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Unexploded ordnance (UXO)

A guide for the construction industry

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Foreword

One unintended outcome from construction activity is that unexploded ordnance (UXO) is occasionally discovered. When it is, it usually generates considerable media interest and causes major disruption to the public. Fortunately experience shows that the risk of casualties has been very low. However as it is a high consequence but low probability event, appropriate allowance should be made at the design stage for assessing the risk of encountering UXO on-site and for mitigating that risk if significant.

UXO arises from both hostile and defensive military activity often related to World Wars I and II. Many parts of the country, both urban and rural are affected.

There has long been uncertainty over the extent to which designers and others should undertake investigatory work to establish if a potential development site is free of the presence of UXO and how that risk should best be mitigated. This guide aims to help end this uncertainty. It is the work of a very enthusiastic and experienced group of people and HSE supports and welcomes its publication.

Dr Donald Lamont

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Health and Safety Executive

Executive summary

The legacy of unexploded explosive ordnance (UXO) has caused many problems for construction projects throughout the UK. Invariably these problems have led to delays and an associated increase in costs, especially during the site investigation and groundwork phases of construction. In many cases these problems could have been avoided if an appropriate risk management procedure had been carried out at the initial stages of the project design process.

Clients have a legal duty under CDM2007 to provide designers and contractors with project specific health and safety information needed to identify hazards and risks associated with the design and construction work. The possibility of UXO being encountered on a site falls within the category of a potentially significant risk, and it should be addressed as early as possible in the lifecycle of a project.

Recommendations for good practice

The principal purpose of this document is to provide the UK construction industry with a set and defined process for the management of risks associated with UXO from WWI and WWII aerial bombardment. Also it will be broadly applicable to the risks from other forms of UXO that might be encountered.

This publication is a construction industry guide. It focuses on the needs of the construction professional if there is a suspected UXO on site and covers issues such as what to expect from an UXO specialist. However the guide is not intended to give details guidance for the EOD contractors or contracting practices.

In many cases, an important question for construction clients is whether and when UXO specialist advice is needed. A UXO specialist adds more value where the project and/or degree of UXO contamination and its associated risk is very high but less when the risk posed by UXO is relatively benign and straightforward to deal with.

To help the client to decide when will be the appropriate time to seek such advice, it is important to understand and follow a risk management process that is divided into the following four distinct stages:

1 **Preliminary risk assessment.** The purpose of the preliminary risk assessment is to enable the non-UXO specialist to place a site in context with the potential risk from UXO and to identify whether more detailed assessment is required. The assessment is based on data obtained from a desktop review of historical information regarding site location, previous site development, wartime bombing records etc.

> It is anticipated that the majority of sites in the UK will be identified as having a low probability of a UXO hazard to take place and would be excluded from further consideration following the completion of the preliminary risk assessment. However this is an important initial step to help construction professionals to assess sites with potential UXO risk.

If a potential UXO risk is identified at the preliminary risk assessment, it is important that a UXO specialist is commissioned by the client. This should take place during the initial stages of the project planning and ideally before the start of

any detailed design. This early involvement may also enable the project team to identify appropriate techniques to reduce potential risks through considered design, without the need for UXO specific mitigation methods.

2 **Detailed risk assessment.** This assessment enables an estimate to be made of the likelihood of creating a UXO hazard on a site, giving due consideration to the development type and construction methods to be employed.

3 **Risk mitigation.** The purpose of risk mitigation is to eliminate risk or reduce it to an acceptable level. The risk mitigation process provides a framework that identifies appropriate mitigation methods for the various risk scenarios that may be identified by the detailed risk assessment. Identified options are then assessed to ensure that an efficient and cost effective risk mitigation programme is selected.

4 **Implementation.** The final phase of the risk management process is to ensure that the selected risk mitigation plan is carried out correctly and efficiently during the construction phase of the development works and that the works are verified as having been completed to a satisfactory level.

Details of these four stages are given in Figure 4.1.

For sites where there is the possibility of a UXO hazard, there should be an emergency response plan in place. The plan should provide clear and precise guidance on what to do should a UXO be encountered, and/or initiated as part of the site works, with accompanying emergency management team roles and responsibilities. This should be included in the health and safety plan for the proposed works and should be communicated to the work force at the operational level, typically as part of a tool box brief.

On completion of each work stage the UXO specialist should produce a report detailing the nature of the work done. Also, on completion of the final stage of risk mitigation, the UXO contractor should produce a verification report detailing all the works undertaken with specific reference as to how the individual risks identified as part of the risk assessment process have been addressed.

A poster version of Figure 4.1 *Risk management framework* is contained at the back of this guide.

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Glossary

Abandoned bomb	UXB that was abandoned during WWII rather than being dealt with at the time by bomb disposal teams due to benign position, difficulty of access, or a lack of resources.
Abandoned bomb register	Official and current records of abandoned bombs held and updated by central government (not local authorities).
Aerial delivered ordnance	Ordnance used by air forces. In the UK, most likely to be German aerial delivered bombs.
Alienated site	Ex MoD land that has been returned to non-military use.
Ammunition	A complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological or chemical material for use in military operations, including demolitions.
Anecdotal evidence	Evidence of potential UXO from sources such as local newspaper records, local historical groups and local residents.
Anti-personnel bomb	Aerial delivered bombs containing small quantities of high explosive. Often booby-trapped and designed to be triggered by individuals.
Anti-personnel mine	A landmine designed to injure or kill one or more persons. Usually detonated when they are stepped on or when a tripwire is disturbed, also set off by the passage of time or by controlled means.
Anti-tank mine (also known as anti-vehicle mine)	A landmine designed to disable or destroy vehicles, including tanks. Can be detonated by pressure (though normally significantly more than required to activate an anti-personnel mine) or remote control, as well as by magnetic influence or through the disturbance of a tilt rod (a sort of vertical tripwire).
Artillery	Guns of larger calibre than machine guns, equipment, supplies and ammunition.
Bedrock	The natural consolidated rock underlying a site.
Benign UXO related items	UXO related items Free From Explosives, generally comprising empty cartridge cases, inert/expended ordnance etc.
Bomb Census	Census undertaken by the Ministry of Home Security during the war to provide intelligence relating to bombing raid patterns, types of ordnance used and consequent damage. Held at the National Archives.
Bomb damage maps	Maps maintained by many local authorities during WWII that provided a record of bomb damage sustained.
Bomb penetration assessment	Assessment of the likely maximum depth of burial of aerial delivered ordnance.

