EXPLOSIVE ORDNANCE (EO) THREAT ASSESSMENT (EOTA)

MAYFIELD DEPOT, FAIRFIELD STREET, MANCHESTER, M1 2QF

This assessment draws together all the available information with regards to the site of concern regarding potential Explosive Ordnance (EO) Contamination. It assigns an Explosive Ordnance Threat Level and proposes an appropriate Risk Management Strategy to reduce any associated risks.

This assessment has been produced in compliance with the Construction Industry Research and Information Association guidelines (Report CIRIA 681, dated Dec 08) for the preparation of detailed Risk Assessments in the management of UXO risks in the construction industry, for which PLANIT was an instrumental driver for improved UXO risk management and transparency.

CLIENT CONTACT DETAILS

Client Company:	**Buro Happold Ltd** 2 Brewery Place Brewery Wharf LS10 1NE
Tel:	T: +44 (0)113 204 2200 DD: +44 (0)113 204 2220
POC:	George Mitchell, Ground Engineer
Email:	George.Mitchell@BuroHappold.com

OUR CONTACT DETAILS

Company:	**PLANIT UXB Limited**
Address:	PO BOX 285 Nunburnholme York YO42 9AU
Tel:	08000 588 747
Email:	help@planit-international.com

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Document Reference:	
Date of Issue:	14 July 2017
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Document Review	Name	Signature
Author Review:	Daniel WHELAN	
Peer Review:	Andrew HAMILTON	

EXECUTIVE SUMMARY

SITE DESCRIPTION

The site is located approximately 1.5km east of Manchester city centre and the Exhibition Centre, immediately south of Piccadilly Station. The site is loosely bounded by the main line railway running east to west forming the northern boundary of the site, to the west London Road runs north to south and the site's southern boundary is formed by the A635 (M) leading into Mancunian Way.

National Grid Reference for the approximate centre of the site is **SJ 851 976** and the nearest postcode is **M1 2QF**.

POTENTIAL THREAT SOURCE

The following items of explosive ordnance are thought to remain as potential threat sources to ongoing engineering operations at the site of concern:

- WW2 German air-dropped bombs – High Explosive (HE).
- British Anti-Aircraft Artillery (AAA) projectiles.

THREAT PATHWAY

For the purposes of this assessment, it has been assumed that development works would include piled foundations and excavations beyond WW2 ground levels. It is anticipated that personnel or key equipment may complete the risk pathway during excavation and/or piling operations that may bring them into physical contact with potential threat items.

KEY FINDINGS

There is incontrovertible evidence that the site of concern was directly affected by aerial bombing during WW2. The possibility that the site was affected by Anti-Aircraft Artillery projectiles returning to earth unexploded cannot be reasonably ignored.

- There is no evidence to suggest that other ordnance contamination events occurred at the site of concern.
- There are no Abandoned Bombs or UXBs recorded that would affect the site of concern directly.
- The EO Threat varies across the site of concern.

THREAT LEVEL

The following Ordnance Threat Levels apply:

Ordnance Type	Threat Level
50, 250, 500 and 1,000kg bombs, British AAA projectiles	MEDIUM

THREAT MITIGATION

Considering the findings of this assessment, a **UXO THREAT MITIGATION STRATEGY IS REQUIRED** to be in place prior to intrusive engineering works at this site of concern.

THREAT REVIEW

A review of these recommendations must be undertaken considering any additional, relevant information being provided. Such a review may, if the EO Threat Level is deemed to have altered, make alternative recommendations from those made above to implement work safely.

AIM & METHODOLOGY

The aim of this assessment is to identify any threats that may be posed by EO during the proposed engineering works at the site of concern and, where a threat is identified, to recommend a risk mitigation strategy that will reduce this threat to acceptable levels.

This assessment follows the CIRIA 681 Guidelines, which were compiled using, as a main driver of change, PLANIT's innovative approach to EO risk assessment.

The following key considerations are addressed in this assessment:

- The risk that the site of concern was contaminated by EO.
- The risk that EO remains on site.
- The risk that EO may be encountered during the proposed engineering works.
- The risk that EO may be initiated by proposed engineering works.
- The consequences of encountering or initiating EO.

If the likelihood of encountering EO is significant, information about the types and natures of that EO and the expected levels of contamination is considered within the source-pathway-receptor context of contamination. Should a confirmed pathway exist, the information enters our proprietary Threat Assessment Matrices in order to arrive at a valid and transparent Threat Level.

The Threat Level allows relevant conclusions to be made about the EO Risk at the site of concern, which in turn allows an appropriate Risk Mitigation Strategy to be developed.
The Threat Mitigation Strategy is intended to give the Client a best-fit, safe solution that will allow the level of risk from EO to be reduced to an acceptable level; providing maximum project planning flexibility.

PLANITs approach to EO threat assessment has been fundamental in driving change throughout the UK Commercial EOD Industry and was instrumental in the drafting of CIRIA 681. PLANITs approach provides transparency to our EO risk assessment process allowing the Client to make valid decisions on what is a specialist activity; empowering them to maintain control over this vital aspect of their project - Where necessary, appropriate EO risk mitigation measures will be recommended.

This assessment considers general and site-specific factors, including:

- Historical use of the site in relation to ordnance manufacturing, storage and disposal.
- Historical use of the site in relation to Military training and related facilities.
- Evidence of offensive aerial and naval bombardment during WW1 and WW2.
- Evidence of Unexploded Bombs (UXBs).
- Previous EO incidents and/or EO survey/clearance activities.
- Extent of post-war redevelopment.
- Proposed engineering works.

RELIABILITY OF HISTORICAL RECORDS

This assessment is drawn from detailed research into the available historical evidence. Every effort is made to gather all the relevant material; however, PLANIT cannot be held responsible for any changes to the assessed level of risk or proposed risk mitigation strategies due to subsequent information that may come to light at a later date.

The accuracy and detail of wartime historical records is difficult to verify, not least of which is due to the conditions under which much of this information was gathered and recorded. Additionally, recording of information was less formalised in the early days of the German air campaign against the UK mainland (Pre-Bomb Census Record) and much information recorded early on was lost during subsequent air raids. Records for rural, sparsely populated areas are not always reliable, being based on second-hand information in many cases; records of attacks on military installations was often recorded independently from general records and many such archives have been lost or remain undisclosed to the public.

Consequently, the exact location, quantity and nature of the EO threat cannot be definitive but rather remains subjective and is based on the careful analysis by experts of the available information. PLANIT cannot accept liability for any gaps in the historical record.

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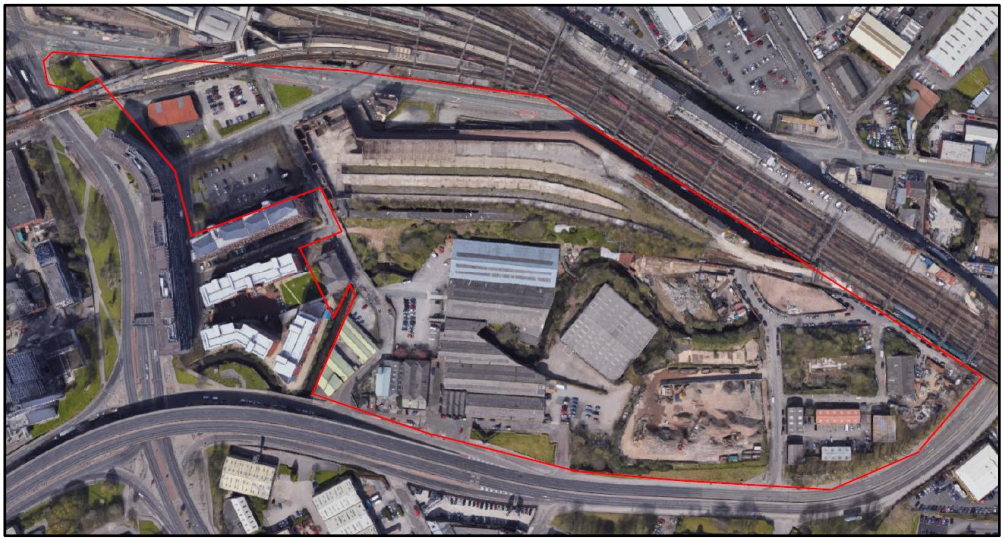
SITE LOCATION & DESCRIPTION

SITE OF CONCERN

The site is located approximately 1.5km east of Manchester city centre and the Exhibition Centre, immediately south of Piccadilly Station. The site is loosely bounded by the main line railway running east to west forming the northern boundary of the site, to the west London Road runs north to south and the site's southern boundary is formed by the A635 (M) leading into Mancunian Way.

