

**A14.3 – Unexploded Ordnance Desk Study
(MACC International)**



MACC UXO Threat Assessment

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November 2011

London Underground

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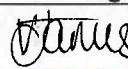
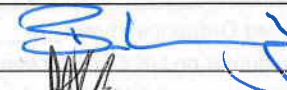
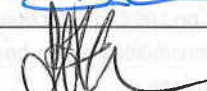
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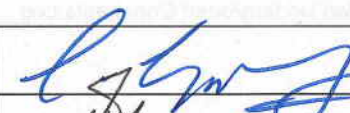

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1. Introduction

1.1 The Scheme

Bank Station is one of the busiest stations on the London Underground (LU) network. The station forms an interchange between the Central, Northern and Waterloo & City lines (LU) as well as the Docklands Light Railway (DLR), and access to the heart of the City of London. Bank Station is interlinked with Monument Station and operationally it is known as the Bank-Monument complex.

The Bank Station Capacity Upgrade Project, “the scheme”, proposes the relief of congestion to the Northern Line platforms by the construction of a new southbound running/platform tunnel located to the west of the existing platform tunnels. The scheme will include:

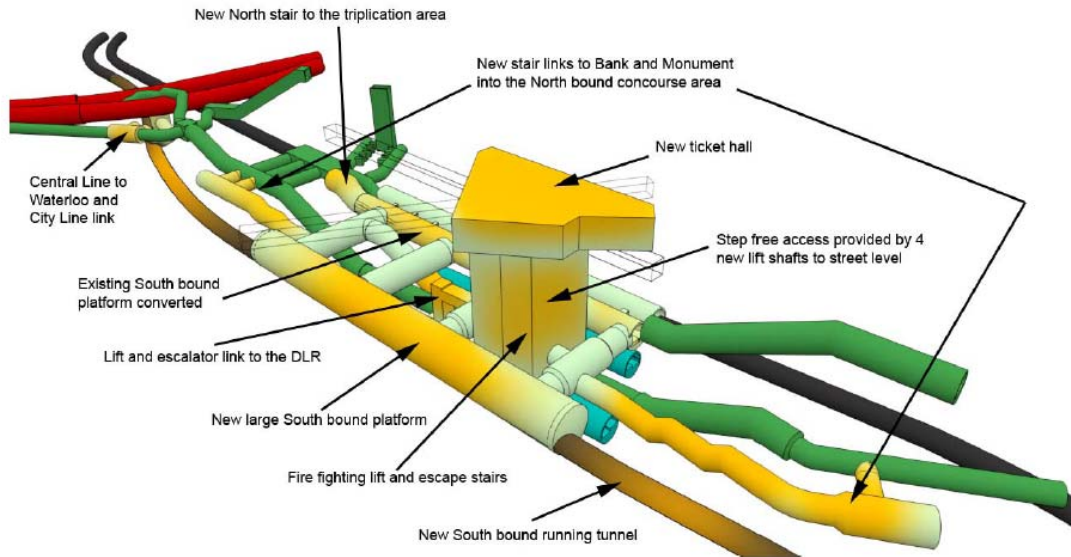
- Transforming the existing southbound platform tunnel into a new central concourse area to support the northbound platform.
- New cross passages linking the newly formed concourse to the new southbound platform.
- Escalators and stairways to link the new cross passages to the DLR beneath and to the rest of the station.
- Direct access to the surface, provided by a central lift core to a new ticket hall located above, at 10 King William Street.
- Step free access, provided by lifts, transferring passengers from street level to the platforms.
- Additional means of escape, provided by the new lifts (which will be designed as evacuation lifts) and through the provision of a central escape stairway.

Benefits include:

- An increase in capacity at platform level, through the passageways to the DLR and in other areas of the station.
- Step free access from train to platform and to street level.
- A platform area and interchange that meets future capacity demands.
- A secondary means of escape both from the platform area and other parts of the station.
- Significantly improved access and facilities for the Fire Service.
- A simple constructible solution causing minimal disruption to the station as a whole.
- A passenger friendly layout with logical and straightforward routes.

The following figure illustrates the proposed scheme.

Figure 1.1: Scheme Layout



1.2 Unexploded Ordnance Threat

During WWII many defensive establishments, cities and towns throughout UK were subjected to comprehensive bombing campaigns, which resulted in extensive damage to city centres, railway infrastructure, docks, associated industrial areas and military installations. The German Luftwaffe mainly achieved this destruction by deploying High Explosive and Incendiary bombs.

Across London an average of 84 bombs, which failed to explode, fell on civilian targets every day between 21st September 1940 and 5th July 1941. The bomb failure rate is highlighted further when considering that more than 200 of the 1,500 bombs dropped in East London by the Germans failed to detonate. Most of the unexploded bombs (UXBs) were dealt with by Army Bomb Disposal Services during the war however a proportion did penetrate the ground unnoticed, only to be encountered many years later.

Government statistics indicate that most unexploded bombs found between October 1940 and May 1941 were either 50kg or 250kg. However UXO can range in size from Small Arms Ammunition to large UXBs weighing more than 2,000 kg. All items containing high explosives have the potential to cause significant harm to those who encounter them.

In recent decades there have been several incidents in Europe where Allied UXBs have been detonated with at least three incidents causing fatalities. Although no fatal incidents related to UXB have occurred in the UK in recent years, data from the Explosive Ordnance Disposal industry show that from 2006 to 2009 approximately 15,000 items of ordnance ranging from aerial delivered bombs to Land Service Ammunition (such as mortar rounds and grenades) have been removed from construction sites. Of that total, it is

estimated that about 5% were live and still fully functioning. The number of items of Small Arms Ammunition recovered during this period possibly runs into tens of thousands.

The legacy of UXO has caused many problems for construction projects throughout the UK.

1.2.1 UXO Encounter on UK Construction Sites Examples

Examples include:

- **Southampton (4th March 2010) – BBC News**

A 200m (220yd) area was cordoned off and buildings evacuated after the 45kg (100lb) device was found by construction workers in London Road on Thursday 4th March 2010 (BBC News)

- **Plymouth (April 2009) – CIRIA (Remediation of a worldwide hazard: Unexploded Ordnance 15 June 2009)**

1,000 homes were evacuated in Plymouth when workers on a building site in the Prince Rock area discovered an UXB sticking six inches out of the ground.

- **Manchester (April 2009) - CIRIA (Remediation of a worldwide hazard: Unexploded Ordnance 15 June 2009)**

A 200 metre cordon was put up near Oxford Road station in Manchester when workmen found an unexploded mortar shell on a building site.

- **Bow, East London (June 2008) - CIRIA (Remediation of a worldwide hazard: Unexploded Ordnance 15 June 2009)**

In June 2008 a 1000kg bomb was found at Bow in East London during construction for the Olympic Games. The Police spokesperson said it was the largest unexploded bomb found in London in three decades. Services on two nearby subway lines were suspended as a precaution while the bomb was being defused.

- **Canary Wharf, London (July 2007) - Reuters**

Police closed streets near Canary Wharf after an unexploded German flying bomb from World War Two was found on a construction site.

Bomb disposal experts were called in to make the V1 missile safe after it was unearthed close to the complex that houses 80,000 office workers during the working week, police said. At weekends the area is busy with shoppers and visitors.

Police closed several roads around the site in Millharbour, a road in the former docklands.

1.3 Employers responsibilities under health and safety legislation

All employers have a responsibility under the Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1999 to ensure, so far as is reasonably practicable, the health and safety of their employees and that of other persons who are affected by their work activities. Construction professionals have further specific duties under the Construction (Design and Management) Regulations 2007 (CDM). Under CDM, the client has the legal responsibility for the way that a construction project is

managed and run and they are accountable for the health and safety of those working on or affected by the project.

1.4 Financial Implications

Although the likelihood of an inadvertent detonation of an item of UXO is low, the presence of an item of UXO at a site can still have significant implications. If sites with potential UXO risks are not managed efficiently, it can lead to programme delays and an associated increase in project costs.

