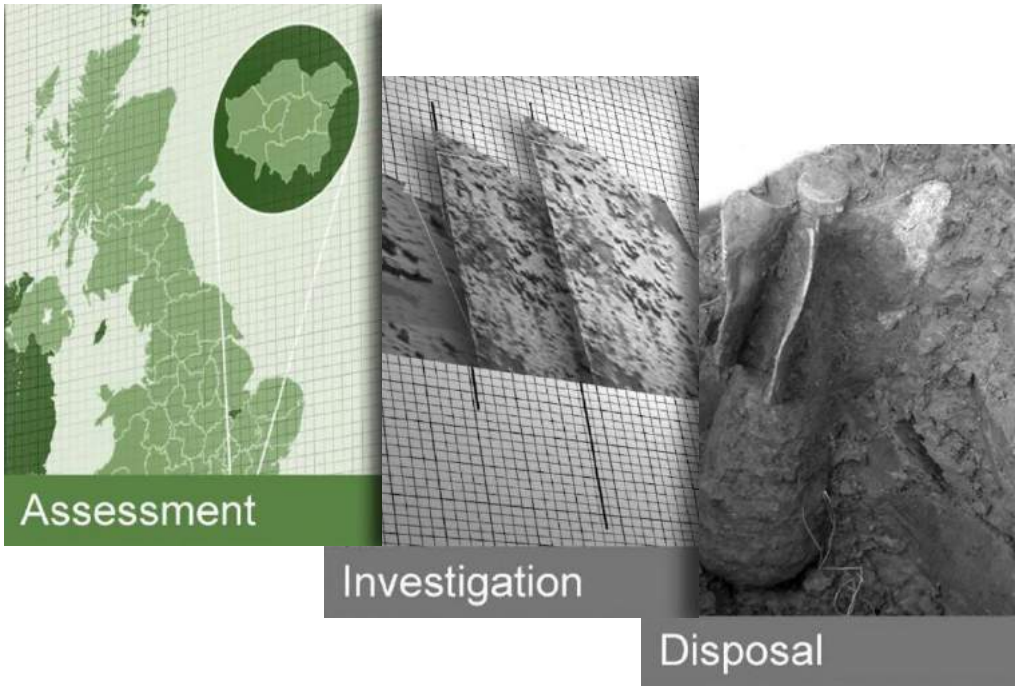


Lower Thames Crossing – UXO Desk Study & Risk Assessment

Drafted by [redacted]
Checked by [redacted]
Authorised by [redacted]

Document Title	**UXO Desk Study & Risk Assessment**
Document Ref.	**HE540039-ZET-GEN-GEN-REP-GEO-00001**
Revision	**3**
Project Location	**Lower Thames Crossing**
Client	**Arcadis**
Date	**31st August 2018**

UXO DESK STUDY & RISK ASSESSMENT

Lower Thames Crossing

EXECUTIVE SUMMARY

Zetica Ltd was commissioned by Arcadis, in association with CH2M and COWI and on behalf of Highways England, to carry out an Unexploded Ordnance (UXO) Desk Study and Risk Assessment for an area of approximately 76 square kilometres (km) centred on an approximately 31km route between Great Warley in the Brentwood Borough of Essex and Cobham in Kent (the 'Site').

The aim of this report is to gain a fair and representative view of the UXO hazard for the Site and its immediate surrounding area in accordance with the Construction Industry Research and Information Association (CIRIA) C681 'Unexploded Ordnance (UXO), a Guide for the Construction Industry' and C754 'Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment'.

5No. potentially significant sources of UXO hazard have been identified on the Site and several parts of the Site have subsequently been assigned a moderate UXO hazard level.

Each Hazard Zone is identified by a code (M1-M5) relating to the anticipated hazard in that area. These are described below, with their extents shown in the figures on the following pages and on the accompanying UXO hazard zone plan, HE540039-ZET-GEN-GEN-MAP-GEO-00001:

WWII Bombing (M1)

Records indicate that during World War Two (WWII) in excess of 440No. **High Explosive (HE)** bombs fell on the Site. At least 175No. of these were recorded as Unexploded Bombs (**UXB**).

It is considered prudent to assign a moderate UXO hazard level to 8No. parts of the Site where an elevated bombing density and high percentage of UXB were recorded.

Estimated bomb penetration depths in these areas vary between 1m and 19.0m depending on the weight of the bomb and the underlying geological materials (see **Table 3**).

River Thames (M2)

Several potential sources of UXO hazard have been identified on the part of the Site encompassing the River Thames.

The main anticipated ordnance hazard is from air-dropped UXB due to the heavy WWII raids in the region and Unexploded Anti-Aircraft (UXAA) **Shells** fired from the numerous gun batteries in the vicinity of the Site.

This part of the Site is therefore assigned a moderate UXO hazard level.

Milton Range (M3)

Part of the Site encompasses Milton Range, which has been in use from the 19th century until the present day.

In addition to training with **Small Arms Ammunition** (SAA), records indicate that the range was used for mortar practice during WWII, providing a potentially significant hazard.

This part of the Site is assigned a moderate UXO hazard level due to the potential presence of **Mortars** (and other **Close Combat Munitions** such as **Hand Grenades**) at shallow depths.

Pipe Mines at RAF Gravesend (M4)

Canadian Pipe Mines were laid under the runways and perimeter track at Royal Air Force (RAF) Gravesend at the beginning of WWII so that the airfield could be destroyed in the event of a German invasion.

Part of the Site encroached upon the area that was pipe mined and records suggest that not all of the mines were removed during WWII and post-WWII clearances.

Therefore, it is considered prudent to assign this part of the Site a moderate UXO hazard level to account for the possibility that pipe mines remain in situ.

Bomber aircraft crashes (M5)

There are records of 2No. WWII bomber aircraft crashes on the Site at Botny Farm, near Orsett, and at Clay Tye Hill, near North Ockendon. No records have been found to indicate whether the bombs being carried by these aircraft had already been dropped, exploded on impact, or were retrieved from the crash site.

It is therefore considered prudent to assign these parts of the Site a moderate UXO hazard level at shallow depths to account for the possibility that UXB are present.

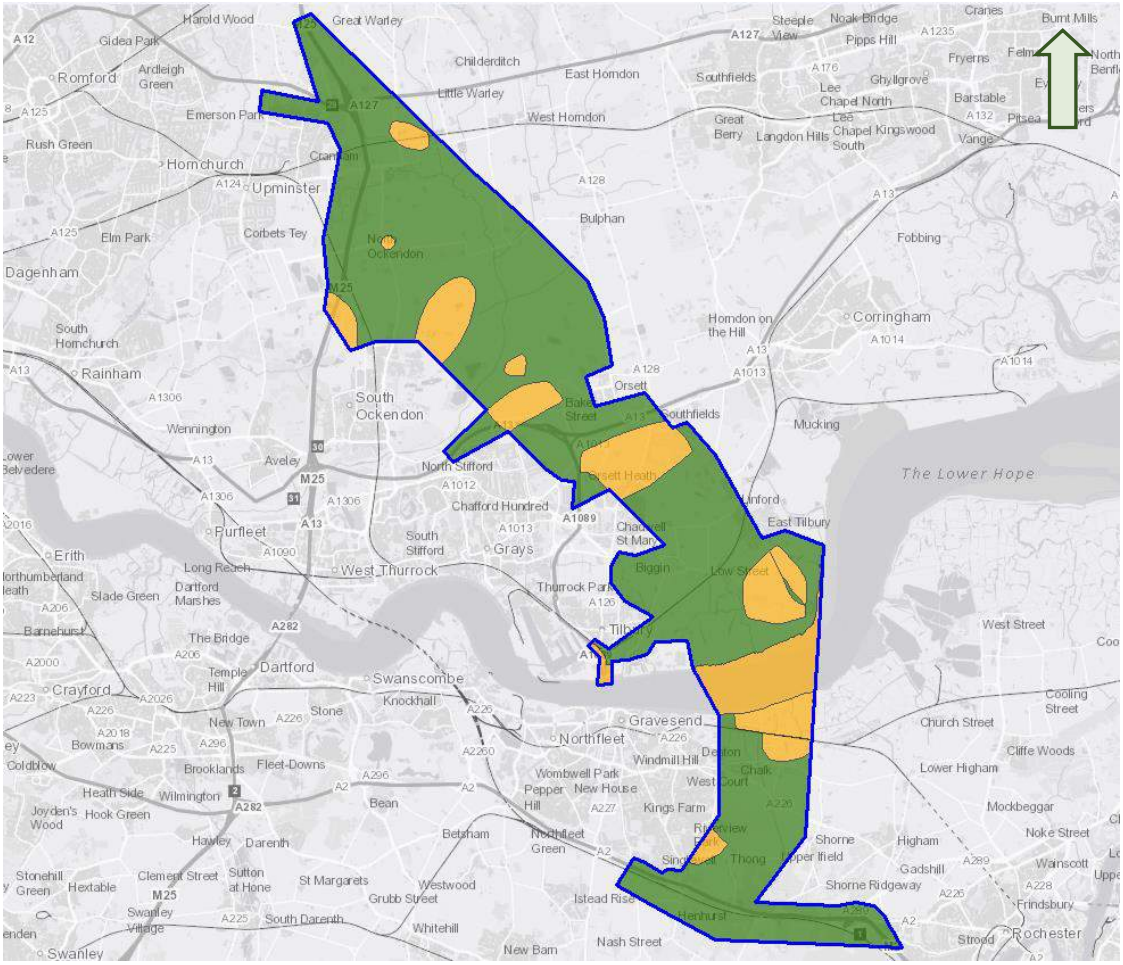
Remainder of the Site

No records of any significant bombing or other sources of UXO hazard have been identified on the remainder of the Site, which is assigned a low UXO hazard level.

