Landmark Information

6 alpha ASSOCIATES



Varley Street

Landmark Order No: 382405966_3

Client Reference: 34922LG

Detailed Unexploded Ordnance (UXO) Threat and Risk Assessment with Risk Mitigation Strategy

Meeting the requirements of the United Kingdom's
Construction Industry Research and Information Association's
Unexploded Ordnance Risk Management Framework:
"Unexploded Ordnance (UXO) – A Guide for the Construction Industry" (C681)
and in compliance with the Construction (Design and Management) Regulations 2015

Landmark Information Group in partnership with 6 Alpha Associates Ltd

Project No.: 12087

8th August 2025

V1.0

Achilles UVDB VERIFIED | BUILDER'S PROFILE | Constructionline Gold Member Verified Member | SafeContractor APPROVED | Institute of Explosives Engineers | REGISTERED ISOQAR UKAS MANAGEMENT SYSTEMS 0029 | ISO 9001, ISO 14001, ISO 45001

Certificate Number 25680

Using This Report

This Detailed UXO Threat and Risk Assessment with Risk Mitigation Strategy is designed to inform the reader whether military related Unexploded Ordnance (UXO) is likely to pose a hazard at the Study Site and if so, to calculate the level of risk generated by proposed or likely ground intrusive operations at the Site. The assessment is intended to meet with the requirement of Stages 2 and 3 of the *Health and Safety Executive* endorsed *CIRIA C681 UXO Risk Management Framework* – for which *6 Alpha* were the lead technical author.

There are two prospective outcomes of this report; either the risk level requires a Risk Mitigation Strategy (Stage 3 of the *CIRIA C681* framework) aimed at reducing UXO risks As Low As Reasonably Practicable (ALARP) in accordance with the Project's minimum legal responsibility; or that no further action is required. In the former instance *6 Alpha* will provide a Risk Mitigation Strategy consisting of proactive and/or reactive risk mitigation measures aimed at reducing the identified risks to ALARP.

Document Control

Version	Author(s)	Reviewed By	Client Reference
1.0	Dominic Barrett	Leo Hayes	34922LG

Landmark Information Group

Imperium, Imperial Way

Reading, Berkshire

RG2 0TD

Tel: +44 (0) 330 036 6618

Web: www.envirocheck.co.uk

Executive Summary

Document Scope

6 Alpha Associates Limited (6 Alpha) has been commissioned in partnership with the *Landmark Information Group* to provide a UXO Threat and Risk Assessment with Risk Mitigation Strategy, for the Site described as "Varley Street, Manchester, M40 8EE". The Study Site is centred on *British National Grid Reference* 385888, 399700.

UXO Threat Assessment Summary

The output of *6 Alpha*'s UXO Threat Assessment is summarised at Table I:

UXO Threat Assessment Summary			
Threat Source		**Result**	**Comments**
	Was the Site or its vicinity considered a primary bombing target during WWII?	✔	*Luftwaffe* aerial photography and mapping identified eight primary bombing targets within 1,000m, with the closest being a *Railway Works* (40m to the north-west).
	Was the Site or its vicinity bombed during WWII?	✔	*ARP* records identified five HE bomb strikes with 360m, with the closest documented 20m to the south-west.
	Was the Site or its vicinity damaged by bombing during WWII?	✔	Official bomb damage mapping recorded *"Damaged Buildings"* and *"Demolished Buildings"* on-site.
	Has any *British* military activity been identified in the area?	✘	No evidence of military activity and/or munitions production or storage was identified on-site or nearby.
	Has ordnance been manufactured and/or stored at the Site or its vicinity?	✘	
	Does UXO contamination pose a potential hazard at the Study Site?	✔	Given the bomb damage recorded on-site and bomb strikes in close proximity, it is considered possible that UXO might be encountered.

Table I: UXO Threat Assessment Summary

UXO Threat Items

Given the evidence presented at Table I, *6 Alpha* consider it reasonably foreseeable that a UXO encounter could occur at this Site. The most probable UXO threat items are *German* HE bombs and IBs. *British* AAA projectiles may also pose a residual threat.

Potential UXO Burial Depth

Given the likely ground conditions at the Study Site, the average WWII bomb penetration depth has been calculated as 7m below WWII ground level at this Study Site. Although larger UXBs could be present below this depth (potentially up to 16m), they were deployed infrequently during WWII and are highly unlikely to be encountered.

UXO Risk Pathways

The Study Site has undergone significant post-WWII development in certain areas, specifically concerning the demolition of numerous structures by 1970, and both demolition and construction activity by 2013. Consequently, it is considered unlikely for a UXO risk pathway to be generated by proposed works within ground that has been disturbed since WWII.

Nonetheless, given the depths of the proposed intrusive works below ground level, a potential UXO risk pathway could be generated by intrusive works within any remaining area(s) of ground that has not been disturbed **since the time it might have been contaminated with UXO**.

UXO Risk Assessment

A Semi-Quantitative UXO Risk Assessment has been undertaken and the UXO risk rating is assessed to be:

HIGH

Such risks may pose harm to human health and damage any equipment involved in intrusive activities; the former is intolerable. Therefore, such risks will require mitigating in accordance with the ALARP principle, through the implementation of a risk mitigation strategy (see below, and Part III of the report).

Risk Mitigation Strategy

6 Alpha recommends that the UXO risk to the proposed intrusive works is reduced ALARP, through the implementation of both proactive and reactive UXO risk mitigation measures.

Recommended UXO Risk Mitigation Measures

There following risk mitigation measures summarised at Table II, are recommended as a minimum in order to reduce risks ALARP during intrusive works in **all previously undisturbed ground**.