1.5 Bank Station Capacity Upgrade Project Preliminary Assessment

Mott MacDonald undertook a preliminary assessment of the potential for UXO to be encountered during the intrusive works for the Bank Station Capacity Upgrade Project in line with CIRIA C681. The findings of the risk assessment concluded that it was prudent to have the risk of UXO formally assessed by a UXO specialist before the commencement of either ground investigation or construction works.

The UK Registered, ISO 9001:2008 and ISO 14001:2004 accredited, Explosive Ordnance Disposal (EOD) - Bomb Disposal Company, MACC International Ltd was subsequently commissioned by Mott MacDonald Ltd to conduct the Unexploded Ordnance (UXO) Desk Study for the Bank Station Capacity Upgrade Scheme.

This document presents the findings of the Unexploded Ordnance (UXO) Desk Study for the Bank Station Capacity Upgrade.

2. Unexploded Ordnance (UXO) Desk Study

2.1 Objectives of the UXO Desk Study

The objective of the desk study risk assessment was to estimate the likelihood of encountering a UXO hazard present on the site, giving due consideration to the development type and construction methods to be employed.

2.2 Scope of the UXO Desk Study

The scope of the Desk Study is presented within the Bank Station Capacity Upgrade Project Survey Request Scope (ref: CRF MN 036) issued on 10 June 2011 (Appendix A). In summary the desk study was required to comply with recognised best practice advocated by the Health and Safety Executive (HSE) and comply with:

- The United Nations (IMAS) standards for UXO/Mine Level 1 Survey (Desk Top Study)
- The CIRIA C681 “Unexploded Ordnance (UXO) – A guide for the Construction Industry”
- The quality and environmental aspects of the study comply with:
 - UKAS Accredited ISO 9001:2008
 - UKAS Accredited ISO 14001:2004

In carrying out the Desk Study, the specialist was required to undertake a sufficiently detailed review of the history of the site in order to determine:

- The likely type(s) of ordnance stored and used, including their age, condition and sensitivity;
- The potential for UXO to exist, i.e. whether ordnance could have been employed and failed (e.g. on a range), or simply discarded, either deliberately or accidentally;
- The likely distribution of UXO across the site, i.e. whether there are areas of higher and lower risk.

In order to assess the risk posed by UXO to the construction activities in question, the specialist was required to consider:

- The depth, location and extent of intrusive work in relation to the potential areas of UXO contamination;
- The likelihood of initiating UXO with the proposed intrusive methods;
- The consequences of initiating UXO.

Finally, the specialist was required to recommend UXO risk mitigation to eliminate risk or reduce it to an acceptable level. The risk mitigation process was to provide a framework that identifies appropriate mitigation methods for the various risk scenarios that may be identified by the Desk Study.

2.3 Unexploded Ordnance Risk Assessment

A copy of the Unexploded Ordnance (UXO) Desk Study is presented in Appendix B.

A log of the comments received by London Underground and subsequent responses are presented in Appendix C.

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Appendix A. Unexploded Ordnance (UXO) Desk Study Survey Request Scope



Bank Station Capacity Upgrade Project

Survey Request Scope (SRS)

Request Date:	10/06/2011	Job Number:	CXXX	Submitted to LU Access Team on:	
Survey Requester:	Graham Taylor	Design Programme ID:	<i>(as stated on the agreed Stage D Design Prog.)</i>		
Discipline:	Lead Geotechnical Engineer	Call Off Contract No:	TfI/01501-3100345701		
Brief Location & Description:	Undertake UXO Threat Assessment for Bank Station site	Variation No:	CRF MM 036		

Survey Scope of Works:

- 1. Describe purpose and reason for carrying out survey:** *(detailed explanation or full justification in explaining in detail why and what survey requirements need to be undertaken)*

The proposed construction site is located in Central London and therefore is subject to the threat of unexploded ordnance (UXO) from World War II. During the air raids in World War II, some of the bombs dropped failed to function. During the post WWII period extensive works have been carried out to remove all UXO but not all of them were discovered. Hence a UXO risk assessment is required before the commencement of either ground investigation or construction works to identify the risk of encountering UXO during these works and ensure that the works can be undertaken safely. Costs estimated to be £6K.

- 2. Access Requirements:** *(e.g. private property, access to rail assets, road closure/track possession required, timeframe and persons involved to be specified)*

The survey will comprise a desk top study.

3. **Specify reference documents, standards and drawings to be used:** *(including specified criteria for survey accuracy and tolerance requirements, why particular standards or documents are required for use e.g. EIA, legislation etc)*

The UXO Threat Assessment will be carried with reference to 'Unexploded ordnance (UXO), A guide for the construction industry', CIRIA C681, London, 2009.

4. **Clearly describe type and location of elements to be surveyed:** *(use any necessary supporting information, drawings, diagrams to clearly show and indicate location or survey scope area, Note; this must be provided in a format that is readable e.g. PDF)*

The envisaged construction site and in particular those areas where excavations are to be carried out.

5. **Describe required reporting format of survey data / output to be supplied:** *(e.g. number of copies, format & content of report if applicable, CAD standards, or other survey specification requirements, what and how these outputs of information fit in to the overall reporting process eg design, ES or TWA application)*

A report in accordance with the recommendations of CIRIA C681. The threat assessment will inform both the ground investigation and the design of the scheme.

6. **Indicate earliest / latest date of receipt of survey data:**

Prior to the issue of the tender for the ground investigation.

7. **Identify any known or suspected hazards:** *(clearly outline the envisaged risks specific to the planned survey activities and including proposed mitigation measures)*

None envisaged.

8. **Any other requirements:**



Mott MacDonald

None envisaged.

Issue and Revision Record

Version	Date	Originator	Checker	Approver	Description
0.1	10 June 2011	G R Taylor <i>Graham Taylor</i>	D Byrne <i>D Byrne</i>	M Savill <i>M Savill</i>	First draft



Mott MacDonald

LU Accredited Discipline Engineers/Key Stakeholders

Name	Position	Signature	Date
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3			
4			
5			
6			

C Appleyard			
O Morgan			

Appendix B. Unexploded Ordnance Desk Study

MACC



UNEXPLODED ORDNANCE DESK STUDY BANK STATION CAPACITY UPGRADE

Prepared for: Mott MacDonald Ltd

Project Number: 3322

Version: 1.2 Issue Revision 2

Dated: 6th October 2011

This document has been produced in the United Kingdom by MACC International Limited and meets the requirements of CIRIA C681 "Unexploded Ordnance (UXO) – A guide for the Construction Industry" It has been provided solely for the purpose of assessment and evaluation. It is not intended to be used by any person for any purpose other than that specified. Any liability arising out of use by a third party of this document for purposes not wholly connected with the above shall be the responsibility of that party, who shall indemnify MACC International Limited against all claims, costs, damages and losses arising out of such use.

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Project Number: 3322
Version: 1.2 Revision 2
Dated: 06/10/2011

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Keith Burrows is the Managing Director of MACC International Limited which he established in 1995 having served twenty two years in the Royal Engineers Bomb Disposal Regiment. He is a qualified EOD Diver and has conducted EOD, Diving and Demining Operations worldwide including senior project management in UK, N Ireland, Falkland Islands, EU, Malaysia, DRC, Libya, Cambodia and Iran.

Signature: 

Date: 06/10/2011

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Carl Anthony Percival served in the Royal Engineers Bomb Disposal Regiment for nine years before joining the commercial sector in 1991. He has conducted EOD and Demolition Operations worldwide including projects in the UK, Falkland Islands, EU, Qatar, Kuwait and the Yemen. He qualified as an Explosives Engineering Supervisor and holds Blast Design and Shot Firing Licenses. He is an experienced UXO risk researcher, assessor and mitigation engineer. He currently holds the post of Support Manager within MACC International Limited.