It is therefore considered that the UXO hazard level on the Site can be zoned from low to moderate, as shown in the Figure below, reproduced as Figure 21 in the main report.

The definitive hazard plan is given in the accompanying HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Figure	UXO hazard zone plan of the Site



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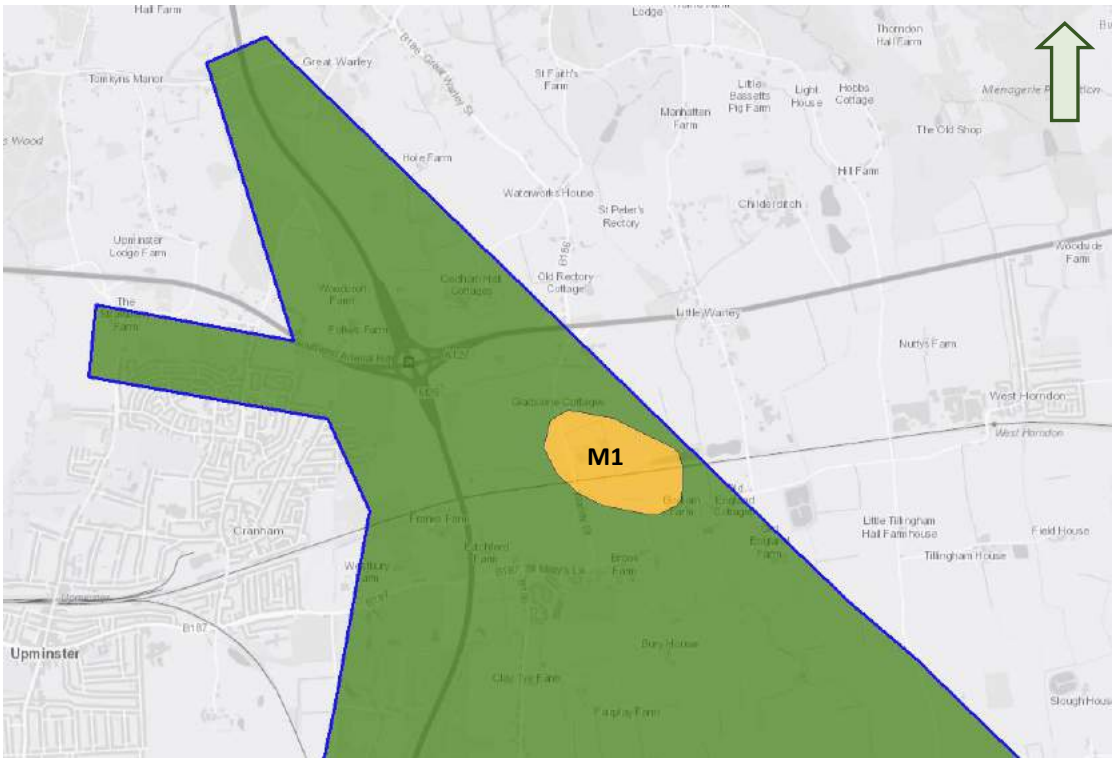
Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

The Figures below, reproduced as Figures 22 to 27 in the main report, provide more detailed extracts of the moderate UXO hazard level zones on the Site.

Figure	UXO hazard zone plan of the Site (Great Warley to Upminster)



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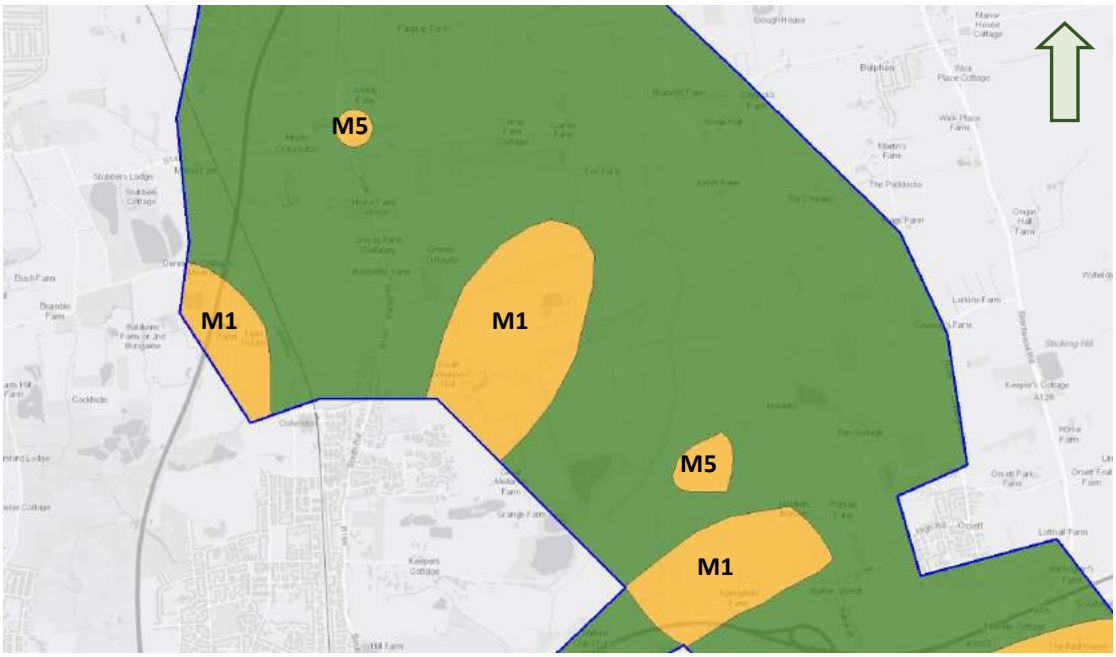
Legend					
	Very Low		Low		Moderate	
	High		Very High		Site boundary	

Figure	UXO hazard zone plan of the Site (North Ockendon to Baker Street)



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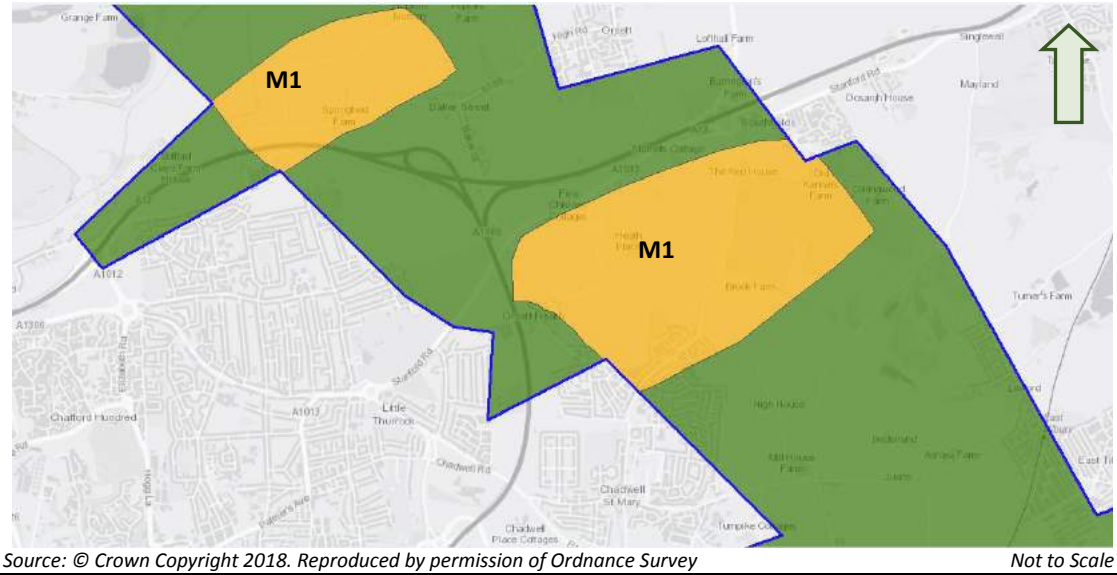
Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure	UXO hazard zone plan of the Site (Baker Street to Linford)



