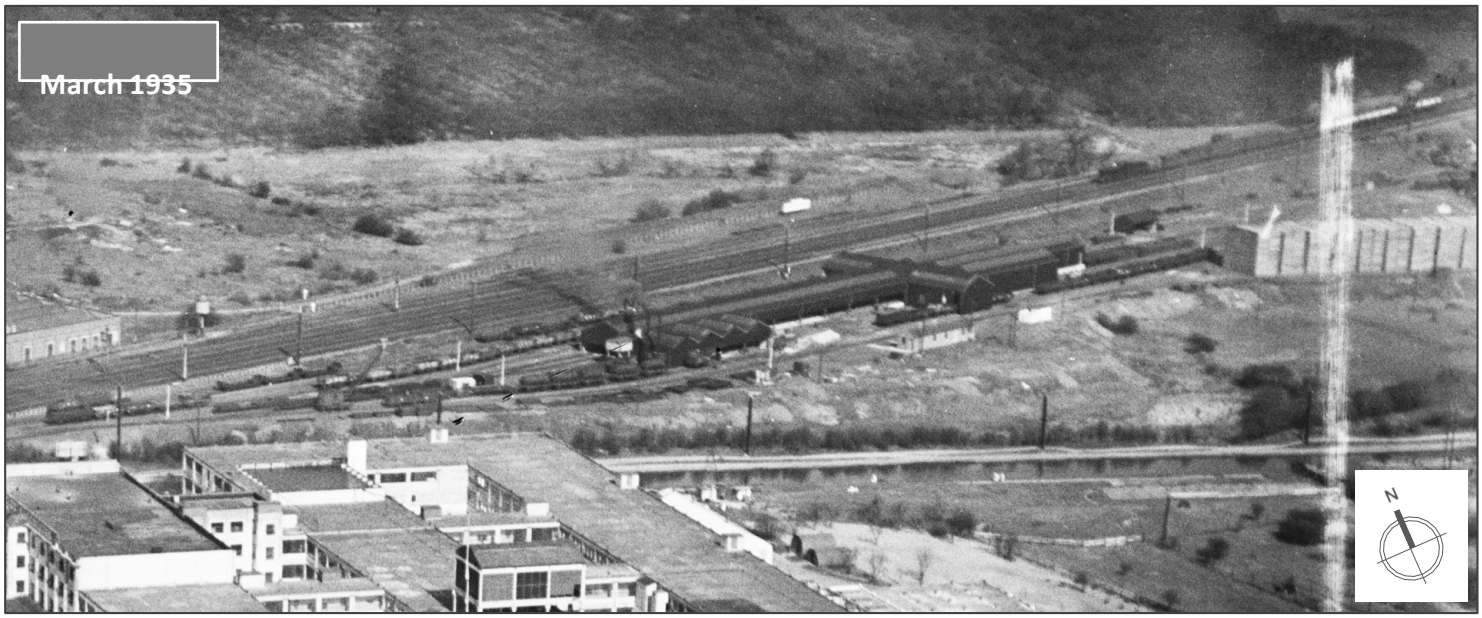
Title:	HISTORICAL OS MAPPING - 1934/35	FIGURE: 4



N	Project	Bulls Bridge Industrial Estate, Hayes
	Client:	Paragon Building Consultancy Limited
	Report Ref:	DRA-19-1105
	Approx. Site Boundary	Info Source: Groundsure

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

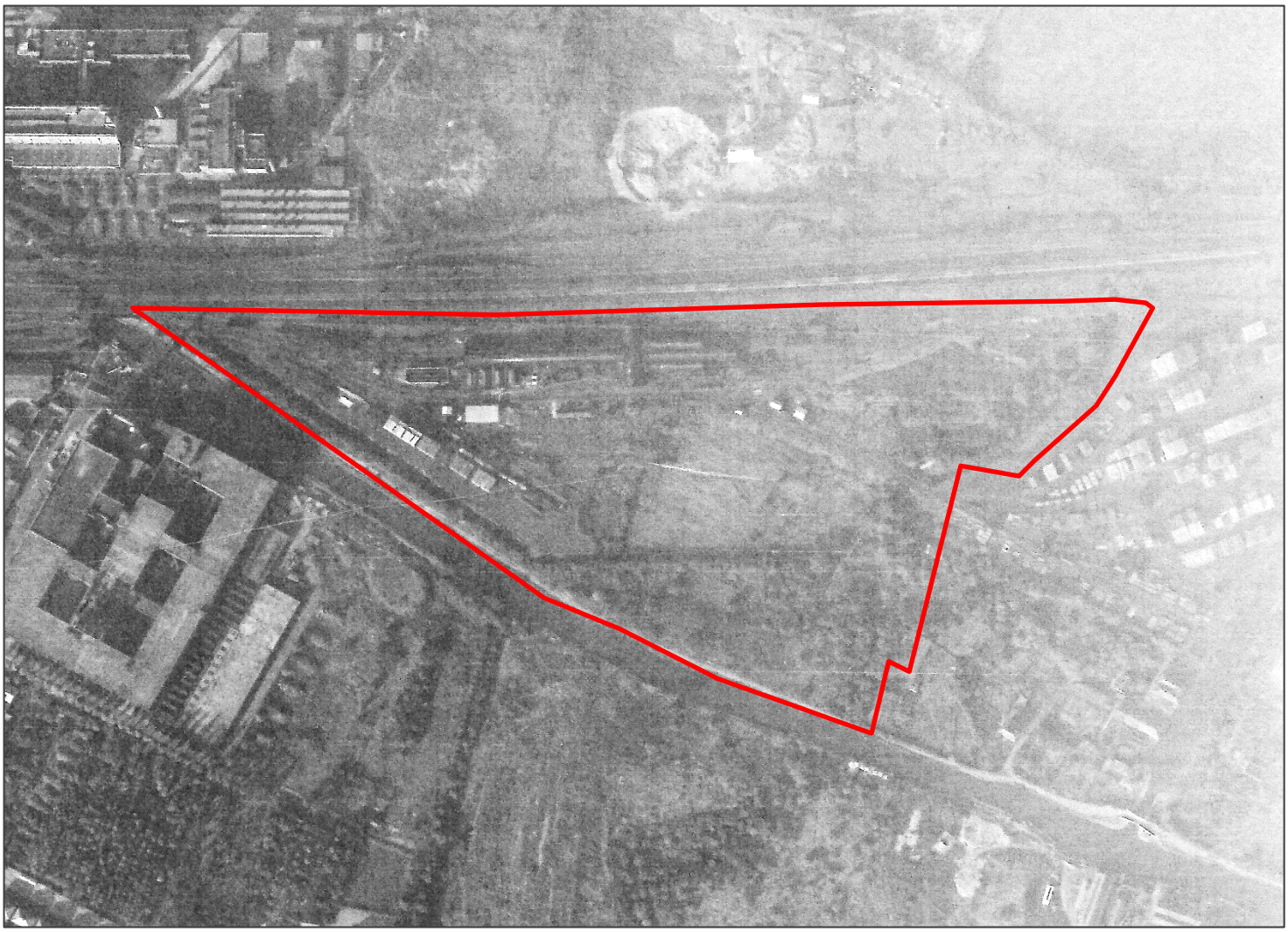
Title:	HISTORICAL AERIAL PHOTOGRAPHY - 1930s	FIGURE: 5.1



Project	Bulls Bridge Industrial Estate, Hayes	
Client:	Paragon Building Consultancy Limited	
Report Ref:	DRA-19-1105	
	Info Source:	Historic England