UXO Risk Mitigation Measures Overview							
Proposed Intrusive Works		Emergency Response Plan	Safety and Awareness Briefings	On-Call EOD Engineer	UXO Watching Brief	Non-Intrusive UXO Survey	Intrusive UXO Survey
Open Works	Trial Pits	✔	✔	✘	✔	✔	✘
	Excavations	✔	✔	✘	✔	✔	✘
Blind Works	Boreholes	✔	✔	✘	✘	✘	✔
Residual UXO Risk Rating		ALARP					

Table II: UXO Risk Mitigation Measures Overview

Recommended Next Steps

We recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, the detailed designs of the recommended UXO risk mitigation measures as outlined above.

Table of Contents

EXECUTIVE SUMMARY II

TABLE OF CONTENTS V

ACRONYMS AND ABBREVIATIONS VI

PART I: INTRODUCTION 1

1 DOCUMENT OVERVIEW 2

2 INTRODUCTION TO UXO RISK MANAGEMENT 3

3 UXO THREAT AND RISK ASSESSMENT METHODOLOGY 5

PART II: UXO THREAT & RISK ASSESSMENT 7

4 UXO THREAT ASSESSMENT 8

5 UXO BURIAL DEPTHS 11

6 UXO RISK PATHWAYS 14

7 UXO RISK ASSESSMENT 16

PART III: UXO RISK MITIGATION STRATEGY 18

8 UXO RISK MITIGATION STRATEGY 19

APPENDICES 22

List of Appendices

Appendix 1 – Site Location

Appendix 2 – Site Boundary

Appendix 3 – Modern Aerial Photography

Appendix 4 – WWII High Explosive Bomb Density

Appendix 5 – WWII *Luftwaffe* Bombing Targets

Appendix 6 – WWII Bomb Strikes

Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
ALARP	As Low As Reasonably Practicable
ARP	Air Raid Precaution
AXO	Abandoned Explosive Ordnance
BDO	Bomb Disposal Officer
bgl	Below Ground Level
BGS	British Geological Survey
BH	Borehole
BPD	Bomb Penetration Depth
CIRIA	Construction Industry Research and Information Association
CS	County Series
EOD	Explosive Ordnance Disposal
HE	High Explosive
HDD	Horizontal Directional Drilling
HSE	Health and Safety Executive
IB	Incendiary Bomb
kg	Kilogram
km	Kilometre
LCC	London County Council
LSA	Land Service Ammunition
m	Metre
m^2	Square Metres
NEQ	Net Explosive Quantity
NGR	National Grid Reference
OS	Ordnance Survey
PoW	Prisoner of War
RAF	Royal Air Force
RMS	Risk Mitigation Strategy
RN	Royal Navy
SAA	Small Arms Ammunition
SQRA	Semi-Quantitative Risk Assessment
TA	Territorial Army
TARA	Threat and Risk Assessment
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V Weapons	*Vergeltungswaffen* – Vengeance Weapons
WWI	World War One
WWII	World War Two

Part I: Introduction

1 Document Overview

1.1 Scope of Work

6 Alpha Associates Limited (6 Alpha) has been commissioned in partnership with the *Landmark Information Group* to provide an Unexploded Ordnance (UXO) Threat and Risk Assessment with Risk Mitigation Strategy, for the Site described as "Varley Street, Manchester, M40 8EE".

1.2 Study Site Location

The Study Site is situated within the *City of Manchester* and totals an area of 1.68ha. The Study Site is centred on *British National Grid Reference* 385888, 399700 and consists of a single structure, hardstanding, and areas of undeveloped ground.

The Site's Location and Site Boundary is depicted at Appendices 1 and 2, with aerial photography of the Study Site presented at Appendix 3.

1.3 Aims and Objectives

This document has the following aims and objectives:

1.3.1 Aims

The document aims to assess and evidence the nature and scope of the UXO risks to people, plant, equipment and/or the environment at this Study Site. In the event that an intolerable UXO risk is identified, a recommended UXO risk mitigation strategy will also be articulated.

1.3.2 Objectives

The document has the following objectives:

- To assess the nature and scope of potential UXO contamination at the Study Site;
- To assess whether any UXO contamination generated at the Site is likely to remain extant;
- To consider whether the proposed intrusive works will generate a viable UXO risk pathway;
- To identify those sensitive receptors likely to be impacted by an inadvertent UXO encounter during the proposed intrusive works;
- To assess the UXO risk to those sensitive risk receptors during intrusive works;
- To outline proportional risk mitigation measures that are consistent with a coherent overarching risk mitigation strategy, in order to effectively manage the UXO risk ALARP.

2 Introduction to UXO Risk Management

2.1 Definition of UXO

For the purposes of this risk assessment, *6 Alpha* have adopted the definition of UXO outlined in the undermentioned *CIRIA C681* guide, as follows:

"Explosive ordnance that has been primed, fuzed, armed, or otherwise prepared for use and used in an armed conflict. It may have been fired, dropped, launched or projected and should have exploded but failed to do so…UXO also refers to explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it..."

2.2 Generic UXO Threats

There are multiple factors which may have contributed to the UXO contamination of a construction site in the *UK* but generally, UXO contamination is likely to result from the warfighting activity associated with WWI and WWII, the military occupation and use of land such as airfields, camps and training areas, and/or the manufacture of munitions to support the armed forces.

For example, *WWII Bomb Census* data compiled by the *Ministry of Home Security* calculated that approximately 10% of bombs dropped on *Britain* during WWII failed to function as designed. If the bomb did not detonate when it was dropped, the force of impact enabled the Unexploded Bomb (UXB) to penetrate the ground. Whilst efforts were made to locate and render safe those UXBs that were observed entering the ground (or left behind clear evidence of having done so) during WWII, evidence of such UXBs was readily obscured by bomb damage debris, vegetation and a lack of footfall in some settings – thus, ensuring that an unquantifiable number of UXBs were left *in situ* below the surface of the ground.

