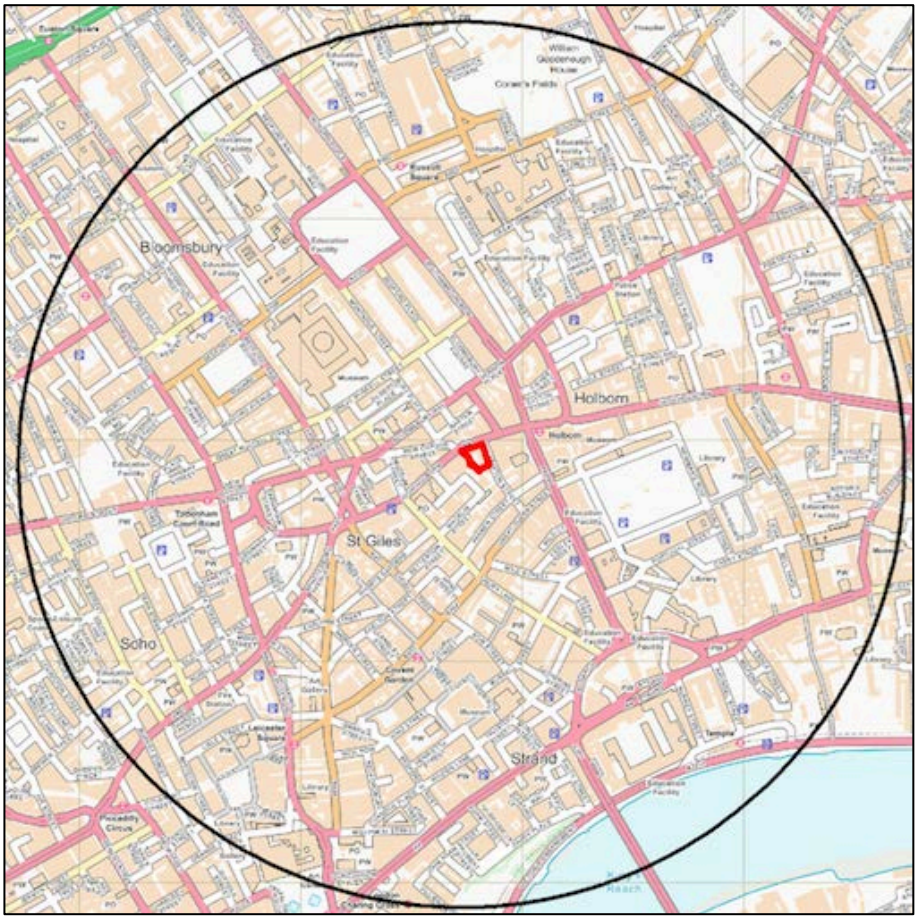
Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

Meeting the requirements of *CIRIA* C681 'Unexploded Ordnance (UXO) A guide for the Construction Industry' Risk Management Framework



PROJECT NUMBER	P6399	**ORIGINATOR**	S. Barratt
VERSION NUMBER	1.0	**REVIEWED BY**	B. Wilkinson (31st January 2018)
CLIENT	Ennismore Capital	**RELEASED BY**	L. Askham (31st January 2018)
SITE	The Hoxton Holborn, 199-206 High Holborn, WC1V 7BD		
RATING	**VERY HIGH** - This Site requires further action to reduce risk to ALARP during intrusive activities.		

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Acronyms and Abbreviations

AA	Anti-Aircraft
AAA	Anti-Aircraft Ammunition
AAC	Army Air Corps
AFS	Advanced Flying School
ALARP	As Low As Reasonably Practicable
AOD	Above Ordnance Datum
ARP	Air Raid Precaution
ATS	Auxiliary Territorial Service
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
bgl	Below Ground Level
BGS	British Geological Survey
BH	Borehole
BPD	Bomb Penetration Depth
CDP	Cast Driven Piles
CFA	Continuous Flight Auger
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetration Testing
CS	County Series
EFTS	Elementary Flying Training School
ELG	Emergency Landing Ground
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
FAA	Fleet Air Arm
FPP	Flight Pilot Pool
FTS	Flight Training School
GI	Ground Investigation
GIS	Geographic Information Systems
GL	Ground Level
GP	General Purpose
GPS	Global Positioning Systems
HAA	Heavy Anti-Aircraft
HE	High Explosive
HO	Home Office
HSE	Health and Safety Executive
IB	Incendiary Bomb
IED	Improvised Explosive Device
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
kg	Kilograms
km	Kilometres
LAA	Light Anti-Aircraft
lb	Pounds
LCC	London County Council
LDV	Local Defence Volunteers
LE	Low Explosive
LSA	Land Service Ammunition
m	Metres
MACP	Military Aid to the Civil Power
MoD	Ministry of Defence
mm	Millimetres
NATO	North Atlantic Treaty Organisation
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OD	Ordnance Datum
OS	Ordnance Survey
OTU	Operational Training Unit
PBG	Polar Blasting Gelignite
PM	Parachute Mine
PoW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RBL	Rifle Breach Loaded
RDX	Research Department Explosives
RFC	Royal Flying Corps
RML	Rifle Muzzle Loaded
RN	Royal Navy
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
Sqn	Squadron
TA	Territorial Army
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V Weapons	*Vergeltungswaffe* – Vengeance Weapons
WAAF	Women's Auxiliary Air Force
WD	War Department
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Study Site

The Client has defined the Study Site as "The Hoxton Holborn, 199-206 High Holborn, WC1V 7BD". The Site is located at NGR 530398, 181445.

Risk Level

VERY HIGH

Potential Threat Sources

The most probable UXO threat is posed by WWII *German* HE bombs, whilst IBs and *British* AAA projectiles (which were used to defend against *German* bombing raids) pose a residual threat.

Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.

Key Findings

During WWII, the Study Site was situated within the *Holborn Metropolitan Borough,* which recorded 216 HE bomb strikes per 100 hectares, a very high level of bombing.

Luftwaffe aerial reconnaissance photography associated with the Site identified a drainage system (located immediately west) and command posts (located 630m to the south-south-east and 735m to the south) as primary bombing targets. In addition, railway stations (located 815m to the south-east and 960m to the south) may have been considered secondary bombing targets. Furthermore, research also identified numerous pillboxes (five located within 900m; the closest being 460m to the south east) and gun emplacements (located 665m to the south-south-east and 720m to the south-south-east), which are likely to have been targeted in an attempt to reduce *Luftwaffe* aircraft losses.

ARP records associated with the Site did not note any HE bomb strikes within it, however six HE bomb strikes were recorded; one 35m to the east, 70m to the south, 80m to the west, 80m to the west, 85m to the south-east and 90m to the south-east. In addition, a UXB disposal task was carried out 145m to the north. Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted.

An analysis of the *LCC* maps associated with the Site identified "Seriously Damaged but Repairable at Cost" (located 15m to the east), "General Blast Damage; Minor in nature" (located 30m to the south-west, 45m to the south-east and 75 to the south-west), "Clearance Areas" (located 60m to the north-west) and "Total Destruction" (located 170m to the north-east). Furthermore, an analysis of post-war mapping identified a "ruin" located 60m to the north-west.

Pre-WWII mapping (1938) and aerial photography (1945) associated with the Site shows that it was located within a densely developed urban area during WWII, with the Site itself consisting of structures. As a result, it is likely that a local civilian would have observed and reported any UXB entry holes within the Site, which would have been dealt with at the time. However, given the close proximity of recorded bomb damage, it is possible that bomb damage debris may have concealed a UXB entry hole, and therefore it may have gone unnoticed.