National Grid Reference for the approximate centre of the site is SJ 851 976 and the nearest postcode is M1 2QF.



The site is dominated by a multitude of large, multi-storey industrial buildings with large areas of hard standing for vehicle manoeuvre, parking and material storage associated with the Goods Yard supporting Piccadilly Station. Small, isolated areas of scrub/ grass with shrubs and small trees are dotted across the site area.

Maps showing the site location and layout are at Annex A.

SCOPE OF PROPOSED WORKS

The details of the proposed development are unknown at the time of writing this assessment.

For the purposes of this assessment, it has been assumed that development works could include intrusive engineering beyond WW2 ground levels. It is anticipated that personnel or key equipment may complete the risk pathway during excavation and/or piling operations that may bring them into physical contact with potential threat items.

GEOLOGICAL ENVIRONMENT

The available geological information (Ref 2) shows the site to be underlain by superficial deposits in the form of Late Glacial Flood Gravels. This masks the solid geology beneath the site which comprises the Bunter Sandstone strata of the Triassic Period.

According to the, "Factual Ground Investigation and test report for redevelopment of land to the south of Manchester Piccadilly Railway Station, Manchester", by Buro Happold, dated 8 Oct 09, the specific ground conditions are:

Strata	Depth (m)	Thickness (m)
Made Ground: Turf on gravelly sand with cobbles, brick and concrete. Tarmac in places over concerete.	0.80	0.80
Soft to firm very sandy gravelly friable clay.	1.90	1.30
Orange brown silty fine to medium sand.	3.20	Not proven

REVIEW OF RELEVANT DATASETS

SOURCES OF INFORMATION

PLANIT ensures that Explosive Ordnance Risk Assessments (EORAs) are as comprehensive as possible and detailed research is undertaken to collate all the available EO-related information that relates to the site of concern. Information sources may include, but are not restricted to:

- National Historic Archives.
- Local Authority & Council Archives.
- English Heritage National Monuments Record.
- Ministry of Defence Archives.
- PLANITs extensive archives drawn from many years of detailed research and operational experience of UXO Risk Management activities in the UK and abroad.
- Joint Service EOD Centre (JSEOD).
- Historic Mapping and Aerial Photography.
- Specific UXO-related documents such as military bombing and casualty records.
- Local libraries and history groups.
- Open sources such as published books and internet searches.
- Anecdotal evidence from eye witnesses.

NB: The MoD information office that deals with requests for information relevant to EO clearance operations completed by the MoD is currently facing significant delays. Although a request has been submitted, any information that may be relevant has not yet been forwarded for timely inclusion in this assessment. However, if any relevant information comes to light from this source that affects the threat assessment, this will be notified to the client as a matter of urgency.

SITE HISTORY

Up to **1905**, the site was occupied by what appear to be residential houses but by **1923** they have been cleared to make way for Mayfield Station which is now dominating the northern part of the site. The site layout is constant until the map record of **1956,** which shows cleared areas more than likely because of bomb damage during WW2. Mayfield Station itself has been reduced by half and there are other clear areas of bob damage across large areas of the site. There is also a notable addition to the site area in this map sheet which is the addition of a large structure, built immediately post-War, in the centre of the site.

By **1968**, Mayfield Goods Station has been fully restored and other previously cleared areas of the site have been redeveloped. This work appears to be complete with the addition of some small buildings to the western edge of the site area by **1985**. This site layout remains constant until at least **2010** but by **2013**, the Goods Station roof has been removed.

ORDNANCE MANUFACTURE & STORAGE

During WW1 and WW2, Lincolnshire housed many facilities involved in the manufacture, storage, filling and testing ordnance. The nearest explosive manufacturing sites (known as His Majesty's Explosive Filling Factories (HMEFs)) were:

	• Trafford Park (HMEF). • Hyde Road, Gorton, Manchester (National Shell Factory – manufacturing 4.5" shell (projectile) casings). The nearest Royal Ordnance Facilities (ROFs) established in the run up to WW2 were: • ROF Chorley. • ROF Radway Green. None of these sites would have posed a potential threat to the site of concern.
MILITARY HISTORY	There is no evidence to indicate that the site was ever used for military purposes.
CIVIL DEFENCE	Manchester possessed a peak of 56 Heavy Anti-Aircraft Batteries during WW2, including 4.5, 3.7 and 3-inch Anti-Aircraft (AA) guns, sited in some 70 separate locations. None of these were sited on or near to the site of concern to have created a direct source of potential ordnance contamination. Due to the relatively high failure rate of Anti-Aircraft Ammunition (AAA) during this time, there remains the possibility that such ordnance fell back to earth creating additional UXO hazards. This type of ordnance had the potential to penetrate the ground to significant depths and cannot be entirely discounted as a potential threat source although its potential presence is impossible to determine with any quantifiable degree of certainty. As would be expected, Manchester had several Civil Defence ('Starfish') sites designed to protect London from aerial attack. Manchester's Starfish Sites were located at: • Chat Moss. • Tatton Park. • Park Moor (now in Lyme Park Country Park). • Churnal Moor. • Mossley. • Carrington Moss. • Ludworth Moor. • Reddish. • Elkstone (north Staffordshire). None of these sites would indicate the possibility that erroneous Luftwaffe bombing would have produced a consequent UXO risk on the site of concern.
WW1	Greater Manchester suffered two aerial bombardments during WW1; on 26 Sep 1916 Zeppelin L21 dropped 20 HE bombs on Bolton, mistaking the town for Derby. Significant damage was caused and 13 people were killed. On 12 Apr 1918 Zeppelin L61 bombed Wigan at 2300hrs in a raid that lasted some 12 minutes. Three people were killed and a further nine were injured during the raid. Neither of these raids would have affected the Site of concern and therefore the risk from WW1 unexploded ordnance is negligible.
WW2	During WWII, the site sat close to several industrial and strategic installations key to the war effort that were located in the area – including Mills, Quarries and Railway infrastructure. Luftwaffe target maps do not list specific locations on or close to the site although the concept of specific targets, when bombing in and around Manchester, was only relevant prior to the accidental Luftwaffe raid on London on 24th Aug 1940. This attack broke the unofficial agreement not to bomb opposing capitals and led to the gradual breakdown of the Amsterdam draft international rules prohibiting the attacking of civilian infrastructure outside of combat zones

(purely industrial areas); Great Britain, including Manchester, was now opened to air attacks. As well as the air raids targeting Manchester itself, unused bombs were routinely jettisoned whilst returning to base following an unsuccessful raid. In addition, the high-altitude area bombing during this period was notoriously inaccurate with areas surrounding specific targets suffering during attacks on the targets themselves.

The site in question sits in the middle of the main areas within Manchester that were targeted, mostly during the 'Manchester Blitz' of Dec 22-24 1940 - Salford Docks, Manchester's industrial centre and Trafford Park (with the areas surrounding them also being affected by the same air raids). Many Manchester companies were involved in war production work including the Fairey Aviation plant at Ringway, the Ferranti factory at Hollingwood, Metropolitan Vickers works at Trafford Park and the A.V. Roe (Avro) plant at Chadderton. In addition, Ford operated a factory in Eccles building Rolls Royce Merlin engines for the Lancaster bomber and the Mosquito fighter bomber.