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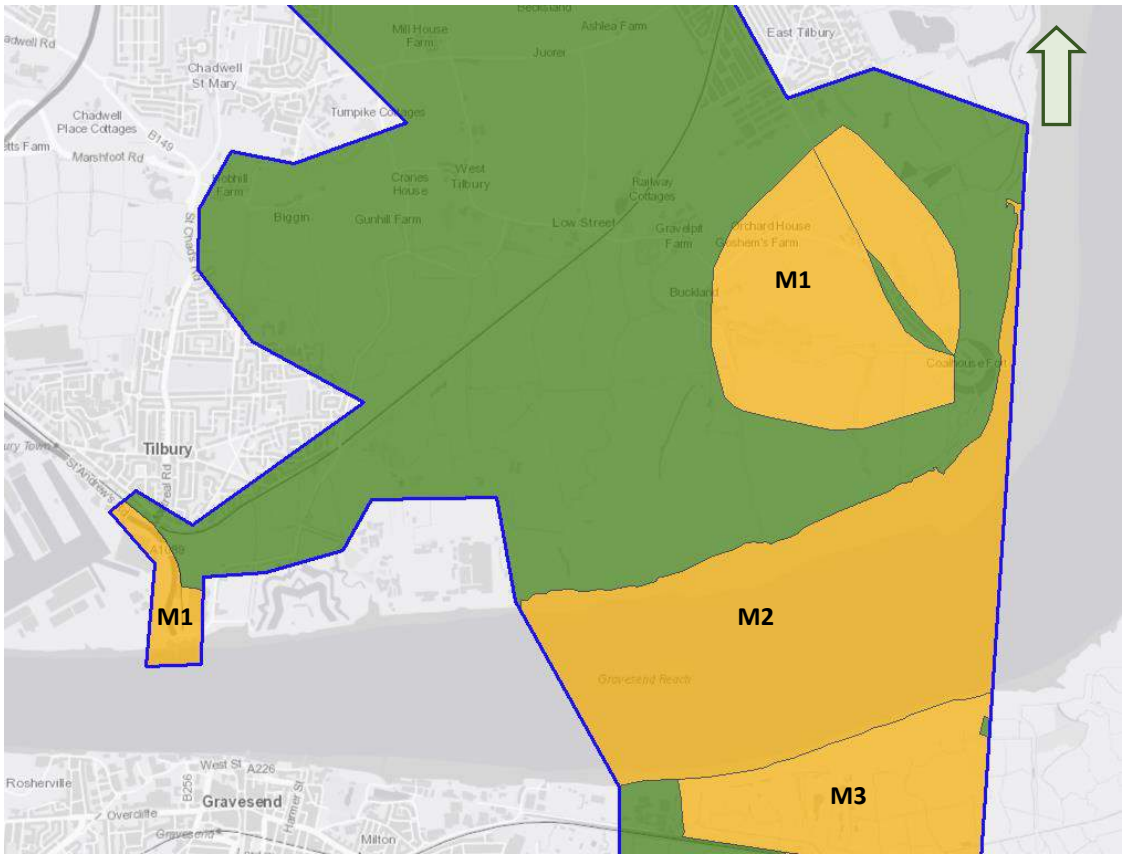
Legend					
	Very Low		Low		Moderate	
	High		Very High		Site boundary	

Figure	UXO hazard zone plan of the Site (Tilbury)



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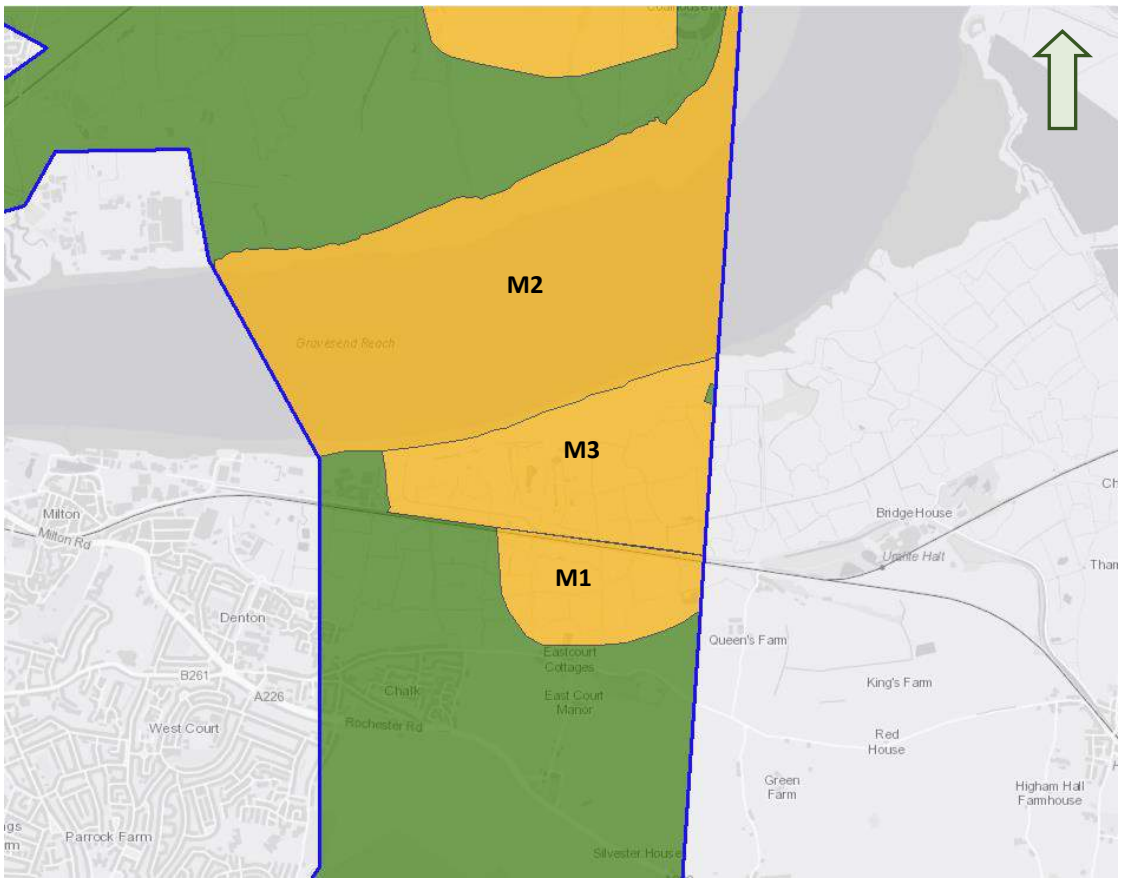
Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure	UXO hazard zone plan of the Site (River Thames to Filborough Marshes)



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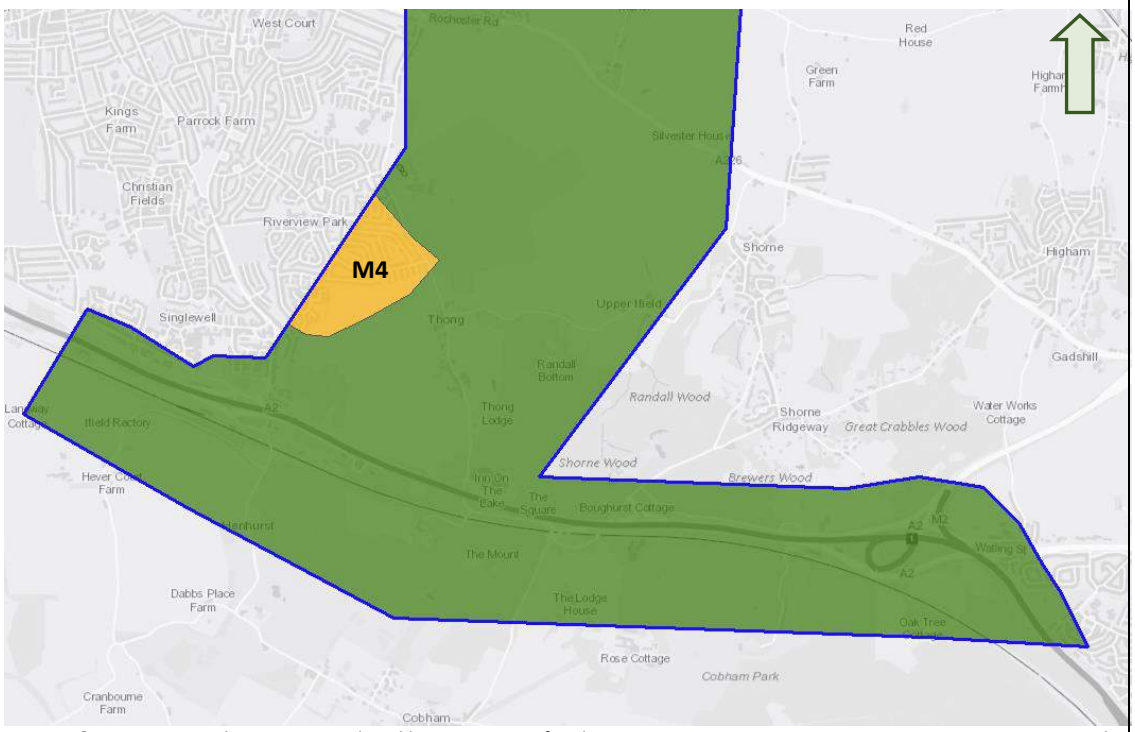
Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure	UXO hazard zone plan of the Site (Chalk and Thong)



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Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

The main findings of the report are summarised below.