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	HISTORICAL AERIAL PHOTOGRAPHY - OCT 1945	FIGURE: 5.2

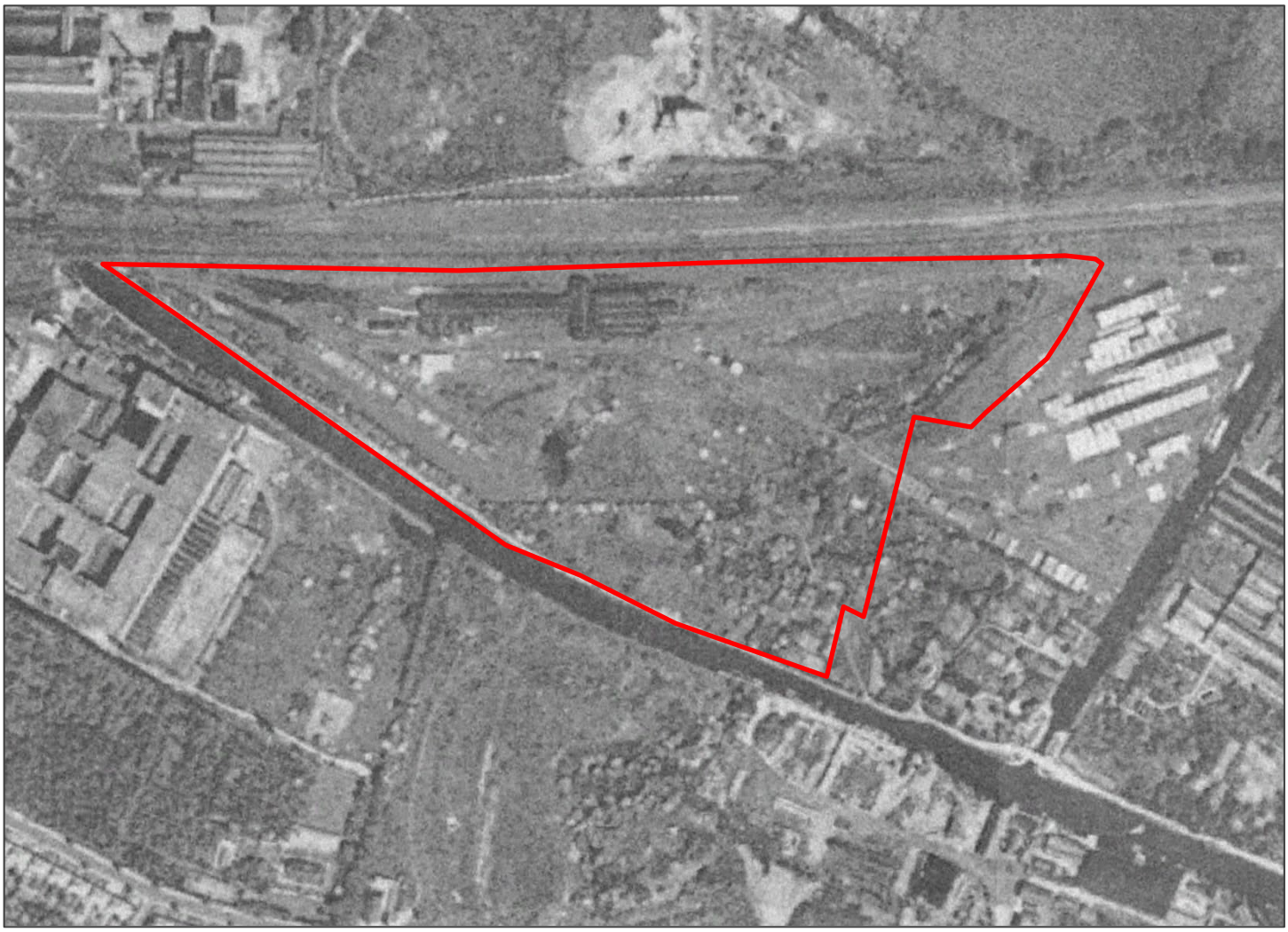


N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: Historic England

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	HISTORICAL AERIAL PHOTOGRAPHY - *circa* 1948	FIGURE: 5.3

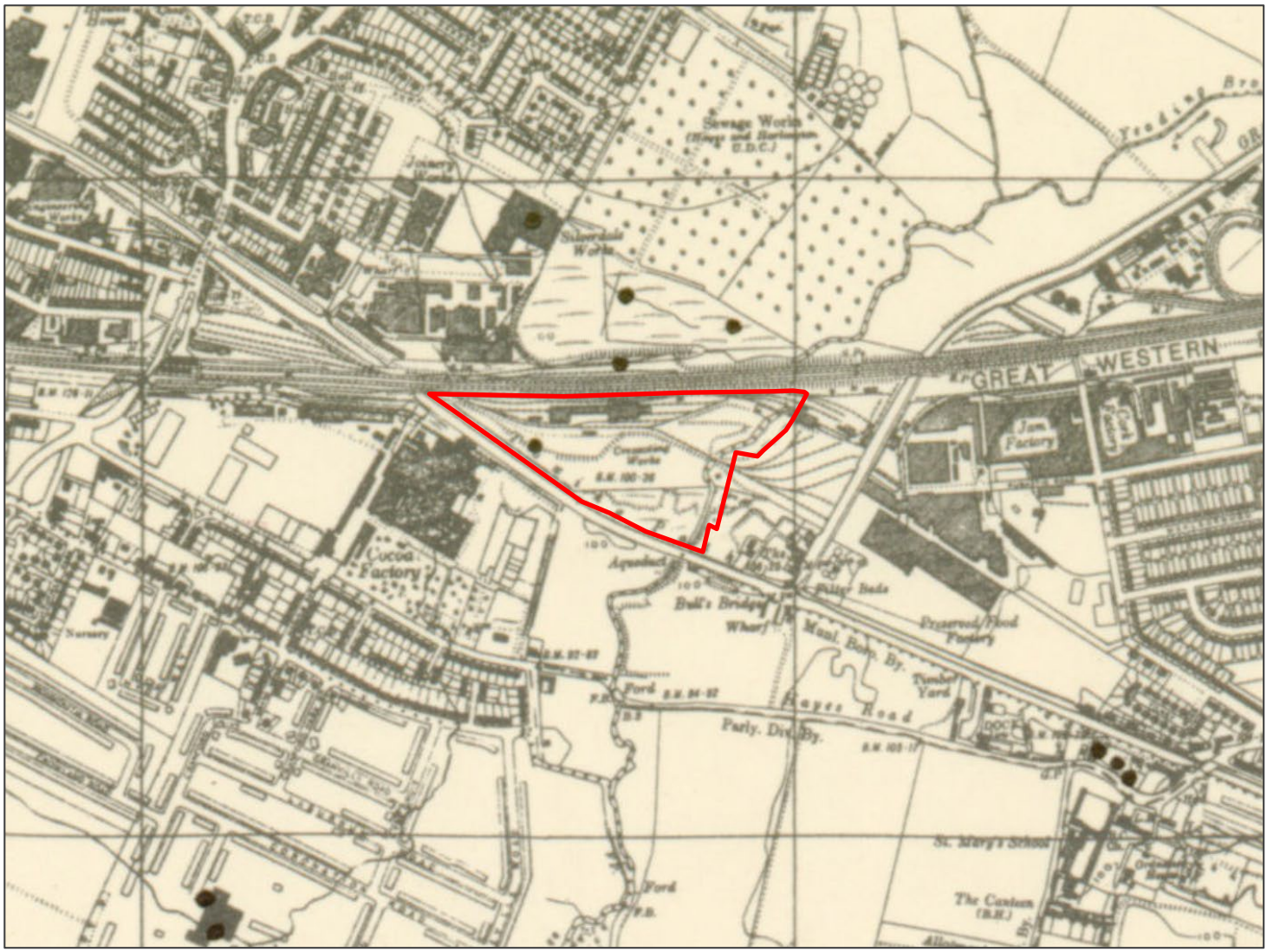


N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: GeoInformation Group

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	LONDON CONSOLIDATED NIGHT BOMBING CENSUS MAP - 07/09/1940 till 07/10/1940	FIGURE: 6.1



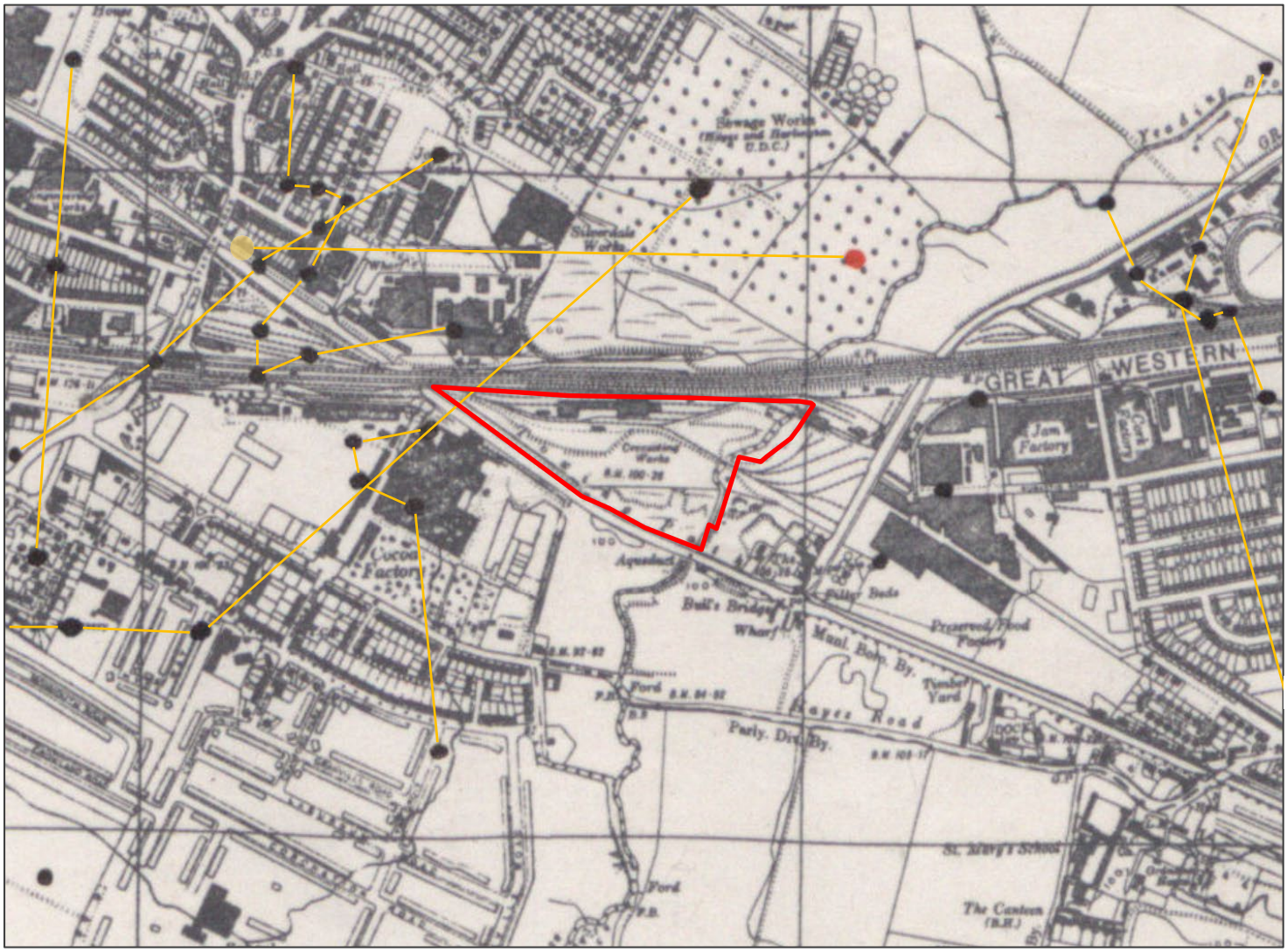
Note: No corresponding collection of weekly bomb plot maps available, so it has not been possible to identify bomb-sticks.