The Luftwaffe mounted consecutive heavy attacks on the Manchester area on the nights of 22/23rd and 23/24th Dec 1940. Large areas of Manchester, Salford and Stretford were devastated, killing some 684 people and injuring a further 2,364. The first raid of this 'Manchester Blitz' saw 272 tons of HE bombs and 1, 023 canisters of Incendiary Bombs (IBs) dropped. During the second raid, 171 aircraft dropped a further 195 tons of HE bombs and 893 canisters of IBs.

The site is in Region 10 (Manchester) for Civil Defence purposes. Manchester received some 3, 465 Tonnes of HE bombs throughout the war although Cheshire and Chester were much less affected:

Ordnance Type	Number of Bombs		
	Region 10	Cheshire	Chester Rural District
50Kg HE	1403 (79)* + 576 (1)**	594 (25)	1
250Kg HE	727 (49) + 368	301 (19)	13
500Kg HE	114 (7) + 57 (3)	58 (6)	10 (1)
1000Kg HE	2 (2) + 6	1 (1)	
Parachute Mine	514 (77) + 592	139 (16)	
V1 'Doodlebug'	14	6	1
V2 Long Range Rocket	0		
Small Incendiary Bombs	25 454	3 639	
50Kg Phosphorus Bomb	Unknown		
Fire Pots	Unknown		
Oil Bomb	212 (4) + 202	48 (1)	
Containers	Unknown		
Unclassified Ordnance	8 114 (1 341) + 10 658	2 806 (524)	

The bombs recorded as falling on the County Borough of Manchester are summarised below:

Area Acreage	27, 255
High explosive Bombs (All Types)	712
Parachute Mines	18
Oil Bombs	7
Phosphorus Bombs	-
V1 'Doodlbug'	1
Total	738
Items per 1000 acres	27.1

UNEXPLODED BOMBS (UXBs)

Between 1940 and 1945, Bomb Disposal (BD) Teams cleared over 50,000 items of German air-dropped ordnance of 50Kg or larger, 7 000 anti-aircraft (AA) projectiles and more than 30 000 beach mines – This work claimed the lives of 394 Officer's and men. The War Office at the time stated that over 200 000 HE bombs exploded in

Britain during WW2 with some 25 195 remaining a threat as UXBs i.e. 11%. Some 93% of all UXBs were 50Kg HE and 250Kg HE aerial bombs.

The types of ordnance discovered as UXBs give an indicator of the type of ordnance that may be encountered on or near the site of concern. In this instance, there are no records of UXBs that may present a threat to the site.

ABANDONED BOMBS

A post-air raid search of damaged buildings and facilities would have included a specific search for bomb entry holes. If such evidence was discovered, then BD Teams would have been tasked (in order of strict priority from Category A, the highest priority, to category D, the lowest) to assess the potential UXB and to recommend a course of action. For UXBs that were deemed to be a high enough priority were tackled by the BD Teams who made strenuous efforts to recover and dispose of these items. However, it was not always possible to recover such bombs either through physical constraints, a lack of resources or a change in priority. Such UXBs were noted as 'Abandoned'.

Due to the low priority of abandoned bombs, records that detail them are sketchy and sometimes contradictory. Others were subsequently recovered after the War when time and resources permitted and others remain 'abandoned'. It is worth remembering that 'abandoned' bombs may also include suspected UXBs that were reported but not confirmed, but simply efforts to locate the 'bomb' were exhausted.

The Abandoned Bombs recorded near the site are:

Reference/ Location	Item
CD 49.3822 – Fields 600yds SE of Grove Farm, Chorlton by Beckford.	1 x AA Shell
CD 53.3825 – Fiels near rear of Gun Site Acres Lane, Upton Heath.	1 x AA Shell
CD 56.3826 – Staok Grange Farm, Little Stanney.	1 x AA Shell
CD 84.3843 – Wood Farm, Grove Road, Mollington, 500yds W of Lee Holme.	1 x AA Shell
CD 82.3842 – 50yds W of Dunkirk Lane, Capenhurst Hall Park Farm, Capenhurst.	1 x AA Shell
CD 81.3841 – 100yds S of Pitts farm, Woodbank, Shotwick.	1 x AA Shell
CD 59.3827 – Shotwick Park, S of No. 9/10 Holding Arterial Road.	1 x AA Shell

None of these are considered to present a potential UXO-related threat.

BOMB CENSUS MAPS

Manchester's Bomb Census Records are comprehensive and indicate that several large, air-dropped bomb fell within the site itself with further bomb being suggested by the large-scale building clearances in the east of the site (See Annex C). Mayfield station directly suffered the effects of bombing during World War II, when it was hit by a parachute mine on 22 December 1940.

The relevant Bomb Census Map extract is at Annex B.

HISTORICAL STREEP MAPS

Historical street plans of the period are a useful indicator of whether an area may have suffered bomb damage. The street layout prior to WW2 is the 'start state' and major changes to street layouts or building boundaries may indicate that the change was due to bomb damage. In this instance, there are some significant changes to the street layout that probably indicate bomb damage within the site boundary and there is clear bomb damage in the wider area surrounding the site. Mayfield Station itself and the building complex immediately to the south have received direct bomb/ parachute mine strikes.

The relevant Historical Street Plans are at Annex C.

HISTORICAL AERIAL PHOTOGRAPHY	The same rational applies with historic aerial photography as it does when examining historical street plans – changes between pre-war and post-war images may indicate the possibility of damage caused by bombs falling on the site. Sometimes, detail is such that it allows bomb damage to be seen directly on sites of concern. In this instance, historical aerial photography from the period is not available and therefore no comparisons can be made.

THREAT ANALYSIS	
IS THERE EVIDENCE THAT THE SITE WAS AFFECTED BY ANY EXPLOSIVE ORDNANCE CONTAMINATION EVENTS?	Yes. The historical record is acknowledged as being incomplete from a National perspective but there is clear evidence within the relevant extract from the Manchester Bomb Census Maps that the site of concern was directly affected by bombing during WW2; which included large air-dropped bombs and parachute mines and/or British anti-aircraft artillery falling back to earth as UXBs. Not much of the site area escaped unscathed, and there is clear evidence that the site did receive direct bomb strikes as well as widespread bomb blast damage. The bomb damage would have been significant and the possibility that another bomb fell on the same area and remained underground, undiscovered as a UXB must be considered plausible. It was also a common error to mistake the havoc wreaked by a large bomb falling through built structures unexploded, which is considerable, with a smaller bomb detonating as intended.
IF ENCOUNTERED, WHAT ORDNANCE TYPES ARE ANTICIPATED?	There is explicit evidence that the site received a number direct hits from large, air-dropped bombs/ parachute mines during WW2. Parachute mines, due to their nature, would have remained on the surface if unexploded and would have been dealt with at the time and can therefore be discounted as potential threat items today. There is no explicit evidence that the site directly received Anti-Personnel or incendiary bomb strikes. Whether the area received AAA returning to earth unexploded is impossible to answer but it would be prudent to accept the worst-case scenario in this case and accept that they probably did. The site is not known to have been used for ordnance manufacture or storage and neither was it a former Military installation. So, we can discount the possibility that the site was contaminated by ad hoc military activity. The type and degree of post-War redevelopment is significant in that it would reduce the encounter potential for smaller items of ordnance such as anti-personnel bombs or AAA projectiles to such a degree across the site that this potential threat source may effectively be discounted. This would not be the case for areas of the site that have not been significantly redeveloped since the end of the War or within ground volumes that have remained undisturbed by intrusive engineering since this time. The following potential threat items may remain under the site within 'at risk' ground volumes: • Large, air-dropped, German HE Bombs including 50, 250, 500kg bombs (of WW2 vintage). • British AAA projectiles.
WHAT IS THE EXPLOSIVE ORDNANCE / UXB ENCOUNTER DEPTH?	Ministry of Homeland Defence Security Bomb Penetration Studies. A major study was completed by the Ministry of Homeland Security during WW2, during which the penetration depths of 1328 air-dropped bombs (as reported by the BD Sections of the day and mostly in the Birmingham area). It was concluded, not surprisingly, that the penetration depths of different sized bombs varied according to the geology into which they fell. The average penetration depth of 430 x 50Kg HE bombs in London Clay was found to be 4.6m and that for a 250Kg bomb 6.1m. Also, they concluded that a 500Kg bomb, the largest common bomb dropped during the War, had a likely penetration depth of 6m in sand and 8.7m in clay – the maximum observed for a 500Kg was

10.2m and for a 1000Kg bomb was 12.7m. It should be remembered that these depths were achieved unencumbered by obstacles to penetration such as buildings, concrete and brickwork.