The Site was subjected to post-WWII redevelopment in the 1980's when the structures on-site were demolished, and a large hotel structure was built in replacement. However, the south-eastern sector has remained as hard standing. Consequently, it is considered likely that any UXO within the structural foundations of post-war buildings would have been discovered and removed, however, the potential for deep buried UXO to be present within remaining areas is assessed to be extant. As such, pro-active risk mitigation measures are recommended during intrusive works in all previously undisturbed ground i.e. that which has not previously been excavated, probed, drilled or otherwise intrusively disturbed since it had potentially become contaminated with UXO.

EXECUTIVE SUMMARY (…continued)

Recommended Risk Mitigation

All Groundworks in All Areas:

1. **Operational UXO Emergency Response Plan;** appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or confirmed UXO discovery (this plan can be supplied by *6 Alpha*);

2. UXO Safety & Awareness Briefings; the briefings are essential when there is a possibility of an–UXO / UXB encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of an UXO / UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXO / UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The Safety & Awareness briefing is an essential part of the *Health & Safety Plan* for the Site and helps to evidence conformity with the principles laid down in the *CDM* regulations 2015 (this briefing can be delivered directly, or in some cases remotely, by *6 Alpha*).

Trial Pits and Excavations into Previously Undisturbed Ground:

3. Non-intrusive UXO Survey and/or EOD Banksman Support; Where 'open' intrusive works into previously undisturbed ground are proposed and where the extent is considered to be within the capabilities of non-intrusive UXO survey equipment and implementation of this is assessed as likely to prove effective, a non-intrusive geophysical UXO survey should be trialed and, if it proves successful, should be employed to survey site-wide, or in specific areas where 'open' intrusive works are to be implemented, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. If the survey proves partially or wholly ineffective, an EOD Engineer should be present in the UXO Banksman role to monitor ongoing 'open' intrusive works to identify any suspicious items that may be UXB or UXO related (this service can be provided by *6 Alpha*).

Window Sampling, Boreholing and Piling into Previously Undisturbed Ground:

4. Intrusive UXO Survey; Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the *assessed average bomb penetration depth* or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by *6 Alpha*).

For further information, please contact *6 Alpha Associates*:

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ASSESSMENT METHODOLOGY

Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this Site, by employing a process advocated for this purpose by *CIRIA*. The *CIRIA* guide for managing UXO risks in the construction industry (C681) not only represents best practice but has also been endorsed by the *HSE*. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to ALARP at best value.

UXO hazards can be identified through the investigation of local and national archives associated with the Site, *MoD* archives, local historical sources, historical mapping as well as contemporaneous aerial photography (if it is available). Hazards will have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. The amalgamation of information is then assessed to enable the researcher to provide relevant and accurate risk mitigation practices.

The assessment of UXO risk is a measure of *probability of encounter* and *consequence of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other 'sensitive receptors', such as equipment) to the hazard, at the moment of encounter.

If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce them to ALARP. We advocate the adoption of the legal ALARP principle because it is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the Client's tolerability of UXO risk. In essence, the principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. This does not mean that there is never a requirement for UXO risk mitigation, but that any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits and that consume disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXB and UXO risks will rarely be reduced to zero (nor need they be).

Important Notes

Key source material is referenced within this document, whilst secondary/anecdotal information may be available upon request.

Although this report is up to date and accurate at the time of writing, our databases are continually being populated as and when additional information becomes available. Nonetheless, *6 Alpha* have exercised all reasonable care, skill and due diligence in providing this service and producing this report.

The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and third party data sources. Wherever possible, *6 Alpha* has sought to corroborate and to verify the accuracy of all data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. *National Archive* or other library sources), and over which *6 Alpha* cannot exercise control.

STAGE ONE – SITE LOCATION AND DESCRIPTION

Study Site

The Client has defined the Study Site as "The Hoxton Holborn, 199-206 High Holborn, WC1V 7BD". The Site is located at NGR 530398, 181445. The Site location and Site boundary are presented at *Figures 1* and *2* respectively.

Location Description

The Study Site is situated within *Holborn Metropolitan Borough* and covers an area of approximately 0.2 hectares (ha).

Furthermore, the Site is bounded by:

- North: *High Holborn* and commercial buildings*;*
- East: *Newton Street* and commercial buildings*;*
- South: residential flats;
- West: commercial buildings.

Aerial Photography (Current) (*Figure 3*)

Current aerial photography corroborates the information above and shows that the Site is situated within a densely developed urban area.

Proposed Works

The Client has described the following:

- Windowless Sample;
- Rotary cored hole;
- Rotary open hole;
- Hand dug trial pit.

In addition, the client has provided a report titled 'The Hoxton Hotel, Holborn London WC1V 7BD Desk Study' which states that 'piling will be required to support the proposed extension, likely to extent to a significant depth into the ground.

As a result, *6 Alpha* will assume that a number of geotechnical investigative and construction methodologies will be undertaken, including trial pits, window sampling, boreholes, excavations and piling.

Ground Conditions

It is important to establish the specific ground conditions in order to determine the maximum *German* UXB penetration depth as well as the potential for other types of munitions to be buried.

If the Site investigations and/or construction methodologies change, and/or if a specific methodology is to be employed, and/or if the scope of work is focused upon a specific part of the Site, then *6 Alpha* are to be informed so that the prospective UXO risks and the associated risk mitigation methodology might be re-assessed. Certain ground conditions may also constrain certain types of UXO risk mitigative works e.g. magnetometer survey is adversely affected in mineralised and made ground.

The Client has described the ground conditions as follows: "The geological sequence at the site comprises Made Ground over River Terrace Deposits, London Clay, Lambeth Group, Thanet Sand Formation and Chalk".

STAGE ONE – SITE LOCATION AND DESCRIPTION (…continued)

Ground Conditions

BGS borehole log 'TQ38SW1676 – High Holborn-Newton Street BH1' (located in the Site's western sector), recorded the following strata:

Depth bgl (m)	Strata	Description
0m to 0.10m	Concrete and wooden floor	
0.10m to 2.90m	Basement	
2.90m to 3.80m	Concrete	
3.80m to 5.90m	Gravel	Dense to very dense brown sandy fine to coarse gravel
5.90m to 6.30m	Clay	Stiff fissured brown silty clay
6.30m to 13.00m	Clay	Stiff fissured grey silty clay with partings of silt from 8.00m

STAGE TWO – REVIEW OF HISTORICAL DATASETS

Sources of Information Consulted

The following primary information sources have been used in order to establish the background UXO threat:

1. *6 Alpha*'s *Azimuth* Database;
2. *Home Office* WWII Bomb Census Maps;
3. WWII and post-WWII aerial photography;
4. Official Abandoned Bomb Register;
5. *LCC* Bomb Damage maps;
6. Information gathered from the *National Archives* at *Kew*;
7. Historic UXO information provided by *33 Engineer Regiment* (Explosive Ordnance Disposal) at *Carver Barracks, Wimbish*.

Potential Sources of UXO Contamination

In general, there are several activities that might contaminate a site with UXO but the three most common ways are: legacy munitions from military training/exercises; deliberate or accidental dumping (AXO) and ordnance resulting from war fighting activities (also known as the Explosive Remnants of War (ERW)).

During WWII, the *Luftwaffe* undertook bombing campaigns all over the *UK*. The most common type of UXO discovered today is the aerially delivered high explosive (HE) bomb, which are comparatively thick-skinned and dropped from enemy aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the UXO to penetrate the ground, often leaving behind it a UXB entry hole. These entry holes were not always apparent and some went unreported, leaving the bomb buried and unrecorded. More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia V1* and *V2* rockets, Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

Although the *Luftwaffe* had designated primary bombing targets across the *UK*, their high-altitude night bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were sometimes struck.

As the threat of invasion lingered over *Britain* during WWII, defensive actions were undertaken. The *British* and *Allied Forces* requisitioned large areas of land for military training and bomb storage (including HE bombs, naval shells, artillery and tank projectiles, explosives, LSA and SAA). Thousands of tonnes of these munitions were used for the *Allied Forces* weapon testing and military training alone. It has been estimated that at least 20 per cent of the *UK*'s land has been used for military training at some point.