Bombing density	Number of bombs per hectare.
Booster	A separate (intermediate stage) component and placed next to the high explosives – it is activated by the fuse and/or primer. It initiates the HE.
Brownfield	As opposed to a greenfield site, a brownfield site is a generic term for land used previously for an industrial, residential or commercial purpose, being available for redevelopment towards new industrial, commercial or residential use.
Caesium vapour magnetometer	Instrument that measures the Earth's total magnetic field at a point in space. Items high in ferrous or ferric components will cause significant changes in the fields. They are manufactured in sealed units, which consist of four elements: 1 A caesium light (ie photon) emitter. 2 An absorption chamber (containing optically pumped caesium vapour). 3 A buffer gas (that emitted photons pass through). 4 A photon detector.
CDM co-ordinator	For projects to be notified to the Health and Safety Executives or ORR under the Construction (Design and Management) Regulations 2007 a person appointed to advise the client on the health and safety risks associated with the project including the potential presence of UXO. The CDM co-ordinator must seek specialist advice and must be satisfied that the sources are suitable. If requested, the CDM co-ordinator must advise the client on the competence that is needed by the designer, principal contractor and other contractors. If the CDM co-ordinator does not have relevant expertise themselves, they are required to identify the need for a UXO specialist to provide advice on potential risks from UXO and advise the client on their competency needed.
Charge	A bagged, wrapped or cased quantity of explosive without its own integral means of ignition.
Clearance certificate	A clearance certification is issued by the MoD and other organisations. The level of clearance will also depend on the available technology, resources and practices of the day. The existence of a clearance certificate does not provide a 100 per cent guarantee that UXO will not be encountered later, but rather that trained staff using the best available technology of the time have been applied to reducing the potential risk from residual items of ordnance (see Section 7.11.2).
Clearance report	A report issued by UXO contractor following the completion of the risk mitigation works at a site detailing all the works undertaken to date and any residual risk.
Cleared area/cleared land	An area that has been physically and systematically processed by an UXO contactor to ensure the removal/clearance and/or destruction of all mine and UXO to a specified depth.

Collateral damage	Unintentional damage or incidental damage affecting facilities, equipment or staff.
Competence	An individual's demonstrated capacity to perform, ie the possession of appropriate knowledge and skills to enable an individual to effectively perform a specific role.
Cone Penetration Test (CPT) rig	Device by which a cone is pushed into the ground at a constant rate and to which a magnetometer may be attached to give continuous measurements.
Construction (Design and Management) Regulations 2007 (CDM)	Regulations carried out under the Health and Safety at Work etc Act 1974 and setting out duties in respect of the planning, management and monitoring of health, safety and welfare in construction projects, and of the co-ordination of performing these duties by duty holders. Duties applicable to all projects, including those of clients, designers and contractors.
Crash landing	A forced emergency landing of an aircraft.
Decommissioning	The process of taking plant, equipment and buildings out of normal use and leaving in a safe condition.
Designer (CDM)	Under CDM, designers are those who are involved in preparing designs for construction work, including variations. This includes preparing drawings, design details, specifications, bills of quantities and the specification (or prohibition) of articles and substances, as well as all the related analysis, calculations, and preparatory work or arranging for their employees or other people under their control to prepare designs relating to a structure or part of a structure. It does not matter whether the design is recorded (for example on paper or a computer) or not (for example it is only communicated orally).
Destroy/destruction *in situ* or blow *in situ*	The destruction of any item of ordnance by explosives without moving the item from where it was found, normally by placing an explosive charge alongside. Also known as a controlled explosion.
Detection	The discovery by any means of the presence of UXO.
Detonation	A violent chemical reaction due to heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the un-reacted material. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium, forming a propagating shock wave that originally is of supersonic velocity. When the material is located on or near the surface of the ground, a crater normally characterises a detonation.
Detonation pathway	The mechanism that may cause a UXO to detonate. This is the second component of risk. The first component of risk is the presence of UXO.
Detonator	The component within an explosives train that, when initiated, detonates a less sensitive but larger high explosive charge (usually the booster), or when containing its own primer initiates the detonation.

Disarm	The act of making safe by removing the fuse or igniters. The procedure normally removes one or more links from the firing chain.
Emergency management team	Multi-disciplinary team usually consisting of senior management staff. Established to carry out and control a suitable response to an emergency situation.
Explosive ordnance	All munitions containing explosives, nuclear fission or fusion materials and biological and chemical agents, this includes bombs and warheads, guided and ballistic missiles, artillery, mortar, rocket and small arms ammunition, all mines, torpedoes and depth charges, demolition stores, pyrotechnics, clusters and dispensers, cartridges and propellant actuated devices, electro explosive devices, clandestine and improvised explosive devices and all similar or related items or components explosive in nature.
Explosive ordnance disposal (EOD)	The detection, identification, evaluation, rendering safe, recovery and disposal of UXO.
Explosive	A substance or mixture of substances that, under external influences, is capable of rapidly releasing energy in the form of gases and heat.
Exudation	The process in which a chemical reaction occurs over a period of time within an explosive compound. Mainly generated by organic impurities melting and exuding from the main body of an unexploded bomb around the fuze pocket. This can make an UXB extremely sensitive to chock and/or friction. The main visual signs are: ■ white or dirty white encrustations ■ brownish viscous substance ■ yellowish liquid ■ coloured crystals.
Failure rate	The proportion of aerially delivered bombs and other explosive ordnance that fail to detonate as intended.
Fluxgate magnetometer	Instrument that measure variations in the Earth's magnetic fields. They are manufactured in sealed units, which consist of a small (magnetically susceptible) core, wrapped by two coils of wire. See also *Gradiometer*.
Free From Explosive (FFE)	Term used to signify that an item that may have been associated with UXO has been assessed by a qualified EOD engineer and identified as no longer containing any explosive substances.
Fuze	A designed and manufactured mechanism to activate a mine or munitions. It can be designed for use by electrical, chemical or mechanical systems, by push, pull, pressure, release and time activation, singly or in combination. Usually consists of an igniter and detonator.
Geophysical survey techniques	Methods of investigating the spatial distribution of physical characteristics of the subsurface methods. These can be classified into two distinct types:

	1 **Passive:** those that detect variations within the Earth (eg gravitational, magnetic). 2 **Active:** those in which artificially generated signals are transmitted into the ground (eg electrical and electromagnetic fields).
Gradiometer	Instrument that measures changes in the magnetic field of the Earth at a known distance apart allowing a gradient to be derived.
Greenfield	Land that has never been built upon.
Grenade	A small explosive bomb hand thrown or projected from a rifle or purpose built grenade launcher.
Ground penetrating radar (GPR)	Instrument used in non-intrusive surveys that emits short pulses of radio-frequency electromagnetic energy into the subsurface from a transmitting antenna. It produces a visual representation of the subsurface. See also *Bomb penetration assessment*.
Ground penetration capacity	The extent an item of ordnance can potentially penetrate below ground level.
Hazard	Anything with the potential for harmful effects.
Hazard assessment (UXO)	An assessment of the potential for a UXO hazard to exist at a site. The assessment is based on data obtained from a desktop review of historical information regarding site location, previous site development, wartime bombing records etc.
Hazard characterisation (UXO)	Assessment of the potential for a UXO hazard to: ■ detonate ■ cause harm. The assessment is based on data obtained from a desktop review of historical information regarding the UXO type, geology, proposed construction and the construction methods.
Health and Safety at Work etc Act 1974	Regulations stating every employer must 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 activity.
High explosive (HE)	An explosive that normally detonates rather than burns, ie the rate of detonation exceeds the velocity of sound.
High explosive (HE) bombs	Aerial delivered ordnance containing high explosives generally with sufficient mass, velocity and suitably streamlined shape to enable them to easily penetrate the ground if they failed to explode on the surface.
High risk UXO	Large bombs that are dangerous because of the presence of a potentially unstable fuze charge within the mass of high explosive.
His Majesty's factory	WWI explosive manufacturing factories.
Home Guard	This was the organisation active in Britain during WWII to help defend the country against ground invasion. It comprised of local volunteers otherwise ineligible for