Additionally, it has been estimated that at least 20% of the *UK's* land surface area has been used for military training activities or has otherwise been requisitioned for military use historically. Therefore, *British* Abandoned Explosive Ordnance (AXO), Land Service Ammunition (LSA), Small Arms Ammunition (SAA) and aerially delivered ordnance is also commonly encountered in areas that were formerly occupied by military forces (such as *Royal Air Force* (RAF) airfields, military camps and/or military training areas). Conventional and chemical munitions dumping was also prevalent in these periods with little consideration given to future safety implications. There was also widespread unrecorded dumping of LSA and SAA below the ground that was rarely recorded because the activity was often perceived to be inconsequential.

2.3 Generic UXO Risks

The explosive or chemical fill within UXO rarely becomes inert or loses its effectiveness with age, but the explosive fill may change or crystallise over time – increasing the high explosive's sensitivity to a physical shock or an impact. Trigger mechanisms and fuses, which may have failed, may corrode and deteriorate over time, becoming more sensitive to detonation. It is therefore possible that a significant impact on the UXO case, and the resultant effect upon the fuse, may cause its inadvertent detonation.

2.4 UXO Industry Best Practice

In the absence of specific legislation concerning the management of UXO risks during construction projects, the *UK*'s *Construction Industry Research and Information Association* (CIRIA) has published a best practice guide for the assessment and management of UXO risk in the construction industry (*CIRIA* document reference C681). The *CIRIA C681* guide has been judged and recognised by the *Health and Safety Executive* (HSE) as a minimum standard of good practice, that satisfies the law when applied in an appropriate manner.

6 Alpha were *CIRIA's* lead technical author for their *C681* publication and as such, are in a unique position to ensure that Clients manage UXO risk in a safe, cost-effective and time-efficient manner.

2.5 UXO Risk Management Strategic Framework

At Section 5 of *CIRIA's* C681 guide, a framework for the management of UXO risk is articulated and consists of four key stages. These correspond with the framework employed by *6 Alpha*, as presented at Table 1.

6 Alpha Risk Management Framework	UXO Risk Management Phase	CIRIA C681 Risk Management Framework	Delivered within Report? (✔/✘)
UXO Threat Assessment	**STAGE ONE**	Preliminary Risk Assessment	✔
UXO Risk Assessment	**STAGE TWO**	Detailed Risk Assessment	✔
Risk Mitigation Strategy	**STAGE THREE**	Risk Mitigation	✔
Implementation	**STAGE FOUR**	Implementation	✘

Table 1: 6 Alpha and CIRIA UXO Risk Management Frameworks

3 UXO Threat and Risk Assessment Methodology

3.1 Source – Pathway – Receptor Risk Model

The source-pathway-receptor model is a conceptual risk model employed by *6 Alpha* across all projects and it informs how UXO risks are assessed. The model also helps to explain the link between the separate sections of this report and the UXO risk assessment at Section 7. The components of the model are as follows:

3.1.1 UXO Sources

The nature and scope of the UXO threat is summarised in the UXO threat assessment (at Section 4) and it forms the source element of the source-pathway-receptor model.

3.1.2 UXO Pathways

The UXO pathways are the routes by which the sources can reach the receptors. UXO pathways are likely to be either by contact and/or through soil energy transfer, through which the resulting shock wave (generated by a UXO source, or sources) may reach potential receptors. Nonetheless, surface events may also generate a through-air risk pathway in which blast and fragmentation from the UXO sources may also reach the receptors.

UXO risk pathways may be generated by a variety of operations that interact with the ground. Therefore, likely operations have been assessed and summarised (at Section 6), to demonstrate the potential risk pathway elements of the model.

3.1.3 UXO Receptors

Receptors are defined as anything which might be adversely affected by the consequences of an inadvertent detonation of any UXO source through an identified pathway. The proximity, robustness, and sensitivity of such receptors is essential in determining their capacity to withstand such high explosive effects and defining what degree of UXO risk might be tolerated (if any).

3.2 Semi-Quantitative Risk Assessment Methodology

The assessment of UXO risk is a semi-quantitative measure of the probability of UXO encounter and initiation and the consequence of an inadvertent UXO initiation; the former being a function of the identified hazard and proposed development methodology and the latter being a function of the type of hazard and the proximity of personnel (and/or other sensitive receptors) to the hazard.

UXO risk is calculated using the following formula:

Risk **(R)** = Probability **(P)** x Consequence **(C)**

3.3 Information Sources

Significant archive research associated with the Study Site has been undertaken to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter. For the production of this report, *6 Alpha* have reviewed information from the following sources:

- Information gathered from the *National Archives* at *Kew*, including but not limited to:
  - *Ministry of Home Security WWII Bomb Census* statistics;
  - *Air Raid Precaution* (ARP) written records and associated bomb strike mapping;
  - *Ministry of Home Security Daily Intelligence Reports*;
  - Official WWII bomb damage mapping;
- *Ministry of Defence* (MoD) *Abandoned Bomb Register*;
- *Former 33 Engineer Regiment* (Explosive Ordnance Disposal) records at *Carver Barracks, Wimbish*;
- Post-WWII *RAF* aerial photography;
- *County Series* (CS) and *Ordnance Survey* (OS) mapping.

3.3.1 Azimuth© UXO Threat Database

The above list is not exhaustive, and *6 Alpha's Azimuth*© database has also been heavily drawn upon to deliver the UXO threat assessment element of this report. The *Azimuth*© database contains digitised historic charts, aerial photographs and other extensive analogue records from an exhaustive range of additional national, regional and global archives and/or data sets that have been digitised.

3.4 Constraints

This UXO threat and risk assessment is constrained and limited by that information which is reasonably available to *6 Alpha* at the time of writing, as well as that UXO information that is reasonably accessible in a variety of archives, which *6 Alpha* have digitised and georeferenced or have otherwise summarised in written form.