● 'iron' bomb

Project	**Bulls Bridge Industrial Estate, Hayes**
Client:	**Paragon Building Consultancy Limited**
Report Ref:	**DRA-19-1105**
Approx. Site Boundary	Info Source: National Archives, London

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	LONDON CONSOLIDATED NIGHT BOMBING CENSUS MAP - 07/10/1940 till 30/05/1944	FIGURE: 6.2



Notes: By comparing this map with a collection of weekly bomb plot maps, it has been possible to identify individual bomb-sticks, illustrated here by orange lines.

Unhighlighted bomb strikes were not replicated on the corresponding weekly plot map.

Orange spot represents a bomb from a weekly plot map, not replicated here.

'iron' bomb

Parachute Mine

Project	Bulls Bridge Industrial Estate, Hayes		
Client:	Paragon Building Consultancy Limited		
Report Ref:	DRA-19-1105		
Approx. Site Boundary		Info Source:	National Archives, London

BRIMSTONE SITE INVESTIGATION

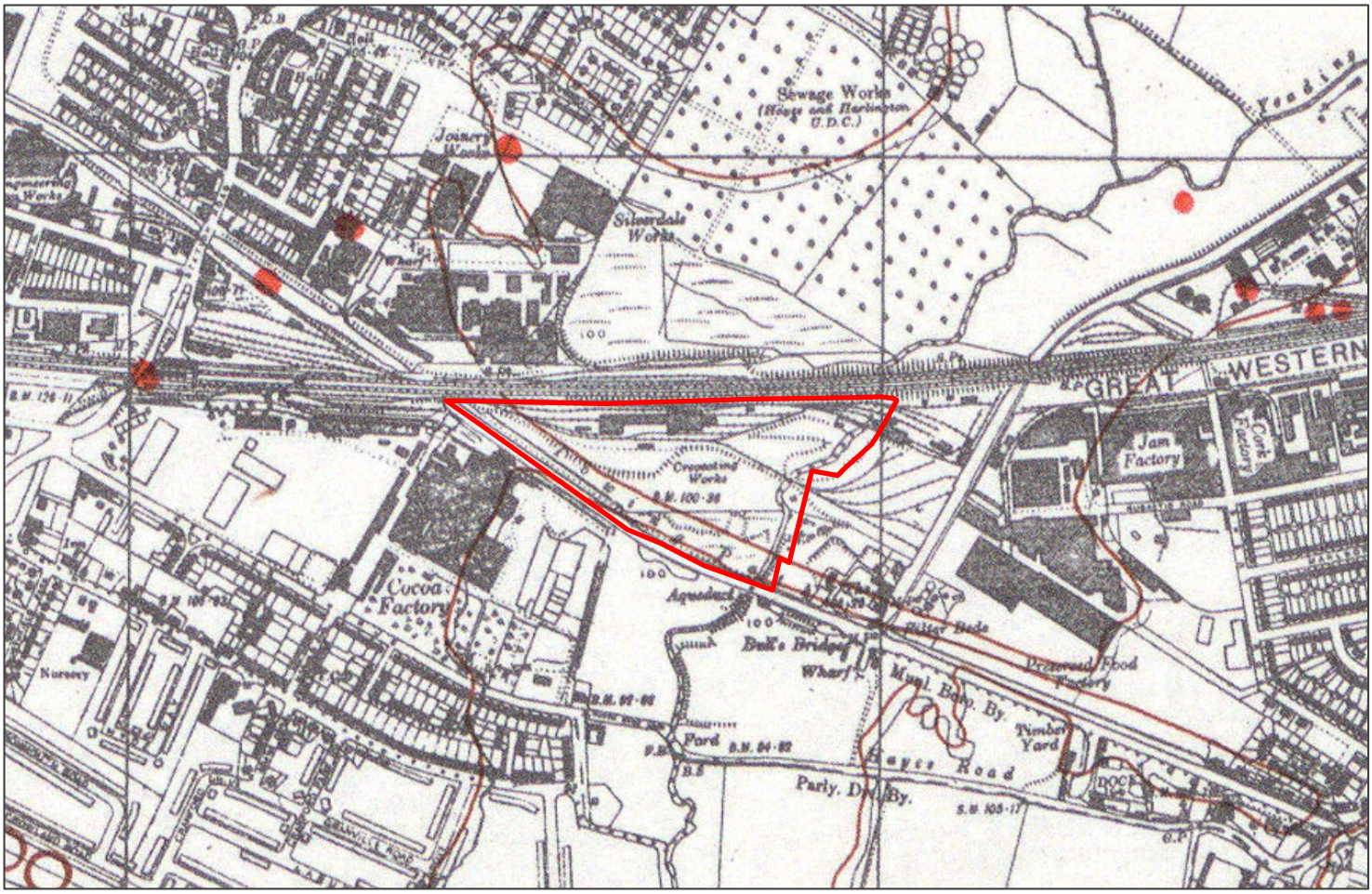
1-3 Manor Road, Chatham, Kent, ME4 6AE

+44 (0) 207 117 2492

www.brimstoneuxo.com

enquire@brimstoneuxo.com

Title:	LONDON CONSOLIDATED DAY BOMBING CENSUS MAP - 07/10/1940 till 30/12/1941	FIGURE: 6.3

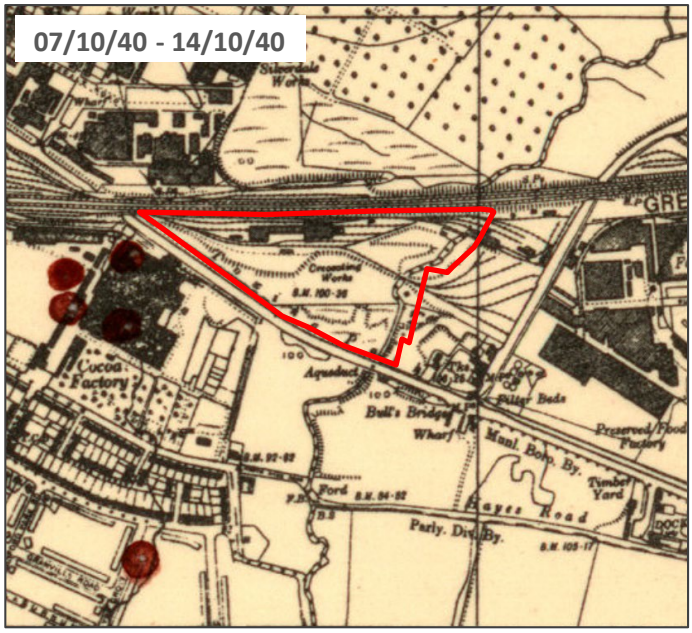


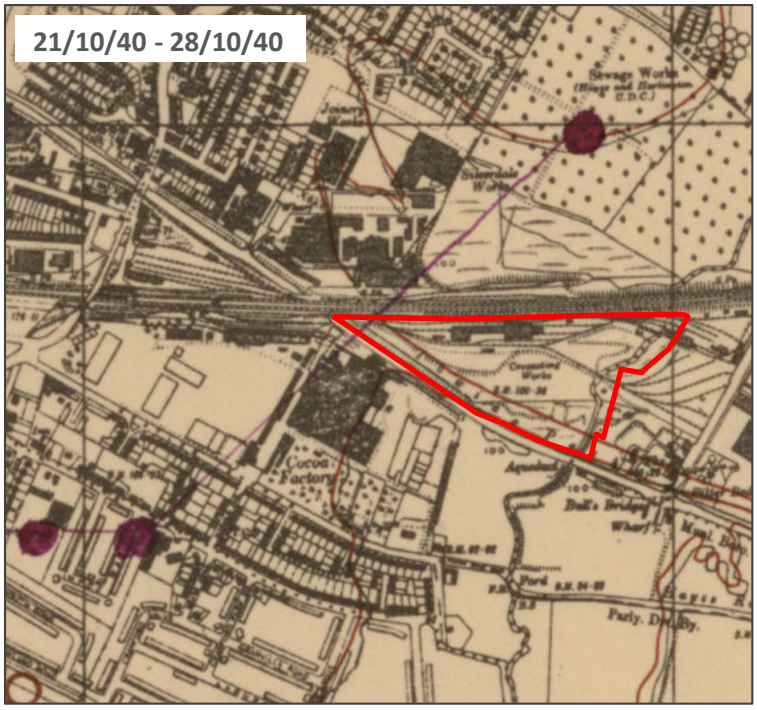
'iron' bomb

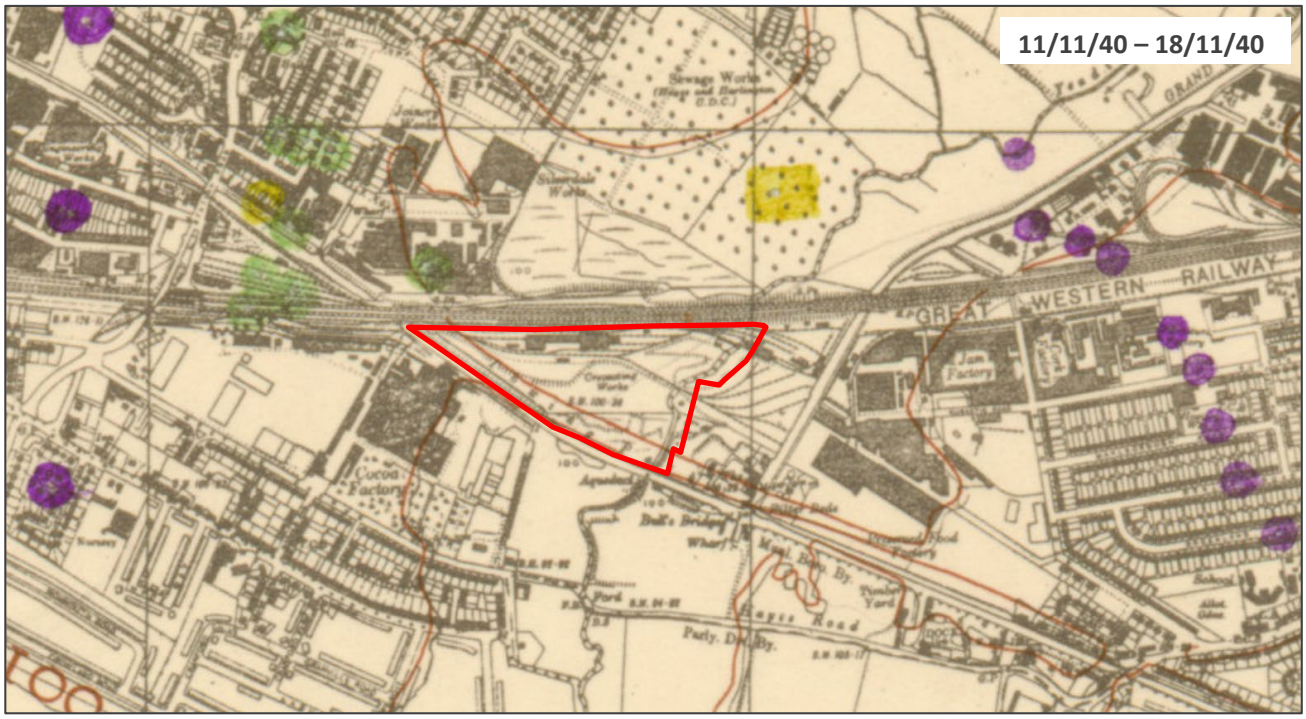
Project	Bulls Bridge Industrial Estate, Hayes	
Client:	Paragon Building Consultancy Limited	
Report Ref:	DRA-19-1105	
Approx. Site Boundary	Info Source:	National Archives, London

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	SELECT LONDON WEEKLY BOMB CENSUS MAPS - 07/10/1940 till 30/05/1944	FIGURE: 6.4







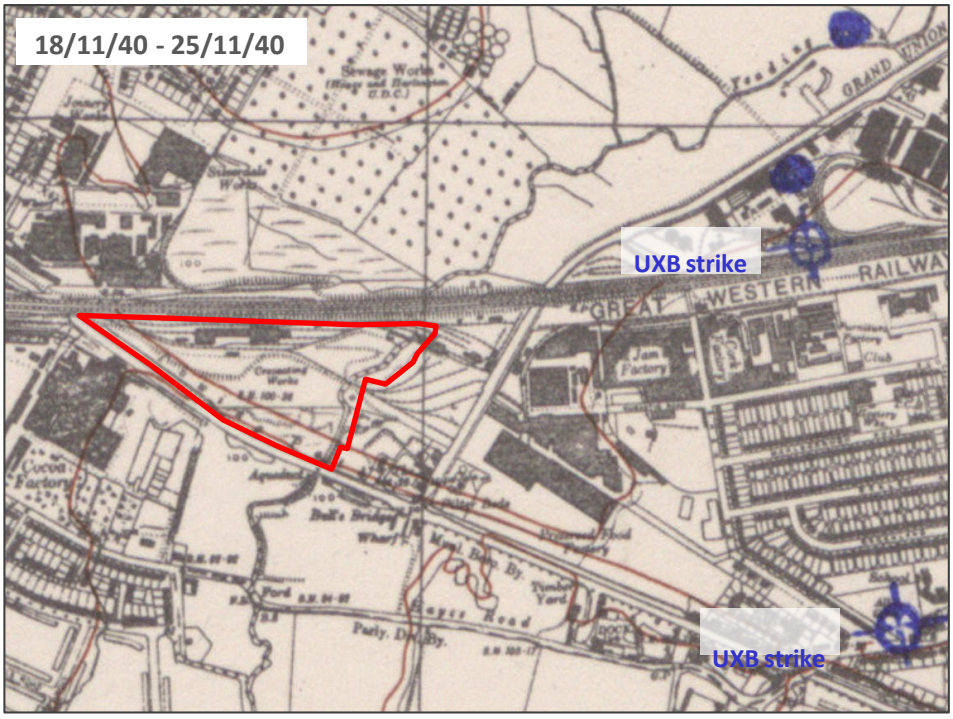
Note: the 14th - 20th October 1940 map is missing from the collection

N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: National Archives, London

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	SELECT LONDON WEEKLY BOMB CENSUS MAPS - 07/10/1940 till 30/05/1944	FIGURE: 6.5



N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: National Archives, London

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	RISK MAP: LIKELIHOOD OF UXO REMAINING	FIGURE: 7

LOW UXO RISK ZONE
Low likelihood of German or British UXO remaining.

MODERATE UXO RISK ZONE
Elevated likelihood of British UXO remaining.
Elevated likelihood of German HE UXB remaining.

Former Power Station - Approximate footprint

N

Project	Bulls Bridge Industrial Estate, Hayes
Client:	Paragon Building Consultancy Limited
Report Ref:	DRA-19-1105
Approx. Site Boundary	Info Source: N/A

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

APPENDICES: 1 - 7

BRIMSTONE
SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Recent German UXB Finds in the UK + Historical Analysis

- ***23rd May 2019*** - An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Kingston upon Thames, London. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest approximately 3 to 4m bgl.*