The best practice guide for dealing with your UXO risks on land (CIRIA publication C681) suggests that approximately 10 per cent of all munitions deployed failed to function as designed. ERW are therefore, still commonly encountered, especially whist undertaking construction and civil engineering groundwork.

Furthermore, in exceptional circumstances, UXO is discovered unexpectedly and without apparent rational explanation. There are several ways this might occur:

- When *Luftwaffe* aircraft wished to swiftly escape e.g. from an aerial attack, they would jettison some or all of their bombs and flee. This is commonly referred to as *tip and run* and it has resulted in bombs being found in unexpected locations;
- Transportation of aggregate containing munitions to an area that was previously free of UXO, usually related to construction activities employing material dredged from a contaminated offshore borrow site;
- Poor precision during targeting (due to high altitude night bombing and/or poor visibility) resulted in bombs landing off target, but within the surrounding area.
- *British* decoy sites were also constructed to deliberately cause incorrect targeting. For obvious reasons, such sites were often built in remote and uninhabited areas.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

Site History

From an analysis of the CS and OS historical mapping associated with the Site, the following Site history can be deduced:

Year	On-Site	Vicinity
1896 CS Map	The Study Site consisted of structures site-wide.	The Site was situated within a developed urban area.
1916 CS Map	The structures in the centre of the Site changed structural footprint.	*Little Queen Street* located east of the Site was developed into *Kingsway* and nearby residential properties were developed into commercial buildings.
1938 CS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
1952 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
1968 OS Map	Changes were not recorded at the Study Site.	Structures to the west and north-west of the Study Site were demolished and redeveloped.
1983-1990 OS Map	The structures on-site were demolished and a new large structure was built in replacement.	Changes were not recorded in the vicinity.
1999 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
2016 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
2014 Aerial Photography	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.

WWII Site Use

The CS mapping prior to WWII (1938), shows that the Study Site was located in a large urban area, with the Site itself consisting of structures site-wide.

Aerial Photography (1945) (*Figure 4*)

The aerial photography (1945) identified that structures occupied the entire Site. Nonetheless, the resolution of the photograph is insufficient to be able to identify accurately, the precise local features and/or type of structures, then within the curtilage of the Site.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

WWII Bombing of *London*

The most intensive period of bombing over *London* was the nine months between October 1940 and May 1941, known as 'The Blitz'. During this period, the *Luftwaffe* attempted to overwhelm *Britain's* air defences, destroy key military and industrial facilities, as well as logistical capabilities, prior to invasion.

A total of 18,000 tons of bombs were dropped on *London* between 1940 and 1945. Many residential, commercial and industrial buildings were targeted during air raids and sustained large scale damage. Public services were also affected, with gas, electricity and water supplies often cut-off following damage to either the installations themselves or to the supply infrastructure. In addition, thousands of civilians were killed and injured, and many were forced to evacuate as their homes were destroyed.

WWII Luftwaffe Bombing Targets (*Figure 5A & 5B)*

Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial facilities for attack, in the event of war. In addition, logistics infrastructure and public services, such as railways, canals, power stations, reservoirs, water and gas works were also considered viable bombing targets.

Luftwaffe aerial reconnaissance photography associated with the Site identified a drainage system (located immediately west) and command posts (located 630m to the south-south-east and 735m to the south) as primary bombing targets. In addition, railway stations (located 815m to the south-east and 960m to the south) may have been considered secondary bombing targets. Furthermore, research also identified numerous pillboxes (five located within 900m; the closest being 460m to the south east) and gun emplacements (located 665m to the south-south-east and 720m to the south-south-east), which are likely to have been targeted in an attempt to reduce *Luftwaffe* aircraft losses.

WWII HE Bomb Strikes (*Figure 6*)

During WWII, ARP wardens compiled detailed logs of bomb strikes across their respective districts. However, ARP records associated with the Site did not note any HE bomb strikes within it, however six HE bomb strikes were recorded; one 35m east, 70m south, 80m west, 80m west, 85m south-east and 90m south-east. Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted.

In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, the main threat came from *V* type weapons. The first recorded *V1* strike on *London* was on the 13th June 1944, with the first recorded *V2* strike on *London* on the 8th September 1944. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons. Despite this, there is no evidence to suggest that the Site (or its immediate vicinity) was subjected to rockets strikes during WWII.

WWII Bomb Damage (*Figure 7*)

An analysis of the *LCC* maps associated with the Site identified "Seriously Damaged but Repairable at Cost" (located 15m to the east), "General Blast Damage; Minor in nature" (located 30m to the south-west, 45m to the south-east and 75 to the south-west), "Clearance Areas" (located 60m to the north-west) and "Total Destruction" (located 170m to the north-east). Furthermore, an analysis of post-war mapping identified a "ruin" located 60m to the north-west.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

WWII HE Bomb Density (*Figure 8*)

The Study Site was located within the *Holborn Metropolitan Borough,* which recorded 216 HE bombs per 100 hectares, a very high level of bombing.

Abandoned Bombs

An examination of the official abandoned bomb records has not identified any abandoned bombs within 1,000m of the Site boundary.

Records of WWII UXB Disposal Tasks

An examination of the civil defence records listing UXBs dealt with in the *Holborn Metropolitan Borough* from 1940-45 has identified the following tasks within the Site's vicinity:

- One UXB was removed from *Vernon Place* (situated approximately 265m to the north) on the 8th September 1940;
- One UXB was removed from *Bloomsbury Square* (situated approximately 210m to the north) on the 13th September 1940;
- One UXB was removed from *22 Red Lion Square* (situated approximately 350m to the north-east) on the 13th September 1940;
- One UXB was removed from *Victoria House, Southampton Row* (situated approximately 310m to the north) on the 13th September 1940;
- One UXB was removed from *Bedford Place* (situated approximately 360m to the north) on the 29th September 1940;
- One UXB was removed from *Montague Place* (situated approximately 355m to the north-west) on the 4th October 1940;
- One UXB was removed from *The British Museum* (situated approximately 360m to the north) on the 4th October 1940;
- One UXB was removed from *Great Russel Street* (situated approximately 245m to the north-west) on the 17th November 1940;
- One UXB was removed from *Sicilian Avenue* (situated approximately 145m to the north) on the 11th December 1940.

Records of Post-WWII UXB Disposal Tasks

Post-WWII BDO tasks were not available. In addition, further research did not reveal any UXO operations within the Sites vicinity.

STAGE THREE – DATA ANALYSIS

Was the ground undeveloped during WWII?

No; according to the CS mapping prior to WWII (1938), the Study Site consisted of structures site-wide.

Is there a reason to suspect that the immediate area was a bombing target during WWII?

Yes; *Luftwaffe* aerial reconnaissance photography associated with the Site identified a drainage system (located immediately west) and command posts (located 630m to the south-south-east and 735m to the south) as primary bombing targets. In addition, railway stations (located 815m to the south-east and 960m to the south) may have been considered secondary bombing targets. Furthermore, research also identified numerous pillboxes (five located within 900m; the closest being 460m to the south east) and gun emplacements (located 665m to the south-south-east and 720m to the south-south-east), which are likely to have been targeted in an attempt to reduce *Luftwaffe* aircraft losses.

As WWII progressed, major towns and cities became targets within their own right as the *Luftwaffe* switched from specifically targeting industrial and military facilities to a more general method of *carpet bombing*, and as a result, suburban and residential areas were frequently bombed.

Is there firm evidence that ordnance landed on Site?

No; ARP records associated with the Site did not note any HE bomb strikes within it, however six HE bomb strikes were recorded; one 35m east, 70m south, 80m west, 80m west, 85m south-east and 90m south-east.

Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted.