This document may require updates and changes, especially wherever and whenever the circumstances and factors associated with assessing UXO risk change. For example, if UXO threats are subsequently discovered and they are different from those that have been anticipated, and/or if the proposed intrusive operations are significantly changed.

In such circumstances, risks may require re-evaluation, and any such changes are to be made by *6 Alpha*, to ensure the continued technical veracity and risk management efficacy of this document.

Part II: UXO Threat & Risk Assessment

4 UXO Threat Assessment

4.1 WWII Aerial Bombing

Manchester's importance to the *British* war economy as an inland port, industrial centre, and aircraft manufacturer, meant the city and surrounding area represented a significant bombing target for the *Luftwaffe*. The first air raids occurred during August 1940 and continued until 1942. Many of these small-scale raids were across the city's suburbs causing damage to properties and minimal casualties.

The *Luftwaffe* bombing campaign of *Manchester* peaked between the 22nd and the 24th December 1940 (the *Manchester,* or *Christmas, Blitz* as it was known) and involved over 400 enemy aircraft deploying more than 460 tons of HE bombs and 37,000 IBs. Following this raid, approximately 65 warehouses, 200 business premises and 150 offices were destroyed or damaged with the *Manchester Cathedral*, the *Royal Exchange,* and the *Free Trade Hall* among the significant buildings damaged. An estimated 684 people were killed, and a further 2,364 people were injured.

Manchester continued to be bombed throughout the war and on the 24th December 1944 *V1* rockets were launched towards the city. The rockets failed to meet their intended targets with one stray bomb impacting *Oldham*, killing 27 civilians.

4.1.1 WWII HE Bomb Density

The Study Site was located within *Manchester County Borough,* as presented at Appendix 4. This region recorded six HE bomb strikes per 100 hectares, a "very low" level of bombing. However, further site-specific data has been considered regarding the potential bombing of the Site during WWII.

4.1.2 WWII Luftwaffe Bombing Targets

Luftwaffe aerial reconnaissance photography did not identify the Study Site itself as a primary bombing target. Nonetheless, eight primary bombing targets were documented within a 1,000m radius of the Site boundary; a *Railway Works* (40m to the north-west), an *Iron Works* (305m to the east-north-east), a *Factory* (390m to the south-east), *Philips Park Gas Works* (580m to the north-east), a *Gas Works* (690m to the south-east), an *Iron & Steel Works* (720m to the east-north-east), and *Manchester Works* (780m to the south) *Oldham Road Station* (830m to the south-west).

The locations of *Luftwaffe* bombing targets, in relation to the Study Site, are presented at Appendix 5.

4.1.3 WWII Bomb Strikes

During WWII, *ARP* wardens and other local officials compiled detailed logs of bomb strikes across their respective districts that were then often consolidated and mapped at the end of WWII. These records did not note any HE bomb strikes within the Study Site. Nonetheless, 29 were recorded within a wider

1,000m radius, with five in the Site's immediate vicinity; 20m to the south-west, 150m to the north-west, 190m to the north-west, 265m to the north-west and 360m to the south-west. Furthermore, whilst IBs may have fallen within the Study Site, they were dropped in large clusters and accurate record keeping was often either non-existent or perfunctory. Nonetheless, four IB strikes were noted in the wider area, with the closest impacting 680m to the north-east and 740m to the south-east. Finally, further research noted a parachute mine detonation on *Reather Street* approximately 640m to the south-west.

In addition to IBs and HE bomb strikes, during the latter stage of WWII, when more conventional aerial bombardment of the *UK* had significantly declined, the main threat came from *V* type weapons. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons and generally exploded upon impact and thus, are less likely to pose a UXO threat. There is also no evidence to suggest that the Study Site (or its immediate vicinity) was subjected to rockets strikes during WWII.

The locations of WWII-era bomb strikes, in relation to the Study Site, are presented at Appendix 6.

4.1.4 WWII Bomb Damage

Official *Manchester Corporation* bomb damage mapping associated with the Study Site identified both *"Damaged Buildings"* and *"Demolished Buildings"* on-site, in its south-western sector. Additional *"Damaged Buildings"* were documented 15m to the south-west and 20m to the south-west, along with *"Demolished Buildings"* 15m to the south-west and 25m to the south-west.

Official bomb damage mapping associated with the *Miles Platting* area corroborated the larger *Manchester Corporation* mapping, as well as noting *"Blitzed Areas and Sites of Demolished Property"* 70m to the north-west and 95m to the west.

Finally, an analysis of post-war mapping identified a *"Ruin"* 170m to the north-west near *Thornton Street* – which is likely indicate of bomb damage given the bombing in the wider area.

4.1.5 UXB Entry Holes

The CS mapping prior to WWII (1923) and aerial photography (1944) shows that the Study Site was located within a densely developed urban area during WWII, with the Study Site itself consisting of multiple structures, including residential properties, and roads. Therefore, it is likely that the Study Site would have been accessed frequently during WWII. Despite this, as significant bomb damage was recorded on-site, it is possible that bomb damage debris may have concealed a UXB entry hole causing it to have gone unnoticed.

4.2 *British* Military Activity

There is no evidence to suggest that the Study Site or its immediate vicinity has previously been occupied by military personnel. Therefore, it is considered unlikely that munitions were previously stored, located and/or fired from this Study Site.

4.3 Previous UXO Encounters

An analysis of historic records noted several UXO encounters within the vicinity of the Study Site, as follows:

4.3.1 Abandoned Bombs

The Abandoned Bomb register was compiled from wartime records and was published in the form of a written answer to the *House of Commons* in 1996. The list initially only covered abandoned bombs in *London* but has since been released for the rest of the UK.

An examination of the *MoD*'s official abandoned bomb records has not identified any abandoned bombs on-site or within 1,000m of the Study Site boundary.