- Milton Range was established on the Site in the 19th century. It was used extensively for rifle training during World War One (WWI) and WWII, in addition to being used for mortar practice. It has remained operational post-WWII.
- No records of bombing on the Site during WWI have been found.
- During WWII, the main strategic targets in the vicinity of the Site included Tilbury Docks, Milton Range and industrial works engaged in the war effort.
- During WWII, the Site passed through 6No. local authorities which officially recorded moderate regional bombing densities.
- Records have been found indicating that at least 446No. HE bombs fell on the Site during WWII. 188No. of these were recorded as UXB.
- Land on and in the vicinity of the Site was part of a D-Day Marshalling Area during WWII, which included military roads, storage areas and camps at Great Warley and Orsett. This activity is not considered to provide a significant source of UXO hazard to the Site.

The Table below, reproduced as Table 9 in the main report, provides a UXO risk assessment for proposed ground investigation works on the Site.

Further details on the methodology for the risk assessment are provided in Section 14.1 of the main report.

Table UXO risk assessment for the Site

Hazard Zone	Potential UXO Hazard	Anticipated Works	PE	PD	P = PE x PD	Likelihood	Severity	Risk Rating	UXO Risk
M1	UXB	Shallow Excavations	2	3	6	3	5	15	**Moderate**
		Deep Excavations	3	3	9	3	5	15	**Moderate**
		Boreholes/CPT	2	4	8	3	4	12	**Moderate**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA[1]	Shallow Excavations	2	1	2	2	2	4	**Low**
		Deep Excavations	2	1	2	2	2	4	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**
M2	UXB	Boreholes/CPT	3	4	12	3	4	12	**Moderate**
	UXAA Shells	Boreholes/CPT	2	4	8	3	3	9	**Moderate**
	Close Combat Munitions	Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Boreholes/CPT	2	1	2	1	2	4	**Low**
M3	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	3	3	9	3	4	12	**Moderate**
		Deep Excavations	3	3	9	3	4	12	**Moderate**
		Boreholes/CPT	2	4	8	3	3	9	**Moderate**
	SAA	Shallow Excavations	4	1	4	2	2	4	**Low**
		Deep Excavations	4	1	4	2	2	4	**Low**
		Boreholes/CPT	2	1	2	2	2	2	**Low**

UXB – Unexploded Bomb; **UXAA** – Unexploded Anti-Aircraft; **SAA**– Small Arms Ammunition; **Close Combat Munitions**– see **Appendix 3**.

[1] For further information, see for example Prugh R W, The Effects of Explosive Blast on Structures and Personnel; Process Safety Progress (Vol 18 No. 1), 1999

Table	UXO risk assessment for the Site (continued)								
Hazard Zone	**Potential UXO Hazard**	**Anticipated Works**	**PE**	**PD**	**P = PE x PD**	**Likelihood**	**Severity**	**Risk Rating**	**UXO Risk**
M4	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	2	1	2	2	2	4	**Low**
		Deep Excavations	2	1	2	2	2	4	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**
	Pipe Mines	Shallow Excavations	2	5	10	3	4	12	**Moderate**
		Deep Excavations	3	2	6	3	4	12	**Moderate**
		Boreholes/CPT	2	3	6	3	3	9	**Moderate**
M5	UXB	Shallow Excavations	2	3	6	3	5	15	**Moderate**
		Deep Excavations	2	3	6	3	5	15	**Moderate**
		Boreholes/CPT	2	4	8	3	4	12	**Moderate**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	2	1	2	2	2	4	**Low**
		Deep Excavations	2	1	2	2	2	4	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**
Low	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	1	1	1	1	2	2	**Low**
		Deep Excavations	1	1	1	1	2	2	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**
PE (Probability of Encounter), PD (Probability of Detonation), P (Overall Probability)									
Shallow excavations defined as <1.0m below ground level (bgl).									
UXB – Unexploded Bomb; **UXAA** – Unexploded Anti-Aircraft; **SAA**– Small Arms Ammunition; **Close Combat Munitions**– see **Appendix 3**.									

Risk Mitigation Recommendations

Table 9 in the main report gives recommended actions in relation to the potential UXO risk level and the anticipated Site activity.

To ensure that the UXO risk is reduced to As Low As Reasonably Practicable (ALARP) the following mitigation is advised:

Ground Investigation Works (Land)

Low Risk

Excavations

Where a low risk of UXO encounter is anticipated, industry good practice is simply to raise the awareness of those involved in excavations so that in the unlikely event that a suspect item is discovered, appropriate action is taken.

This awareness is to be provided through formal UXO awareness inductions. Typically ~1hour in duration, these briefings will be expected to provide site workers with:-

• Background to the potential UXO hazards that could be encountered.

• Awareness of how the UXO hazard could present a risk.

• Knowledge of what to do in the event that a suspect item is encountered.

The UXO awareness induction is to be provided along with back-up materials such as UXO awareness posters, emergency contacts numbers and other background information to assist site workers in becoming familiar with what potential UXO can look like. The materials can also be used by key staff to cascade out the salient points of the induction to others who visit or work on the Site.

By providing the UXO awareness induction, it ensures that in the unlikely event that UXO is encountered:-

• All site staff take appropriate action.

• The likelihood of harm to persons or property is reduced.

• Delays in works can be minimised.

It is the responsibility of the contractor to ensure that all staff have received an appropriate UXO awareness induction. A combination of identification badges and helmet stickers can be used to provide confirmation that staff onsite have undergone such an induction.

Boreholes/CPT

Clearance certification for borehole or CPT locations is considered prudent only if a zero tolerance to risk is adopted. Zero tolerance is commonly adopted for sites that have safety critical infrastructure such as nuclear establishments and oil refineries.

Moderate Risk (Hazard Zone M1)
Excavations
UXO awareness It is considered essential to raise the awareness of those involved in excavations as per low risk. **Non-intrusive UXO detection** Where a potential UXO hazard has been identified at a shallow depth, a non-intrusive UXO detection survey is considered appropriate. Ferrous targets (such as UXB) should be detected using a magnetometer. As part of the procedure for the survey, at least 2No. inert ordnance-sized items should be temporarily buried on the Site at 0.5m depth. The UXO contractor should then undertake surveys over these targets in order to provide practical (rather than just theoretical) references for target selection for the burial setting of the Site. After surveying, identified anomalies can be modelled against the typical responses of the anticipated UXO type by an experienced and competent geophysicist. A list of targets which may be UXO can then be compiled. Where excavations are proposed that are deeper than the instrument detection range, the above technique can be employed in ~2.0m layers to achieve the required detection depth. **Target investigation** Where the survey has identified targets that may be UXO, an intrusive investigation should be undertaken by an experienced Explosive Ordnance Clearance (EOC) team. Typically all excavation works are conducted by hand. Where the ground proves too hard to economically hand excavate, a mechanical excavator and operator may be required. The EOC Engineer will carry out a visual assessment on any suspect items and classify them as potential UXO or other material. If an item of UXO is identified, the UXO contractor should oversee and manage the disposal process. After the investigation of all targets, a clearance report should be produced, detailing the detectability of anticipated targets, results of the target investigation, and the reduction of the UXO risk. **EOC Engineer supervision** As an alternative to prior detection and removal of UXO, an EOC Engineer can be used to supervise during excavation works. This option is typically employed where UXO detection is not feasible due to ground conditions (such as excessive geophysical noise limiting detection of individual targets) or restricted access. The EOC Engineer will carry out a visual assessment on any suspect items uncovered during the excavation task and classify them as potential UXO or other material.

Boreholes/CPT
Where deep (>3.0m) UXB detection is required, a magnetometer should be advanced into the ground at the proposed location of a borehole or CPT position. This technique enables detection of ferrous metal targets such as UXB. The MagCone or MagDrill UXB technique can be used depending on the encountered geology, the MagDrill specifically where a more robust drilling technique is required. **MagDrill -** this is a system that is suitable for working with ground investigation drillers. It allows a magnetometer to be lowered into the borehole to ensure the route is clear of potential UXB. This saves the mobilisation of a separate drilling or probing rig. Typical radius of detection should be approximately 1.0m for a 50kg bomb. **MagCone -** this is a CPT based system that facilitates the pushing of a magnetometer into the ground at the proposed GI location. MagCone is suitable for cohesive/loose soils and has a much higher speed of operation compared to drilling based techniques. Typical radius of detection should be approximately 1.0m for a 50kg bomb. Assuming no objects comparable to the UXB detection range are identified, then the borehole or CPT position can be considered clear of UXB.
Moderate Risk (Hazard Zones M3 & M5)
Excavations
UXO awareness It is considered essential to raise the awareness of those involved in excavations as per low risk. **Non-intrusive UXO detection** Where practical, non-intrusive UXO detection techniques (as detailed above) should be employed to detect shallow-buried UXO. Note that where non-ferrous targets are anticipated (such as some grenades and mortars), an electromagnetic survey technique is appropriate. **EOC Engineer supervision** As an alternative to prior detection and removal of UXO, an EOC Engineer can be used to supervise during excavation works (as detailed above).
Boreholes/CPT
Non-intrusive UXO detection and intrusive investigation of identified targets in advance of drilling or CPT is recommended. As the anticipated UXO hazards in these areas are at shallow depths, deep UXB detection (MagDrill or MagCone) is not appropriate.