Is there firm evidence of bomb damage on Site?

No; an analysis of the *LCC* maps associated with the Site identified “Seriously Damaged but Repairable at Cost” (located 15m to the east), “General Blast Damage; Minor in nature” (located 30m to the south-west, 45m to the south-east and 75 to the south-west), “Clearance Areas” (located 60m to the north-west) and “Total Destruction” (located 170m to the north-east). Furthermore, an analysis of post-war mapping identified a “ruin” located 60m to the north-west.

Would a UXB entry hole have been observed and reported during WWII?

Possibly; the Site was located within a densely developed urban area during WWII, with the Site itself consisting of structures. Therefore, it is likely that a local civilian would have observed and reported any UXB entry holes within the Site, which would have been dealt with at the time.

Is there any reason to suspect that live firing or military training may have occurred at this location?

No; there is no supporting evidence to suggest that military training, guns or associated artillery (or other types of) munitions were ever stored, manufactured, located and/or fired from this Site during WWII nor subsequently.

What is the expected level of UXO contamination?

The most likely source of UXO contamination is from *German* aerially delivered ordnance, which ranges from small IBs through to large HE bombs (the latter forms the principal threat). Additional residual contamination may be present from *British* AAA projectiles (which were used to defend the UK against *German* bombing raids).

STAGE THREE – DATA ANALYSIS (…continued)

Would previous earthwork have removed the potential for UXO to be present?

Possibly; from an analysis of the post-WWII mapping associated with the Site, the following phases of Site activity were evident:

1983-1990 OS Map – The structures on-site were demolished, and a large hotel structure was built in replacement.

On this evidence, it is apparent that the Site had not been subjected to any significant post-WWII redevelopment until the 1980's when a hotel was built, however some areas of the Site (particularly the south-eastern sector) have remained as hard standing. As a result, it is likely that any UXO within the structural foundations of post-war buildings would have been discovered and removed, however the potential for deep buried UXO to be present within remaining areas is assessed to be extant

Does the probability of a UXO discovery vary across the Site?

Yes; the probability of discovering UXO within the hotels structural footprint is considered to be remote, however, the probability of UXO discovery within all previously undisturbed areas of the Site is extant.

STAGE FOUR – RISK ASSESSMENT

Threat Items

The most probable UXO threat items are *German* HE bombs, whilst IBs and *British* AAA projectiles pose a residual threat. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

Maximum Bomb Penetration Depth

Considering the ground conditions (highlighted in Stage 1), the average BPD for a 250kg *German* HE bomb within gravel and clay is assessed to be approximately 5m bgl, with the maximum BPD considered to be approximately 14m bgl. Although it is possible that the *Luftwaffe* deployed larger bombs in the area, their deployment was infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.

WWII *German* bombs have a greater penetration depth when compared to IBs and AAA projectiles, which are unlikely to be encountered at depths greater than 1m bgl.

Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities (i.e. boreholes and piling) may generate a significant risk pathway. Whilst not all UXO encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injury to personnel, damage to equipment and project delay.

Prospective Consequences

Consequences of UXO initiation include:

1. Fatally injure personnel;
2. Severe damage to plant and equipment;
3. Deliver blast and fragmentation damage to nearby buildings;
4. Rupture and damage underground utilities/services.

Consequences of UXO discovery include:

1. Delay to the project and blight;
2. Disruption to local community/infrastructure;
3. The expenditure of additional risk mitigation resources and EOD clearance;
4. Incurring additional time and cost.

UXO RISK CALCULATION

Site Activities

Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, a number of investigative and construction methodologies have been described for analysis at this Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, *6 Alpha* has conducted separate risk rating calculations for trial pits, window sampling and boreholes.

Risk Rating Calculation

6 Alpha's Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

STAGE FOUR - RISK ASSESSMENT (…continued)

UXO RISK CALCULATION TABLE – ALL AREAS

Activity	Threat Item	Probability (SHxEM=P)	Consequence (DxPSR=C)	Risk Rating (PxC=RR)
Trial Pits	HE Bombs	2x2=4	2x3=6	4x6=24
	AAA Projectiles	1x2=2	3x1=3	2x3=6
	IBs	1x2=2	3x1=3	2x3=6
Window Sampling	HE Bombs	2x2=4	2x3=6	4x6=24
	AAA Projectiles	1x22	3x1=3	2x3=6
	IBs	1x2=2	3x1=3	2x3=6
Boreholes	HE Bombs	2x3=6	3x2=6	6x6=36
	AAA Projectiles	1x3=3	3x1=3	3x3=9
	IBs	1x3=3	3x1=3	3x3=9
Excavations	HE Bombs	2x2=4	2x3=6	4x6=24
	AAA Projectiles	1x2=2	3x1=3	2x3=6
	IBs	1x2=2	3x1=3	2x3=6
Piling	HE Bombs	2x3=6	3x2=6	6x6=36
	AAA Projectiles	1x3=3	3x1=3	3x3=9
	IBs	1x3=3	3x1=3	3x3=9

Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES

If a geophysical survey is required are the ground conditions an issue?

Non-Intrusive Methods of Mitigation – Magnetometer results may be affected by ferro-magnetic contamination due to previous construction activities and made ground within the Site.

Intrusive Methods of Mitigation – Intrusive magnetometry may be effective on this Site, prior to boreholing and piling especially. However, any ferrous metal/red brick contamination in made ground/old foundations may affect the detection capability of the UXB survey equipment, as it passes through the contaminated layer especially. Nonetheless, beyond the contaminated strata such a survey should prove effective.

MITIGATION MEASURES TO REDUCE RISK TO 'ALARP'

Activity/Area	Risk Mitigation Measures	Final Risk Rating
All Activities in All Areas	**1. Operational UXO Emergency Response Plan;** appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery (this plan can be supplied by *6 Alpha*); **2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety awareness briefing is an essential part of the *Health & Safety Plan* for the Site and helps to evidence conformity with the principles laid down in the *CDM* regulations 2015 (this brief can be delivered directly, or in some cases remotely, by *6 Alpha*).	**ALARP**
Trial Pits and Excavations in All Previously Undisturbed Areas	**3. Non-intrusive UXO Survey and/or EOD Banksman Support;** Where 'open' intrusive works into previously undisturbed ground are proposed and where the extent is considered to be within the capabilities of non-intrusive UXO survey equipment and implementation of this is assessed as likely to prove effective, a non-intrusive geophysical UXO survey should be trialed and, if it proves successful, should be employed to survey site-wide, or in specific areas where 'open' intrusive works are to be implemented to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. If the survey proves partially or wholly ineffective, an EOD Engineer should be present in the UXO Banksman role to monitor ongoing 'open' intrusive works to identify any suspicious items that may be UXB or UXO related (this service can be provided by *6 Alpha*).	
Window Sampling, Boreholing and Piling in All Areas	**4. Intrusive UXO Survey;** Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the *assessed average bomb penetration depth* or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by *6 Alpha*).	