- ***15th May 2017 -*** An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Aston, Birmingham. *Historical Analysis: The UXB landed in a small back garden belonging to a terraced house, part of a row. It J-Curved under a neighbouring garden and came to rest at just 1.4m bgl. NB: These houses had not sustained bomb damage.*
- ***2nd March 2017 -*** A 250kg HE bomb was found during deep excavations at a building site in Brondesbury Park, London. *Historical Analysis: UXB landed in a large residential back garden. A single storey building was built on top of the UXB post-WWII.*
- ***19th January 2017 -*** An SD50 (semi-armour piercing 50kg HE bomb) was dredged from the Thames during barge dredging works near Westminster Bridge, London.
- ***12th May 2016 -*** A 500kg HE bomb was found buried just 1m below the playground of the former Royal High Junior School in Bath. *Historical Analysis: The UXB landed in a plot of neglected, unmaintained vegetation in between the school gym and main school building.*
- ***23rd September 2015 -*** A 1,000kg HE bomb was encountered by a mechanical excavator on a building site in Paradise Street, Coventry. *Historical Analysis: the UXB landed in a large residential back garden occupied by dense vegetation. A two storey building was built on top of the UXB post-WWII.*
- ***10th August 2015 -*** A 250kg HE bomb was found immediately beneath a basement floor during refurbishment works in Temple Street, Bethnal Green (London). *Historical Analysis: The UXB struck a house that had been damaged beyond repair during a previous air raid. The existing house was then built on top of UXB post-WWII.*
- ***21st May 2015 -*** An SC50 (general purpose 50kg HE bomb) was found during deep excavations at a construction site in Wembley, London. *Historical Analysis: UXB landed in a large residential back garden.*
- ***23rd March 2015 -*** A 250kg HE bomb was found during deep excavations at a building site in Grange Walk, Bermondsey (London). *Historical Analysis: inconclusive - reported UXB position is likely inaccurate.*

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

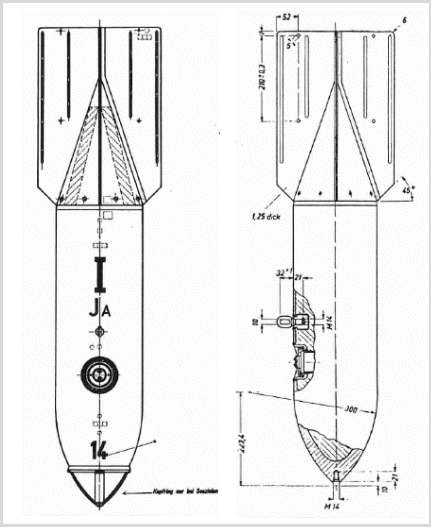
Initiation of WWII Allied Bombs

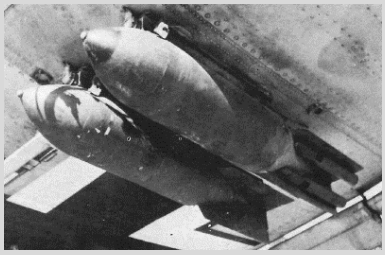
- ***6th January 2014 -*** Mechanical excavator stuck a WWII bomb in Euskirchen (Germany) causing it to explode, killing the operator and injuring 13 more, two critically. The explosion was so large it damaged buildings 400m away.
- ***1st March 2013 -*** During piling at a construction site in Ludwigshafen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

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

SC 50

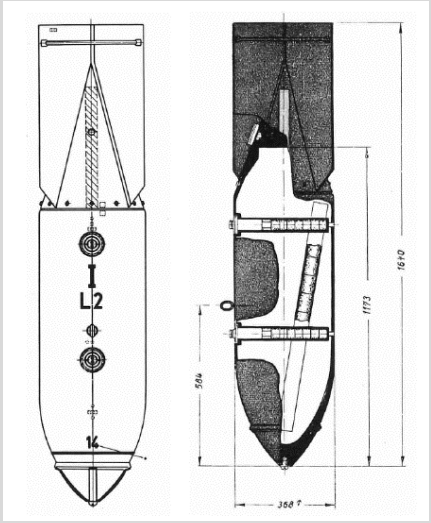
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow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