Signature: 

Date: 21/07/2011

Assessment Manager: J Morrison

John Morrison served in the Royal Engineers Bomb Disposal Regiment for twenty two years before joining the commercial sector in 1999. He has conducted EOD, Security and Threat Assessment Operations worldwide including project management in UK, N Ireland, Falkland Islands, EU, Malaysia, Zimbabwe, Taiwan, Canada, Columbia and Hong Kong. He has been the lead risk assessor and mitigation design engineer for major organisations and was a member of the CIRIA C681 project steering group. He currently holds the post of Operations Manager within MACC International Limited.

Signature: 

Date: 06/10/2011

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REFERENCES

Publications

Sources of information used in the compilation of this study included:

London County Council Bomb Damage Maps. National Archives 2007
German Air Raids on Britain 1914-18. Morris 1925
Unexploded Ordnance (UXO) – A guide for the Construction Industry. CIRIA C681
Dangerous Energy. Cocroft 2000
The Blitz Then and Now Volumes 1 to 3. Ramsey 1987
Advanced German Weapons WW2. Ford 2000
Dealing with Munitions in Marine Aggregates. UMA 2008
United Nations International Mine Action Standards (IMAS). UN 2010
Military Engineering Volume XII. War Office 1956
German Bomb Fuzes. USN 1945
Fields of Deception & Anti Aircraft Command. Dobinson 1988
Target Reconnaissance Photography. Luftwaffe 1939-44
In-situ Soil Testing. Brouwer 2007

Internet Information

Additional information was provided through the following credible internet sites, their assistance is credited where appropriate:

Army EOD Incidents
RAF EOD Incidents & Air Situation Reports 1939-45
Royal Navy EOD Incidents
RN Mine Warfare & Clearance Incidents
International EOD Reports & Alerts
Luftwaffe Strategy & Tactics
Luftwaffe Bomber Specifications
WO Defence Arrangements 1939-45
News Reports Witness Accounts 1939-45
News Reports

Project Information

Site and project information was provided by Mott MacDonald Ltd under reference: LUSTN-0008798-DWG-000666 & London Underground under reference: St Mary Abchurch

TERMS AND DEFINITIONS

Anti Aircraft Ammunition (AAA)

High Explosive shells ranging from 30mm to 155mm used by air defence batteries to attack or deter enemy air attack.

Air Dropped Munition

A bomb or container dropped from an aircraft which is designed to detonate at a pre determined altitude, on impact or using a delay mechanism; after impact.

Air Dropped Sub-Munitions (Bomblet)

Small sub-munitions dispensed from a larger carrier which may be fixed to the aircraft or dropped as a single container munition which was designed to open above the target spreading its contents over a large area. Some designs are extremely dangerous and fitted with anti-handling devices.

Area Clearance

This is the term used for the systematic clearance of explosive ordnance from land, including military property, firing and bombing ranges, airfields and training areas. When the land is a former wartime battle ground, the term used is Battle Area Clearance (BAC)

Blast Zone

This term refers to the area around an explosive detonation where the explosive overpressure (Blast) can cause damage, injury or death.

Explosive Ordnance (EO)

All manufactured or improvised items designed to contain explosive, propellant, pyrotechnic and fissionable material or biological or chemical agents or pre-cursors which when coupled with an initiation or dispersal system are designed to cause damage, injury or death.

Explosive Ordnance Disposal (EOD)

A series of recognised procedures and protocols which are used by specialists in the detection, identification, evaluation, risk assessment, render safe, recovery and disposal of any item of explosive ordnance or improvised explosive device.

Fragmentation Zone

This is the term which refers to the danger area in which a piece of an item of explosive ordnance will travel on detonation. This zone is normally greater than the blast zone.

Geophysical Survey

The use of magnetometers, ground penetrating radar or other geophysical data gathering systems, which is then used for evaluation, risk assessment and to quantify further mitigation requirements.

High Explosive (HE)

High explosives react/detonate at a rate of around 9,000 metres per second, to all intents and purposes, instantaneously.

Incendiary Bomb (IB)

Incendiary bombs ranged from 1kg in size to 500kg the larger sizes were designated as Oil Bombs. Fills range from Thermite mixtures, Phosphorus, Kerosene or other pyrotechnic mixtures.

Intrusive Search

This term refers to the process of introducing a specialist magnetometer by pushing or drilling the sensor in to the ground to a pre determined depth, thus allowing construction activities such as: piling, soil testing and deep intrusive ground works to be conducted safely.

Land Service Ammunition (LSA)

LSA is a term that refers to all items containing explosives, pyrotechnic or noxious compounds which are placed, thrown or projected during land battles.

Oil Bomb (OB)

Large airdropped bomb or modified ordnance container containing flammable material and accelerant, these weapons normally range in weight from 250 – 500kg.

Pilot-less Aircraft (UAV)

This is the technical reference to the V1 rocket flying bomb (Doodlebug) or predecessors designed to deliver an explosive warhead of 1,000kg or less. The term has now been replaced by the terms; Drone or Unmanned Aerial Vehicle (UAV).

Parachute Mine (PM)

Air-dropped mine designed to detonate at a pre set altitude above the ground. Essentially a large blast bomb with an explosive content of 1600 kg commonly fitted with anti-handling or anti-removal fuzes.

Secondary Fragmentation

In an explosive event, fragmentation that was not originally part of the UXO but may be part of the surrounding structures etc. The most common secondary fragmentation is glass.

Small Arms Ammunition

This term refers to infantry projectile weapons which usually do not contain an explosive projectile, they may however contain an incendiary tracer mix and will have a fixed propellant case containing a low explosive (Cordite)

Unexploded Bomb (UXB)

Any air dropped bomb that has failed to function as designed.

Unexploded Ordnance (UXO)

Explosive ordnance that has been primed, fused, armed or otherwise prepared for use or used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction or design or for any other cause.

War Office (WO)

This was the United Kingdom Government department responsible for defence of the realm, forerunner of the Ministry of Defence (MoD).

White Phosphorus (WP)

Munitions filled with WP are designed for signalling, screening and incendiary purposes. They achieve their effect by dispersing WP, which burns on contact with the air.

1 INTRODUCTION

1.1 Instruction & Scope

MACC International Ltd was commissioned by Mott MacDonald Ltd to conduct an Unexploded Ordnance (UXO) Desk Study for the Bank Station Capacity Upgrade Scheme. The scope of the study is to determine the likelihood of an encounter with UXO and the consequences of such an encounter within the context of the execution of the intrusive geotechnical investigations and other construction ground-works to be undertaken during the project.

1.2 Methodology & Purpose

The methodology used in the study complies with the United Nations (IMAS) standards for UXO/Mine Level 1 Survey (Desk Top Study), the CIRIA C681 "Unexploded Ordnance (UXO) – A guide for the Construction Industry" and the recognised best practice advocated by the Health and Safety Executive (HSE). The quality and environmental aspects of the study comply with UKAS Accredited ISO 9001:2008 and ISO 14001:2004 standards. The purpose of the study is that of evaluation and to provide an aid in decision making by our client.

2 DETERMINING THE LIKELIHOOD OF ENCOUNTER

2.1 Research Restrictions & Indemnity

This study has drawn upon Ministry of Defence (MoD) and other archive records which are within the public domain; these are however acknowledged to be incomplete. Consequently, some incidents may have occurred where the records no longer exist or could be located. The Secretary of State of the United Kingdom and MACC International Ltd does not accept responsibility for the accuracy or completeness of the information contained within the records. Some records regarding the UXO situation on some sites may not yet be within the public domain. Consequently such information was not available for evaluation by MACC International Ltd.

2.2 Aim of Research

Research of the site history, with regard to military usage, bombing raids and bomb impacts has been undertaken to establish the following:

- Frequency and intensity of enemy bombing raids for the site and immediate vicinity.
- Bomb impacts and associated damage on the site and in the immediate vicinity.
- The potential for UXO to remain on the site and in the vicinity.
- Records of UXO removal activities for the site and the immediate vicinity

2.2 Official Archive Records

Archive records which were made available to the authors. It should be noted that no archive is considered complete. The following sources were searched and are considered to provide a reasonably accurate picture of wartime activity on site and its current condition.