This assessment has been conducted based on the information provided by the Client, should the proposed works change then *6 Alpha* should be re-engaged to refine this risk assessment

Report Figures

Figure One

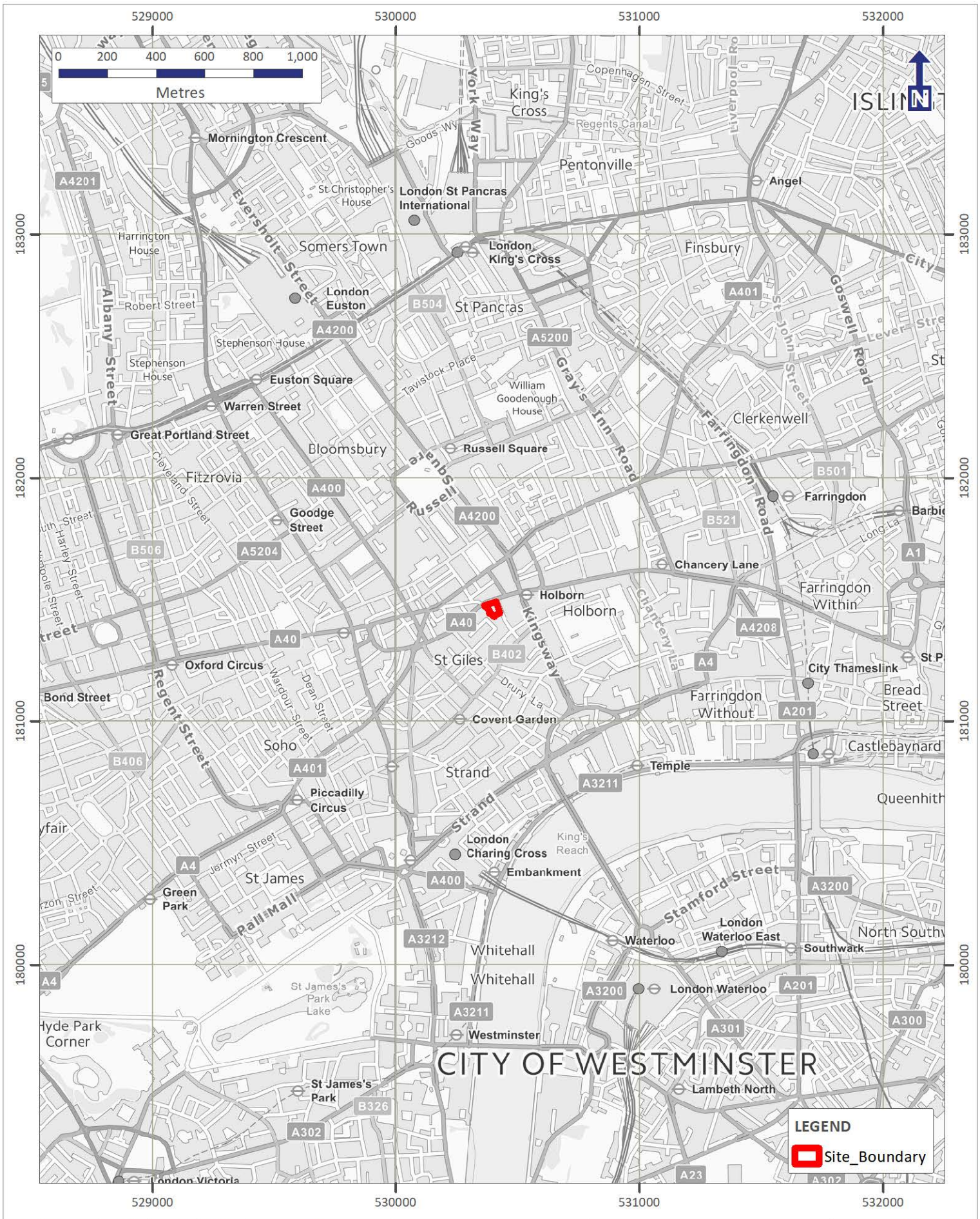
Site Location

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

Site Location

BRITISH NATIONAL GRID

BOMB SEARCH
WWW.6ALPHA.COM



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P6399	1	SB	RG	26 January 2018	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.	alpha ASSOCIATES

Figure Two

Site Boundary

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

Site Boundary

BOMB SEARCH
WWW.6ALPHA.COM

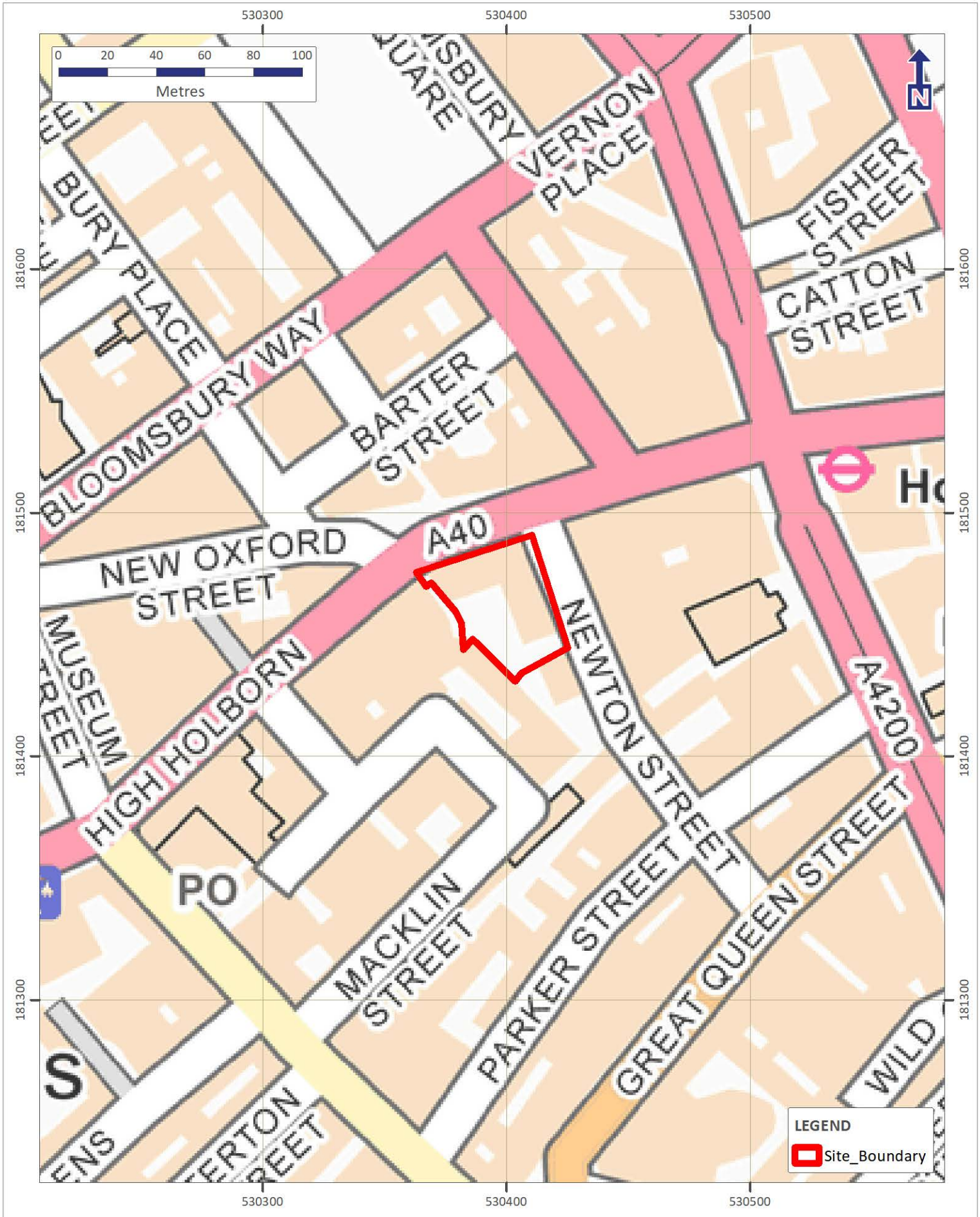

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Figure Three

Aerial Photography (2017)

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

Aerial Photography (2017)