The 'J' Curve. The 'J-curve' describes the path of a bomb (dropped from a normal altitude of about 5 000m) into homogenous ground will continue its line of flight (unless deflected by a substantial obstacle) but then turn upwards towards the surface before it stops. The horizontal distance (the 'offset') between the point of entry and final resting position was typically 1/3 of the ultimate penetration depth for a bomb. Therefore, if a bomb fell close to the exterior of a building or site and did not explode, the path that the bomb subsequently travelled beneath the ground, the "J-Curve", may have delivered it beneath the building or site footprint. The J-curve is often misunderstood, and used to describe the path taken by a bomb dropped from low flying aircraft to which it should not be applied.

The final penetration depth of an air-dropped depends upon several factors; the velocity of the bomb (as a function of the mass, speed) – PLANIT uses a standard velocity of 267m/s for assessment purposes – the angle of penetration of the bomb and the physical features through which the bomb travelled prior to impact with the ground and the geology of the ground into which it entered - Generally, the softer the ground, the deeper the expected penetration depth of the bomb. Peat, alluvium and soft clays are easier to penetrate than gravels and sand and water content plays a part. In addition, it must be remembered that 'barrier geology' such as very dense gravels or bedrock i.e. geology dense enough to stop the progress of a bomb underground, is an important factor in determining the median bomb penetration depth.

Given the ground cover at the time that the bombs fell, the anticipated geology and accepting the norm for the impact angle and velocity of a large UXB, it is reasonable to assume the norm when considering the potential Bomb Penetration Depth (BDP). Therefore, it is estimated that the average penetration depths of Explosive Ordnance (EO) at this site would be:

- British AAA projectiles – 2m
- 50kg HE – 4m
- 250kg HE – 6m
- 500kg HE – 8m
- 1000kg HE – 10m

HOW COULD AN UNCONTROLLED DETONATION BE BROUGHT ABOUT?

Unexploded Bombs rarely spontaneously explode (although some incidents claim to contradict this statement). High Explosive (HE) requires a great deal of energy to create the necessary conditions for detonation to occur. In the case of WWII German bombs being disturbed during intrusive ground works, there are many scenarios to be considered:

- **Direct impact onto the main body of the bomb**. Although this is a possibility, there is little chance of generating enough energy to detonate the explosive fill unless the fuse itself is directly struck.

- **Re-starting the mechanical clock-timer in a bomb fuse**. This is a possibility. It is probable that environmental conditions have corroded the fuse sufficiently to prevent clockwork mechanisms from functioning. However, under some conditions, fuse elements will be in a good condition and additional movement of a bomb fuse may be sufficient to restart a previously 'jammed' mechanical clockwork mechanism.

- **Induction of a static charge, creating a sufficient current to initiate an electric fuse**. This is an unlikely event. Environmental conditions are likely to have corroded the fuse, degrading its components sufficiently to prevent them from functioning. Any elements of the fuse capable of holding a charge would have dissipated in the time since the bomb failed to function.

- **Friction impact initiating fuse elements causing bombs to detonate**. Although remote, this is the most likely scenario that may result in a bomb detonating. Weathering within the fuse pocket can cause the explosives within the fuse to breakdown, crystallize and exude from the fuse itself. Violent physical disturbance of this exuded material carries the remote possibility of initiating the fuse mechanism which in turn will initiate the bomb.

WHAT WOULD THE EFFECTS OF SUCH A DETONATION BE TO THE SITE?

The effects of WWII German bombs detonating have been the subject of several well recorded studies. The general effect of an explosive detonation will depend upon:

- The size of the bomb and its Net Explosive Quantity (NEQ) (i.e. how much explosive material it contains).
- The type of fill in the bomb (i.e. high explosive, incendiary, photoflash).
- The physical location of the bomb. Whether it is:
    - On the surface.
    - Partially buried.
    - Buried (A bomb is 'buried' when it is more than 2½ times its own length below ground level and covered).
- The locations of the bomb in relation to other structures.
- The strength and design of structures near to the seat of an explosion.
- The nature of the ground (i.e. sand, gravel, clay, marsh etc).
- The location of the bomb in relation to human and animal populations.

There would be the potential for ground shock to damage important underground structures including sewers, communication cables, and foundations.

The potential Damage Radii to various underground structures has been assessed by extrapolating from the Joint Service Publication 364 which is the MOD Manual for assessing bomb damage. Potential damage radii for underground structures are assessed as:

Structure	Dist (m)
Brick Walls	30
Foundations	60
Cast Iron/ Concrete Pipes	15
Earthenware/ brisk Sewers	25
Electric Cables/ Steel Pipes	12

WOULD THE SITE CONDITIONS AFFECT THE BOMB FAILURE RATE?

There is no evidence to suggest that bomb failure rate at the site of concern would have been any different from that routinely experienced, i.e. 10-15% of all bombs dropped.

WOULD UXBs HAVE BEEN DISCOVERED DURING WW2?

Density of Bombing. Manchester received a high density of bombing in WW2, and the site sits within the focus of those attacks. We know that the site itself received direct bomb/ mine strikes which caused significant damage. This factor would have made data gathering at the time more complicated and the likelihood of overlooking UXBs higher.

Frequency of Access. Since the site was occupied and used at the time of the air raids, the site of concern would have been subject to post-air raid survey and clearance. The fact that the site itself was affected by bombing, and given its key industrial role, any post-raid survey activities would have been thorough. This would have made the likelihood of identifying smaller items of EO (such as Incendiaries and AP bomblets) quite high whilst larger UXBs would have been more readily identified. However, entry holes and UXBs could easily have been overlooked due to their diminutive size, or gone unnoticed if they fell into water.

Ground Cover. The site was industrial in nature at the time of the attacks and as such it's physical characteristics would act to retard the progress of UXBs underground by reducing their overall velocity prior to impact. However, bomb penetration statistics were collected at the time in similar conditions and therefore the