4.3.2 WWII UXO Disposal Tasks

An examination of pertinent historical records including official bomb strike mapping has identified two unexploded bombs within 1,000m of the Study Site: 450m to the north-west and 790m to the north-west.

4.3.3 Post-WWII UXO Encounters

The following UXO encounters have been recorded at the Study Site and/or in its immediate vicinity since the end of WWII:

- One WWII-era grenade was encountered during magnet fishing in *Ashton Canal*, *Shawhill Walk,* (located 815m to the south-south-east), on 10th July 2024;
- One inert shell was encountered during magnet fishing in *Rochdale Canal*, *Grimshaw Lane, Newton Heath* (located 845m to the east-north-east), on 2nd February 2020.

4.4 UXO Threat Summary

Given the evidence presented above, *6 Alpha* consider it reasonably foreseeable that a UXO encounter could occur at this Site. The most probable UXO threat items are *German* HE bombs and IBs. *British* AAA projectiles may also pose a residual threat as they were likely fired in defence of the local area during WWII bombing raids.

5 UXO Burial Depths

5.1 Overview

It is important to establish the likely burial depth for threat spectrum UXO at the Study Site. The potential penetration depth of an UXB was dependent on a number of factors including but not restricted to those prior to striking the ground (e.g. velocity and orientation of the UXB), which in turn will be influenced on factors such as the release altitude from the aircraft and encounters with infrastructure during its fall, those encountered at the point of impact (i.e. was the impact on concrete, grass, water etc.) and finally, the below ground level conditions (e.g. infrastructure/services, basements, foundations, and geology).

Accordingly, the ground conditions at the Study Site must be understood in order to determine the average and maximum *German* UXB penetration depths, as well as the potential for other types of munitions to be buried. The provenance of made ground must also be considered in order to accurately determine the ground levels at the time when UXO contamination may have occurred (so as to accurately determine the average/maximum bomb penetration depths) and subsequently to inform any further recommendations.

5.2 Ground Conditions

BGS borehole log "*SJ89NE13 – Manchester Corp. Off Oldham Road*" (located on-site), recorded the following strata:

Depth bgl (m)	Strata
0.00m to 0.60m	Clay
0.60m to 7.90m	Clay
7.90m to 8.20m	Clay
8.20m to 8.40m	Clay
8.40m to 8.70m	Clay

Table 2: Ground Conditions Summary

In addition, an analysis of *BGS* mapping associated with the Study Site suggests that the Site is likely to be underlain by a bedrock of "*Pennine Upper Coal Measures Formation - Mudstone, siltstone and sandstone*".

5.3 UXB Burial Depths

Based on the ground conditions described above, the average BPD for a 250kg *German* HE bomb is assessed to be approximately 7m bgl, with the maximum BPD considered to be approximately 16m bgl.

Although it is possible that the *Luftwaffe* deployed larger bombs in the area, an analysis of WWII bomb census data clearly evidences that their deployment was infrequent. Therefore, to use such larger bombs for BPD calculations **is not justifiable under the ALARP principle and thus, CIRIA C681 guidance**.

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.

5.3.1 The J-Curve Effect

As a UXB penetrated the ground, it's velocity naturally slowed where it either came to an abrupt stop (e.g., against foundations) or would continue along a route of least resistance – which often resulted in a curving of the trajectory back towards the surface. This is known as the "J Curve" effect and often resulted in a considerable horizontal off-set from the point of entry. This explains why UXBs have been discovered against or under the foundations of buildings which were present during WWII, or many meters from their entry holes. A diagrammatical representation of the "J Curve" effect is presented at Figure 1.

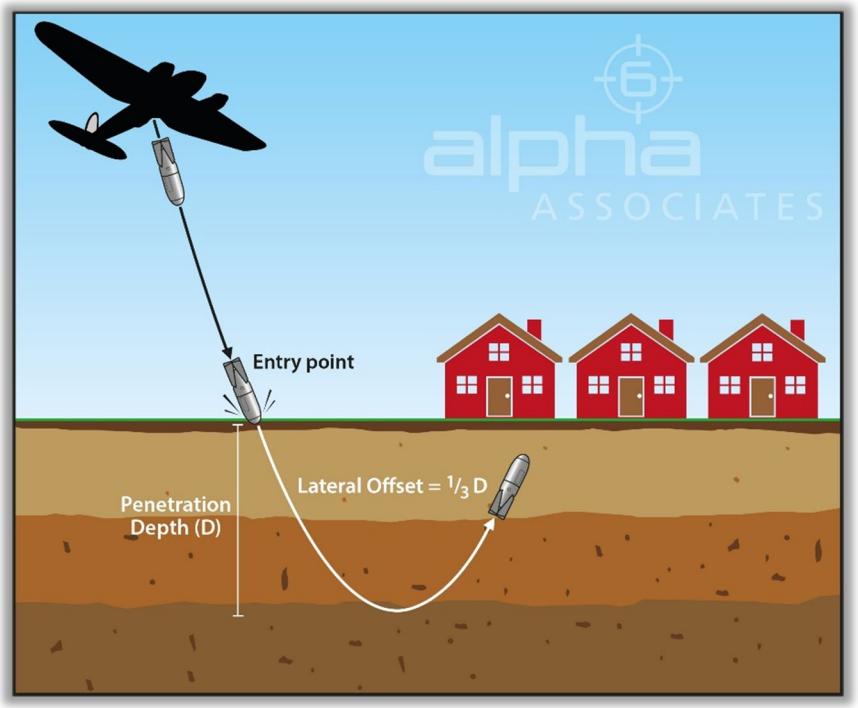


Figure 1: The J-Curve Effect

6 UXO Risk Pathways

6.1 Overview

In order to assess whether a viable UXO risk pathway might exist at the Study Site, potential UXO contamination sources must be assessed (and have been at Section 4 of the report) and the likely depth of UXO contamination ought to be established (as per Section 5 of the report). Additionally, the Site's construction history ought to be considered to assess whether any previous intrusive works will have encountered and removed any UXO contamination previously generated at the Site.