	military service, usually owing to age. The Home Guard protected main coastal areas of Britain and other important sites such as factories and explosives stores. They were armed with basic munitions and weapons, however due to shortages of conventional weapons, many improvised devices were developed, eg Molotov Cocktails.
ICE Conditions of Contract for ground investigation works	Standardised form of contract produced by the Conditions of Contract Standing Joint Committee (CCSJC) of the ICE.
ICE Conditions of Contract for minor works	Standardised form of contract for minor works produced by the Conditions of Contract Standing Joint Committee (CCSJC) of the ICE.
Implementation	The final phase of the risk management process that ensures the selected risk mitigation plan is carried out correctly and efficiently and that the works are validated as having been completed to a satisfactory level.
Improvised explosive device (IED)	Those devices placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic or incendiary chemicals, designed to destroy, disfigure, distract or harass. They may incorporate military material but are normally devised from non-military components.
Incendiary	A highly exothermic composition or material that is primarily used to start fires.
Incendiary bombs	Aerial delivered ordnance (also known as fire bombs) initially containing oil but typically made of magnesium alloy, which is initiated by a small thermite charge.
Inert ordnance	An item of ammunition that contains no explosive, pyrotechnic, lachrymatory (eg tear gas material) radioactive, chemical, biological or other toxic components or substances.
Initiation	See *Detonation*.
International Mine Action Standards (IMAS)	The standards in use for all United Nations mine action operations. They were initially endorsed by the UN Inter-Agency Coordination Group on Mine Action on 26 September 2001.
Intrusive survey	A survey with some elements of the works taking place below the ground surface and requiring equipment to be progressed into the underlying soils.
J-curve	The term used to describe the characteristic curve followed by an aerial delivered bomb dropped from height after it penetrates into the ground. Typically, as the bomb is slowed by its passage through the underlying soils its trajectory curves around to a final heading that point back towards the ground surface. Many UXO are found with their nose section pointing upwards towards the ground surface as a result of this effect.
Lithology	The physical characteristics of a soil or rock formation.

Acronyms and abbreviations

AAA	Anti-aircraft artillery
ACE	Association for Consultancy and Engineering
ACoP	Approved code of practice
AP	Anti-personnel
APM	Association of Project Management
ARP	Air raid precaution (wardens)
BH	Borehole
BD	Bombing density
BDO	Bomb disposal officer
BGS	British Geological Survey
CBI	Confederation of British Industry
CDM	Construction (Design and Management) Regulations (2007)
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetration Test
DE & S	MoD's Defence Equipment and Services
DEODS	Defence Explosive Ordnance Disposal School
DEMSS	Defence Explosives, Munitions and Search School
DGPS	Differential global positioning system
EMT	Emergency management team
EOC	Explosive ordnance clearance
EOD	Explosive ordnance disposal (engineer)
ESG	MoD DE & S Environmental Science Group
FDEM	Frequency domain electromagnetic
FFE	Free From Explosives
FR	Failure rate
GPS	Global positioning system
HE	High explosive
HMF	His Majesty's Factories
HSE	Health & Safety Executive
HSW	Health and Safety at Work etc Act 1974
IB	Incendiary bomb
ICE	Institution of Civil Engineers
IED	Improvised explosive devices
IMAS	International Mine Action Standards

ITT	Invitations to Tender
JSEODOC	Joint Services Explosive Ordnance Disposal Operations Centre
ISO	International Organization for Standardisation
LSA	Land service ammunition
MHSWR	Management of Health and Safety at Work Regulations (1999)
MICE	Member of the Institution of Civil Engineers
MIExpE	Member of the Institute of Explosives Engineers
MoD DE & S	Environmental Science Group MoD Defence Equipment and Support
MoD	Ministry of Defence
NFF	National Filling Factory
NVQ	National Vocational Qualification
ORR	Office of Rail Regulation
PI	Professional indemnity
PVC	Polyvinyl chloride
QA	Quality assurance
QC	Quality control
RAF	Royal Air Force
RIBA	Royal Institute of British Architects
RICS	Royal Institute of Chartered Surveyors
ROF	Royal Ordnance Factory
SAA	Small arms ammunition
SI	Site investigation
SIP	Self igniting phosphorous
TDEM	Time domain electromagnetic
USEPA	United States Environmental Protection Agency
UXB	Unexploded aerial delivered bombs
UXO	Unexploded explosive ordnance
WWI	World War One
WWII	World War Two
V1	Flying bombs or doodlebugs
V2	Long range rockets

1 UXO and the construction industry

There is a concern within the construction industry that advice relating to UXO risks can vary widely depending on the adviser. There is a general desire among construction practitioners for greater transparency in the preparation of UXO risk assessments and for more consistency in approach between UXO specialists. This publication seeks to give clarity to the processes and procedures used for UXO assessments, and provide clients and their professional advisers with the tools to assist them in assessing the suitability of a UXO specialist to undertake the work and to understand the advice being given.

This publication is a construction industry guide. It focuses on the needs of the construction professional if there is a suspected UXO on site and covers issues such as what to expect from an UXO specialist. However the guide is not intended to give details guidance for the EOD contractors or contracting practices.

1.1 WHY BE CONCERNED ABOUT UXO?

In recent decades there have been several incidents in Europe where Allied UXBs have been detonated with at least three being fatal.

The reasons why fatal incidents have not yet occurred in the UK could include:

- the relative scale of German bombing (20 times lower than the Allied bombing of Germany)
- the preferred use of mechanical as opposed to electrical fuses
- good fortune.

There is no available data regarding the number of UXO incidents on construction sites within the UK. To place the potential risk posed by UXO to the UK construction industry into context with other more commonly considered construction risks, estimates have been obtained from UXO specialists[1]. These estimates are based within the UK regarding the occurrence of UXO hazards on UK construction sites for the period 2006 to 2008.

During this period it is estimated that about 15 000 items of ordnance ranging from high explosive aerial delivered German bombs to smaller items such as mortar rounds and grenades (but excluding small arms ammunition) have been removed from UK construction sites. Of these items it is estimated that about five per cent were live, ie still fully functioning. The number of items of small arms ammunition recovered during this period runs into the tens of thousands.

1.1.1 Employers responsibilities under health and safety legislation

All employers have a responsibility under the Health and Safety at Work etc 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 activity. Construction professionals have further

1 Information provided by the UK's two largest UXO specialist companies. This number would be significantly higher if data from the other UK UXO specialist companies is included.

specific duties under the Construction (Design and Management) Regulations 2007 (CDM2007). Under CDM2007, 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 (see Section 3.1.2).