	maximum potential bomb penetration depths must be considered as the 'worst case'. This is also true of bombs falling into water. Peripheral Bomb Damage. We know that the site of concern was subject to serious bomb damage during the War. This increases the possibility of post-air raid operations failing to identify entry holes of potential UXBs.
DOES THE SITE'S DEVELOPMENT HISTORY AFFECT THE POTENTIAL FOR UXO ENCOUNTER?	Yes. The fact that there has been a degree of post-War development at the site is worthy of note in that any potential contamination from shallow EO (i.e. AP bombs and IBs) would likely have been discovered during these works and dealt with at the time. Apart from the renovation of the Station with the notable exception of the new structure which appeared in the centre of the site by 1956 (foundation design unknown), much of the site within which the bombs are recorded as falling have seen little redevelopment ibn terms of large, industrial buildings since the end of the War. In areas where redevelopment has not been significant, the potential for UXO encounter as it did immediately post-War. For other areas, it is worth remembering that development either immediately post-War or in the 1960/ 70/ 80s would not have taken any account of the potential for UXBs at the site of concern nor would any effective technology be available to detect such potential threat items. Modern structures tend to have foundation designs that go deeper than historic buildings and risk encountering UXBs at depths beyond existing historic foundation levels or within historic foundation structures that were not detected by excavation or historical bomb survey. Ground volumes between that which has been redeveloped significantly post-War down the maximum anticipated bomb penetration depth (BPD) must be considered potentially at risk from large, deep buried, air-dropped bombs or large Anti-Aircraft Artillery (AAA) Projectiles. If future engineering is to impact on these ground volumes the potential for UXO encounter in this area remains as it did immediately post-War.
DOES THE UXO THREAT VARY ACROSS THE SITE?	Yes. Volumes of ground across the site that have already been subjected to extensive redevelopment involving the displacement of earth, may be considered free from the threat of UXO/EO *within the volumes of ground excavated/disturbed*. The same cannot be said of areas of the site that have not been subjected to the same degree of physical disturbance. Areas of the site that have been subjected to historical piling *cannot be automatically considered to be free from the threat of UXO/ EO within the volumes occupied by the piling layout although the threat is significantly reduced* – there is a possibility that historical piles have either missed UXBs at depth or pushed these items aside without incident when they were emplaced. Further, the volume of ground below such piled areas cannot be considered free from the threat of UXO/ EO down to the maximum BPD. Volumes of post-War made ground may be considered free from the threat of UXO/EO also, unless a cross-contamination event has occurred, which would be almost impossible to ascertain.

THREAT ASSESSMENT

POTENTIAL EXPLOSIVE ORDNANCE THREAT ITEMS

The following items are considered to remain under the site as potential threat items:

- Large, air-dropped, German HE Bombs including 50, 250, 500kg bombs (of WW2 vintage).
- British AAA projectiles.

CURRENT EXPLOSIVE ORDNANCE THREAT LEVELS

The Ordnance Threat Levels for the site of concern from the Threat Assessment Matrices are assessed as:

Ordnance Type	Threat Level
50, 250, 500 and 1,000kg bombs, British AAA projectiles	MEDIUM

ENGINEERING WORKS

Intrusive Site Investigation, piled foundations, bulk excavations etc.

RISK PATHWAY

For the purposes of this assessment, it has been assumed that development works could include excavations and/or intrusive engineering beyond WW2 ground levels. It is anticipated that personnel or key equipment may complete the risk pathway during excavation and/or piling operations that may bring them into physical contact with potential threat items.

WHAT ARE THE CONSEQUENCES OF AN UNCONTROLLED DETONATION?

The consequences of the uncontrolled detonation of any of the items of ordnance listed above are:

Asset	Consequence
People	Lost Time Injury >7 Days
Plant	Unit Level Damage
Property	Major Wider Damage
Environmental	Major Effect

THREAT MATRICES

ORDNANCE CATEGORY

The 'Ordnance Category' is assessed for the different types of ordnance in terms of the 'Damage Radii' that may result were the ordnance subject to an uncontrolled explosion and is a function of the calibre of the ordnance and whether it is encountered on the 'surface' or 'buried'.

Ordnance Category	Ordnance Category Description	Danger Radii (m)	Potential Threat Item
0	No Explosive Ordnance (EO) suspected to be present	NA	NA
1	Landmines, Anti-Personnel, HE; HE in Bulk <5Kg; Pyrotechnics	< 75	NA
2	Projectiles, HE <75mm calibre; Projectiles, Mortar, HE 50mm to < 75mm calibre; Grenades, Hand, HE; Grenades, Rifle, HE.	< 100	NA
3	Projectiles, HE < 125mm calibre; Rockets, HE, Anti-Tank (HEAT); Bombs PIAT, HE; Arial Bombs, HE, 50-250Kg (Surface & Buried); Aerial Bombs, Blast, HE & Sea Mines 20-250Kg; Aerial Bomb, HE, 250-500Kg (Buried)	< 250	British AAA 50kg HE Bombs
4	Bombs, Mortar, HE <105mm calibre; Bombs, Mortar, Spigot, HE; Landmines, Anti-Tank, HE; Aerial Bombs, HE, 250-500Kg (Surface)	< 300	250-500kg HE Bombs
5	Projectile, HE > 125mm calibre; Aerial Bombs, HE, 1500-2500Kg (Surface); Aerial Bomb, Blast, HE & Sea Mines 500-1500Kg (Surface)	< 500	NA
6	Aerial Bombs, HE, 2000-10000Kg (Buried); Aerial Bombs, Blast, HE & Sea Mines 1500-4000Kg (Surface)	< 800	NA

ORDNANCE THREAT

This table assigns the 'Ordnance Threat', which is a function of the Ordnance Category and the anticipated encounter depth. i.e. the smaller and deeper the ordnance the less threat is present to people and property at the surface.

	ORDNANCE CATEGORY						Depth of Encounter (m)
0	1	2	3	4	5	6	
	ORDNANCE THREAT						
							>10
				250-500kg Bomb			5<10
			50kg Bomb				2.5<5
			British AAA				0.5<2.5
							0<0.5
							Surface

ORDNANCE THREAT LEVEL

The 'Ordnance Threat Level' is arrived at by comparing the 'Ordnance Risk' with the 'Likelihood of Encounter' of a ordnance as a function of the level of expected ordnance contamination of a given type at a site of concern.

Ordnance Threat	ASSETS AFFECTED				LIKELIHOOD OF ENCOUNTER				
	People	Plant	Property	Environ ment	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
	First aid injury	Slight damage	Slight damage	Slight Effect					
	Medical injury	Item repair	Minor damage	Minor Effect					
	Lost time <7 days	Item write off	Major damage	Local Effect					
British AAA, 50-500kg Bomb	Lost time injury >7 days	Unit level damage	Major wider damage	Major Effect	British AAA, 50-500kg Bomb				
	Fatality	Multiple damage	Catastrophe	Massive Effect					

ORDNANCE THREAT LEVEL		
No special measures required	NEGLIGIBLE	
Monitor & manage potential risks	LOW	
Review & emplace strict control measures if necessary	MEDIUM	X
Control measures required to mitigate risks to acceptable levels	HIGH	
Intolerable Risk Level. Immediate control measures prior to any further works	EXTREME	