6.2 Study Site Construction History

From an analysis of CS and OS mapping, together with aerial photography, the following site history can be deduced:

Year	Development History
1924 CS Map	The Study Site was situated in a densely developed urban area and comprised multiple structures and roads.
1944 Aerial Photography	Several structures in the south-western sector had been demolished.
1970 OS Map	Numerous structures in the central and western sector had been demolished.
1984 OS Map	An additional structure in the northern sector was demolished.
1992 OS Map	Changes were not recorded at the Study Site.
2003 Aerial Photography	Changes were not recorded at the Study Site.
2013 Aerial Photography	Additional structures in the eastern sector were demolished, and a new structure developed in the northern sector. Hardstanding was visible in the central sector.
2025 OS Map	Changes were not recorded at the Study Site.

Table 3: Study Site Development History

As per Table 3, it is apparent that the Study Site has undergone significant post-WWII development in certain areas, specifically concerning the demolition of numerous structures by 1970, and both

demolition and construction activity by 2013. Consequently, it is considered likely that any UXO contamination within ground that has been disturbed since WWII would likely have been discovered and removed. Nonetheless, it is apparent that the previous intrusive works are unlikely to have mitigated the UXO risk in all areas of the Study Site down to the likely average UXO burial depth of 7m bgl.

6.3 Proposed Works

An outline of the proposed intrusive works is also presented in order to evidence the potential UXO risk pathways that may be generated, should such work encounter those threat spectrum UXO that have been identified in Section 4.

A general overview of the scope of works for the project has been communicated to *6 Alpha* and consists of:

- *"Ground Investigations: Medium Trial Pit between 1m and 5m below ground level, Window Sampling up to 1m below ground level, Other;*
- *Borehole Depth: WS up to 6m, CP & RBH to 30m;*
- *Intrusive Work: Cable Percussion Boreholes to 15m with Rotary follow on to 30m;*
- *Excavation Depth: 30m."*

Consequently, it is apparent that the proposed works might generate a UXO risk pathway in ground that has not been previously disturbed (including any ground below post-WWII intrusive work) to a depth of 7m bgl.

If the planned methods are changed, then the risk assessment is to be reviewed and updated if necessary.

7 UXO Risk Assessment

7.1 Threat Items

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

7.2 Risk Pathways

Given the nature and scope of the prospective UXO hazard at the Study Site, all types of aggressive intrusive activities (i.e., investigative groundworks and construction methodologies) into previously undisturbed ground (including ground below any post-WWII redevelopment) to a depth of 7m bgl may generate a significant risk pathway.

7.3 Risk Receptors

The likely risk receptors include:

- Site personnel;
- Plant and equipment;
- Third-party infrastructure (utilities/services) and buildings;
- The natural environment.

The consequences of a UXO initiation may include:

- Injuries and/or fatalities to personnel;
- Damage to plant and equipment, nearby buildings and/or infrastructure;
- Rupture and damage underground utilities/services and the natural environment.

The consequences of an unexpected and unplanned UXO discovery might include:

- Incurring delays and additional costs through the expenditure of additional risk mitigation resources and EOD clearance;
- Disruption to local community;
- Negative publicity.

7.4 Semi-Quantitative Risk Assessment

A semi-quantitative risk assessment has been undertaken and the results of the SQRA are presented at Table 4.

Activity	UXO Threat Item	Probability (SH+EM=P)	Consequence (D+PSR=C)	Risk (PxC=R)
Trial Pits	Aerial Bombs	2+2=4	3+3=6	**4x6=24**
	AXO/LSA/SAA	0+2=2	3+2=5	**2x5=10**
	AAA Projectiles	1+2=3	3+1=4	**3x4=12**
Boreholes	Aerial Bombs	2+3=5	3+2=5	**5x5=25**
	AXO/LSA/SAA	0+3=3	3+2=5	**3x5=15**
	AAA Projectiles	1+3=4	3+1=4	**4x4=16**
Excavations	Aerial Bombs	2+2=4	3+3=6	**4x6=24**
	AXO/LSA/SAA	0+2=2	3+2=5	**2x5=10**
	AAA Projectiles	1+2=3	3+1=4	**3x4=12**

Table 4: UXO SQRA Results

7.4.1 SQRA Conclusions

The SRQA has determined that the proposed intrusive works may generate, as a reasonable worst-case scenario, a ***HIGH*** level of risk at the Study Site. Such risks may pose harm to human health and damage any equipment involved in intrusive activities; the former are intolerable. Therefore, such risks will require mitigating in accordance with the ALARP principle, as per Part III of this report.

Part III: UXO Risk Mitigation Strategy

8 UXO Risk Mitigation Strategy

8.1 Strategic Overview

As per *CIRIA* C681 guidance, *6 Alpha* recommended that the identified UXO risks are reduced ALARP. Crucially, the ALARP 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 consumes disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXO risks will rarely be reduced to zero (nor need they be).

Consequently, the following proactive and reactive UXO risk mitigation measures ought to be implemented ahead of proposed intrusive operations at the Study Site in order to reduce the identified UXO risks to ALARP.

8.2 Proactive UXO Risk Mitigation Measures

The following proactive risk mitigation measures should be undertaken prior to the commencement of intrusive works:

8.2.1 Non-Intrusive UXO Survey and/or EOD Engineer in the Watching Brief Role

Where "open" intrusive works into previously undisturbed ground are proposed and where the extent is likely to be within the effective capabilities of survey equipment, a non-intrusive geophysical UXO survey should be trialed.

If the trial proves successful, a non-intrusive geophysical UXO survey should be employed either site-wide, or in specific areas where intrusive works are proposed, to identify for signs of sub-surface anomalies which may model as the threat spectrum UXO in advance of said works.