Moderate Risk (Hazard Zone M4)

It is understood that no GI works will take place in Hazard Zone M4, where there is a possibility of encountering pipe mines. If this changes, then a proactive approach to mitigation is essential due to the increased risk of an accidental detonation.

A surface non-intrusive geophysical scan, using a magnetometer, should be undertaken over a <50m by 50m square area centred on each GI location within this hazard zone.

This will provide a map of shallow-buried below ground features where, subject to ground conditions, linear features such as pipe mines will be more readily identifiable.

Rather than targeting potential pipe mines, the aim of each scan is to allow for the avoidance of potential shallow-buried UXO at the proposed locations.

Ground Investigation Works (Marine)

Moderate Risk (Hazard Zone M2)

Jackup Equipment for GI Work

Non-intrusive UXO detection

Non-intrusive UXO detection methods and either avoidance of or intrusive investigation of identified targets is recommended where practical. The aim of such surveying is to locate or make an area free of UXO for the safe deployment of jackup equipment for borehole and CPT investigations. See below for further considerations relating to the actual borehole and CPT investigation works.

The Client is understood to be planning a marine geophysical survey on the Site to detect potential buried UXO. Such a survey should achieve complete coverage of:

- The area of any proposed jackup equipment
- Additional extent allowing for possible repositioning of the jackup equipment
- An additional 5m radius to allow the jackup rig to be positioned with an exclusion zone from any potential UXO.

Based on the findings of this desk study, the main anticipated UXO types on the Site in the River Thames comprise air-dropped UXB and UXAA shells. These are likely to be located between the river bed and the maximum bomb penetration depth, and are unlikely to be relocated by tidal currents between the times of the survey and construction.

Either a total magnetic field strength or a vertical magnetic gradient system would be considered appropriate, but it is noted that survey altitudes typically need to be lower for vertical gradient systems to achieve the same detectability limits.

To detect the above items, it is recommended that the survey has an altitude of no more than 2m and a survey line spacing of no more than 1m. A 1m line spacing may be achieved by the use of an array of sensors, and an appropriate swath spacing to achieve full coverage at 1m intervals.

The minimum survey altitude is controlled by:-

- Survey noise levels (depending on the magnetometer system used, the geology and the amount of scrap metal on the Site; a system/site with low noise levels will allow detection of an anomaly from a higher survey altitude).

The survey line spacing in a survey is controlled by:-

- Survey altitude (at higher altitude, anomalies become smaller).
- Survey noise levels (a system/site with low noise levels will allow detection of an anomaly at lower amplitudes where the anomaly will be wider).
- The anticipated anomaly width of the UXO items anticipated (a UXAA shell will typically have an anomaly width of <2m).

Our recommendations are based on experience with a range of data quality levels. Based on modelled anomaly amplitudes, and assuming data quality and site conditions are consistent with our past experience, the anticipated UXO items would be detectable at up to 2 to 3m from the magnetometer. A recommendation to survey at a higher altitude should be supported by a surrogate item trial (SIT) survey.

The effectiveness of the marine geophysical survey should also be verified and demonstrated through the use of an SIT survey. An SIT survey uses one or more surrogate items, which should have similar material properties and dimensions to the UXO object of concern. Where possible, the items should be degaussed to remove any permanent magnetisation. The surrogate item should be deployed on the river bed in an area free of other ferrous anomalies (a pre-deployment survey is typically used to select a location for the surrogate item). The SIT survey should be conducted with the same equipment and survey configuration proposed for the main survey to verify detection capabilities. If practical, the SIT should also include surveys of the surrogate items at different survey altitudes to enable a depth limit of detection to be determined.

Review of contractor proposals and/or survey results can be provided by Zetica on request.

Boreholes/CPT

As described above, a marine geophysical survey will only be capable of detecting the anticipated UXO items (UXB and UXAA shells) to a distance of 2 to 3m below the magnetometer sensors. The anticipated items could be located anywhere from river bed and the maximum theoretical bomb penetration depth (19.0m).

Clearance certification for any borehole or CPT location is considered essential.

This can be achieved by advancing a magnetometer into the ground at the location in order to provide detection of ferrous metal targets such as UXB (as detailed above).

Assuming no objects comparable to the UXB detection range are identified, then the position can be considered clear of UXB.

Given the changing morphology of the seabed, there is potential for items of UXO to be buried or uncovered. Therefore marine geophysical surveys have a limited shelf life and due consideration should be given to the timing of the survey and the subsequent construction, as stated in CIRIA C754 'Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment'.

Future Works

This desk study should help inform any future works on the Site and, if required, Zetica can be consulted prior to any such works taking place to confirm that the risk mitigation being employed is appropriate for the anticipated hazard and the proposed work activity.

The report can be updated and refined as a more detailed construction plan becomes available.

Risk Mitigation Plan

It is recommended that a detailed risk mitigation plan is devised based on the information provided in this desk study and risk assessment, the proposed construction methodology, and the requirements of any planning conditions.

This should outline the recommended risk mitigation techniques in relation to the identified UXO hazards, proposed construction methods, and intended phase of works.

These risk mitigation measures are to be discussed and confirmed with the client to ensure that the level of proposed mitigation is appropriate for the intended use and the client's risk tolerance, and carefully addresses the often emotive issue surrounding UXO and development.

Outline Explosive Ordnance Disposal (EOD) proposals are also to be detailed to account for the type of UXO anticipated.

The contents and structure of any risk mitigation plan can be discussed with Zetica prior to compilation.

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Figures, Plates, Tables & Maps

Accompanying Maps

HE540039-ZET-GEN-GEN-MAP-GEO-00001

Appendices

UXO DESK STUDY & RISK ASSESSMENT

Lower Thames Crossing

Note: To aid the reader of this report, Zetica has colour coded each paragraph. Paragraphs with black text on a white background are paragraphs that provide site-specific information or information specifically researched as part of this project.

Paragraphs in a dark green text with a green background are paragraphs providing general information and, where appropriate, links to online resources giving further detail on particular sources of UXO.

1 INTRODUCTION

1.1 Project Outline

Zetica Ltd was commissioned by Arcadis, in association with CH2M and COWI and on behalf of Highways England, to carry out an Unexploded Ordnance (UXO) Desk Study and Risk Assessment for an area of approximately 76 square kilometres (km) centred on an approximately 31km route between Great Warley in the Brentwood Borough of Essex and Cobham in Kent (the 'Site').

The proposed scheme consists of twin bore tunnels under the River Thames and a new dual carriageway extending between Junction 28 of the M25 to the A2/M2, south of Gravesend. The northern tunnel portal is in the Goshems Farm landfill area and the southern tunnel portal south of the Thames and Medway Canal.

The report is focused on potential sources of UXO hazard within the extent of the Site boundary unless considered appropriate. The approximate outer limit of the provided Site boundary is outlined in blue on plates and figures throughout the report.

The findings of this report are derived from the research and interpretation of Zetica's risk assessment team, which has extensive experience of undertaking UXO desk studies. Where appropriate, additional input has been received from Zetica's geophysicists, engineering geologists, Explosive Ordnance Disposal (EOD) Engineers and mapping experts.

The aim of this report is to gain a fair and representative view of the UXO hazard for the Site and its immediate surrounding area in accordance with the Construction Industry Research and Information Association (CIRIA) C681 'Unexploded Ordnance (UXO), a Guide for the Construction Industry' and C754 'Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment'. This hazard assessment includes:

- Likelihood of ordnance being present.
- Type of ordnance (size, filling, fuze mechanisms).
- Quantity of ordnance.
- Potential for live ordnance (UXO).
- Probable location.
- Ordnance condition.

It should be noted that some military activity providing a source of UXO hazard may not be readily identifiable and therefore there cannot be any guarantee that all UXO hazards within the Site have been identified in this report.

1.2 Abbreviations

The following is a list of the main abbreviations used throughout this report. **Appendix 2** provides a glossary of key terms used in the report.