- MACC International in-house records previously released by official sources
- Ministry of Defence records
- National Archives, Local Authority records & National Government Records Office
- British Geological Survey (BGS) maps and publications

2.3 Relevant Publications

Published sources of information used in the compilation of this study are listed within the reference section of this study including those provided by the client. Particular thanks are expressed to the London Underground for providing historic information concerning the site and Mott MacDonald for the detailed technical information concerning the project.

2.4 Credible Internet Information

Additional information was provided through credible internet sites, their assistance is credited where appropriate and details are listed within the reference section of this study.

3 THE SITE

The site is located beneath existing buildings in the City of London with the geographical focal point on King William Street, which runs south towards the Thames from the junction of Queen Victoria Street/ Mansion House Street, Princes Street, Threadneedle Street, Cornhill and Lombard Street, in the City of London. The national grid reference of the footprint limits are: Northern limit; 532673E, 181196N. Southern limit: 532845E, 180710N. The area subjected to assessment has included all of the land within the red dashed line, including streets roads etc. (See Annex 'A')

4 FUTURE DEVELOPMENT

The goal of the project is the construction of a new southbound running/platform tunnel located to the west of the existing platform tunnels. It is anticipated to require:

- Site investigations including borehole drilling, trenching and sampling
- Shafting, deep excavations & tunnelling
- Foundation construction including shafting and deep excavations

5 HISTORICAL INFORMATION

5.1 British Archives

Prior to 1942 the United Kingdom did not operate a national recording system for EO/UXO incidents or military use of land. The records compiled during 1939-1942 were conducted under local arrangements and were only as detailed and accurate as the availability of time, personnel and the ease of access to information would allow. Densely populated areas associated with the major cities tended to have a greater number of records than those produced for the more provincial or rural areas. In April 1942 the Ministry of Home Security instigated a training programme for all personnel maintaining bomb census records, these standardised national records and greatly improved the accuracy of the information recorded.

5.2 The Site during WWI & WWII

The Bank Station was extant before WWI with the surrounding streets and buildings in the general configuration as they are today.

5.3 Manned Air Raids & Unmanned Rocket Attack Reports

The area was subjected to bombing during WWI. However, no evidence was found of bombs having struck within the site footprint during this period.

During WWII the site fell within Region 5 of Air Raid Precautions (ARP) reporting system which came into being when Hitler authorised retaliatory bombing in response to the allied bombing of Berlin. London was designated as "Target Area A" by the German High Command and the attack plan was issued by the General Officer Commanding 1 Air Corps which demonstrates the makeup of a typical air raid. (See Annex 'B')

The saturation bombing of London started on the 7th September 1940 (The London Blitz). 348 German bombers escorted by 617 fighters attacked the capital in the late afternoon, forming a 20 mile wide block of aircraft filling 800 square miles of sky. 448 people were killed. London was bombed every day or night from 7th September until 2nd November 1940. By May of 1941 the worst of the blitz was over when the resources of the Luftwaffe were diverted to support Hitler's invasion of the Soviet Union. In London as a whole over this period over 20,000 civilians were killed, 1,400,000 made homeless.

The records produced by London County Council (LCC) indicate that the bomb density for the area was over 600 bombs per 1,000 acres. Based on investigations made into bomb failure rate the assumed percentage of bombs which did not function as intended was placed at 10%. This would provide a minimum UXB bomb density of 60 per 1,000 acres (0.15 UXB per ht). Some 3,000 UXB were dealt with by units of the Royal Engineers Bomb Disposal Regiment within the LCC.

The published history of St Mary Abchurch Church records several bomb strikes, the first in 1940 on the City Carlton Club resulting in blast damage to St Mary's, the second strike in 1941 caused more damage with a further three V1s inflicting further damage in 1944-45. (Courtesy of London Underground.)

On the night of 10th January 1941 the Bank Underground station sustained a direct hit by a HE bomb. The bomb detonated within the escalator machinery room with the blast travelling through the ticket hall. Such was the level of destruction that the figures given for the total number of people killed in the incident from 50 to 117. (Most credible number is considered to be 56 deceased and 69 seriously injured.)

The official report on the January 10th incident notes: *“At the foot of the escalator to the Central London railway there are two steel doors for the prevention of floods giving access to each side of the tube platforms. These doors were open and the main casualties were those sheltering at the foot of the escalator, who were blown through the doors against the wall of the tube opposite. Had these doors been shut, the technical officer of the Transport Board advises that the blast might have blown in the sides of the tube tunnels.”*

National Archive records relating to local air raids have been examined. It should be noted, that air records in no way constitute a full account of all attacks that may have occurred during the war period, but given the location of the site these are considered to provide a reasonable picture of the situation during WWII. Relevant records searched were:

- HO186/639
- HO 56/20/SE all map folios.
- HO193 all folios
- HO198 all folios
- BC4's City of London

5.4 **Prior UXO Incidents, UXO Clearance & Abandoned Bomb Reports**

MoD are yet to release their records to MACC however in-house records do not indicate that a formal UXO clearance has ever been conducted on site by the military or a civil UXO contractor. Also; in-house records indicate that no abandoned bombs are recorded in the local area.

5.5 **Airdropped Sub-Munition Reports**

Records indicate that air dropped Incendiary and/or Anti-Personnel sub munitions (bomblets) did strike on or close to the site perimeter. While this type of munition has little ground penetrating potential, they leave little evidence of entering the ground and still pose a credible risk of functioning if disturbed. Their relatively small explosive and pyrotechnic content will limit their ability to cause damage, injury or death in the immediate area of the detonation.

5.6 **Anti-Aircraft Ammunition (AAA) Reports**

Local fixed and mobile Anti-aircraft batteries are known to have fired at incoming German raiders. Approximately 30% of all AAA failed to function as intended and while no specific reports of incidents of this type were found on site, the presence of such items of unexploded AAA cannot be entirely discounted. Smaller than Air Dropped Bombs, (30-155mm) these items do not have the potential to penetrate deeply into the ground normally coming to rest between 2-3 metres below the surface.

5.7 Migration of UXO Contamination

The provenance of any “Made Ground” within the site footprint cannot at present be ascertained. It should be noted that the possibility exists, albeit unlikely, that items of UXO may have been imported onto site within the fill material.

6 DETERMINING THE NATURE OF RISK

6.1 General

Records indicate that the area suffered extensive bombing during WWII, with bombs dropped around the site footprint. While High Explosive bombs are very unlikely to detonate if left undisturbed it remains inherently dangerous and may function if subjected to suitable stimuli. The most common of these stimuli are shock, friction or heat which may cause the fuze to function or unstable explosive materials (Picrate Acid) to explode. However in the case of incendiary bombs containing White Phosphorus (WP) exposure of the WP to oxygen will result in its violent ignition.

6.2 German Bombing Tactics

The manned bombing tactics employed by the German Air Force during WWII show that they had a wide variety of bombs at their disposal. The most common ranged in weight from 50 kg through to 500 kg. Some models in this range of bombs were designed to be “carrier” bombs. These containers could hold potentially hundreds of smaller sub-munitions (anti personnel, incendiary bomblets) designed to be dispersed at pre set altitude above the target. Although dropped in lesser quantities, the German arsenal also included larger airdropped bombs and parachute mines up to 1,400 kg in weight. Unmanned attacks were also mounted by the Germans using V1 Rockets and V2 Missiles, each with a warhead around 1,000 kg in weight.