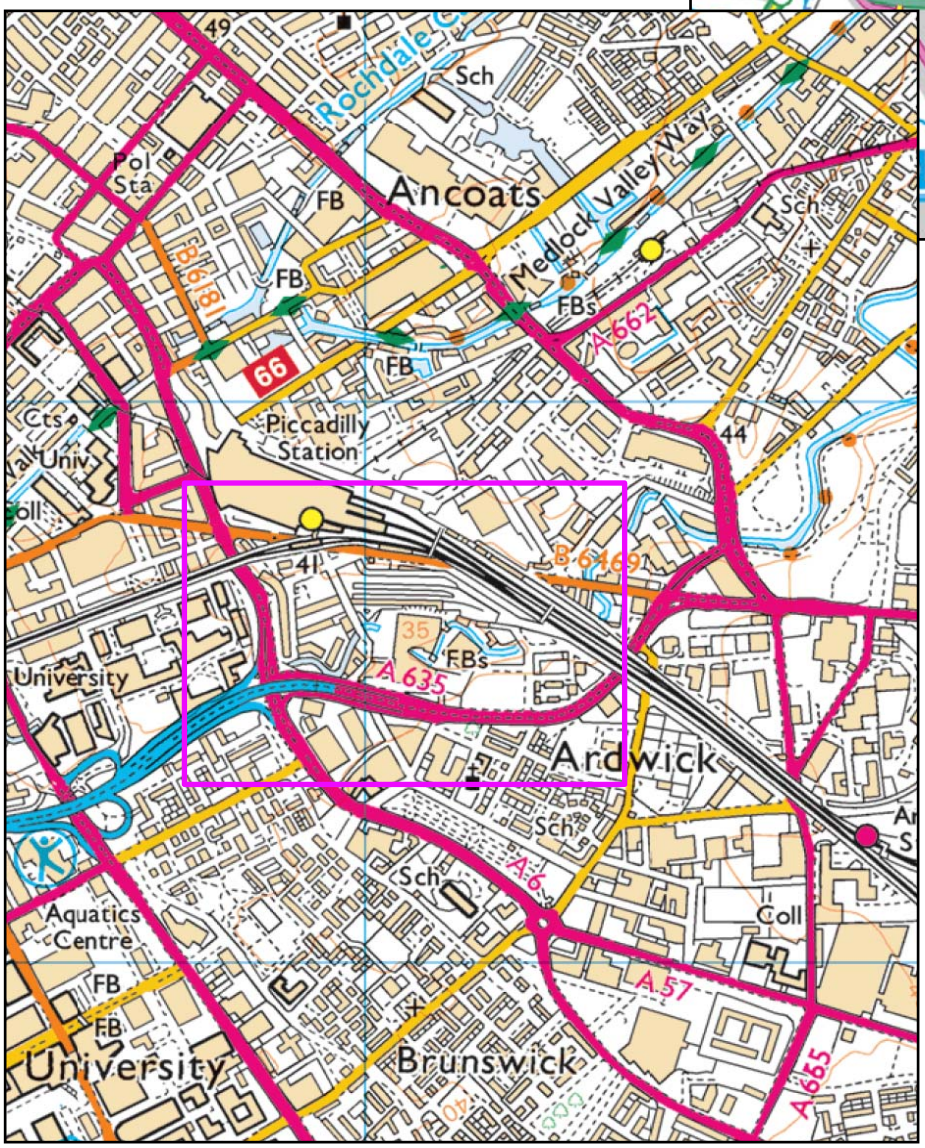
THREAT MITIGATION		
ACTIVITY	THREAT MITIGATION MEASURES	FINAL THREAT LEVEL
All Activities	If planned engineering works are going to enter potentially 'at risk' ground volumes, then a threat management strategy **IS REQUIRED** to be in place prior to intrusive engineering works at the site of concern. **Explosive Ordnance Safety Awareness Briefings.** An explosive ordnance Safety Briefing should be included as part of routine site health and safety training and form a key element of the Site Health & Safety Plan. This should be conducted by a trained specialist and would assist conformance with the CDM Regulations 2007. The briefing will instruct all personnel on the identification of EO hazards, actions to take in the event of an EO incident to protect personnel, key equipment, property and the public. **Explosive Ordnance Site Safety Instructions.** Explosive Ordnance Site Safety Instructions should be drafted for inclusion in the site-specific health and safety manual and would include information on dealing with an EO incident safely and appropriately. These instructions would form part of the permanent site documentation and will be an aide memoire for identifying potential EO hazards, making a preliminary threat assessment as well as specific guidelines on what to do in the event of a confirmed incident.	AS LOW AS REASONABLY PRACTICABLE (ALARP)
SITE INVESTIGATION WORKS	Site investigation works should be supported by UXO survey as appropriate. Consideration should be given to whether the works are shallow or deep from the perspective of UXO Survey. 'Shallow' Survey is survey of the ground from 0.0m bgl to 6.5m bgl and 'Deep' UXO Survey is that beyond 6.5mbgl. • **Boreholes.** PLANIT can conduct a non-intrusive survey of a 5m x 5m box which will accurately allow your borehole to proceed into a volume of ground under which there are no ferrous obstructions. Several locations may be provided within a survey box, allowing maximum flexibility for positioning and preventing any boreholes being terminated because of encountering a potential threat item at depth. • **Trial Pits.** Using shallow non-intrusive survey, the area for your trial pit can quickly be surveyed and confirmed as free from ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle. • **Window Sampling.** Using shallow non-intrusive survey, the area for your window sample can quickly be surveyed and confirmed as free from ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle.	AS LOW AS REASONABLY PRACTICABLE (ALARP)

SHALLOW INTRUSIVE ENGINEERING WORKS	Where 'shallow' engineering may complete the risk-receptor pathway, there are two options available to effectively deal with the EO Threat when conducting shallow intrusive ground works. On-Site UXO Support. On-site UXO Support for shallow ground works would involve the presence of an appropriately trained and experienced UXO Technician during this phase of construction. The role of the UXO Technician is to: • Conduct EO Safety Awareness Briefings as required. • Monitor all intrusive ground works using visual and instrument aided means to locate any EO that may be uncovered during site works. • Provide an immediate and expert assessment of any EO that may be discovered. • Assist in implementing an appropriate and safe response to an EO incident. • Design and emplace protective works as an immediate response to protect personnel, key equipment, property and the public as may be required. • Advise on best safe working practice considering the perceived EO Threat. • Act as the liaison with the Authorities on behalf of the Client in the event of an EO incident. Shallow Non-Intrusive UXO Survey. PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (if ground conditions permit) to identify potential EO Threat Items. Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the site of concern since all EO Threats would have been identified and dealt with.	AS LOW AS REASONABLY PRACTICABLE (ALARP)
DEEP INTRUSIVE ENGINEERING	There are a few options available to effectively deal with potential EO Threats when conducting deep intrusive ground works. Which approach is applicable will depend upon the ground conditions of the site of concern: Deep Non-Intrusive UXO Survey. PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (if ground conditions permit) in order to identify potential EO Threat Items at depth – UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower. As a benchmark, PLANITs Deep Non-Intrusive Survey is capable of identifying a 500Kg HE bomb to some 8.0m bgl in average ground and larger bombs deeper. This approach is ideal for covering large areas quickly and can be employed to survey piling runs and borehole locations. Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the site of concern since all EO Threats would have been identified and dealt with. Magcone UXB Survey. PLANIT can deploy world class Magcone Survey Systems to survey either pile locations or small areas ahead of intrusive	AS LOW AS REASONABLY PRACTICABLE (ALARP)

	engineering including piling and drilling. The Magcone system is very versatile and can survey to great depths if required. Down-Hole Magnetometer UXO Survey. PLANIT can deploy down-borehole UXO Survey equipment that will clear ahead of a piling or borehole rig as it descends underground. The main drawbacks of this approach are that it is time consuming, 'blind' (insofar as the borehole may proceed for some depth before a potential threat item is identified, at which stage the borehole will have to be terminated and relocated, wasting time and money), equipment heavy and expensive. Any anomalies identified during this survey that may be EO should either be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them or relocate the borehole or adjust the piling plan. UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower.	

ANNEXES

A. Site Location & Layout.
B. Bomb Census Map.
C. Historical Street Maps.



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Project Ref:	Mayfield Manchester		
Client:	Buro Happold		A - 1