From 2006 to 2007 the Health and Safety Executive[2] reported a total of 77 fatalities, 3711 major injuries and 7108 injuries resulting in over three days of lost time for workers within the UK construction industry. No reported injuries to construction workers during this period were attributed to incidents involving UXO.

1.1.2 Financial implications

Although the liklihood 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 (see Case studies 1.1 and 1.2).

Inner city brownfield sites have recently been the subject of development, however many of these areas were heavily targeted during WWII and have remained largely untouched since then. So the likelihood of encountering UXO during the construction phase of projects on these sites is significantly increased.

Case study 1.1 ***The financial implications of the unexpected occurrence of UXO***

Construction had just started at the site of major gas pipeline in the UK. During the initial stages of intrusive works, an observant site operative noticed something unusual in the ground. On closer inspection the operative became suspicious that the item might be a UXO, possibly a mortar round. The operative had some military experience and recognised that the item could be ordnance related.

As construction works were already underway, the contractor had mobilised all the required plant, equipment and staff required to undertake the laying and welding of pipes. However, immediately on discovering the suspect item, the whole construction team were stopped from working, removed from the area and put on standing time.

The contractor contacted the police who contacted the Army. A bomb disposal unit was deployed to the site and following careful investigation, the suspect item was confirmed as a mortar round. The mortar round was destroyed *in situ* by the Army and the immediate threat of an uncontrolled explosion averted.

Until this stage the contractor had not considered the potential risk posed by UXO and was naturally concerned when informed by the Army bomb disposal team that, where there is one mortar round, there is a good chance that there are others.

Acting upon this advice, the contractor then brought in a UXO detection and clearance specialist to undertake an assessment and investigation of the pipeline route. This investigation lasted for many weeks and during this period hundreds of UXO and UXO related items were discovered. Each individual item required careful consideration to make safe, involving further time delays. All the while the pipe welding and pipe laying teams remained on standing time.

Ignoring the UXO specialists' fees, the estimated cost of delay was in excess of £1m. For the next phase of the pipeline construction, the contractor, who was now fully aware of the potential implications of unexpectedly discovering UXO during a construction project, ensured that the rest of pipeline route was assessed, investigated and cleared of any potential UXO by their appointed UXO specialist well in advance of the start of the construction phase of works.

2 For more information visit: <www.hse.gov.uk/>.

Case study 1.2 ***Minimising financial risk by effective UXO risk management***

While compliance with health and safety legislation may be seen as one of the main aims behind the effective management of UXO risks, in real terms the most likely effects on construction are delays to programme and increased cost.

In the summer of 2008 a high explosive (HE) bomb was discovered during development works for the 2012 Olympics in East London. An exclusion safety zone was established around the UXO, resulting in a site investigation on a nearby site being suspended and workers told to evacuate the area. The UXO was discovered on a Monday morning and it took until the following Friday evening for the bomb to be made safe and the site investigation team to be allowed to return to the site. This inevitably caused significant delay to the site investigation programme and led to a delayed start to the construction phase of works.

The temporary suspension of the site investigation works, with four drilling rigs and associated staff and equipment on standing time for a period of five days, resulted in a significant cost overrun. However, the delays were minimised as the issue of potentially encountering UXO during site works had been taken into consideration by the client's team at the planning stage of the site investigation works. So the site investigation contractor had only to carry out the mitigation measures already established for such an event. If this had not been the case site investigation works may have been delayed further while the issue of risk was addressed.

1.2 LACK OF UK GUIDANCE ON UXO AND THE IMPLICATIONS

There has been UK guidance published regarding the clearing of explosives from sites that were involved in the manufacturing, processing and testing of explosives. However, there is currently little publicly available guidance to specifically assist construction professionals (particularly clients, developers and ground works contractors) in assessing the risks associated with encountering a UXO during the construction phase of a project.

Construction professionals often depend solely on specialist advice to deal with potential UXO risk because there is:

- limited guidance
- lack of direct legislation
- limited knowledge many developers have of the subject.

However in some cases dealing with potential UXO risk at a site or the potential threat from UXO may not be considered at all.

These limitations have resulted in project delays, which often force developers to pay for unnecessary and expensive mitigation measures.

1.3 AIMS AND OBJECTIVES OF THIS GUIDE

This publication provides good practice guidance for the management of risks presented by UXO to the construction industry. It is intended to increase the understanding of the subject for the construction industry professional and clarify the benefits and limitations of the services offered by UXO specialists.

The aims of the guide are to explain:

- current good practice methodology for carrying out a tiered risk assessment of encountering and detonating a UXO at both site investigation and construction phases (Chapters 4 to 7)
- how to prepare a transparent and robust risk assessment to provide a clear basis for decision making about the possible need for mitigation measures (Chapters 4 to 8)

- how to select specialists to prepare UXO risk assessments for sites at risk (including issues relating to the preparation of specifications for specialists) (Chapter 9)
- how to encourage independence of the advice given by UXO risk assessors and detection and clearance professionals (Chapter 9).

This guide is written for use primarily for sites in the UK. The UXO risk and associated legal environment may be different in other countries (though the basic principles of this guide should still be applicable).

1.4 WHO IS THE TARGET AUDIENCE?

The guide is targeted at clients, developers, designers, consultants and contractors dealing with building, civil engineering, geotechnical investigation and remediation works associated with a construction project. It should also be useful to the Health and Safety Executive, Environment Agency, local authorities and other regulators, insurers, investors, landowners and other professionals who are involved in development projects on construction sites.

1.5 WHAT DOES THIS GUIDE COVER?

This guide covers situations arising from conventional military munitions but does not address the discovery of improvised explosive devices (IEDs) with the exception of WWII Home Guard munitions. It also covers land formerly used for defence purposes but now available to the public and commercial sectors.

1.6 WHAT DOES THIS GUIDE NOT COVER?

The guide's coverage is limited and although the information contained within it is broadly applicable to the investigation and risk management of all UXO, it does not directly address those situations that are already covered under existing guidance and legislation (Table 1.1).

The guidance does not apply to the current Defence Training Estate. The guidance does not address issues regarding the potential toxicological risks associated with the chemical components of UXO or from other materials used in their construction, and their possible effects on human health and the environment.

Table 1.1 ***Situations not specifically covered by this guidance***

Situation	Existing guidance
The occurrence of UXO below the high water mark.	Construction Industry Publications (2004) "Work over water", Section 8E, *Construction health and safety manual* Crown Estate (2006) *Dealing with munitions in marine aggregates*, Guidance Note
The occurrence of UXO on current munitions manufacturing and storage sites	Confederation of British Industry (CBI) (1993) *Management guidance for the safe decommissioning of explosives sites* Confederation of British Industry (CBI) (2007) *Guidance for the safe management of the disposal of explosives*
The occurrence of secondary environmental contamination resulting from UXO (eg chemical contamination)	BULLOCH, G *et al* (2001) *Land contamination: technical guidance on special sites: MoD land,* R & D Technical Report P5-042/TR/01, Environment Agency (ISBN: 1-85705-580-2) BULLOCH, G *et al* (2001) *Land contamination: technical guidance on special sites: explosives manufacturing,* R & D Technical Report P5-042/TR/03, Environment Agency (ISBN: 1-85705-582-9)

1.7 STRUCTURE OF THE GUIDE

The guide is structured to address the objectives as presented in Section 1.3.