AA	Anti-Aircraft
ALARP	As Low As Reasonably Practicable
AP	Anti-Personnel
APB	Anti-Personnel Bomb
API	Armour-Piercing Incendiary
ARP	Air Raid Precaution
AT	Anti-Tank
BDU	Bomb Disposal Unit
BGS	British Geological Survey
DCLG	Department of Communities and Local Government
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
ERFTS	Elementary & Refresher Training School
GI	Ground Investigation
HAA	Heavy Anti-Aircraft
HE	High Explosive
HER	Historic Environment Record
IB	Incendiary Bomb
LAA	Light Anti-Aircraft
LDV	Local Defence Volunteers
LG	Lewis Machine Gun

MoD	Ministry of Defence
MU	Maintenance Unit
OB	Oil Bomb
PLUTO	Pipe Line Under The Ocean
PM	Parachute Mine
POL	Petroleum, Oils and Lubricants
RAF	Royal Air Force
RASC	Royal Army Service Corps
REME	Royal Electrical and Mechanical Engineers
SAA	Small Arms Ammunition
SIP	Self-Igniting Phosphorous
SLG	Satellite Landing Ground
USAAF	United States Army Air Forces
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
VM	Vickers Machine Gun
VP	Vulnerable Point
ZAA	Rocket Battery

1.3 Historical Information

With most locations, the potential presence of UXO as a result of enemy action, unauthorised disposal or unrecorded military activity can never be totally discounted.

Detailed records of military activity are rarely released into the public domain. Even when military information is made public there may be gaps in the records because files have been lost or destroyed.

Records for periods such as WWII are only as detailed and accurate as the resources and working conditions would allow at the time. Densely populated areas tend to have a greater number of records than rural areas. Such records may be inaccurate due to the confusion surrounding continuous air raids.

Press records can supplement local information, although this source of information must be treated with caution, as inaccuracies do exist, either inadvertently or intentionally in order to confuse enemy intelligence. Classified official records can sometimes be considered inaccurate for the same reason.

Recent research indicates that England alone had 17,434No. recorded defence sites, of which 12,464No. were classified as defensive anti-invasion sites. The precise locations of many of these sites are still to be identified, illustrating the scale of the problem when establishing potential risks from limited historical data.

1.4 Sources of Information

Zetica Ltd researched the military history of the Site and its surrounding area utilising a range of information sources. The main sources of information are detailed in the following sections and referenced at the end of this report.

1.4.1 Zetica Ltd Defence Related Site Records

Zetica Ltd's in-house records were consulted, including reference books and archived materials from past work in the region. Relevant documents have been cited within the bibliography of this report.

1.4.2 Zetica Ltd Bombing Density Records and Maps

Reference has been made to the Zetica Ltd bomb risk maps located on Zetica Ltd's website (http://zeticauxo.com/downloads-and-resources/risk-maps/).

1.4.3 Ministry of Defence and Government Records

Various government departments and units within the Ministry of Defence (MoD) were approached for information of past and present military activity in the area. These included the Home Office records of abandoned bombs.

1.4.4 Other Historical Records, Maps and Drawings

Numerous reference documents including historical maps, aerial photographs and drawings have been consulted from sources such as the National Archives, the US National Archives and Records Administration (NARA), the RAF Museum, Historic England and the Defence of Britain Project.

The British Geological Survey (BGS) was consulted for borehole information.

1.4.5 Local Authority Records

Information has been obtained from Kent County Council, Essex County Council and Havering Borough Council.

1.4.6 Local Record Offices and Libraries

Kent Archives & Local History Service and Essex Record Office were consulted.

1.4.7 Local Historical and Other Groups

Local history groups and archaeological societies were consulted, including the Essex Historic Environment Record (HER), the Kent HER and the Greater London HER.

1.5 Data Confidence Level

In general, there is a high level of confidence in the researched information sources used for this report. Exceptions to this are specifically detailed in the text of the report.

2 THE SITE

2.1 Site Location

The Site commences south of Junction 28 of the M25 at Ordnance Survey National Grid Reference (OSNGR) TQ 573904 and ends south of the A2, Watling Street at Cobham, Kent (TQ 669691).

To aid the reader, the Site has been divided into 3No. parts.

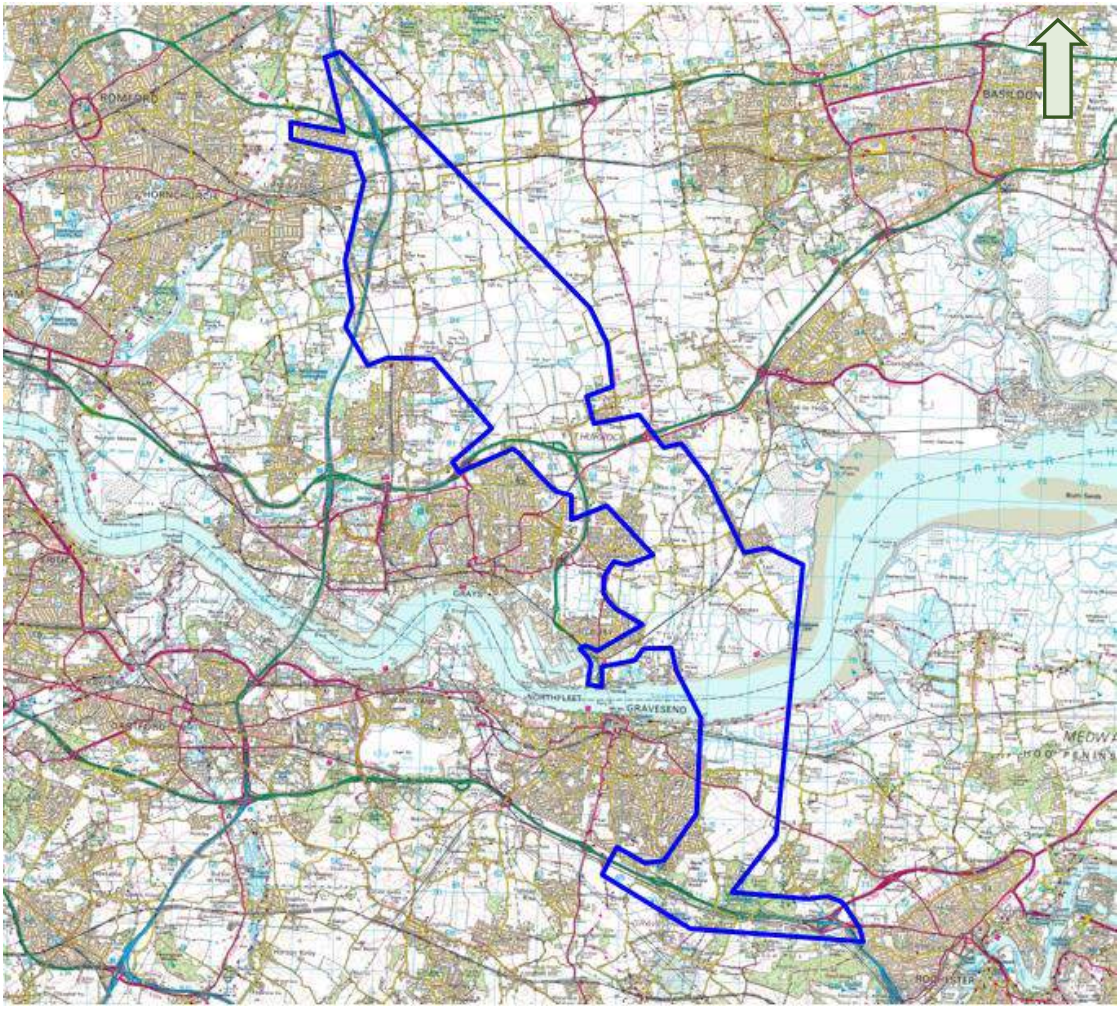
The northern part of the Site commences west of Great Warley (TQ 573904) and ends north of Baker Street (TQ 619825). It mainly comprises roadways and agricultural land.

The central part of the Site commences north of Baker Street (TQ 619825) and continues to the north bank of the River Thames at Tilbury Marshes (TQ 682759). It is bounded to the east by the River Thames and to the west by Tilbury and Tilbury Docks. It mainly comprises parts of the A13 and minor roadways, in addition to areas of marshland.

The southern part of the Site commences at the north bank of the River Thames (TQ 682759) and ends at Cobham (TQ 669691). The southern tip of the Site extends to Strood in the east and near Istead Rise in the west. It comprises the River Thames crossing between Essex and Kent, open marshland and farmland, in addition to parts of the A2 and the A226.