6.3 Bomb Trajectory & Ground Penetration

During WWII the Ministry of Home Security undertook a major study on bomb penetration depths using 1,328 actual bomb impact events to provide statistical analysis of penetration potential. As a result they determined the expected behaviour of a range of bomb weights through different geological strata around the Capital. Their findings remain the only empirical gained figures to have been gathered to date for London. A summary of their findings can be found in Table 1 of this study. A number of factors will influence the behaviour of a bomb on impact with the target and its trajectory through the ground. Relevant factors include: Height and speed of release of the bomb, aerodynamic qualities of the bomb, the angle of flight and impact and the nature of impact surface and sub soil

6.3.1 In determining the potential bomb penetration depths into the ground, the anticipated geotechnical information was available and indicated that it comprised made ground (2.5m) over Alluvium (1.2m) and River Terrace Deposits (6.0m) underlain by London Clay (40.0m). Other factors considered were: Standard German bombing height over UK: 4,545 metres (15,000 ft). Most common GP Bomb used of 500 kg in weight and an impact Angle Range of 90° (tail vertical) to 0° (tail horizontal)

6.3.2 Table 1. Extract of Ministry of Home Security Bomb Penetration Study

Sub Soil Type	Bomb Weights			
	50kg	250kg	500kg	1000kg
Soft Rock or Made Ground	2.442	5.016	6.006	7.062
Gravel	2.442	5.016	6.006	7.062
Dry Clay	3.7	7.6	9.1	10.7
Average Offset (m)	0.8-1.6	1.6-3.7	3-4.5	3.4-5.3

6.3.3 Computer simulations using specialist software were also completed on the penetration potential, the figures derived were found to be in broad agreement with the figures provided by the above table. Given the extensive footprint of the project and possible vagaries in geology from area to area, it was considered prudent to use an average of all expected soil types (c7.0m) until specific geotechnical information is available. To this average was added a reasonable safety factor of (c1.0m) to provide the maximum bomb penetration depth.

6.3.4 Bombs on penetration of the surface do not tend to follow a straight line trajectory, due to a number of factors, shape, angle of entry, weight and speed; they tend to arc or curve; known as a “J” curve. With the horizontal distance from the entry point to the resting point known as the offset. The typical offset is generally taken to be 1/3rd of the penetration depth. However this distance can vary greatly if the bomb strikes an obstacle just below the surface. With this mechanism of offset it is therefore a possibility that a bomb could enter the ground outside a building and come to rest within its footprint.

6.3.5 Having reviewed all of the bomb penetration information and having provided a reasonable safety factor it is considered that:

- The maximum Airdropped Bomb penetration depth on is 8.0 metres
- The maximum Airdropped Sub Munition penetration depth is 1.0 metres
- The maximum AAA penetration depth is on land is 1.0 metres
- The average offset from point of impact on land is 2.6 metres

7 ENVIRONMENTAL IMPACT FROM UXO

7.1 Ground Contamination & Health Risk vectors

While it is acknowledged that there is a potential risk of ground contamination arising from explosive fillings which may leach from a damaged bomb casing into the surrounding soil. The amount of explosive material within the most common bombs is not considered sufficient to pose a significant environmental risk. Nevertheless it should be noted that the following components are commonly used in the manufacture of a high explosive bomb and may pose a localised contamination risk to health:

- Lead, Zinc, Brass, Copper and Steel
- Mercury, Silver Fulminate and Aluminium
- Trinitrophenol, Trinitrotolulene and Trimethylene Trinitramine
- Ammonium and Sodium Nitrate
- Nitro-glycerine

- 7.2 Other contaminants, specifically White Phosphorus (WP) may pose a significant risk of self combusting when exposed to the oxygen in open air. WP will generate large quantities of toxic white smoke when ignited. It is recommended that specialist medical advice be sought to identify specific risks to health posed by these chemical compounds.

8 RISK ASSESSMENT

8.1 Risk Source

National Archive material and in-house MACC records contain sufficient information to confirm that the site footprint and surrounding area was repeatedly struck by airdropped bombs of varying types and sizes.

Records are acknowledged to be incomplete and may include omissions.

No site specific clearance operations are confirmed to have been carried out by the military or a civil UXO Contractor.

The possibility that a bomb struck, failed to explode and was never reported cannot be discounted. Consequently there is a credible risk that it may remain on site to this day.

8.2 Risk Pathway

The risk pathway is considered to be intrusive engineering works which will be conducted as part of the future development of the site which is understood to be:

- Site investigations including borehole drilling, trenching and sampling
- Drilling & tunnelling
- Foundation & support construction

8.3 Consequence

The consequences of a UXB detonation on site during construction works are considered to be a factor of the size of the blast and the proximity of assets and individuals to the point of detonation. These will include:

- Kill or seriously injure personnel
- Destroy or damage high value site assets
- Damage to nearby public and private property
- Destroy or damage ground services and existing infrastructure

8.4 Existing Risk Rating

Table 2 Existing risk rating within the identified risk depth, where:

H = A figure derived from assessing the history of the site weighing up factors such as recorded bomb damage, military use and the scope of any post conflict development. A Low figure is assigned where no attack or risk pathway has been identified and extensive post conflict development has been undertaken without an encounter with UXO. A high figure is assigned where the opposite is the case.

W = A figure derived from assessing the type of the process to be undertaken without putting in place any UXO mitigation measures. A low figure is assigned where the process is relatively non aggressive (minimal ground or point shock); e.g. hand digging. A high figure is used where the work is considered aggressive (significant ground or point shock); e.g. of top driven piling or during mechanical shafting.

L = A figure derived by multiplying figures H and W to provide an overall likelihood of an encounter with UXO.

S = A figure derived by assessing the scope or extent of the works; a low figure is assigned where the volume of risk material to be worked is limited. A high figure is used where for example the volume of risk material is considerable such as “bulk digs” or shafting.

P = A Figure derived from assessing the result of an explosion, including primary and secondary risk pathways and receptors. A high figure is attributed for example in a gas works while a low figure is applied to a remote, rural open space.

C = A figure derived by multiplying figures S and P to provide an overall consequence of an encounter with UXO.

EXISTING UXO RISK RATING			
Activity	Likelihood (H x W = L)	Consequence (S x P = C)	Risk Rating (L x C = R)
Drilling	3 x 4 = 12	3 x 4 = 12	12 x 12 = 144
Tunnelling	3 x 5 = 15	4 x 5 = 15	15 x 15 = 225
Shafting & Deep Excavations	3 x 5 = 15	4 x 5 = 15	15 x 15 = 225
Piling	3 x 4 = 15	3 x 4 = 12	12 x 12 = 144
1 = Minimal 5 = Significant High = 200+ Medium = 100+ Low = -100			

9 STUDY FINDINGS

9.1 Risk Level & Recommendations

The desk study has identified a credible UXO threat to intrusive engineering works. When viewed from likelihood versus consequence standpoint, the current risk level is considered to be **Medium to High** and warrants robust UXO mitigation strategy to be executed to permit the work to proceed in the safest “acceptable” manner.

9.2 Determining Acceptable Level of Risk

The meaning of the term “acceptable” in the context of this study is considered to be in keeping with the Health & Safety Executive directive which identifies the acceptable level as that which is; “As Low as Reasonably Practical” (ALARP) to achieve.

9.3 Post War Land Development

It is noted that some degree of post war development has occurred on part of the site. This activity will reduce the level of risk within the material which has been worked previously. Conversely; where in-filling has occurred using unsearched material from the local area, items of explosive ordnance may have been contained within the fill. Thus, the risk of an encounter may have increased within such in-fill.

10 RISK MITIGATION

10.1 Overview

The following Risk Mitigation Strategy has been designed to reduce the level of UXO risk to an acceptable level (ALARP) in the most efficient and cost effective manner. The Risk Mitigation Strategy will be required to be considered at all levels within the project planning to ensure it has minimum impact to the project’s critical path. Advice should be sought from MACC International Ltd to measure and scope individual mitigation requirements.

10.2 General Mitigation Measures

It is recommended that the following mitigation measures are carried out prior to any work taking place on site:

- Risk Communication: Stakeholders should be made aware that the risk of encounter is considered high and the possible impact it may have on the project
- Risk Planning: Production of a UXO site safety and emergency procedures plan.
- Safety Training: UXO Safety Induction Training should be provided to everyone working or visiting the site. The training should be commensurate with the individual’s responsibilities and duties on site. The training should be provided by a qualified Explosive Ordnance Disposal Engineer and delivered as separate module of the Site Safety Induction Course.