Chapter 2 of the guide provides background information on the sources and types of UXO that may be encountered in the UK. The duties and liabilities relating to the management of UXO risks and the responsibilities of various project team members are described in **Chapter 3**.

The basics of risk management and a framework for good management of UXO risks are described in detail in **Chapter 4**. Included in **Chapter 4** is a risk management flow chart that details the processes to be followed to ensure that the risk at a particular site has been addressed as far as is reasonably practicable. **Chapters 5 and 6** describe respectively the processes for undertaking a preliminary UXO risk assessment and detailed UXO risk assessment. Typical risk mitigation strategies are described in **Chapter 7** and a suggested emergency response procedure in the event of encountering a suspected UXO is given in **Chapter 8**.

Chapter 9 provides guidance on how to appoint a suitable UXO specialist including deliverables, contractual arrangements, execution of works, the issuing of verification reports and the provision of risk management plans for end users.

The appendices give further related information to support this publication. **Appendix A1** contains a list of information sources. **Appendix A2** contains an extract from a government communiqué regarding the failure rate of WWII German aerial delivered bombs. **Appendix A3** contains a copy of a written answer to the House of Commons regarding the number and location of abandoned bombs in London. The information within these appendices will assist the non-UXO specialist when undertaking preliminary risk assessments.

Three samples of desk studies and risk assessment reports provided by UXO specialists regarding both aerial delivered UXO and military UXO are included in **Appendix A4**. These were gathered during the consultation stage of this publication and demonstrate the range of information that can be obtained. In some cases clients may require or prefer an historical perspective particularly in the early stages of planning. Others may prefer a more direct analytical probabilistic approach or indeed a combination of the two.

While these samples provide examples of many of the points raised in this CIRIA guide, they also demonstrate the different styles of presenting the results of desk studies and the different methods of undertaking and presenting the results of a risk assessment.

An overview of UXO survey and investigation techniques is provided in **Appendices A5** and **A6**.

Appendices A7 and **A8** contain example verification reports and examples of clearance certificates issued by commercial UXO specialists.

2 An introduction to UXO

Unexploded ordnance (UXO) is defined by the United Nations[3] as:

> "Explosive ordnance that has been primed, fused, armed, or otherwise prepared for use and used in an armed conflict. It may have been fired, dropped, launched or projected and should have exploded but failed to do so."

However, for the purposes of this guide the definition is expanded to include unexploded ordnance that may have been dumped, buried or otherwise discarded. This is defined by the United Nations[3] as:

> "Explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it. Abandoned explosive ordnance may or may not have been primed, fused, armed or otherwise prepared for use."

UXO can range in size from small arms ammunition to large unexploded bombs weighing more than 2000 kg (unexploded aerial delivered bombs are often referred to as unexploded bombs or UXBs, see *Glossary*) and all have the potential to cause significant harm to those who encounter them. They can be found on the surface but are more usually buried underground with no surface markers to indicate their presence.

2.1 SOURCES OF POTENTIAL UXO

UXO found at construction sites in the UK originate from three principal sources:

1 Munitions deposited as part of military training exercises.

2 Munitions dumped as part of a deliberate act, accidental disposal or disposed of ineffectively due to poor working practices during munitions storage and manufacture.

3 Ordnance resulting from wartime activities including enemy bombing events during WWI and WWII, long range shelling, munitions deliberately placed as a means of area denial (mine fields, pipe mines etc) and munitions from other home defence activities (anti-aircraft batteries, coastal artillery emplacements etc).

2.1.1 UXO from defence activities

The Ministry of Defence (MoD) and its predecessors owned or occupied large areas of the UK and used a significant proportion of land for the storage, training, production, development and testing of weapons. Land, sea and air ranges were, and continue to be, used for training using a wide variety of military ordnance including high explosives and pyrotechnics.

3 Protocol on "Explosive remnants of war" (Protocol V to the 1980 Convention) *United Nations Convention on prohibitions or restrictions on the use of certain conventional weapons which may be deemed to be excessively injurious or to have indiscriminate effects,* 28 November 2003.

4 Busé, M (2000) *Journal of Mine Action*, version 4–2, June 2000.

It is estimated that over 20 per cent of the UK's land area has been used, at one time or another, for military training[4]. WWII in particular saw significant areas of the countryside requisitioned and used by British and Allied Forces in preparation for the invasion of Europe. Thousands of tonnes of ordnance were expended in the testing of weapons systems and the training of service staff. The types of ammunition used were varied and included aerial delivered bombs, naval shells, artillery and tank projectiles, mortar rounds, grenades, explosives and small arms ammunition (SAA). It is generally accepted that up to 10 per cent[5] of these munitions failed to function as designed[6] and, given the historical rate of ordnance expenditure and its potential geographic spread, the scope for UXO contamination on MoD land can be envisaged.

A drastic reduction in troop levels took place after WWII, and as a result, less land was required for training, so it was returned to its former owners. Before the land was returned, MoD explosive ordnance disposal (EOD) teams carried out UXO clearance works to the standard practices of the time, using in-service equipment. However, the clearance of ordnance from depots, storage facilities, ranges and training areas was not effectively managed after WWII, and was undertaken to varying degrees of certainty. Similarly, the search and detection equipment used at the end of WWII has since proved ineffective for certain types of UXO, some of which were buried at depths beyond the capability of the metal detectors used at the time. As a result, UXO on former defence sites are still being discovered at historical or alienated sites. The former are WWII historical training sites and the latter is land used for defence purposes, which is now no longer part of the Defence Estate (see Case study 2.1).

2.1.2 UXO on munitions manufacturing and storage sites

In WWI the UK Government took control of all armaments manufacture and supply under the newly created Ministry of Munitions. Explosives and ordnance manufacturing was undertaken at new and existing factories, many of which were operated by privately owned companies from the chemical and engineering industries. The explosive factories were known as His Majesty's Factories (HMFs), and the munitions filling factories were designated National Filling Factories (NFFs).

The majority of WWI munitions factories closed between the wars, leaving a small number of well established factories such as Royal Arsenal Woolwich, Royal Gunpowder Factory Waltham Abbey and Royal Naval Cordite Factory Holton Heath.

The Royal Ordnance Factories (ROFs) were built in the re-armament period before WWII to improve national munitions manufacturing capacity. The ROFs were generally sited in the north and west of the UK, areas less vulnerable to aerial bombing

ROFs involved with explosive manufacture or filling needed, on safety grounds, to be located away from centres of population. However, they also needed access to good transport links, such as railways, the availability of adequate workers within reasonable travelling distance, a plentiful guaranteed supply of clean process water, and (to avoid the danger of freezing the explosives) they tended to be located at, or just above, sea level.