BOMB SEARCH
WWW.6ALPHA.COM

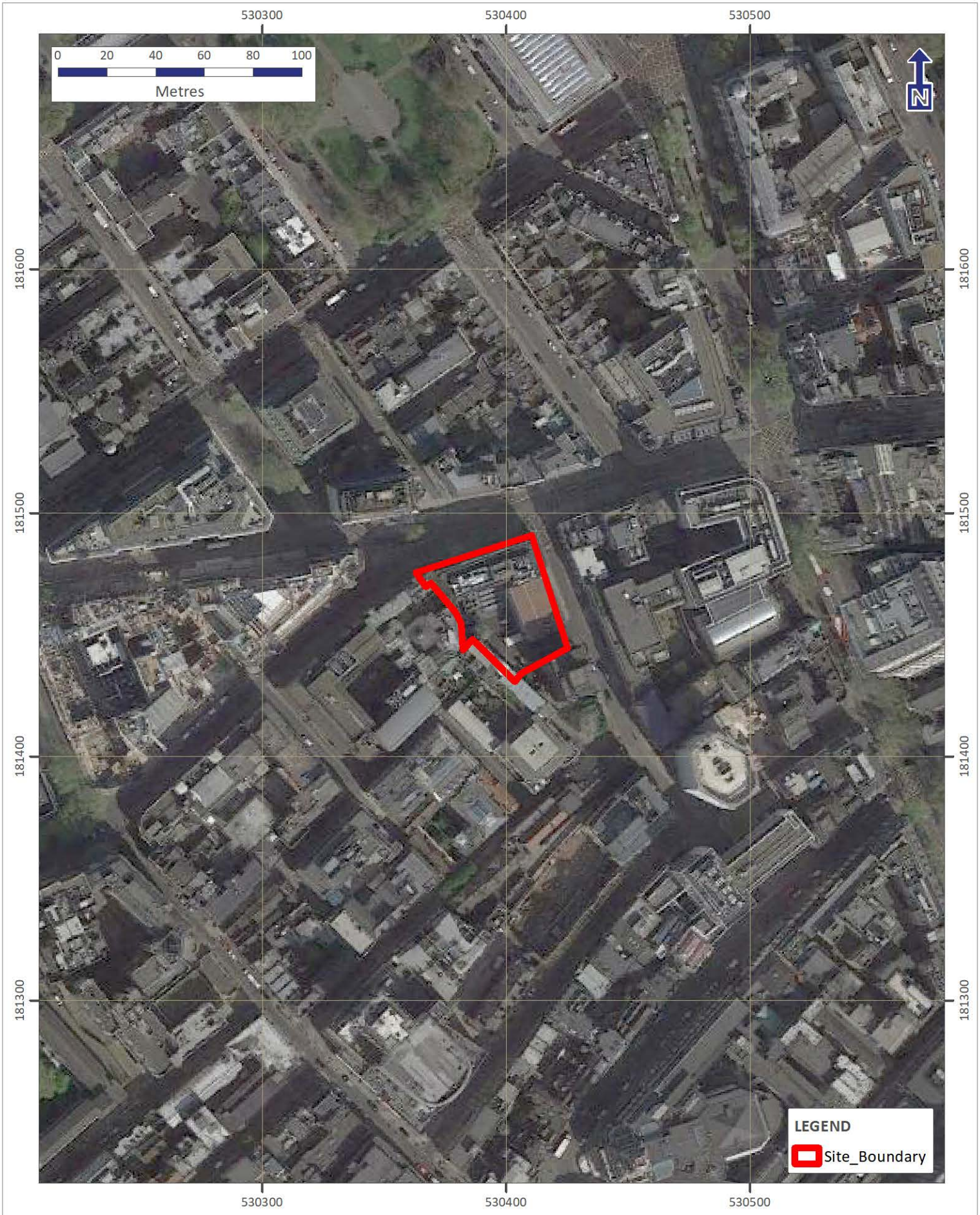

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Figure Four

Aerial Photography (1945)

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

Aerial Photography (1945)

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Figure Five A

WWII Luftwaffe Bombing Targets

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

WWII Luftwaffe Bombing Targets

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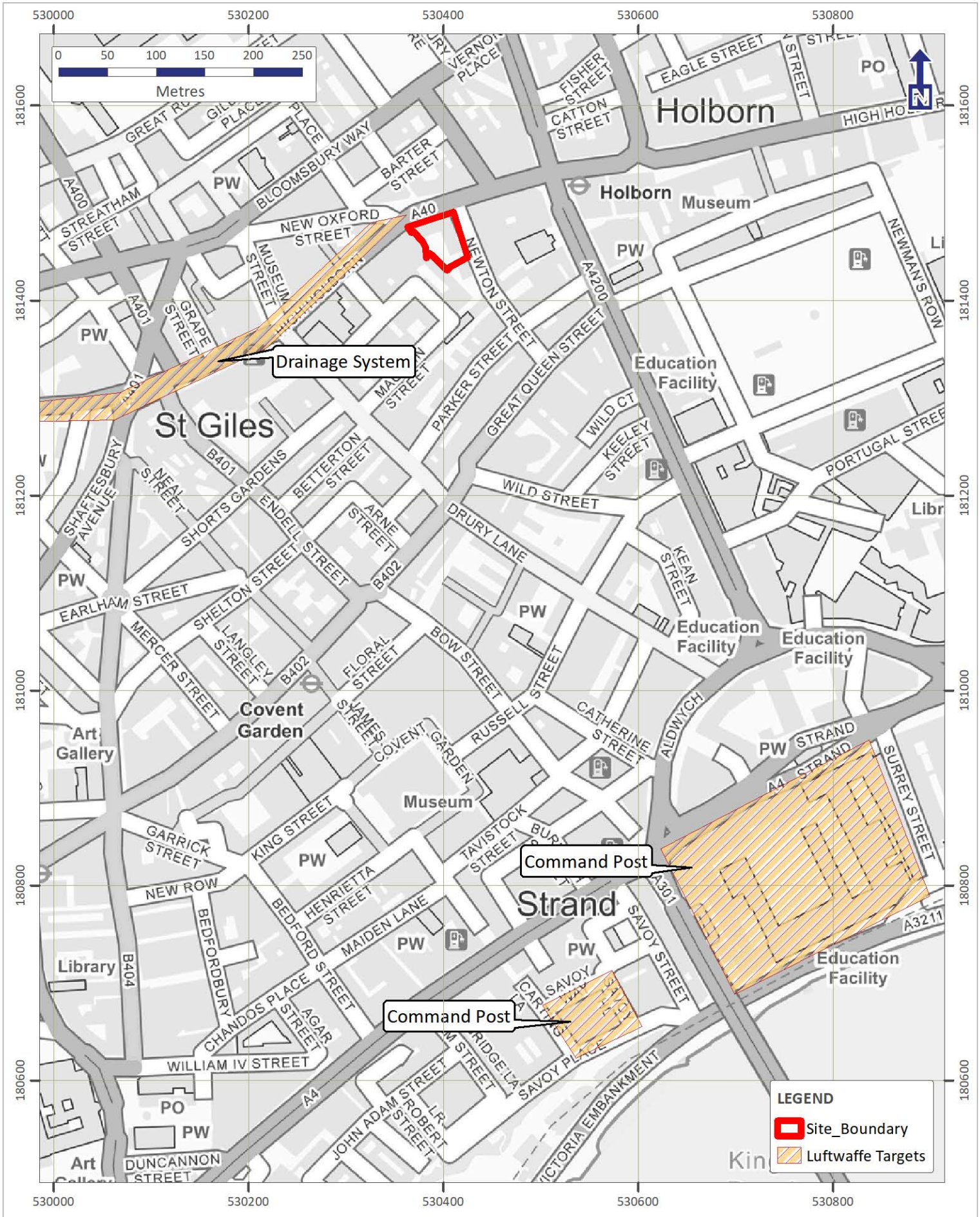

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
P6399	5A	SB	RG	26 January 2018