If the survey proves partially or wholly ineffective, an EOD Engineer should be present in the UXO Watching Brief role to monitor ongoing "open" intrusive works to identify any suspicious items that may be UXO related.

8.2.2 Intrusive Magnetometer 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 of 7m bgl** 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 threat spectrum UXO in advance of said works.

8.2.3 Geophysical UXO Survey Efficacy

Certain ground conditions may constrain geophysical UXO surveys, as magnetometer surveys are adversely affected by mineralised and made ground. Nonetheless, *6 Alpha* can advise the likely efficacy of such survey work in advance of their trial and implementation as and when required.

8.3 Reactive UXO Risk Mitigation Measures

The following reactive risk mitigation measures should also be undertaken for all activities in all areas:

8.3.1 Operational UXO Emergency Response Plan

A UXO-specific Emergency Response Plan 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*).

8.3.2 UXO Safety and Awareness Briefings

A UXO Safety and Awareness Briefing is recommended and is essential when there is a possibility of an explosive ordnance encounter; these briefings are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the following:

- The identification of threat spectrum UXO;
- 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 threat should also be held in the site office and displayed for general information on noticeboards - 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 appropriate health and safety standards and legislation.

8.4 ALARP Safety Sign Off Certification

ALARP safety sign-off certification provides an independent source of evidence that a Client has followed industry best practice and has successfully managed and reduced UXO risks to ALARP. Following the execution of *6 Alpha's* UXO risk mitigation measures, we can deliver ALARP safety sign-off certification, in advance of the proposed operations.

In such circumstances the project will be able to certify for the benefit of all of its stakeholders, that all reasonably practicable measures have been taken to protect contractors from UXO hazards and

that the commissioning Client will have acted in compliance with industry best practice as well as the national safety legislation.

In accordance with best practice therefore, *6 Alpha* ALARP safety sign-off certification does not imply that any site is free from UXO, rather, that the necessary and appropriate UXO risk mitigation measures have been appropriately applied to evidence that UXO risks have been reduced ALARP.

8.5 Recommended Next Steps

We recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, the detailed designs of the recommended UXO risk mitigation measures as outlined above.

Appendices



Site Location

BOMB SEARCH

LEGEND

Site Boundary



British National Grid

Address

Varley Street, Manchester, M40 8EE

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	1	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

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.

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



Site Boundary

BOMB SEARCH

LEGEND

Site Boundary



British National Grid

Address

Varley Street, Manchester, M40 8EE

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	2	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

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.

WWW.6ALPHA.COM
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



Modern Aerial Photography

BOMB SEARCH

LEGEND

Site Boundary



British National Grid

Address

Varley Street, Manchester, M40 8EE

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	3	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

Map data: Google, Airbus

Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

WWW.6ALPHA.COM
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



WWII High Explosive Bomb Density

BOMB SEARCH

LEGEND

Site Boundary

High Explosive Bomb Density

- Less than 15 bombs per 100 hectares
- 16-25 bombs per 100 hectares
- 26-35 bombs per 100 hectares
- 36-45 bombs per 100 hectares
- Over 46 bombs per 100 hectares



British National Grid

Address

Varley Street, Manchester, M40 8EE

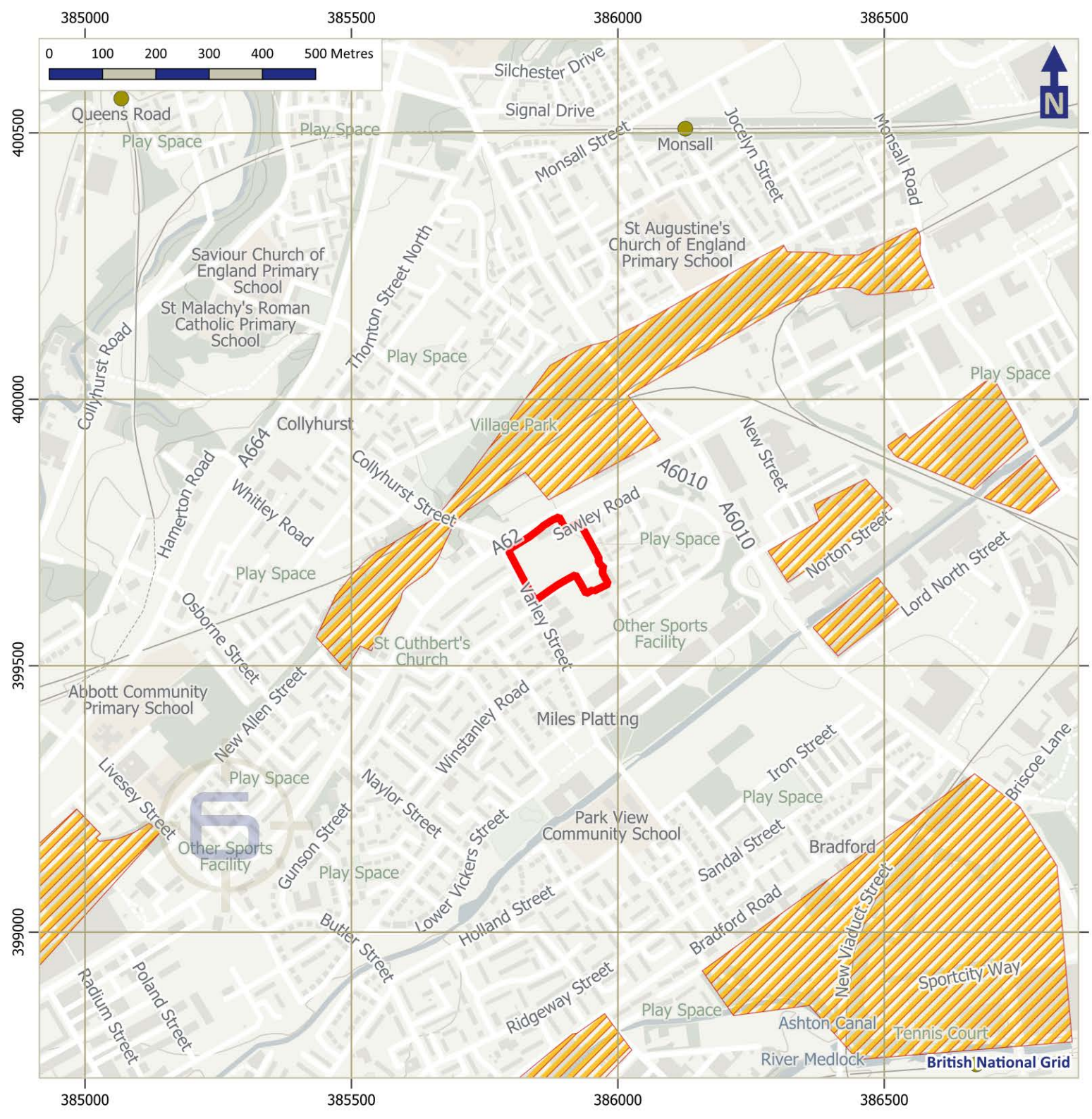
PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	4	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