5 10 per cent is commonly used within the UXO industry to describe the observed failure rate of high explosive German WWII bombs of mass 50 kg or greater. The exact source is unknown although the 10 per cent figure was quoted in an official government communiqué as a "fair guess" (Appendix A2). Further evidence to support this estimate can be found in the following National Archives records:
- HO196/18 *Review of bomb census data for the 457 days of October 1941 to December 1942*. Gives a failure rate of 9.8 per cent
- HO198/244 *Nationwide analysis of bombing*. Gives a failure rate of 11.3 per cent, based on more extensive data.

6 Because of manufacturing tolerances, design limitations, interrupted or oblique impact, as well as incorrect use.

The UK's ROFs were set up and operated as production factories. The design of explosives, propellants and munitions was carried out at separate government-owned research and development establishments such as the research department, which was initially based at Royal Arsenal Woolwich and then Fort Halstead in Sevenoaks Kent and also at Waltham Abbey.

Some ROFs were designated as temporary and were in use for the duration of WWII only. Others were designed to be permanent. Temporary sites included the use of privately owned factories that were already in use for the manufacture of non-military items. These were converted to wartime military production facilities but were later returned to private, non-military uses following the end of the war. Some of the permanent ROFs closed in the late 1950s and others closed in the 1970s. Of these permanent ROF sites some were taken over by other government departments or retained by the MoD as ammunition storage areas. Others were redeveloped for industrial use and some were used as sites for the construction of public buildings, eg prisons. The remaining operational sites were privatised in 1984 to become Royal Ordnance PLC, now part of BAE Systems. The English Heritage publication *Dangerous energy, the archaeology of gunpowder and military explosives manufacture* (Cocroft, 2000) provides a detailed and fairly exhaustive list of explosives and munitions works within the UK and Ireland dating back to the 1700s.

Often the ROFs incorporated an ammunition test firing range to undertake QA/QC testing on munitions. Up to the mid-20th century, some manufacturing and storage sites would dispose of shelf life expired munitions (or possibly a poor production run of munitions) on the site itself and buried munitions have been discovered on ex-ROF sites in the past. Although sites were usually searched for discarded ordnance before being disposed of, this may have only involved undertaking a visual search of the ground surface or an instrument search using a metal detector. A clearance certificate was often produced that declares, while a site may have been searched, that UXO may have been found. The standard of search and clearance operations is discussed further in Section 7.11.

Important note 1

The occurrence of UXO on current munitions manufacturing and storage sites is not covered by this guidance. However, many of the basic principles discussed are still relevant.

Case study 2.1 ***The occurrence of UXO on ex-MoD land***

A former WWII airfield was closed in the early 1960s and was redeveloped in the 1980s as a residential complex. Once building started, discarded UXO were discovered in the form of practice bombs and land service ammunition. The client called in a UXO specialist and the recommended course of action was to conduct a magnetometer survey across the site to identify potential buried UXO.

To maximise survey efficiency the magnetometer survey was designed to search for larger items of UXO than small arms ammunition (SAA). SAA were identified by the UXO specialist as low risk items and a separate disposal procedure was prepared to deal with these items as and when they were encountered.

The later magnetometer survey and target investigation uncovered over 2000 items of UXO including two live WWII aerial delivered German HE bombs, live pipe mines, practice bombs and other associated UXO items.

2.1.3 UXO resulting from wartime activities

During WWII many defensive establishments, cities and towns throughout the 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 poor precision of WWII targeting techniques resulted in the areas around a point target being subjected to extensive bombing. This is particularly relevant to more remote areas surrounding military installations that initially may not appear to present a serious UXO risk.

Apart from air raids that concentrated upon specific targets, indiscriminate bombing of residential areas also took place. This is most famously characterised by the London Blitz, although many other cities and regions were also intensively bombed.

Decoy sites were also set up in WWII, often near to known or suspected Luftwaffe targets (rural targets especially). These decoy sites were partially illuminated at night (while the real sites were blacked out) to encourage the Luftwaffe to concentrate their bombing efforts on the valueless decoy site, minimising the risk to the actual target site. Records of decoy site locations are held at the National Archives (see Appendix A1).

A proportion of aerially delivered bombs failed to function and penetrated the ground without exploding and about 10 per cent[5] of German ordnance or even higher for Allied delivered ordnance failed to function as intended. Although extensive UXO removal/clearance and recovery operations were undertaken during and in the years immediately following the end of the war, unexploded ordnance resulting from aerial bombardment continues to be encountered throughout Britain in general (and London in particular), especially during construction and redevelopment works.

Figure 2.1 ***German 1000 kg bombs ready to be loaded onto bomber aircraft***

Occasionally evidence of UXO was discovered soon after the bombing event, but due to a relatively benign position, access problems or because of a shortage of resources, the UXO could not be exposed and rendered safe. Such an incident may have been recorded as a so called abandoned bomb. Given the inaccuracy of WWII records and the fact that these bombs were abandoned, their locations cannot be considered definitive.

5 10 per cent is commonly used within the UXO industry to describe the observed failure rate of high explosive German WWII bombs of mass 50 kg or greater. The exact source is unknown although the 10 per cent figure was quoted in an official government communiqué as a "fair guess" (Appendix A2). Further evidence to support this estimate can be found in the following National Archives records:

- HO196/18 *Review of bomb census data for the 457 days of October 1941 to December 1942*. Gives a failure rate of 9.8 per cent
- HO198/244 *Nationwide analysis of bombing*. Gives a failure rate of 11.3 per cent, based on more extensive data.

Also, where enemy aircraft had to take evasive action to escape attention from the RAF or anti-aircraft emplacements, and they could not drop their bomb load on the intended (or secondary) target, they would jettison their bomb load before breaking off from their attack and heading for their home airfield. This manoeuvre was commonly known as tip and run and often resulted in bombs being dropped in unusual areas.

Military ordnance can also pose a significant threat and can be divided into five categories:

1 Rockets.
2 Projectiles (including SAA)
3 Grenades.
4 Mortars.
5 Mines (including pipe mines).
6 Bombs.

Because of the vast range and complexity of items of military ordnance basic identification can be difficult to those who are unfamiliar with it. The hazards associated with military ordnance include intense heat and burning, high explosive blast, and very high velocity case fragmentation. Some items of military ordnance can also contain dangerous chemicals (eg white phosphorous or poison gas).

During the early stages of WWII, when the threat of invasion was high, land mines were laid along the east and south coastlines. When the threat of invasion reduced, a deliberate clearance operation was executed to remove all of the defensive minefields and to open the beaches to the public. This operation was completed in the 1950s but land mines are occasionally found, although this is rare.

Important note 2

Wartime activities present the most significant source of UXO that are likely to be encountered by the construction industry outside of the development of ex-MoD land, and are the main focus of this guide.