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Figure Five B

WWII Luftwaffe Aerial Photography

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

WWII Luftwaffe Aerial Photography

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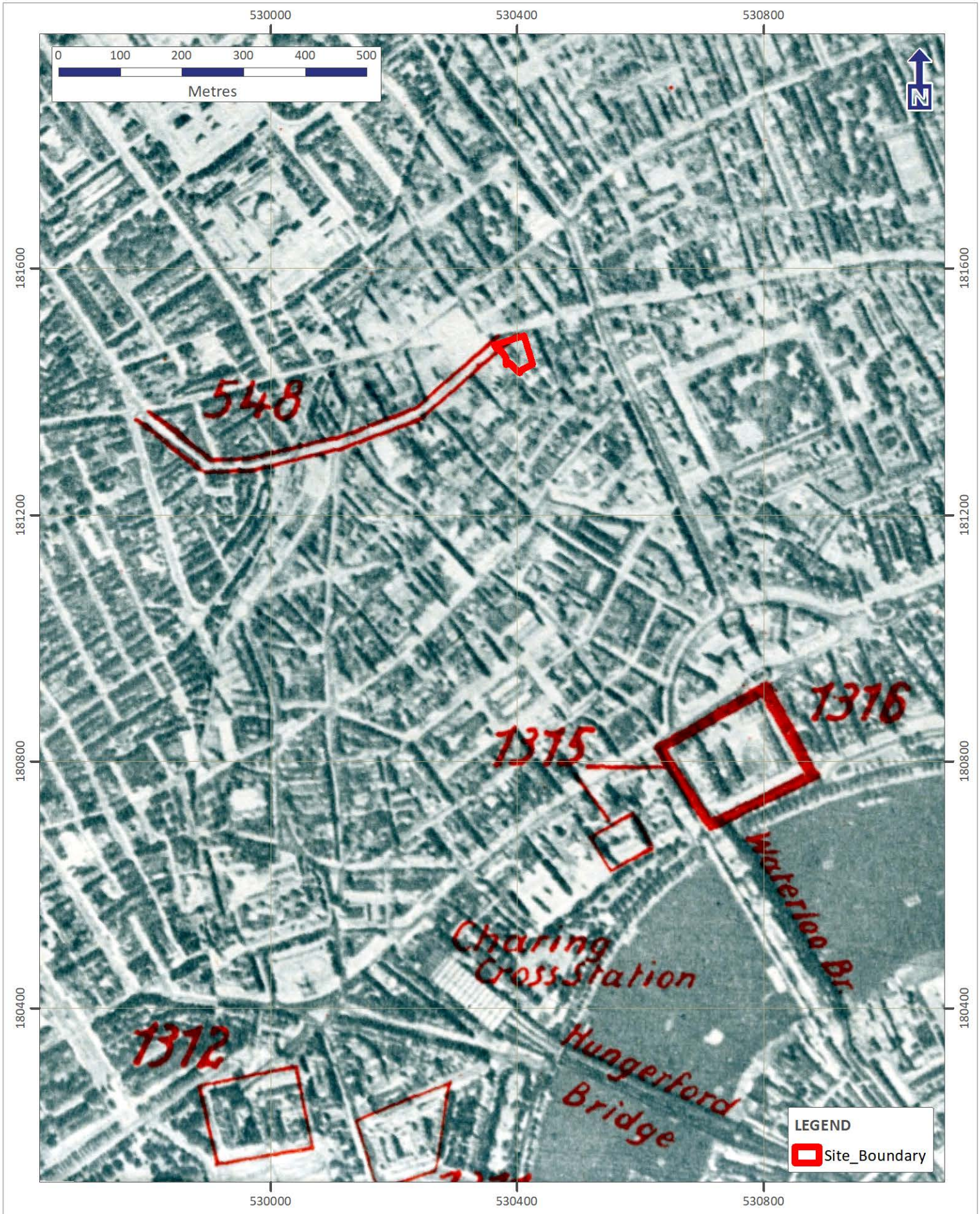

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Figure Six

WWII High Explosive Bomb Strikes

BRITISH NATIONAL GRID

THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

WWII High Explosive Bomb Density

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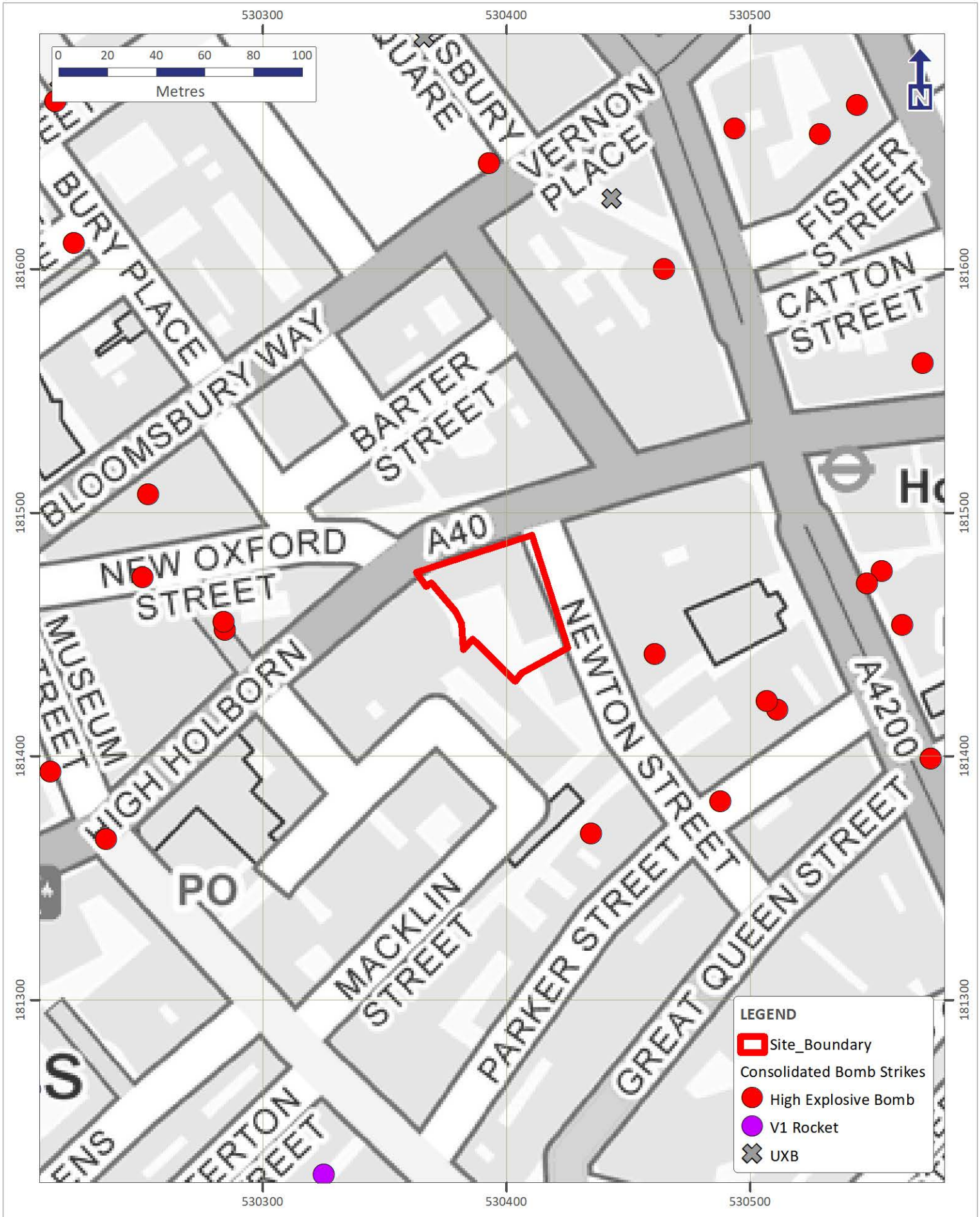

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Figure Seven

WWII London County Council Bomb Damage Map

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THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