10.3 **Open / Deep Excavations, Shafting and Trial Pit Mitigation Measures**

The following risk mitigation measures are recommended for all intrusive earthworks within the identified risk depth including, geotechnical investigations trenches, ground service and drainage laying and shallow foundation construction:

- UXO Safety Monitoring of the open excavations. This should be conducted by a qualified EOD Engineer using a specialist magnetometer to clear the ground ahead of the excavator bucket. Where it is considered unsafe for the Engineer to enter the excavation close visual monitoring from a safe position will be required.

10.4 **Boring and Drilling Mitigation Measures**

- Pre testing and clearance certification of the intended Boring or Drilling. The clearance can be achieved by progressively introducing a specialist magnetometer into the borehole to ensure it is safe to continue drilling. Where possible, Stainless Steel casing should be used in the leading 3.0m of the casing to reduce delays to the drilling process.
- Alternatively it may be possible to pre-test and provide clearance certification of the intended positions using a “Magcone” or other specialist “safe look ahead” capable magnetometer system to test from the existing ground level. If the “Magcone” is equipped with a full Cone Penetration Testing (CPT) instrument package it may complete the clearance for the drilling and gather the required CPT data in a single process.

10.5 **Piling Mitigation Measures**

- A Pre testing and clearance certification of the piling positions to below the identified risk depth using a Magcone or other specialist “safe look ahead” capable magnetometer system.

10.6 **Shafting Mitigation Measures**

- A Pre testing and clearance certification of the intended shaft position and tunnelling route (Where it is within the identified risk depth) using a Magcone or other specialist “safe look ahead” capable magnetometer system.

10.7 **Tunnelling Mitigation Measures**

- A Pre testing and clearance certification of the intended shaft position and tunnelling route (Where it is within the identified risk depth) using a specialist “safe look ahead” capable magnetometer system. This may be introduced into the tunnel route using directional borehole drilling.

11 POST MITIGATION RISK

11.1 Overview

Execution of the recommended risk mitigation strategy covered in paragraph 10 will significantly reduce the risk, however it is emphasised that zero risk is not achievable given the possible variables. The mitigation strategy has been designed based on information provided by the client concerning the intended works. Advice should be sought from MACC International Ltd to re-evaluate mitigation requirements should changes be made to intended works or construction methodology.

11.2 Residual Risk Rating

Table 3 residual risk rating within the identified risk depth, where:

W = A figure derived from assessing the type of the process to be undertaken after the recommended UXO risk mitigation measures have been completed.

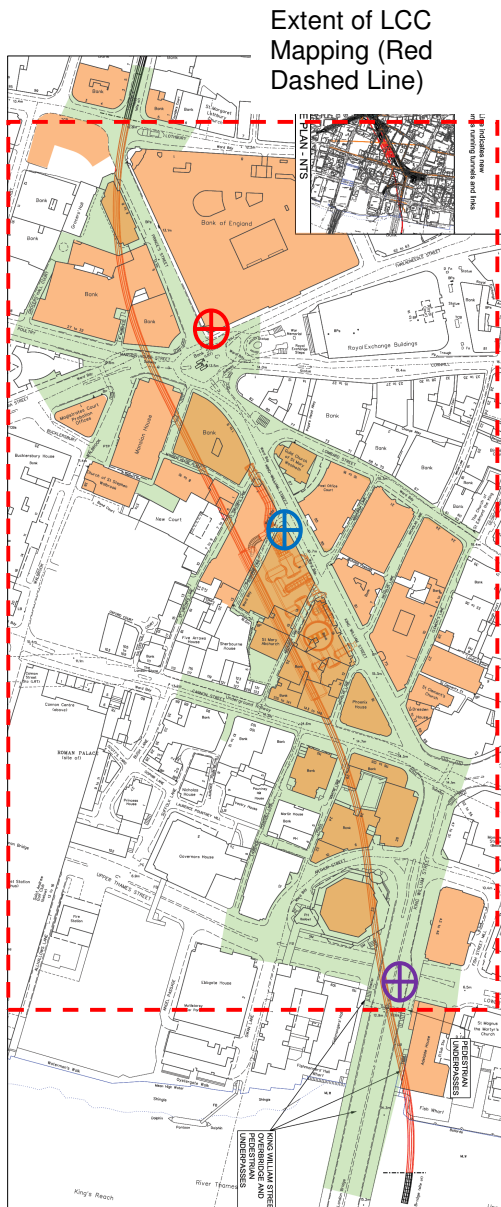
POST MITIGATION UXO RISK RATING			
Activity	Likelihood (H x W = L)	Consequence (S x P = C)	Risk Rating (L x C = R)
Drilling	3 x 1 = 3	3 x 4 = 12	3 x 12 = 36
Tunnelling	3 x 1 = 3	4 x 5 = 15	3 x 15 = 45
Shafting & Deep Excavations	3 x 1 = 3	4 x 5 = 15	3 x 15 = 45
Piling	3 x 1 = 3	3 x 4 = 12	3 x 12 = 36

1 = Minimal 5 = Significant **High** = 200+ **Medium** = 100+ **Low** = -100

11.3 Closing Remarks

The study has confirmed a UXO risk on site and given the project's location and possible consequences of an uncontrolled explosion has made robust recommendations to mitigate the risk to the workforce and general public. An effective risk mitigation strategy will require detailed scoping to achieve its desired results in providing an acceptable level of risk. For further information concerning any part of this study please contact MACC International Limited on 01473 655127 or email macc@macc-eod.com

EXTENT OF WORKS



LCC BOMB DAMAGE MAP



KEY

- BLACK = TOTAL DESTRUCTION**
- PURPLE = DAMAGE BEYOND REPAIR (LATER DEMOLISHED)**
- DARK RED = SERIOUSLY DAMAGED DOUBTFUL IF REPAIRABLE**
- LIGHT RED = SERIOUS DAMAGE REPAIRABLE AT COST**
- ORANGE = BLAST DAMAGE**

NATIONAL ARCHIVE BOMB STRIKE RECORDS

BOMB CESUS MAPPING C SITE LOCATION SHOWN IN RED

ho 193-8 56-20 SE L



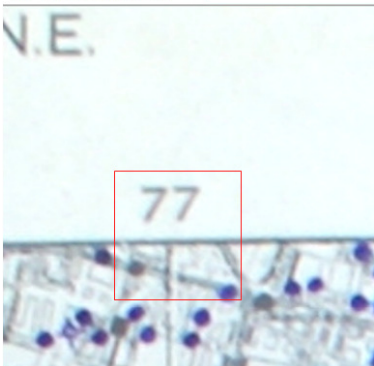
HO 193-11 56 20 SE L



HO 193-1 56-20SE L



HO 193 28 56-18 NE



HO 193 23 56-18 NE



EXPLOSIVE ORDNANCE SAFETY INFORMATION

1 UNEXPLODED ORDNANCE

Since the end of WWII, there have been a number of recorded incidents in the UK where bombs have detonated during construction and engineering works, though a significant number of bombs were discovered and safely disposed of without serious consequences. More commonly on mainland Europe (France, Germany and Belgium) incidents have occurred where ground workers have been killed or injured as a result of striking buried UXO or mishandling items of UXO found during excavation work.

The threat to any proposed investigation or development on the site may arise from the effects of a partial or full detonation of a bomb or item of ordnance. The major effects are typically; ground shock, blast, heat and fragmentation. For example the detonation of a 50kg buried bomb could damage brick/concrete structures up to 16m away and unprotected personnel on the surface up to 70m away from the blast. Larger ordnance is obviously more destructive. Table B-1 shows the MOD's recommended safe distance for UXO. However it should be noted that the danger posed by primary and secondary fragmentation may be significantly greater. Almost 60% of civilian casualties sustained in London during the blitz were the result of flying glass.