Pipe mines (sections of metal tubing filled with high explosive and fitted with a detonation device) were also laid during WWII by British and Allied forces to help point and area defence. A clearance operation was undertaken at the latter stages of WWII when the threat of an invasion had receded, but pipe mines (or parts thereof) are still discovered today. They are highly unstable and very dangerous (please refer to Section 2.2.1).

2.2 TYPICAL ORDNANCE

The following section provides a brief summary of the most common types of ordnance that are likely to pose a UXO risk at construction sites in the UK and discusses their likely effects should a detonation event occur. There are two broad categories to consider:

1 **Aerial delivered ordnance:** concentrates on German aerial delivered bombs (as they are the most likely to be encountered).
2 **Military ordnance:** concentrates on categories of allied ordnance (similarly, they are most likely to be encountered).

2.2.1 Aerial delivered ordnance

The nature and characteristics of ordnance used by most air forces (including the Luftwaffe in WWII) helps an informed assessment of the potential hazards posed by any unexploded items in existence today.

Flying bombs (V1 and V2 rockets)

Figure 2.2

German V2 rocket on transporter vehicle (about 14 m in length)

From 1944 to 1945 there was an aerial delivered hazard in South East England presented by unmanned rockets and missiles (known as V-weapons) fired from aircraft and bases in occupied Holland, Belgium and France as well as Germany. Although the V1 (flying bombs or doodlebugs) and the V2 (long range rockets) caused significant damage and understandable concern to the civilian population, they were thin skinned munitions and often broke up on impact if they failed to explode. Although at their peak period, in July 1944, up to 100 a day were landing, their relatively low numbers (as compared with high explosive bombs) allowed accurate records of their strikes to be maintained. It is considered highly unlikely that an unexploded V1 or V2 rocket would be encountered as an item of UXO.

High Explosive (HE) bombs

Figure 2.3

German WWII 1000 kg bomb being removed from a site in Sunderland (length about 2 m)

It is generally agreed within the industry that the total mass of HE bombs dropped during WWII is far greater than the combined mass of the other types of aerial delivered ordnance. They typically had sufficient mass and velocity and a suitably streamlined shape that enabled them to easily penetrate the ground if they failed to explode on the surface. An HE bomb is thick skinned, ie has a very strong metal case that fragments on detonation. If the bomb fails to detonate, the HE variety has (quite clearly from empirical evidence) sufficient structural strength to penetrate the earth.

Although throughout WWII post-raid surveys were carried out by the fire, police and civil defence staff to assess damage and try to identify any unexploded ordnance, due to the damage and destruction caused by those bombs that did detonate, it is likely that

many entry holes or other indications that a bomb penetrated the ground were missed. Also HE bombs are the most likely aerial delivered ordnance type that may be encountered today as a UXO.

1 kg incendiary bombs

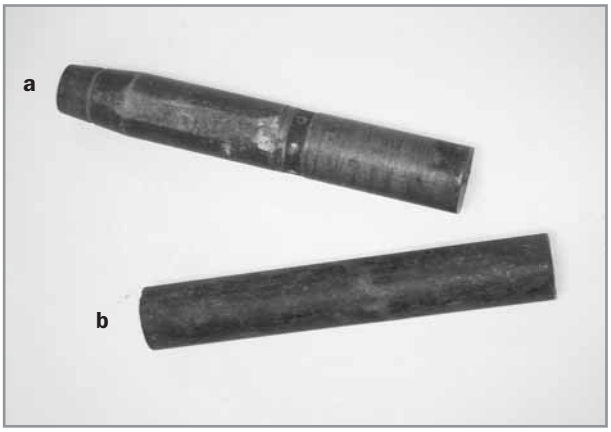

Figure 2.4

WWII German incendiary bomb (a) shown with section of scaffold pole (b)

1 kg German WWII incendiaries (Figure 2.4) consisted of a magnesium shell with a thermite fill. Many hundreds of thousands were used in bombing raids against UK during WWII. They were dropped from aircraft in large containers that opened at height, distributing the bombs over a wide area. They usually did not contain high explosive (though some variants did contain a delayed action charge aimed at injuring fire fighters and distributing the burning weapon). Both the thermite and the magnesium shell burnt.

Larger incendiary bombs

Figure 2.5

C50A phosphorus incendiary bomb that had only partially functioned, reigniting after exposure to air

These can weigh up to 350 kg and were also used (Figure 2.5). Some were filled with fuel oil, known as oil bombs, others used elemental phosphorus as the incendiary material. These bombs usually had the same shape as high explosive bombs. However if they did not function or burst open when hitting the ground they had a limited penetration capability. This is because they are thin skinned, ie designed to split open and spill the contents on the surface (rather than to detonate), setting fire to targets. If they functioned or failed to function they simply burst open rather than penetrate deeply.

Anti-personnel (AP) bombs

Figure 2.6

Anti-personnel butterfly bomb

Anti-personnel (AP) bombs contain small quantities of high explosive (typically one to 10 kg). They were often booby-trapped and were designed to be triggered by individuals (so their AP designation). Because of their mass and shape they had very little ground penetration capacity and most were located by post-raid surveys. They are the least likely form of air delivered ordnance to be discovered today.

2.2.2 Military ordnance

Military ordnance is discovered predominantly on current or former MoD training areas or former munitions manufacturing sites. The seven broad categories of military ordnance that might be encountered are discussed below:

Rockets

Figure 2.7

3.5 inch rockets (length about 400 mm)

Rockets are devices often containing a high explosive warhead that are accelerated to their target using internal propellants, which continue to burn throughout the flight. They are designed for a variety of roles but many are commonly intended as anti-tank weapons. Un-burnt propellant and the HE warhead present the principal UXO hazards. They are unlikely to be found in urban areas but may be discovered on current or historical training sites.

Projectiles

Figure 2.8

Allied 17 pound artillery shells (length about 250 mm)

A projectile is usually fired from a gun and it carries no integral propellant. They are commonly referred to as shells and come in varying sizes, usually categorised by the calibre of the gun it is fired from. They often contain high explosive (HE) (but can contain other substances, eg pyrotechnic compounds that produce smoke) and are initiated by integral fuzes that are usually triggered by impact, area, time delay or a combination of one or more of these mechanisms. They are most likely to be found on current or former MoD training areas or historical sites as well as munitions storage and manufacturing sites. However, shells originating from WWII anti-aircraft artillery (AAA) emplacements may be found in and around more urban areas.

Grenades

Figure 2.9

Allied Type No 36 grenades (length about 150 mm)

A grenade may be hand thrown or projected from a rifle or purpose built grenade launcher. They are often cylindrical or canister shaped (old WWII variants looked like miniature pineapples). They usually contain high explosives (but may contain pyrotechnic compounds that produce smoke) and are a form of anti-personnel weapon. They are commonly initiated by a time delay fuze. Grenades are most likely to be found

on current or former MoD training areas or historical sites as well as munitions storage and manufacturing sites. However, grenades were issued to the Home Guard and may be found in other locations without any obvious history of military use.