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.

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



WWII Luftwaffe Bombing Targets

BOMB SEARCH

LEGEND

- Site Boundary
- Luftwaffe Target



British National Grid

Address

Varley Street, Manchester, M40 8EE

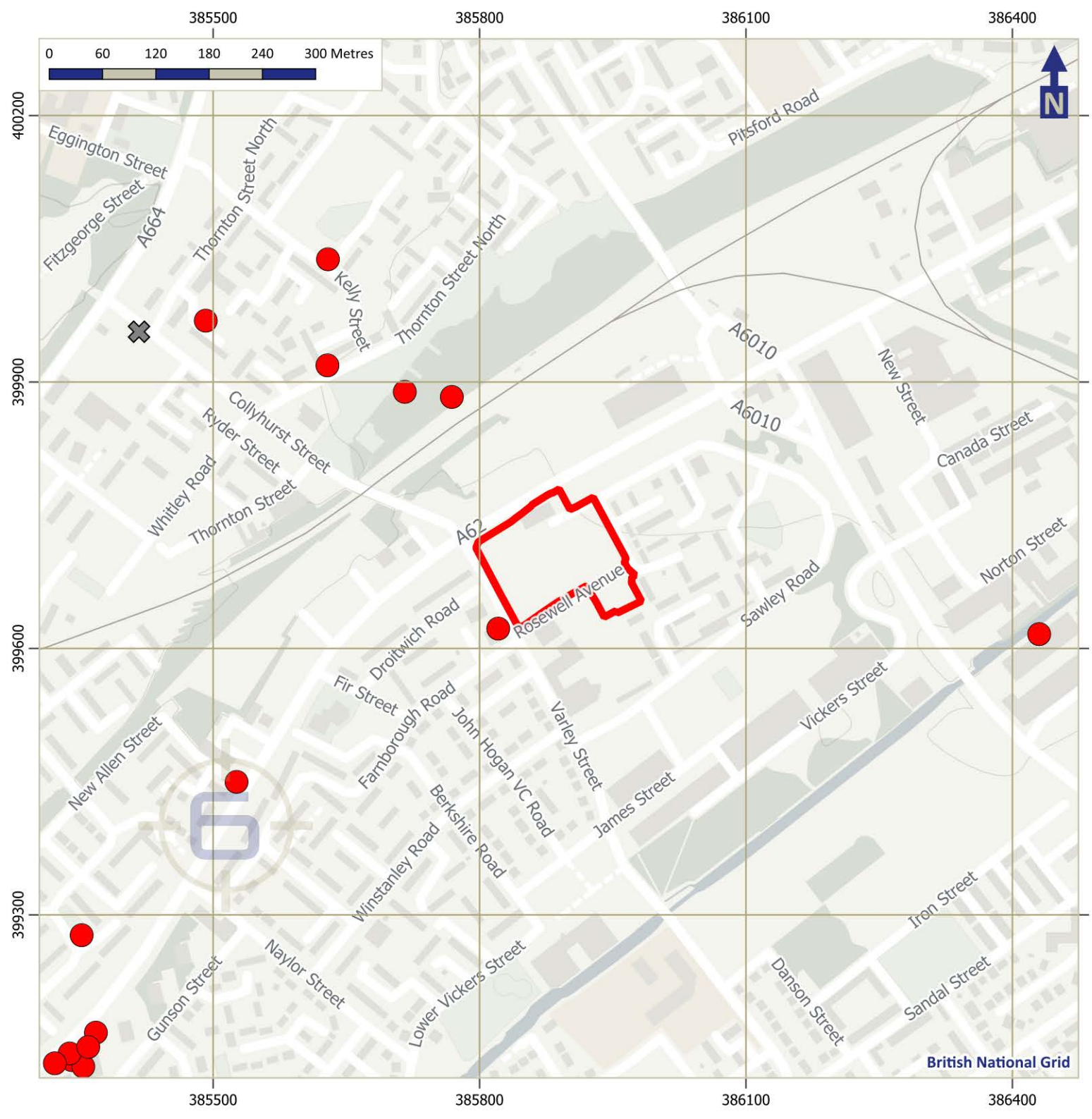
PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	5	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

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.

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



WWII Bomb Strikes

BOMB SEARCH

LEGEND

Site Boundary

Consolidated Bomb Strikes

High Explosive Bomb

Unexploded Bomb



British National Grid

Address

Varley Street, Manchester, M40 8EE

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
12087	6	DB	LG	31/07/2025

alpha ASSOCIATES
special risks consultancy

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.

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900