Figure 1 is a Site location map and Plate 1 is a recent satellite photograph of the Site

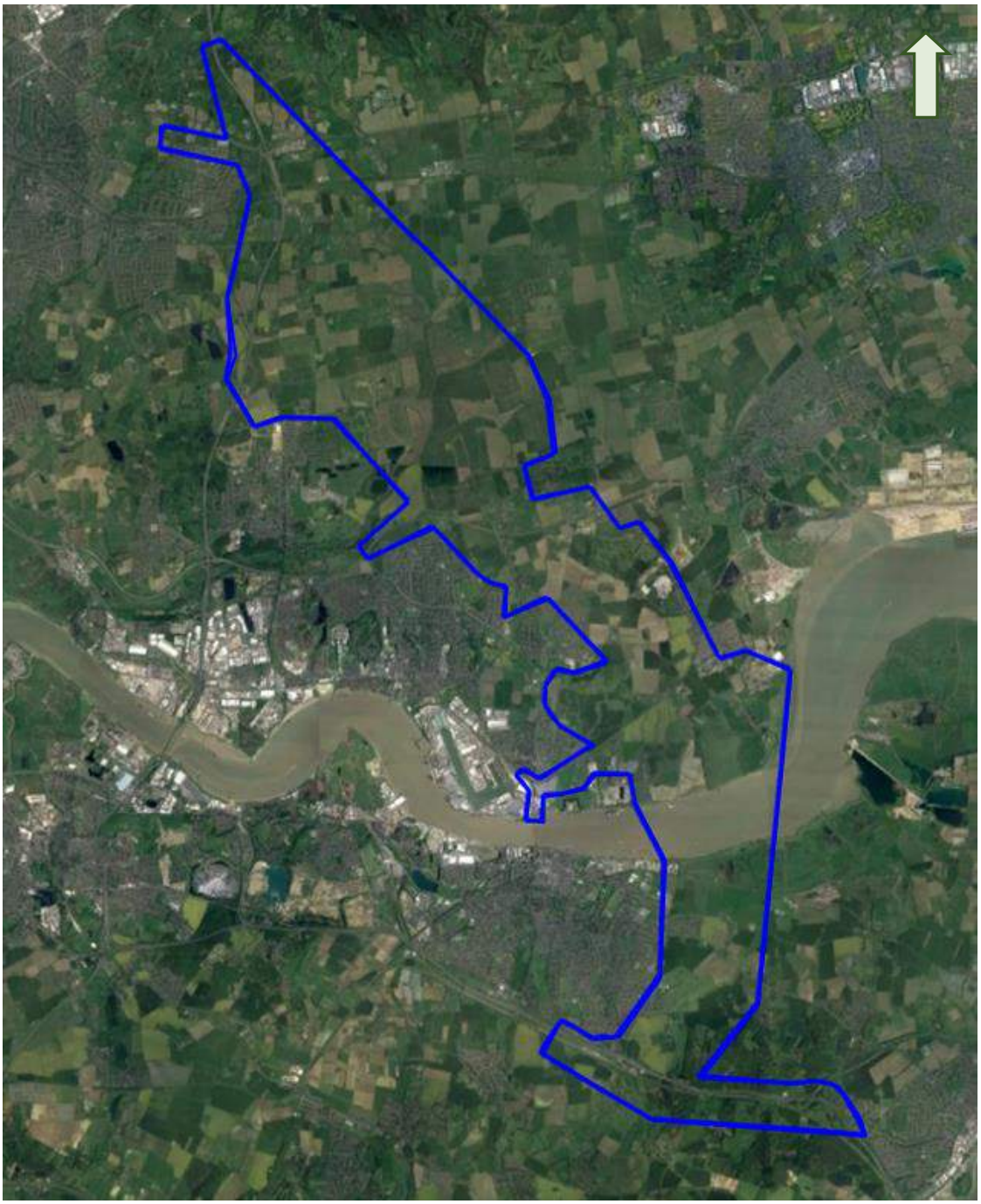
Figure 1	Site location map



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary

Plate 1	Recent satellite photograph of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary

2.2 Proposed Works

Based on the scope in the client-provided document HE540039-CJV-GEN-GEN-SPE-GEO-00008, it is understood that an initial ground investigation will be undertaken on the Site comprising the following:

Scope of Land Based GI

- Cable percussion boreholes with wireline rotary drilling following on at designated locations;
- Dynamic sampling holes (using multipurpose rigs) with wireline rotary drilling following on at designated locations;
- Windowless sampling holes;
- Trial pits;
- Cone penetration tests (CPT) with porewater pressure measurements and seismic cone penetration tests at selected locations.

Scope of River Based GI

- Cable percussion holes with wireline rotary coring follow on to a maximum depth of 55m BGL (Sea bed level), within the River Thames.
- Cone penetration tests with porewater pressure measurement (CPTu) and dissipation tests.

Subsequent works on the Site will involve the construction of a twin bore tunnel under the River Thames between Tilbury and Milton. The final construction design is yet to be formalised.

2.3 Site History

The majority of the Site has historically comprised open farmland and marshland and has been subjected to very little significant development. Tilbury Docks were constructed on land adjacent to the Site in the 19th century.

In the second half of the 20th century, the A2 was built on land crossing the southern end of the Site and the M25 on land traversing the northern end of the Site.

Tilbury Docks were expanded to encroach upon the Site, with the construction of new rail connections.

Some residential development has occurred on the Site at Tilbury, South Ockendon, Chadwell St Mary and Gravesend, although the majority of the Site remains open farmland and marshland.

2.4 Pre-WWI Military Activity

During the 16th century a number of artillery forts defending the Thames Estuary were constructed within approximately 1.5km of the central and southern parts of the Site. This included Coalhouse Fort (TQ 692768) and Shornemead Fort (TQ 693748) which were located on the Site.

In 1862 Milton Range (TQ 679742) was established on the Site for the training of troops garrisoned in Gravesend (see Section 8.1.1 for further details).

2.5 WWI Military Activity

A number of airfields and landing grounds were established in Essex during WWI for the defence of the British coastline. This included a landing ground at Orsett (TQ 659811), which encroached upon the Site (see Section 5.1).

Milton Range remained operational throughout WWI (see Section 8.1.1).

2.5.1 WWI Bombing

During WWI, an estimated 9,000No. German bombs were dropped over Britain. It was the first time that strategic aerial bombardment had been used. Nearly 100No. air raids were carried out over London and South East England, over 40No. of which were by Zeppelin airships.

No records have been found indicating that the Site was bombed during WWI. The nearest recorded incidents are described below.

4th June 1915

5No. **High Explosive (HE)** bombs and 3No. **Incendiary Bombs** (IBs) fell on Gravesend, within approximately 2km of the Site.

2nd September 1916

1No. IB was dropped in the River Thames to the east of Gravesend, within approximately 0.3km west of the Site.

A Zeppelin airship dropped bombs (number unspecified) in the vicinity of Tilbury, within approximately 1km of the Site. The exact locations are not recorded.

23rd-24th September 1916

23No. HE bombs and 21No. IBs fell between South Ockendon and North Ockendon, potentially on the Site.

31st October 1917

Gotha bomber aircraft dropped HE bombs and IBs on Gravesend, approximately 2km west of the Site.

WWI bombing is not considered to provide a source of UXO hazard to the Site.

Potential UXO Hazard

Given the small numbers of bombs that were dropped at any one time during WWI air raids, and the minimal damage caused, it is considered unlikely that an Unexploded Bomb (UXB) would have fallen unnoticed on the Site.

2.5.2 WWI AA Defences

In response to the air raids, Anti-Aircraft (AA) guns were established. These were potential sources of Unexploded AA (UXAA) shells which could land up to 13km from the firing point, although more typically fell within 10km during WWI.

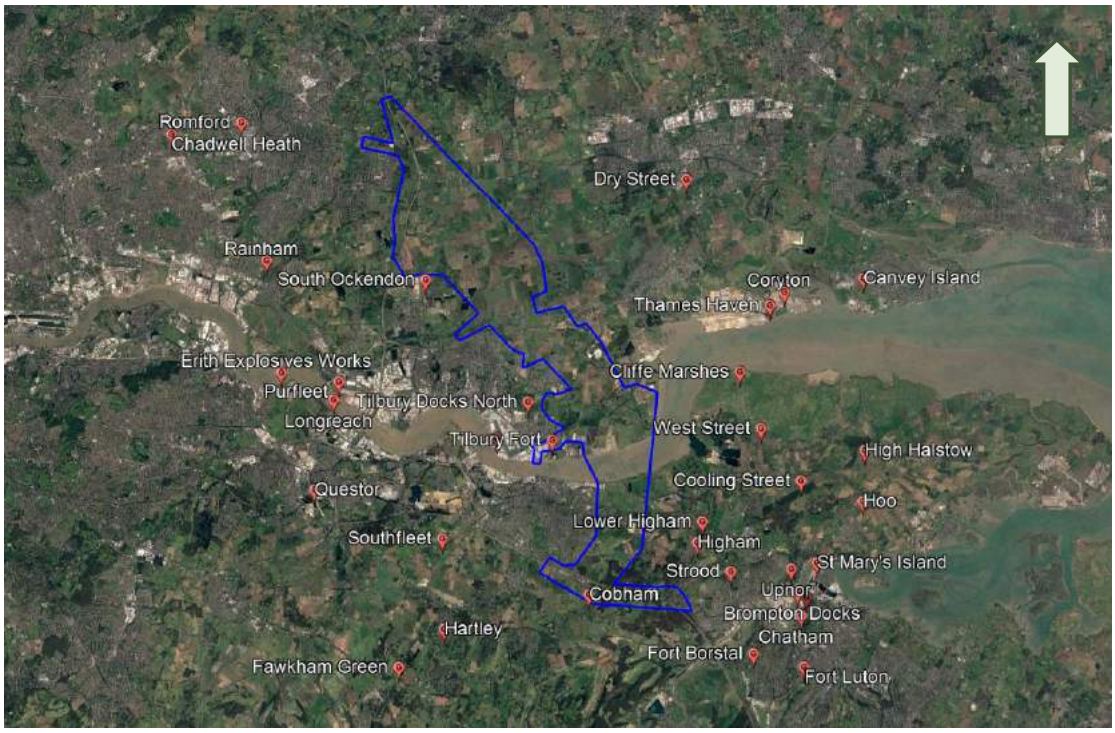
During WWI static AA guns were established throughout the area surrounding the Site.