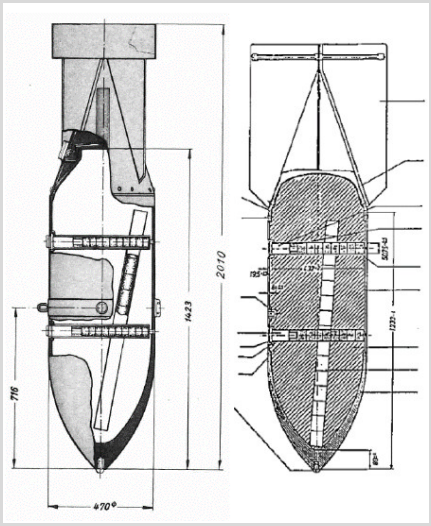
SC 250

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



SC 500

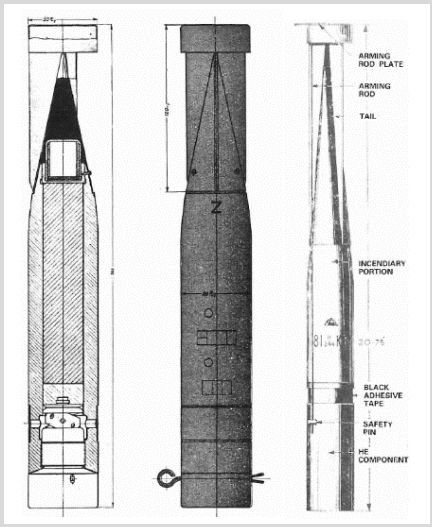
Bomb Weight:	480-520kg (1,058-1,146lb)
Explosive Weight:	220kg (485lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	2 electrical impact fuses or mechanical delayed action fuses
Body Dimensions:	1,423mm length x 470mm diameter
Appearance:	Bomb body and tail painted grey/green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



BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

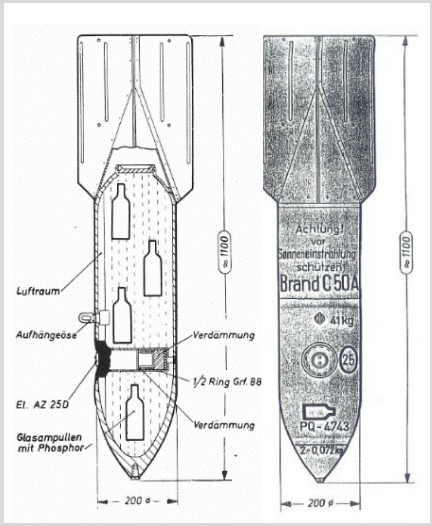
B-1E Sub-Munition

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



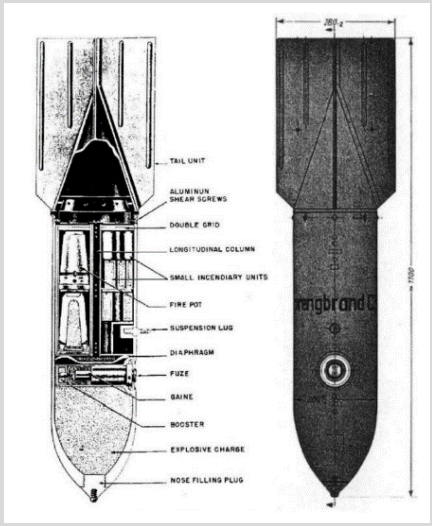
Brand C50

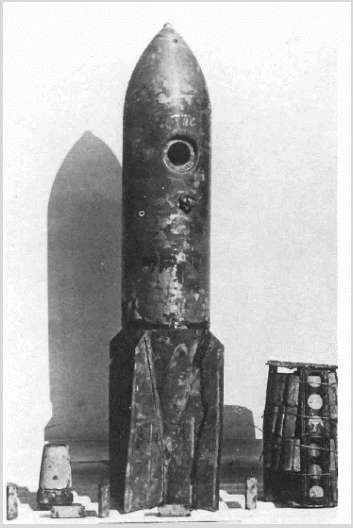
Bomb Weight:	41kg (90.4lb)
Incendiary Weight:	13kg (30lb)
Filling:	Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type:	1 x electrical impact fuse
Bomb Dimensions:	762mm length x 203mm diameter
Appearance:	bomb body and tail painted grey or green with the rear of the bomb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



Spreng-Brand C50 - *Fire Pot*

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

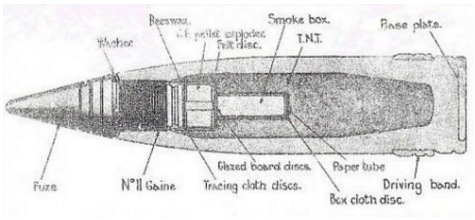




BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

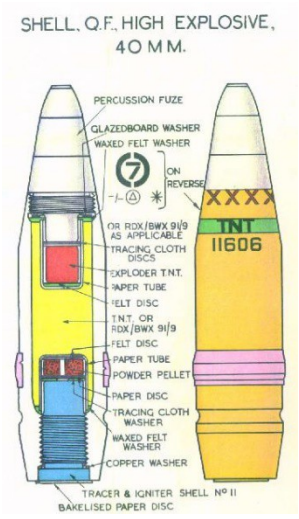
HAA Battery - 3.7" QF Shell

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



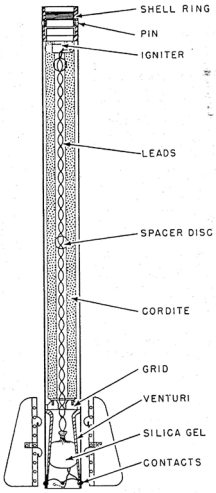
LAA Battery - 40mm Bofors Shell

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



Z Battery - 3" U.P Rocket

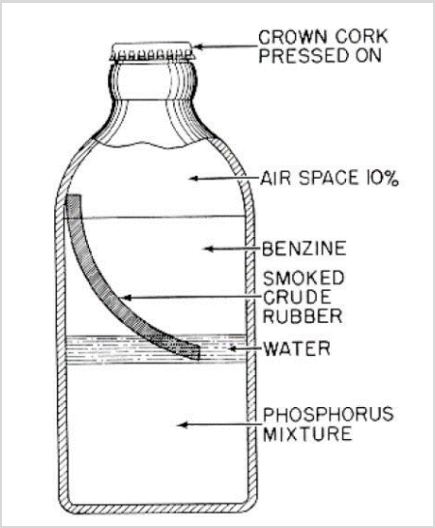
Rocket Weight:	24.5kg
Warhead Weight:	1.94kg
Filling:	TNT warhead. Black Powder solid fuel rocket motor.
Fuse Type:	Mechanical Time Delay fuse
Rocket Dimensions:	1,930mm x 76mm
Ceiling:	6,770m
Operation:	Fired from single, tandem and (later) 36 x rail launchers (Z Batteries). Limited use throughout the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



BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

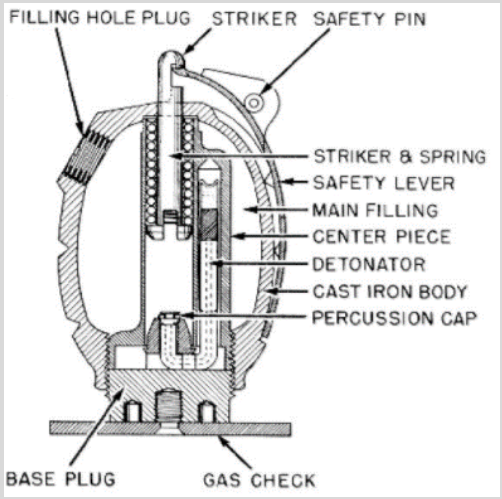
No. 76 Self Igniting Grenade (SIP)

Construction:	Glass bottle and metal stopper
Weight:	0.59kg
Dimensions:	152mm x 63mm
Hazardous Fill:	White Phosphorus and Benzene
Fuse:	n/a
Appearance:	White / off yellow milk bottle
Hazards:	Choking fumes of Phosphorus Pentoxide and Sulphur Dioxide, as well as heat. Severe burns if comes into contact with skin.
Remarks:	By August 1941 well over 6,000,000 of these grenades were available and mainly issued to the Home Guard.



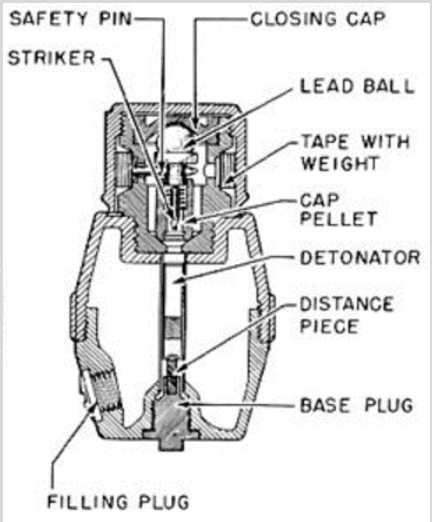
No. 36 Hand Grenade (Mills Bomb)

Construction:	Metal
Dimensions:	95mm x 61mm
Weight:	760g
Fill weight:	71g
Hazardous Fill:	Baratol
Fuse:	Percussion cap and 4 second time delay fuse
Hazards:	Blast, fragmentation. ~30m effective range.
Remarks:	>70 million were produced between 1915 and the 1980s



No. 69 (Blast) Hand Grenade

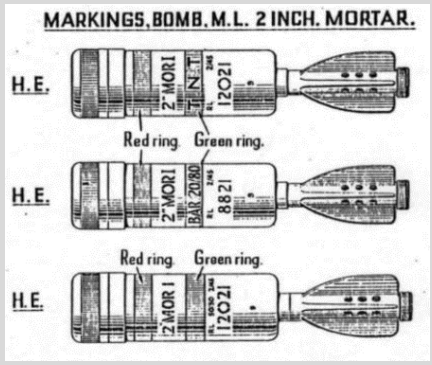
Construction:	Bakelite (plastic)
Dimensions:	114mm x 60mm
Weight:	383g
Fill weight:	92g
Hazardous Fill:	Baratol, Amatol or Lyddite
Fuse:	'All-Ways' Impact fuse
Hazards:	Blast effect. <20m effective range.
Remarks:	Green bands around the grenade signified a HE fill.



BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

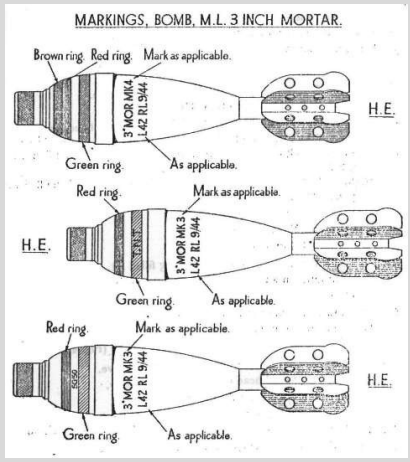
2” ML Mortar - High Explosive

Weight:	1.02kg
Dimensions:	51mm x 290mm
Hazardous Fill:	200g of RDX/TNT
Fuse:	Impact fuse
Appearance:	Cylindrical shape. Brown body, green and red bands, five finned tail
Variants:	Several smoke, inert practice and parachute illumination versions were manufactured
Remarks:	Common anti-personnel weapon in use with British Army throughout WWII. >12.5 million HE rounds were produced in 1942 alone



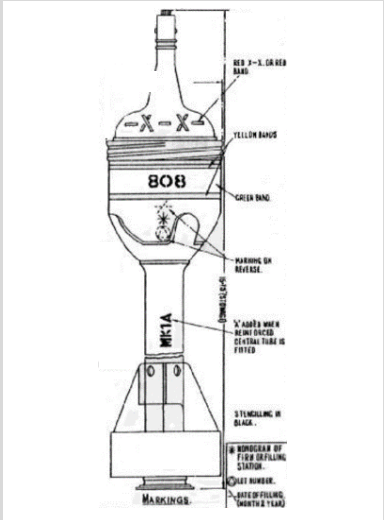
3” ML Mortar - High Explosive

Weight:	4.5kg
Dimensions:	81mm x 490mm
Hazardous Fill:	882g of RDX/TNT
Fuse:	Impact fuse
Appearance:	Pear-drop shape. Brown body, green and red bands, five finned tail
Variants:	Several smoke, white Phosphorus, inert practice and parachute illumination versions were manufactured
Remarks:	Common anti-personnel weapon in use with British Army throughout WWII. >6.5 million HE rounds were produced in 1942 alone



PIAT Anti-Tank Weapon

Projectile Type:	HEAT - shaped charge
Projectile Dimensions:	400mm x 90mm
Hazardous Fill:	Hollow HE charge and small solid propellant charge
Fill Weight:	1.13kg (charge)
Fuse:	Impact fuse
Remarks:	115,000 launchers were produced in Britain during WWII and the PIAT was used by most Allied armies during this conflict



BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

20mm Cannon Ammunition (various)

Cartridge Weight: 256g (approx.)

Total Cartridge length: 182mm (approx.)

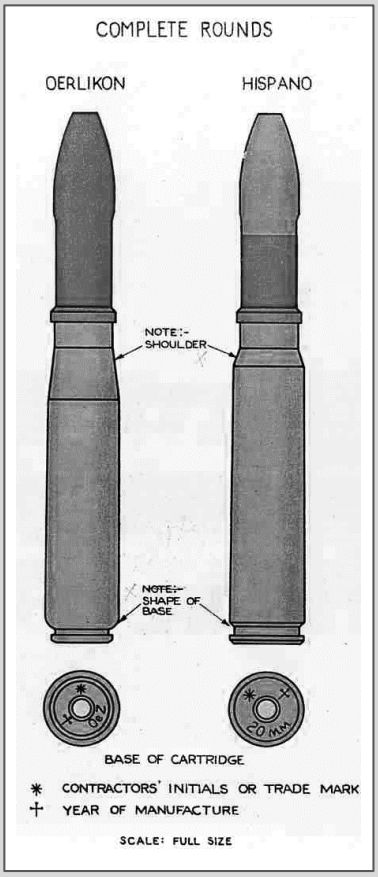
Hazardous Fill: Various HE, incendiary and tracer compositions. Typically TNT, Tetryl and Pentolite.

Fuse: Impact fuse

Appearance: Cylindrical shape. Brown body, green and red bands, five finned tail

Variants: Oerlikon and Hispano 20mm ammunition was deployed in the UK during WWII. These varied slightly in shape and also in the colours used to identify different projectile types.

Remarks: Today, 20mm rounds of WWII vintage may be found unexpended as full single cartridges or in belts of multiple cartridges. Or expended, i.e just the fused projectile without the brass base.

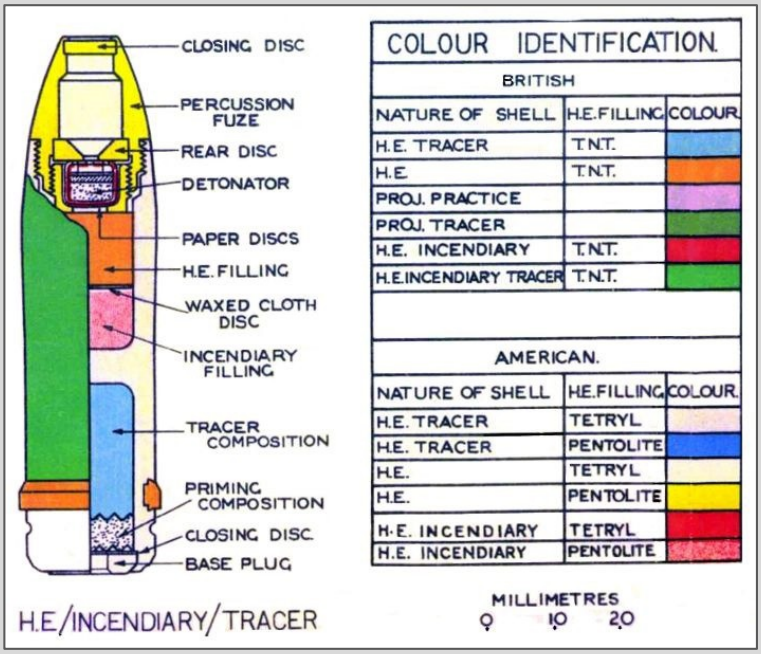


Recent WWII 20mm rounds find

WWII belted 20mm rounds

Bottom Right: Colour identification of Hispano rounds

Bottom Left: Colour identification of Oerlikon rounds



COLOUR IDENTIFICATION

BRITISH

NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	

AMERICAN.

NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	TETRYL	
H.E. TRACER	PENTOLITE	
H.E.	TETRYL	
H.E.	PENTOLITE	
H.E. INCENDIARY	TETRYL	
H.E. INCENDIARY	PENTOLITE	

20mm x 110mm Hispano Armour Piercing - 1935 > Present

20mm x 110mm Hispano High Explosive - 1935 > Present

20mm x 110mm Hispano High Explosive Incendiary - 1935 > Present

20mm x 110mm Hispano High Explosive Incendiary Tracer - 1935 > Present

20mm x 110mm Hispano High Explosive Tracer - 1935 > Present

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

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

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham, Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

- ***Bates. H. E***, Flying Bombs Over England, Frogletts Publications Ltd, 1994.
- ***Bulloch. G***, Steeds J E, Green K, Sainsbury M G, Brockwell J S & Slade N J, Land Contamination: Technical Guidance on Special Sites: MoD Land, Environment Agency, 2001.
- ***CIRIA***, C681: Unexploded Ordnance (UXO), A Guide for the Construction Industry, 2009.
- ***Clarke. N. J***, Luftwaffe Target Reconnaissance, German Aerial Photography 1939-1942, 1996.
- ***Clarke. N. J***, Adolf's British Holiday Snaps: Luftwaffe Aerial Reconnaissance Photographs of England, Scotland and Wales, 2012.
- ***Cocroft. W. D***, Dangerous Energy, Historic England, 2000.
- ***Dobinson. C. S,*** AA Command: Britain's Anti-Aircraft Defences of the Second World War, Methuen Publishing Ltd, 2001.
- ***Dobinson. C. S***, Fields of Deception - Britain's Bombing Decoys of World War II, Methuen Publishing Ltd, 2013.
- ***Fleischer. W***, German Air-Dropped Weapons to 1945, Midland Publishing. 2004.
- ***Jappy. M. J,*** Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War. Channel 4 Books, 2001.
- ***Morris. J***, German Air Raids on Britain: 1914-1918, Nonsuch Publishing, 2007.
- ***Price. A***, Blitz on Britain 1939-45, Sutton Publishing Ltd, 2000.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 1, Battle of Britain Prints International Limited, 1987.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 2, Battle of Britain Prints International Limited, 1988.
- ***Ramsey. W,*** The Blitz Then and Now: Vol 3, Battle of Britain Prints International Limited, 1990.
- ***Whiting. C***, Britain Under Fire: The Bombing of Britain's Cities 1940-1945, Pen & Sword Books Ltd, 1999.