Mortars

Figure 2.10

Allied 2" mortars (length about 150 mm)

A mortar round is projected from a tube (a mortar) but they contain no integral propellant. Mortar rounds have similar functions to projectiles/shells and are classified by the calibre of the mortar tube they are launched from. They often contain HE (but can also contain pyrotechnic compounds that produce smoke) and are fuze initiated. They are most likely to be found on current or former MoD training areas or historical sites.

Land mines

Figure 2.11

WWII 20 pound landmine

There are two types of land mines: anti-tank and anti-personnel. Both types are designed to be shallow buried (up to 100 mm deep) and to detonate when inadvertently actuated by a target passing overhead. Anti-personnel mines are relatively small (typically weighing up to 0.5 kg) when compared to anti-tank mines that may weigh up to 10 kg. They are most commonly laid in defensive groups to form minefields through which an attacking force would have to navigate a safe passage. Both types of mines may be discovered together. In WWII they were laid along the east

and south coast of England in anticipation of a German invasion, special steps were also taken to prepare demolition schemes for those airfields that lay within one hours reach of likely coastal invasion points. Mines are initiated by fuzes and can be fitted with anti-disturbance and anti-handling devices. Although UK minefields were subject to significant clearance operations post-WWII, some mines are still occasionally discovered today, particularly along beaches.

Small arms ammunition (SAA)

Figure 2.12

Various small arms ammunition (length about 30 mm)

SAA is most commonly referred to as bullets or rounds designed to be fired from rifles, machine guns and pistols. They contain a small quantity of explosive propellant, which is initiated by a percussive effect upon firing. The quantity of propellant partly depends on the calibre of the round that will generally vary from 5.56 mm to 12.5 mm. Although they are often considered as low risk items when compared to other ordnance types, they can be dangerous if tampered with or burnt. SAA are most likely to be discovered on current and historical training areas. However, SAA were issued to the Home Guard and may be found in other locations without any obvious history of military use.

Pipe mines

Figure 2.13

Exposed pipe mines lying in base of excavation (about 50 mm diameter pipe)

Pipe mines are sections of metal tubing filled with high explosive and fitted with a detonation device. They were laid during WWII by British and Allied forces to help point and area defence. They were extensively used on selected airfields and some road and railway junctions to enable their destruction in the event of an invasion. A clearance operation was undertaken at the latter stages of WWII when the threat of an invasion had receded. Following the discovery of intact pipe mines in the 1980s, a further clearance operation was carried out. As a part of this second clearance programme local authorities were informed of sites that had been pipe mined within their areas. However, the WWII and 1980s clearances cannot be presumed to have

removed all such devices and pipe mines are still occasionally discovered today. When pipe mines are discovered and the explosives have not been previously removed, they are highly unstable and very dangerous.

Pipe mines at HMS Daedalus, Lee-on-the-Solent were not cleared until September 2006, which caused significant local disruption. The WWII and 1980s clearance cannot be presumed to have removed all devices.

2.3 METHODS OF INITIATION

UXO do not spontaneously explode. All older UXO devices require an external event to create the conditions for detonation to occur. In the case of UXO that might be discovered at a construction site and the types of activities that take place, there are several potential detonation initiation mechanisms:

- direct impact onto the main body of the UXO. For this to initiate the detonation of a UXO there needs to be a significant impact, eg as might occur from piling or from large and violent mechanical excavation. Such an event is believed to have occurred in October 2006, on the A3 Autobahn in Germany. A plant operator was killed and seven others were injured when a WWII bomb was struck while excavating using a mechanical cable trenching machine
- re-starting the clock timer in the fuze. A small proportion of German WWII bombs employed clockwork fuzes, ie the stereotypical ticking bomb. Although it is probable that significant corrosion has occurred over the last 60 years due to water ingress etc and most clockwork mechanisms in UXO would no longer be able to function, there is a small possibility that a fuze of this type could be restarted, if disturbed by direct contact or vibration
- initiating the fuze explosive. The combined effects of seasonal changes in temperature and general degradation over time can cause explosive compounds to crystallise and exude out from the main body of the UXO, a process known as exudation (see *Glossary*). It may only require limited mechanical action to initiate the exuded explosive, which could initiate the main high explosive charge. This is the most likely cause of detonation at a construction site.

2.4 EFFECTS OF DETONATION

When a bomb detonates in soil, the expanding gases reacting against the surrounding earth produce an almost spherical cavity in the soil. This is in contrast to the inverted conical bomb crater often observed with explosions that take place at surface.

Although it may not be visible from surface, the shock wave from subsurface detonations may cause damage to building foundations some distance from the explosion. Trenches, tunnels and underground basements, which are more prone to earth shock, may collapse. Sewers and pipes, especially of low tensile strength materials such as cast iron and ceramic may crack and split but plastic piping and underground cables may not be as badly affected. The level and extent of damage will depend among other things on the mass of high explosive, the ground conditions and the distances of buildings, plant and utility services from the seat of the explosion.

When considering the potential consequences of a detonation event it is necessary to identify the significant receptors that may be affected. The receptors that may potentially be at risk from a UXO detonating on a construction site will vary depending on the site specific conditions but can be summarised as follows:

- **people:** this can include site workers, local residents and in some cases the general public
- **plant and equipment:** this may include utilities equipment such as gas and water mains as well as construction plant in use at a site
- **structures:** not only visible damage to above ground structures but potential damage to foundations, the weakening of support structures such as nearby bridges or tunnels
- **environment:** although not addressed directly within this guide, consideration should be given to secondary receptors that may not be affected by a detonation event but may suffer from secondary effects such as the introduction into the environment of potentially contaminating materials.

Such an event may be highly disruptive on any construction project and due consideration should be given. These will include delay in programme, costs of rebuilding and repairs (including third party structures and infrastructure) and associated negative publicity.

2.5 UXO STANDARDS

In producing this guide, the authors and the CIRIA steering group have considered several technical guidance documents covering the wider UXO industry, including the International Mine Action Standards (IMAS[7]). IMAS is the UN standard in use for all United Nations mine action operations, initially endorsed by the UN Inter-Agency Coordination Group on Mine Action on 26 September 2001. Although, as the title suggests, IMAS is focused upon mine action and the international humanitarian de-mining industry, there are standards contained within it that deal with explosive ordnance disposal (from a humanitarian de-mining context).

In accordance with the view of the steering group, the general principles contained in IMAS concerning safety and explosive ordnance disposal, have been considered and, where appropriate, used in the preparation of this guidance.

2.6 SUMMARY

The preceding sections provide a general overview of the potential sources and types of UXO that may be discovered during construction work. Note that the types of ordnance discussed are not exhaustive and it is possible that UXO may be discovered from a source and of a type not detailed above. Also, the actual appearance of UXO unearthed today will vary considerably, depending on the conditions in which it has lain since it was emplaced. The images given in Figures 2.2 to 2.13 should not be considered as a definitive guide to identification.

7 <http://www.mineactionstandards.org/imas.htm>