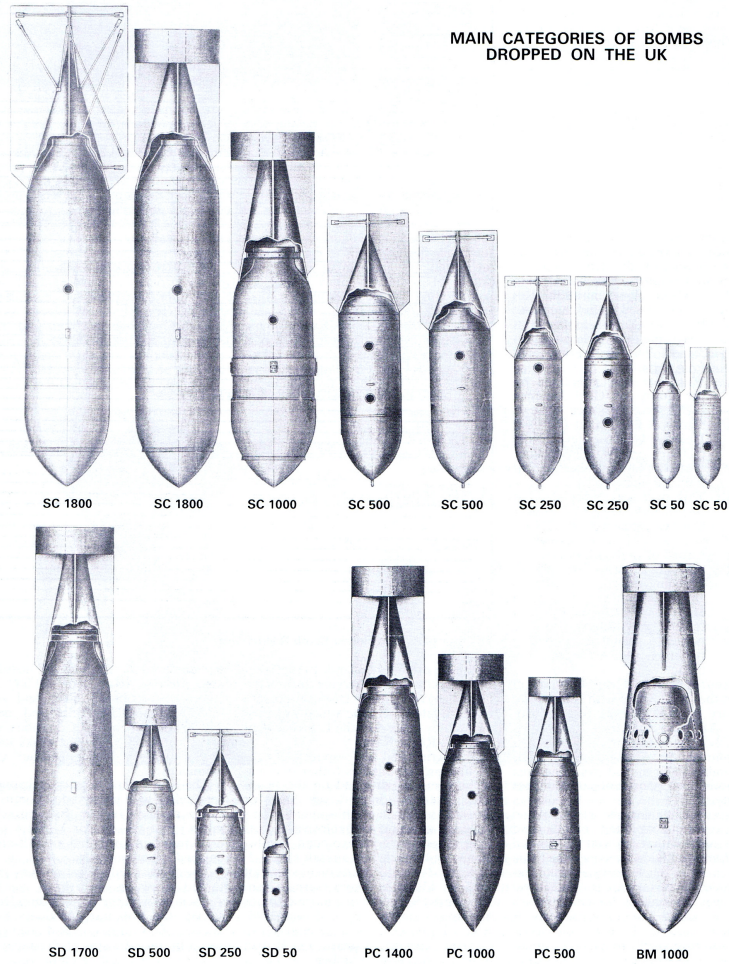
TABLE B-1 SAFETY DISTANCES FOR PERSONNEL

UXO (Kg)	Safety Distances (m)			
	Surface UXO		Buried UXO	
	Protected	Unprotected	Protected	Unprotected
2	20	200	10	20
10	50	400	20	50
50	70	900	40	70
250	185	1100	120	185
500	200	1250	140	200
1000	275	1375	185	275
3000	450	1750	300	450
5000	575	1850	400	575

Explosives rarely become inert or lose effectiveness with age. Over time some explosive materials can become more sensitive and therefore more prone to detonation. This applies equally to items that have been submersed in water or embedded in silt, clay, peat or similar materials.

2 TYPES OF GERMAN AIRDROPPED BOMBS & MINES

2.1 HE Bombs



GERMAN BOMBS AS FOUND TODAY.

2.2 Incendiary, Anti-Personnel Bombs & Parachute Landmines



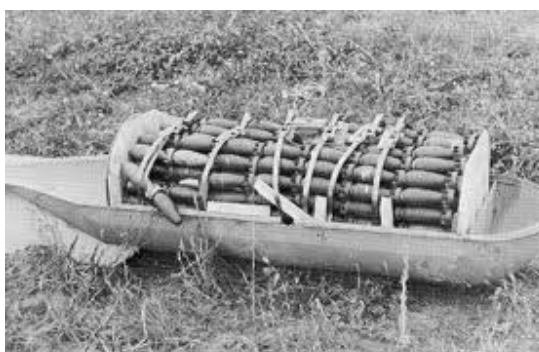
1KG INCENDIARY BOMBLET (TOP AS FOUND TODAY)
BOMBS



FLAM C500, C250 & C50 OIL



SD1 Anti-Personnel Bomblets



SD1 Container Bomb



C & D Parachute Mines



3 Methods of Bomb Release

All German bombers could release their bomb load singly, in salvos or in sticks. The spread of a stick of bombs would vary in length and shape according to the altitude and speed type of the aircraft. A straight stick at regular intervals could only be achieved by straight and level flying during the bombing run.

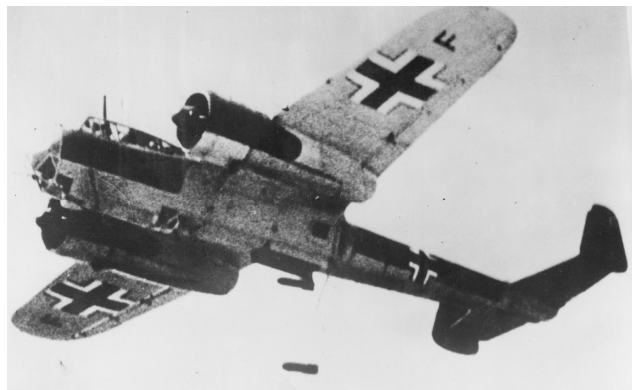
3.1 German Bombers

The following example from the German attack plan for London was issued by the General Officer Commanding 1 Air Corps. It demonstrates the makeup of a typical air raid. The principle German aircraft used to drop bombs on the UK can be seen below

“FLYING ALTITUDES FOR THE BOMBER FORMATIONS ARE TO BE: KG30; 5,000 - 5,500M, KG1; 6,000 - 6,500M AND KG76; 5,000 - 5,500M. TO STAGGER HEIGHTS AS ABOVE WILL PROVIDE MAXIMUM CONCENTRATION OF ATTACKING FORCE. ON RETURN FLIGHT SOME LOSS OF ALTITUDE IS PERMISSIBLE, IN ORDER TO CROSS THE ENGLISH COAST AT APPROXIMATELY 4,000M.

THE INTENTION IS TO COMPLETE THE OPERATION IN A SINGLE ATTACK. IN THE EVENT OF UNITS FAILING TO ARRIVE DIRECTLY OVER TARGET, OTHER SUITABLE OBJECTIVES LISTED IN TARGET LOG MAY BE BOMBED FROM ALTITUDE OF APPROACH.

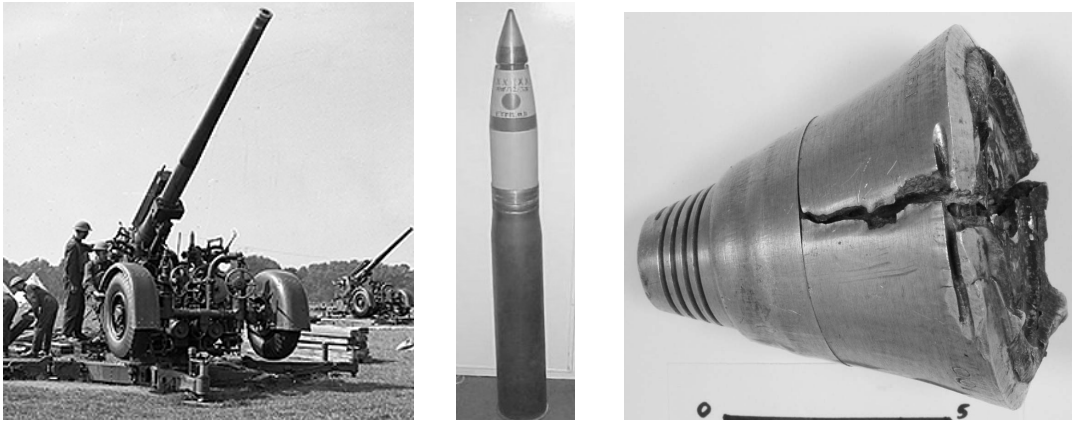
BOMB LOADS FOR THE HE111 AND JU88 ARE TO BE 50KG BOMBS, 20% INCENDIARIES, 30% DELAYED-ACTION 2-4 HOUR AND 10-14 HOUR (THE LATTER WITHOUT CONCUSSION FUSES). THE DO17 ARE TO CARRY 25% DISINTEGRATING CONTAINERS OF B1, EL AND SD 50. LOAD ONLY TO BE LIMITED BY SECURITY OF AIRCRAFT AGAINST ENEMY FLAK.”