BRIMSTONE SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

1-3 Manor Road,
Chatham,
Kent, ME4 6AE

+44 (0) 20 7117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

INTEGRITY • PROFESSIONALISM • KNOWLEDGE

APPENDIX 4: UXO CLEARANCE LETTER

CLEARANCE LETTER

Client:	Paragon Building Consultancy Ltd
Project Location:	North Hyde Gardens, Hayes
Project Ref:	PARA26
Letter Ref:	20220211-CL-PARA26
Revision:	1
Status:	Final
Date:	11st February 2022

Written By:	Joshua Pattinson	Technical Coordinator	josh.pattinson@brimstoneuxo.com
Reviewed By:	Andrew Lane	Operations Manager	andrew.lane@brimstoneuxo.com
Signed By:	Aaron Florence	Managing Director	

QUALITY MANAGEMENT

Brimstone Site Investigation is committed to the provision of UXO risk mitigation services, including the safe removal and disposal, in the UK and overseas. Since our inception in 2016 it has been our goal to provide unsurpassed UXO risk mitigation services. Brimstone is a client-driven organisation, we aim to provide the client the services they need, to the agreed requirement, in accordance with national and international standards.

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

- Integrity in advice, information and the manner in which we conduct ourselves and our operations,
- Professionalism in the way we handle our operations, people and processes, and
- Knowledge in new skills and information, to ensure we remain at the forefront of innovation and strategy.

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

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

Aaron Florence
Founder and Managing Director
Brimstone Site Investigation Ltd.

1 WHAT IS UXO?

UXO is an abbreviation for unexploded ordnance. It is a term that refers to explosive ordnance which has been primed, armed, fused, or otherwise prepared for use, and has been dropped, fired, launched, projected, thrown, or placed and remains unexploded either by malfunction or by design.

UXO is a catch-all term used in the UK to refer to explosive hazard contamination. Although, not all explosive hazards are correctly described as UXO. Abandoned explosive ordnance, or AXO, is ordnance, which is in a safe state, has not been prepared for use or has not been fire, projected, thrown, or otherwise used. Instead, AXO has been buried or hidden, either as a means of disposal or as a cache in anticipation of invasion.

An example of UXO would be an anti-aircraft projectile having been fired at an aircraft, failing to function and the falling back to land, unexploded. An example of AXO would be a 'bomb dump' of expired ordnance, whereby an excavation is filled with unwanted ordnance and backfilled. This was frequently used by the MoD up until the 1980s as a recognised means of disposal.

2 WHY IS LAND CONTAMINTAED BY UXO?

There are four sources of UXO contamination in the UK. These are: enemy action, allied action, military activity or munitions manufacturing and storage locations. Enemy action refers primarily to artillery bombardment and strategic bombing campaign of the Second World War. Allied action refers to defensive activities, again primarily in relation to the Second World War, which includes land and sea mining, anti-aircraft batteries and rocket batteries.

Military training is a significant source of UXO contamination. In former and current military training areas, the risk of encountering UXO is significant, ranging from projectiles, mortars, and grenades. The MoD is the second-largest landowner in the UK, and as such large parts of the UK have historically been used or requisitioned by the military for training our armed forces and allied armed forces.

Finally, munitions manufacturing, and storage sites also present a UXO risk, although the risk is generally localised and in small specific parts of the UK.

3 THE REGULATORY ENVIRONMENT

There are no specific regulations that manage how UXO is dealt with on UK construction sites, and similar operations. However, there are pieces of legislation that must be considered when companies choose how to approach UXO risk, these include those listed below. The CIRIA guidelines are a set of guiding principles that offer a framework to the UK UXO risk mitigation sector, these are explained in the subsequent section.

- Construction (Design Management) Regulation (2015)
- Health and Safety at Work Act (1974)
- Management of Health and Safety at Work (1999)

3.1 Construction (Design Management) Regulations (2015)

CDM 2015 replaces CDM 2007. These regulations define the responsibilities of roles within construction projects. The Principal Designer is responsible for managing health and safety, in that role they must exercise identification, elimination and control of foreseeable risks. UXO is a significant potential hazard and must be considered at the design phase.

3.2 Health and Safety at Work Act (1974)

Employers must ensure as far as is reasonably practicable the health and safety of their employees. They must also ensure the health and safety of others affected by their work activity. When working on a site which is thought to have a UXO

contamination risk, employers have a responsibility to provide a safe system of work that addresses the assessed UXO risk.

3.3 Management of Health and Safety at Work (1999)

This adds on to the Health and Safety at Work Act (1974). The act sets out the general duties which employers have towards employees and members of the public, and those which employees have to themselves and each other. In relation to UXO, the act applied that duty holders are to ensure that proper assessments of foreseeable risks are completed and that necessary measures are taken to control risks to an acceptable level.

4 CIRIA C681 GUIDELINES

CIRIA is the Construction Industry Research and Information Association. Two sets of guidelines provide a framework to the UXO risk mitigation sector in the UK. They are not legally binding, and are optional to follow, but they form the accepted best-practice standards to which the industry operates.

CIRIA C681: Unexploded Ordnance: A Guide for the Construction Industry (2009)

This is the overarching document which provides the four stage UXO risk mitigation framework. Stages are:

1. Preliminary UXO risk assessment – a qualitative screening exercise to assess the likelihood of finding UXO on a site. This can be completed by a non-UXO specialist or a UXO specialist.

2. Detailed UXO risk assessment – A wider and deeper assessment of the site, using bomb damage amps, penetration assessments and other historical information.

3. Recommendations – A proposal of risk mitigation strategies determined in coordination with the client.

4. Implementations – the on-site UXO risk mitigation measures being put in place.

CIRIA C785: Unexploded Ordnance Risk Management Guide for Land-Based Projects (2019)

This guidance document adds on to C681. It provides additional details and structure to the risk assessment process. Both documents are available to purchase on the CIRIA website.

5 ALARP

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

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

Using this principle, BSI aims to reduce client costs by recommending strategies that are proportionate to the assessed risks.

6 MAXIMUM BOMB PENETRATION DEPTHS

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

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

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

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

a) **Impact velocity.** German bombing raids were carried out at altitudes more than 5,000m. The velocity of impact is roughly 313ms^{-1} (not accounting for resistance). It is the same velocity regardless of mass.

b) **Impact angle.** Strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.

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

7 LAND SERVICE AMMUNITION

Land service ammunition (LSA) includes mortars, grenades, rockets, and projectiles. These types of ordnance can contaminate land in the UK due to prior and current training of the UK's armed forces, as well as the activities of other allied nations on British soil. Training areas, airfields, barracks and camps are areas which may have a heightened risk of encountering LSA. During WWII anti-aircraft weaponry was deployed across much of the UK, and as a result contamination from anti-aircraft projectiles can occur in cities as well as in the open countryside.

Page Continued Overleaf

Brimstone Site Investigation
Suite 6, Delta House,
Laser Quay,
Culpepper Close,
Rochester,
ME2 4HU

+44 (0)207 117 24
enquire@brimstoneuxo.com
www.brimstoneuxo.com

This document certifies that the subject area is clear and free of UXO contamination, subject to the following limitations:

a) Detection of UXO is dependent contrast between UXO and its host materials. There is an extremely remote likelihood that ferrous items can be missed by the equipment if its magnetic field is in the same orientation as local magnetic declination.

b) The survey task specifically targets the anticipated risk of ordnance (mortars, grenades, bombs, and alike) within the limits of the equipment capability.

c) As with all UXO survey tasks, 100% clearance certificates cannot be issued. This document certifies that work has been undertaken to mitigate against the risk of UXO, using the ALARP principle. However unlikely, encountering UXO cannot wholly be discounted.

d) Clearance is given only to the area defined below.

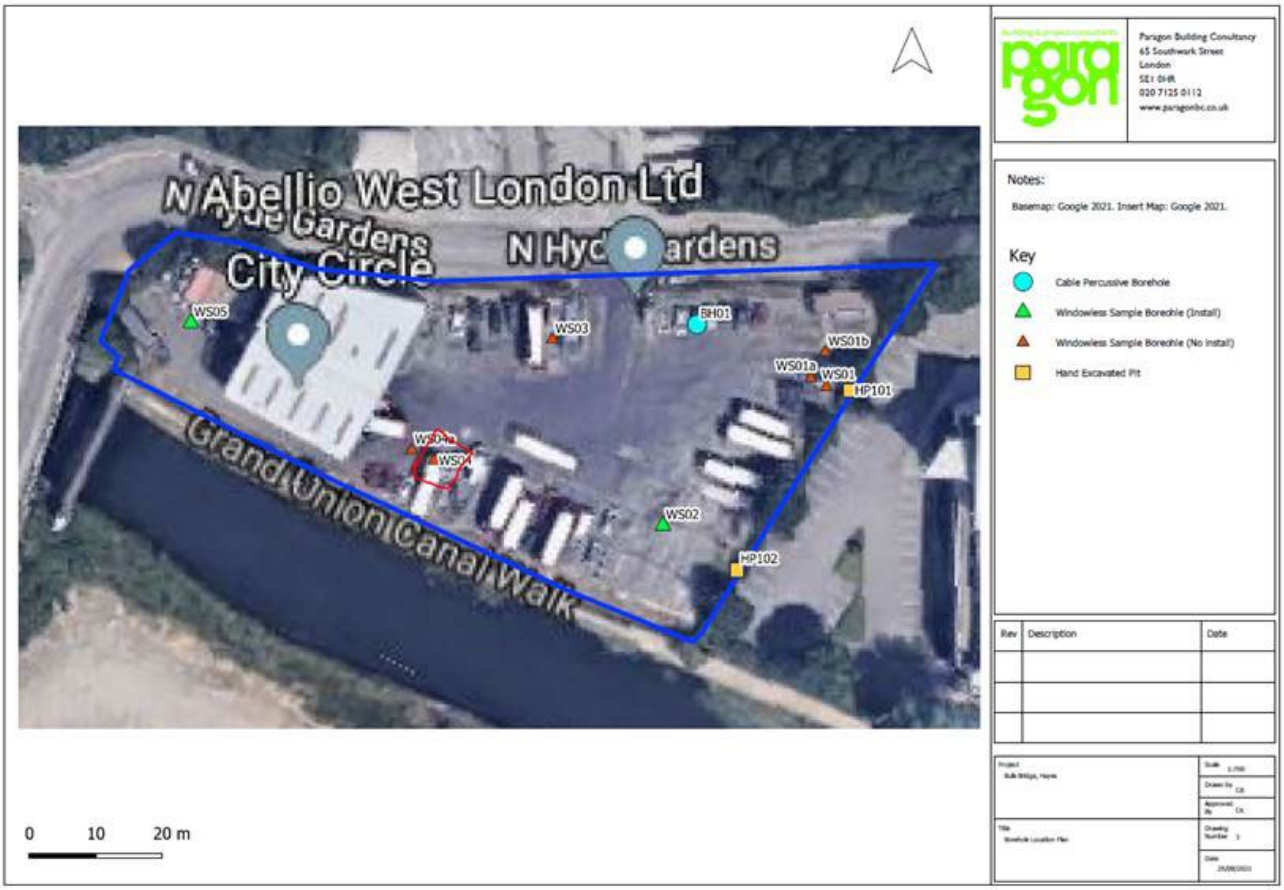
e) Watching Brief / Anomaly Investigation