London County Council WWII Bomb Damage Map

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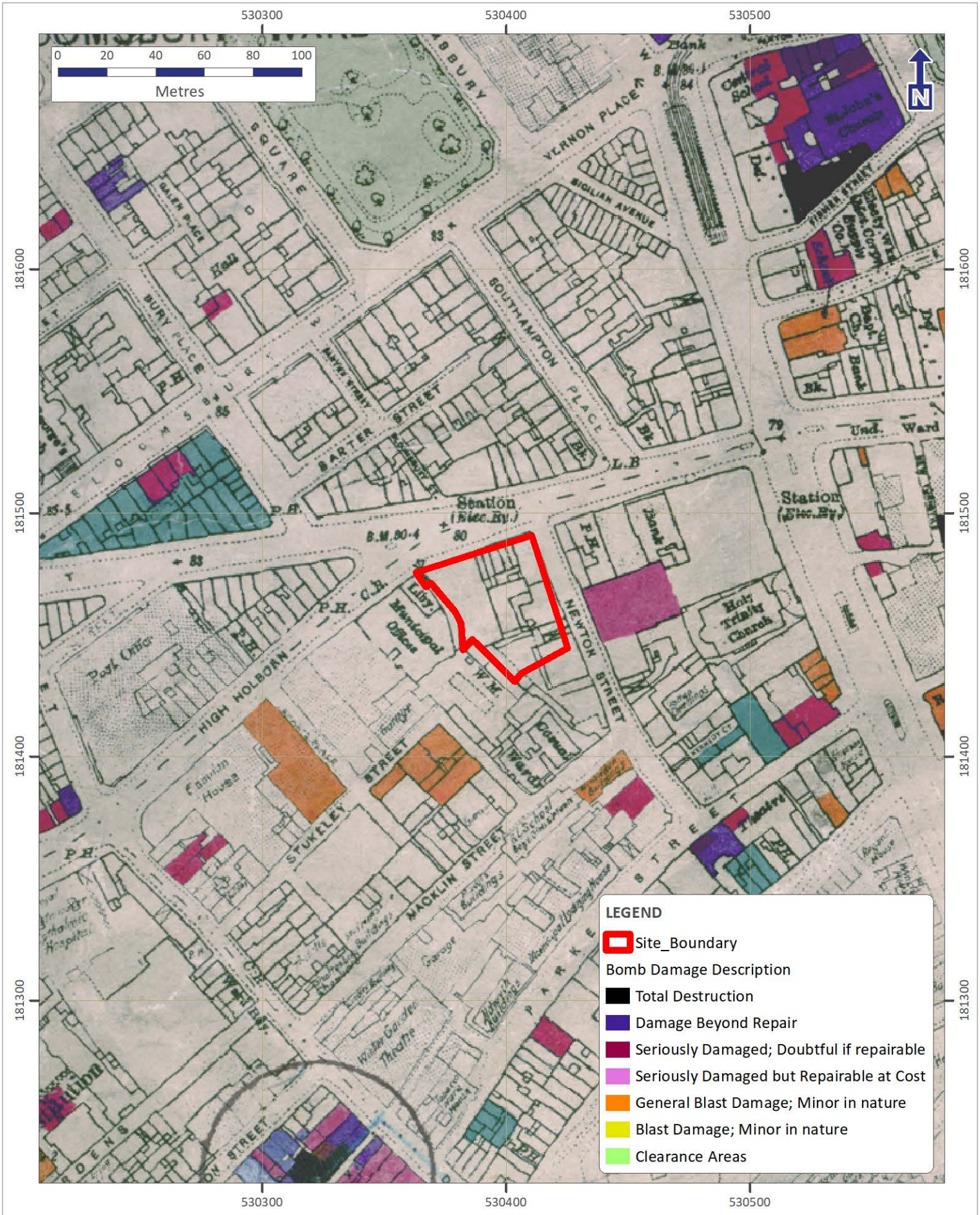

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Figure Eight

WWII High Explosive Bomb Density

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THE HOXTON HOLBORN, 199-206 HIGH HOLBORN, WC1V 7BD

WWII High Explosive Bomb Density

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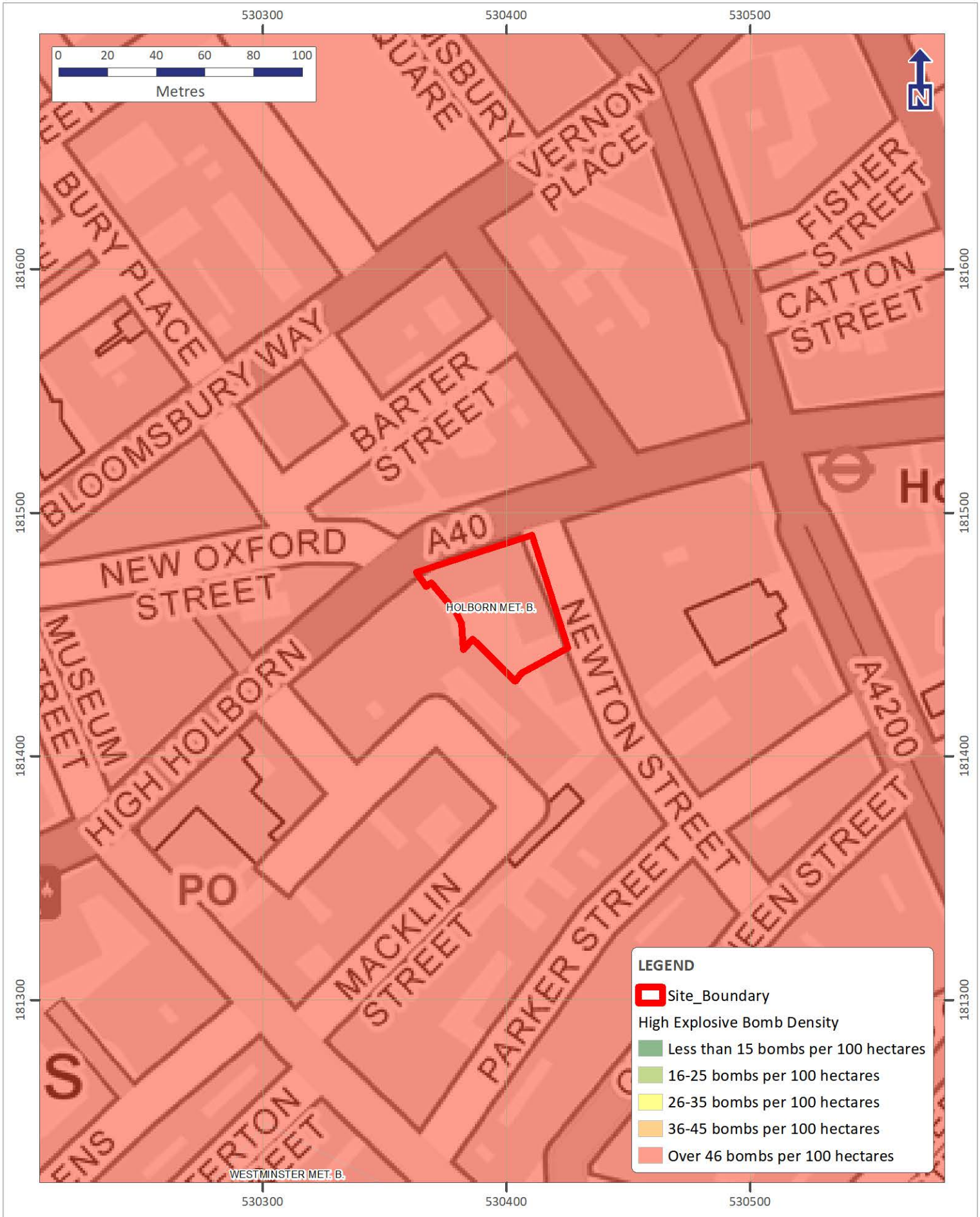

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