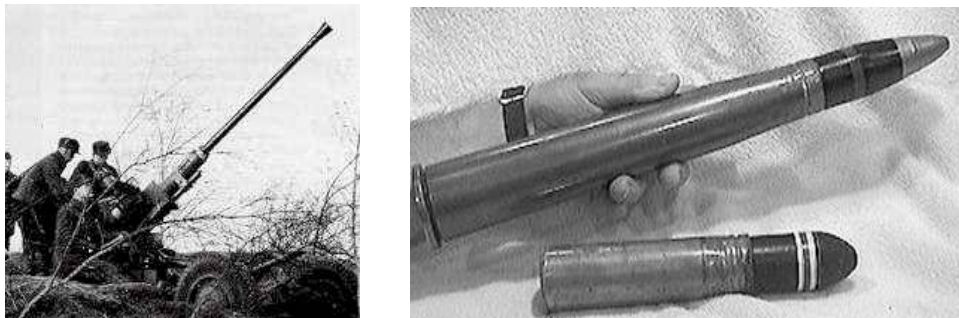
Heinkel He111 (left) capable of carrying 1,500kg of bombs and the Dornier Do17 (right) capable of carrying 1,000kg of bombs

4 British Anti-Aircraft Guns & Rockets

Examples of British Anti-Aircraft Guns and rockets used to defend the UK against German bombing raids can be seen below.



BRITISH H993 GUN IN HYDE PARK 1941. THE 3.7" ANTI-AIRCRAFT GUN COULD PROPEL HIGH EXPLOSIVE AND INCENDIARY SHELLS UP TO 59,000 FEET, HIGHER THAN THE GERMAN BOMBER AIRCRAFT COULD FLY.



The 40mm Bofors Gun anti-aircraft gun could propel High Explosive and Incendiary shells up to 41,000 feet.



3.6" anti-aircraft rocket 'Z' Battery London 1942

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Appendix C. London Underground Comments Log

London Underground Comments Log

Project	Bank Station Capacity Upgrade
Project Reference	UIP 8798
Document to Review	MACC UXO Threat Assessment
Document Hyperlink	http://onespace.tfl.gov.uk/lu/_scp/BankNL/Project%20Documents/MACC%20UXO%20Threat%20Assessment.pdf
Document Reference	LUSTN-0008798-DOC-001220
Report version	V0.2
Document Owner	

Date	19 September 20
Comments Log version	
Comments log reference	

Comments log version	Date	From	To	Version details	Response by
0.1	14/09/2011	LU	LU	Initial comments	23/09/2011
1.0	20/09/2011	LU	MM	MM to address comments	4/102011
2.0	12/10/2011	MM	LU	MM responses to comments	12/10/2011

Red
Green
Observation

LU Participants		Viki James, Billy Kavanagh, Jon Colclough Responsible for the final approval of this report: Olu Morgan - Bank SCU Project Manager						
Discipline <i>Please type your job title and initials</i>	Version of document being reviewed	Section / Page	Sub-section	Issue/Comment <i>Please use one cell per question, query or comment</i>	Consultant's response	Comment accepted/not accepted <i>Enter your initials, date and type if comment accepted or not</i>	Status <i>Type the word green = accepted red = rejected observation</i>	
1 Environment Manager (JC)	1.1	10.2 / p9	2nd bullet	Will MM (or their sub-consultant) be producing the recommended UXO site safety and emergency procedures plan?	<i>This will be within the remit of the Principal Contractor and form part of their Construction Phase Plan.</i>			
2 Environment Manager (JC)	1.1	10.2 / p9	3rd bullet	Will MM (or their sub-consultant) be producing / delivering the recommended UXO Safety Induction Training?	<i>This will be within the remit of the Principal Contractor to organise as part of the site induction training.</i>			
3 Environment Manager (JC)	1.1	10.3-10. 7/ p10		How is it proposed to take forward all these recommendations? For example, is it recommended that these recommendations are included in the Works Information as requirements that the Design/Build Contractor will be responsible for, or, do we need to consider engaging a separate, specialist contractor to undertake this work?	<i>Recommendations will be included in the Pre-Construction Information and Works Information in order that the Principal Contractor can action the hazard mitigation/management measures accordingly.</i>			
4 Surveys PM (VJ)	1.1	5.3 and 6.1	1st para of both	5.3 states 'there is no evidence of bombs having struck within the site footprint'. 6.1 says 'records indicate that the area suffered extensive bombing with bombs dropped around the site footprint' Q - definition of site footprint is required. Just 10 KWS? Does inc footpaths, street etc Q - better clarity is required as statements appear to conflict	<i>The paragraph which is referred to relates to WWI bomb strikes and not WWII strikes, in which case the statement is true and does not necessarily conflict with that of Section 6.1. The description of the site footprint is given in Section 3 and Annex A of the Report.</i>			
5 Surveys PM (VJ)	1.1	8.4	table	Why is the tunnelling risk deemed to be high when 6.3.5 notes that a reasonable safety factor says that maximum penetration is 8.0m and we are tunnelling at a depth of approx 27m?	<i>Tunnelling as an 'activity' within the risk depth (i.e. <8.0m) is considered high risk due to the extensive nature of the ground disturbance. Therefore, the high risk rating would not apply to tunnelling activities below the risk depth (i.e. >8.0m).</i>			

6	Surveys PM (VJ)	1.1	10.7		As above, is this really required for the tunnelling? Agreed that shaft is applicable.	<i>The statement in the report section "A Pre testing and clearance certification of the intended shaft position and tunnelling route (Where it is within the identified risk depth) using a specialist "safe look ahead" capable magnetometer system." clearly states "within the identified risk depth" and therefore beyond the risk depth would be considered as not applicable.</i>		
7	Surveys PM (VJ)	1.1	Annexes		A single map consolidating findings would be a good addition	<i>Due to the quality of the source mapping and the fact that there is likely to have been bombs dropped that have not been recorded on the mapping any integration of the data from the maps into a single plan/ map could prove misleading.</i>		
8	Project Engineer (BK)	1.1	General		There is no evidence of MM having reviewed and accepted this document. Suggest MM cover sheet is added with appropriate signatories and version control.	<i>MML can provide a cover sheet to the Bank Station Capacity Upgrade Project format.</i>		Observation
10	Project Engineer (BK)	1.1	10.3		Review the requirement for magnetometer testing within the road/pavement area. Is this standard practice for disturbed ground likely to have extensive excavation for utilities and maintenance?	<i>It is not always easy to predict areas and overall depths that have been subject to extensive disturbance due to buried service installation, road works, etc. The history of development of the scheme footprint may make it difficult to predict at what level the pre and post war made ground/ reworked ground may exist. It would therefore rely on the competence of the UXO supervision (CIRIA C681 provides guidance on the selection of appropriate suppliers for UXO mitigation works) during the intrusive works on site to take a view on the potential for UXO to be present based on the ground conditions as encountered.</i>		Observation
11	Project Engineer (BK)	1.1	Appendix		The drawing in the appendices are very difficult to read (particularly A-2), please improve.	<i>MML have previously raised this issue with MACC International and the response was accepted. This being, due to the quality of the original source material (i.e. non digital), there is very little that can be done to improve the quality. See also the response to Comment 7 above. The plans provided are only really indicative and only seek to highlight that there were documented bomb strikes in the general area of the proposed scheme. Due to the nature of the bombing undertaken on London during the Blitz (Sept 1940-May 1941) there is a potential for bombs dropped being unrecorded (note the estimated bomb density for the area was 600 bombs per 1,000 acres). See also Section 5 of the UXO report.</i>		