Depth of Clearance

Clearance is given to the boreholes that were surveyed to the depth as observed on the day(s) of the project. No items of UXO were found.

Page Continued Overleaf

Area of Clearance



If any questions or concerns arise from this subject area in relation to this survey, or any question arise in relation to the scope and context of this clearance then please contact Brimstone HQ using the address or details above.

Yours faithfully,

Aaron Florence
Founder and Managing Director
Brimstone Site Investigation Ltd.

APPENDIX 5: SERVICE CLEARANCE CERTIFICATE

PAS128 Utility Survey
Utility Avoidance Report

ID Location:	**WS04-TP**	**Site Name:**	Abellio		
Job No:		**Surveyor:**	JB	**Date:**	26/01/2022
Eastings:		**Northings:**		**Level:**	

Utility Clearance:			
Utility Records provided for location	**Elec / Gas / Water / Sewers / Comms** **Other:**		
Utilities located within proximality of investigation	**Elec / Gas / Water / Sewers / Comms / GPR / Unknown** **Other:**		
Ground Radar Grid performed at location	**Trial Pit** 10 m 10 m ✔	**BH/WS** 5m x 5m	
Scan Saved	**Yes** **No**	**Yes** **No** ✘	
Induction Mode carried out at marked location	**Trial pit each end & middle**	**BH/WS on Location** ✔	
Passive Modes carried out at marked location	**Power / Radio / GPR**		Submit/E-mail Form

Notes:

LV located heading through concrete pad in east of extended survey area heading north. Drain channel located in west section of extended survey area also heading north.

No further targets located via passive EML/GPR within survey area.

Equipment Serial No.- C.A.T: 8kPDLB-142 **Due Date:** 07/06/2022 **Generator:** TX/10-10B-7436 **Due Date:** 07/06/2022

PAS128 Utility Survey
Utility Avoidance Report

ID Location:	WS04-TP	Site Name:	Abellio

Job No:		Surveyor:	JB	Date:	26/01/2022

Plan View:

Disclaimer: Due to the inherent limitations of the technology (i.e. cable locating devices) used, we cannot guarantee the results of the survey and therefore will not be held liable for any damage to services that are penetrated by the client or his sub-contractor or consequential damages as a result of the initial damage, except where negligence by the operator can be proved. In this instance, the liability accepted by Geotechnical Engineering Limited will not exceed the value of the contract.

APPENDIX 6: EXTENT OF SURVEY AND LIMITATIONS

EXTENT OF SURVEY AND LIMITATIONS

This report is for your sole use, and consequently no responsibility whatsoever is undertaken or accepted to any third party for the whole or any part of its contents. Paragon accept no responsibility or liability for the consequences of this document being used for any purpose or project other than for which it was commissioned or a third party with whom an agreement has not been executed. Should any third party which to use or rely upon the contents of the report, written approval must be sought from Paragon, a charge may be levied against such approval.

The report has been designed to address potential source, pathway and receptor pollutant linkages associated with the proposed development, by means of intrusive investigation. The content and findings of the report are based on data obtained by employing site assessment methods and techniques, considered appropriate to the site as far as can be interpreted from desk-based materials and a visual walkover of the site. Such techniques and methods are subject to limitations and constraints set out in the report. The findings and opinions are relevant at the time of writing, and should not be relied upon at a substantially later date as site conditions can changes. For example, seasonal groundwater levels, natural degradation of contaminants etc.

No liability can be accepted for the conditions that have not been revealed by the exploratory hole locations, or those which occur between each location. Whilst every effort will be made to interpolate the conditions between exploratory locations, such information is only indicative and liability cannot be accepted for its accuracy. By their nature, exploratory holes provide a relatively small and localised snapshot of the ground conditions relative to the size of the site.

Specific comment is made regarding the site's status under Part 2A of the Environmental Protection Act (EPA) 1990, which provides a statutory definition of Contaminated Land and as revised under The Contaminated Land (England) (Amendment) Regulations 2012. Unless specifically stated as relating to this definition, references to 'contamination' and 'contaminants' relate in general terms to the presence of potentially hazardous substances in, on or under the site.

The opinions given within this report have been dictated by the finite data on which they are based and are relevant only to the purpose for which the report was commissioned. If additional information or data becomes available which may affect the opinions expressed in this report, Paragon reserves the right to review such information and, if warranted, to modify the opinions accordingly. Paragon reserves the right to charge additional fees for; un-anticipated second opinion reviewing of previous reports.

Paragon has prepared this report with reasonable skill, care and diligence. The recommendations contained in this report represent our professional opinions. These opinions were arrived at in accordance with currently accepted industry practices at this time. The work undertaken to provide the basis of this report comprised a study of available documented information from a variety of sources. We cannot provide guarantees or warranties for the accuracy of third-party data, which is reviewed in good faith and assumed to be representative and accurate.

It should be noted that any risks identified in this report are perceived risks based on the information reviewed. No liability can be accepted for the effects of any future changes to such guidelines and legislation. In the event that guidance / legislation changes it may be necessary for Paragon to update or modify reports. The risk assessment is completed in line with the relevant land use agreed for the site and the time of completing the works. Changes to site conditions or land use may require a reassessment.

DEFINITIONS

For the avoidance of doubt, Paragon Building Consultancy Limited (Paragon) has prepared the following alphabetical list of definitions and reservations to aid the client in understanding the content of our advice and or written reports(s):

Accuracy	Level of agreement between true value and observed value.
ACM's	Asbestos Containing Materials
Conceptual Site Model	Textual and or schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the base of the information from the preliminary investigation and refined during subsequent phases of investigation and which is an essential part of the risk assessment process. **Note 1:** The conceptual exposure model is initially derived from the information obtained by the preliminary investigation. This conceptual model is used to focus subsequent investigations, where these are considered to be necessary, in order to meet the objectives of the investigations and the risk assessment. The results of the field investigation can provide additional data that can be used to further refine the conceptual model.
Contamination	Presence of a substance which is in, on or under land, and which has the potential to cause significant harm or to cause significant pollution of controlled water. **Note 1:** There is no assumption in this definition that harm results from the presence of the contamination. **Note 2:** Naturally enhanced concentrations of harmful substances can fall within this definition of contamination. **Note 3:** Contamination may relate to soils, groundwater or ground gas.
Controlled Water	Inland freshwater (any lake, pond or watercourse above the freshwater limit), water contained in underground strata and any coastal water between the limit of highest tide or the freshwater line to the three-mile limit of territorial waters. **Note 1:** See Section 104 of The Water Resources Act 1991.
Enquiries	Any enquiries undertaken by Paragon of local authorities and statutory undertakers are made verbally in respect of environmental issues. Local searches are not undertaken and no responsibility is accepted for any inaccurate information provided. It is further assumed unless otherwise stated that all necessary licences, permits etc. either run with the property or are transferable to a new occupier as appropriate.
Harm	Adverse effect on the health of living organisms, or other interference with ecological systems of which they form part, and, in the case humans, including property.
Hazard	Inherently dangerous quality of a substance, procedure or event.
Pathway	Mechanism or route by which a contaminant comes into contact with, or otherwise affects, a receptor.
Precision	Level of agreement within a series of measurements of a parameter.
Receptor	Persons, living organisms, ecological systems, controlled water, atmosphere, structures and utilities that could be adversely affected by the contaminant(s).

Risk	Probability of the occurrence, magnitude and consequences of an unwanted adverse effect on a receptor.
Risk Assessment	Process of establishing, to the extent possible, the existence, nature and significance of risk.
Sampling	Methods and techniques used to obtain a representative sample of the material under investigation.
Soil	Upper layer of the earth's crust composed of mineral parts, organic substance, water, air and living matter. **Note 1:** In general accordance with BS 10175:2001 the term soil has the meaning ascribed to it through general use in civil engineering and includes topsoil and subsoil; deposits such as clays, silt, sand, gravel, cobbles, boulders and organic deposits such as peat; and material of natural or human origin (e.g. fills and deposited wastes). The term embraces all components of soil, including mineral matter, organic matter, soil gas and moisture, and living organisms.
Source	Location from which contamination is, or was, derived. **Note 1:** This could be the location of the highest soil or groundwater concentration of the contaminant(s).
Uncertainty	Parameter, associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measurement.