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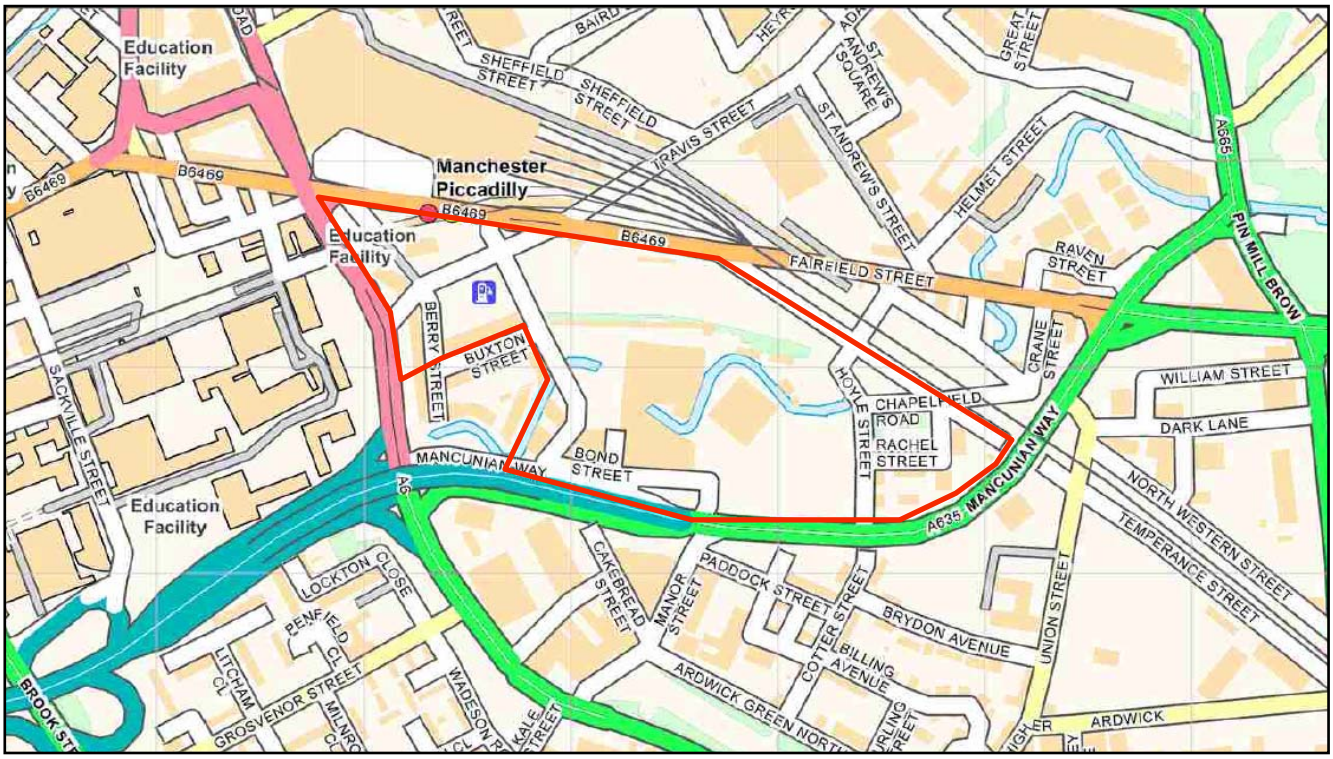

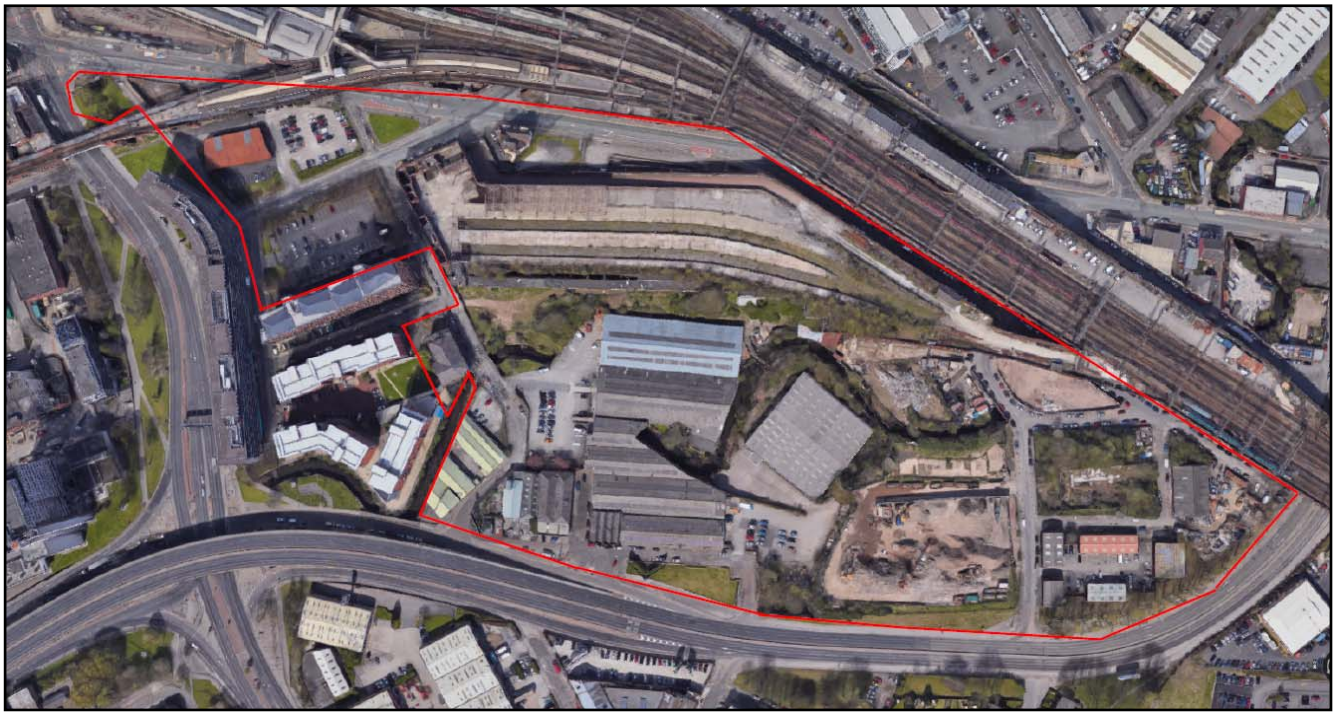

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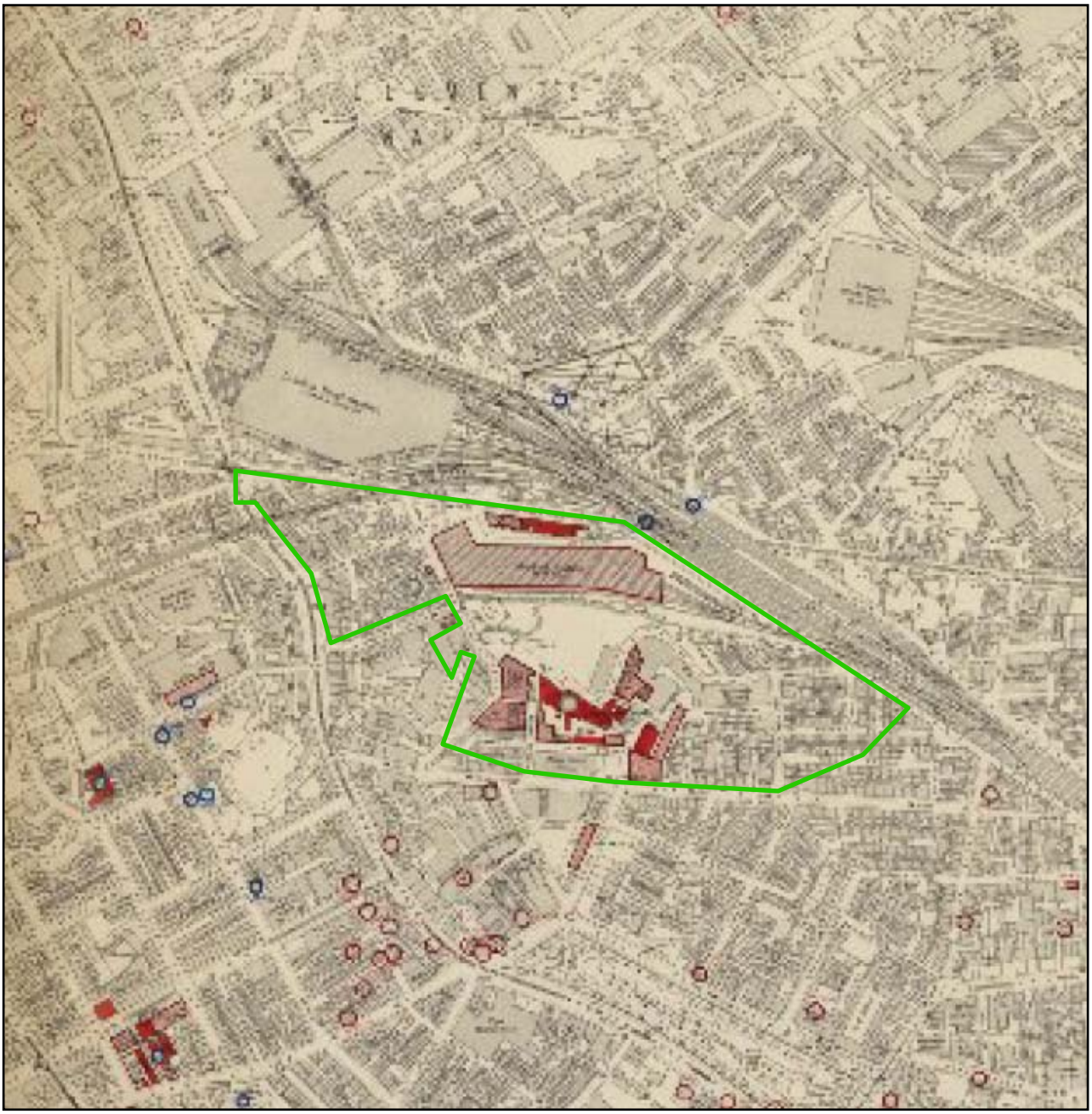
Project Ref:	Mayfield Manchester		
Client:	Buro Happold		A - 2



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Client:	Buro Happold	High Explosive Bombs	B - 1

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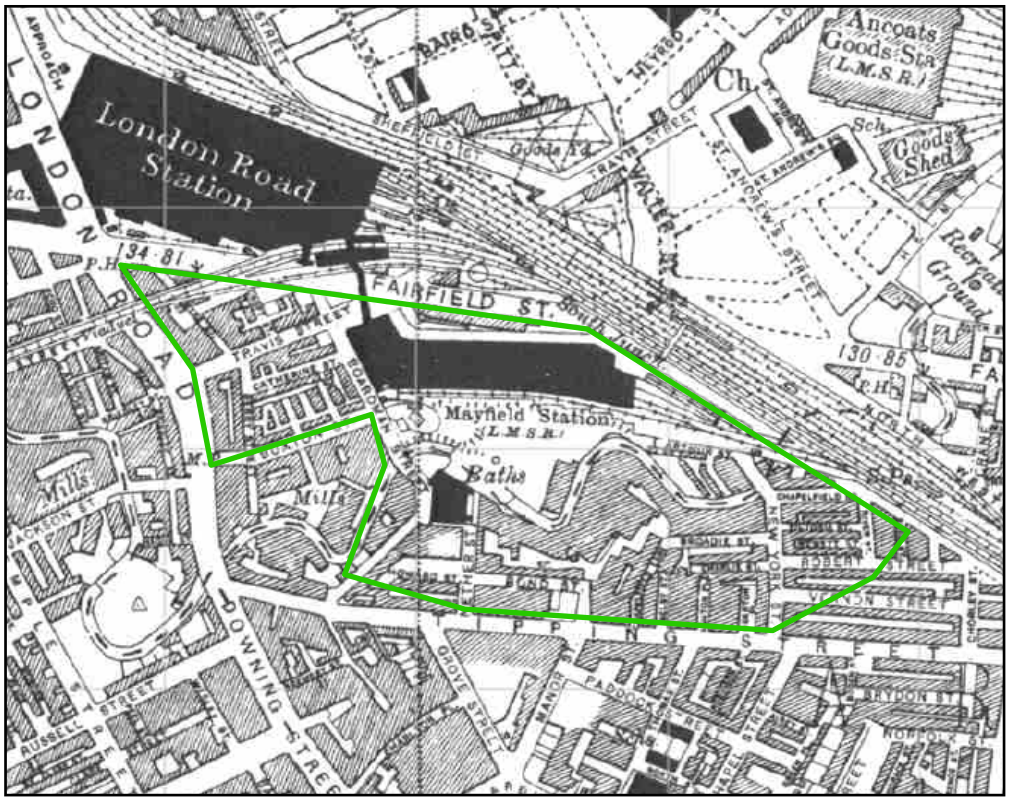

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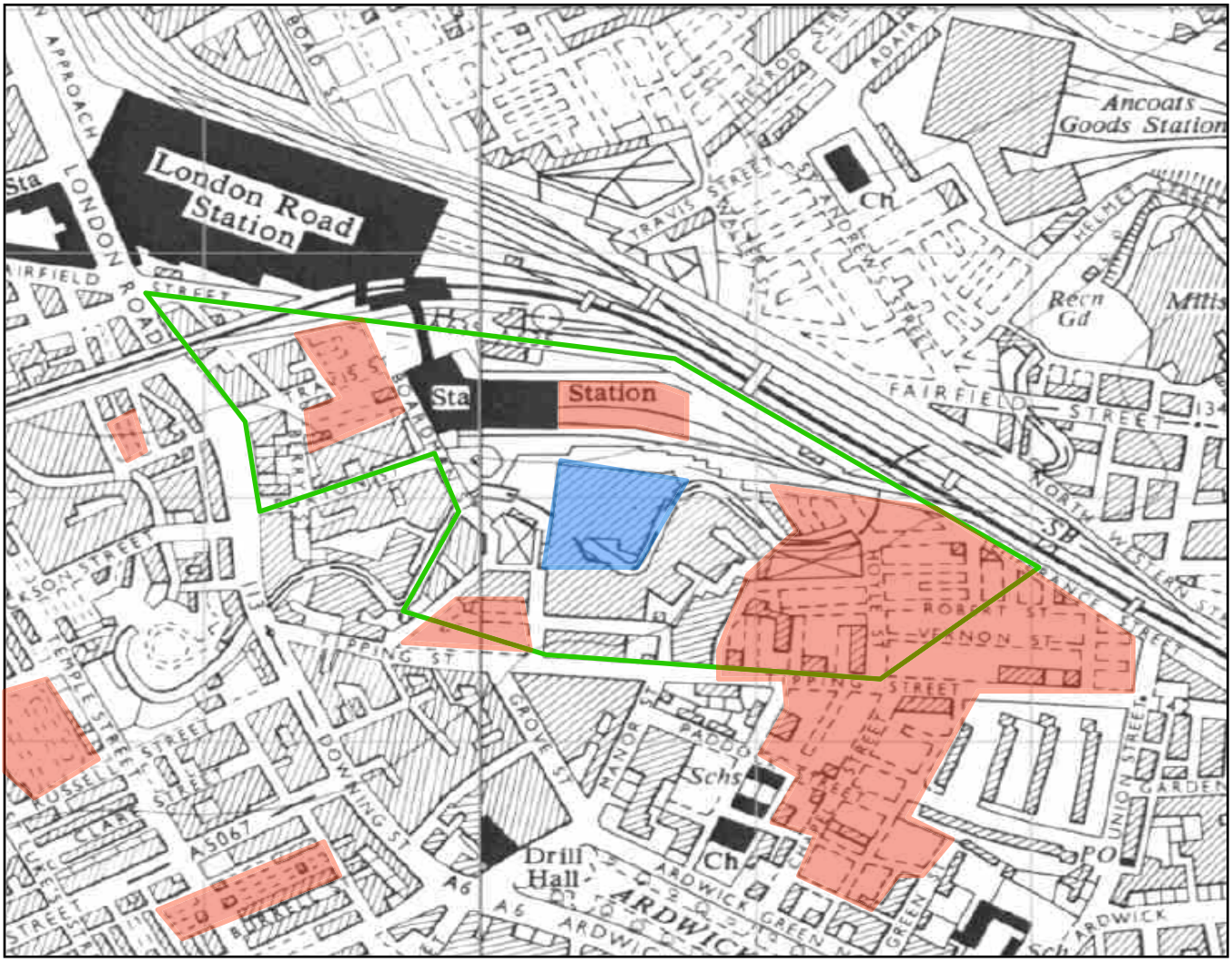

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Project Ref:	Mayfield Manchester		
Client:	Buro Happold		C - 1