Table 1 is a list of recorded WWI Heavy AA (HAA) batteries within 10km of the Site.

Table 1	WWI HAA batteries within 10km of the Site		
Grid Reference	**Location**	**Armament**	**Approximate Distance and Direction from Site**
TQ 650754	Tilbury Fort	Unknown	0.1km SW
TQ 668688	Cobham	1No. 3" gun	0.3km S
TQ 639770	Tilbury Docks North	1No. 6-pdr gun and 1No. 12-pdr gun	0.7km SW
TQ 593821	South Ockendon	1No. 3" gun	0.9km S
TQ 626754	Tilbury Docks	1No. 6-pdr gun	1.3km SW
TQ 714712	Higham	1No. 3" gun	1.6km NE
TQ 729700	Strood	1No. 3" gun	2.2km E
TQ 755702	Upnor	2No. 6-pdr guns	2.2km E
TQ 716721	Lower Higham	1No. 3" gun	2.6km E
TQ 740665	Fort Borstal	1No. 18-pdr gun	3.3km SE
TQ 730786	Cliffe Marshes	1No. 3" gun and 1No. 6-pdr gun	3.7km E
TQ 604710	Southfleet	1No. 12pdr gun	4.1km NW
TQ 740762	West Street	1No. 3" gun	4.7km E
TQ 758692	Brompton Docks	6No. 6-pdr guns	4.7km E
TQ 760682	Chatham	1No. 3" gun	4.9km ESE
TQ 511886	Romford	1No. 3" gun	5.2km W
TQ 762690	Brompton	2No. 6-pdr guns	5.3km E
TQ 606671	Hartley	1No. 3" gun	5.3km SW
TQ 524827	Rainham	1No. 3" gun	5.4km W
TQ 748821	Coryton	2No. 6-pdr guns and 2No. 1-pdr gun	5.6km NE
TQ 557776	Purfleet	2No. 3" guns and 2No. 1-pdr guns	5.7km SW
TQ 766705	St Mary's Island	2No. 6-pdr guns	5.7km NE
TQ 762660	Fort Luton	1No. 18-pdr gun	5.7km SE
TQ 555768	Longreach	1No. 3" gun	6.3km SW
TQ 785754	High Halstow	1No. 3" gun	6.7km E
TQ 758740	Cooling Street	2No. 3" guns	6.8km E
TQ 704868	Dry Street	1No. 12-pdr gun	7.1km NE
TQ 742815	Thames Haven	1No. 12-pdr gun	7.7km NE
TQ 587654	Fawkham Green	1No. 3" gun	7.7km SW
TQ 532779	Erith Explosives works	1No. 4" gun and 1No. 3" gun	7.7km SW
TQ 481880	Chadwell Heath	1No. 3" gun	8.1km W
TQ 785732	Hoo	1No. 3" gun	9.4km E
TQ 548729	Questor	1No. 3" gun	9.5km SW
TQ 782828	Canvey Island	1No. 12-pdr gun	9.9km E

Plate 2 is a recent aerial photograph showing the approximate locations of WWI AA batteries in the vicinity of the Site.

Plate 2	Aerial photograph showing the locations of WWI AA guns in the vicinity of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary	AA gun battery

Given the number of gun batteries in the surrounding area, the potential for a UXAA shell to have fallen unnoticed on the Site during WWI cannot be totally discounted.

2.6 WWII Military Activity

Prior to WWII, military activity in the region rapidly increased. The artillery forts on the banks of the River Thames were used for **Billeting** and training troops, and military training on Milton Range expanded.

Given the proximity to London and the importance of the Thames Estuary as a navigational aid for the Luftwaffe, the area surrounding the Site was subjected to significant bombing raids throughout WWII. Details for air raid incidents on the Site are provided in Section 3 and **Appendix 1**

Numerous defensive and offensive military structures were built in the vicinity of the Site. These included lines of defence (Stop Lines), pillboxes, bombing decoys, minefields and AA guns. Further details are given in Section 4.

Royal Air Force (RAF) Gravesend was established on land encroaching upon the Site prior to WWII. Operational details of the airfield are given in Section 5 and Section 6 describes potential sources of UXO hazard associated with airfield activity.

Munitions production and storage in the vicinity of the Site is discussed in Section 7.

Military training grounds and firing ranges, including Milton Range, are discussed in Section 8.

Other military establishments in the immediate vicinity of the Site, including D-Day Marshalling Areas and military camps, are detailed in Section 9.

2.7 Post-WWII Military Activity

Milton Range remained operational post-WWII, and was sold in 1995 to the Metropolitan Police for training exercises and as a rifle and pistol range (see Section 8.1.1).

The artillery forts on the banks of the River Thames were transferred out of military use and restored as tourist attractions in the 1980s.

3 WWII BOMBING

Bombing raids began in the summer of 1940 and continued until the end of WWII. Bombing densities generally increased towards major cities or strategic targets such as docks, industrial premises, power stations and airfields.

The German bombing campaign saw the extensive use of both High Explosive (HE) bombs and Incendiary Bombs (IBs). The most common HE bombs were the 50kg and 250kg bombs, although 500kg were also used to a lesser extent. More rarely 1,000kg, 1,400kg and 1,800kg bombs were dropped.

The HE bombs tended to contain about half of their weight in explosives and were fitted with one or sometimes two fuzes. Not all HE bombs were intended to explode on impact. Some contained timing mechanisms where detonation could occur more than 70 hours after impact.

Incendiary devices ranged from small 1kg thermite filled, magnesium bodied bombs to a 250kg 'Oil Bomb' (OB) and a 500kg 'C300' IB. In some cases the IBs were fitted with a bursting charge. This exploded after the bomb had been alight for a few minutes causing burning debris to be scattered over a greater area. The C300 bombs were similar in appearance to 500kg HE bombs, although their design was sufficiently different to warrant a specially trained unit of the Royal Engineers to deal with their disposal.

Anti-Personnel (AP) bombs and Parachute Mines (PMs) were also deployed. 2No. types of anti-personnel bombs were in common use, the 2kg and the 12kg bomb. The 2kg bomb could inflict injury across an area up to 150m away from the impact, within 25m of this, death or fatal injury could occur.

PMs (which were up to 4m in length) could be detonated either magnetically or by noise/vibration. Anti-shipping parachute mines were commonly dropped over navigable rivers, dockland areas and coastlines. The Royal Navy was responsible for ensuring that the bombs were made safe. Removal and disposal was still the responsibility of the Bomb Disposal Unit of the Royal Engineers.

WWII bomb targeting was inaccurate, especially in the first year of the war. A typical bomb load of 50kg HE bombs mixed with IBs which was aimed at a specific location might not just miss the intended target but fall some considerable distance away.

It is understood that the local Civil Defence authorities in urban areas had a comprehensive system for reporting bomb incidents and dealing with any UXO. In more rural areas, fewer bombing raids occurred. It is known that Air Raid Precaution (ARP) records under-represent the number and frequency of bombs falling in rural and coastal areas.

Bombs were either released over targets or as part of 'tip and run' raids where bomber crews would drop their bombs to avoid Anti-Aircraft fire or Allied fighter aircraft on the route to and from other strategic targets. Bombs dropped as a result of poor targeting or 'tip and run' raids on rural, river, marsh or coastal areas were often unrecorded or entered as 'fell in open country', 'fell in the sea' or 'fell in the river' and left little evidence of the fall.

3.1 Bombing in Essex and Kent

From 1939 Essex and the southeast coast were subject to reconnaissance flights by the Luftwaffe. From the onset of WWII, mine laying by the Luftwaffe along the coast and in the estuaries of the River Thames and the River Medway became increasingly frequent.

The Thames Estuary and the River Thames were heavily mined during WWII. This included both defensive mines on beaches in order to prevent enemy landings, as well as marine mines laid at sea by both the British and the German forces to destroy ships entering the Thames Estuary. The Thames Estuary was also guarded against enemy submarines by mines and submarine nets.

Inland bombing raids began in the summer of 1940 and continued until the end of WWII. The main Luftwaffe flightpaths to and from London and the industries along the River Thames, including the Tilbury Docks and the Royal Docks, crossed the Site. The region was consequently subject to 'tip-and-run' raids throughout WWII from aircraft flying to and from London and the industrialised Midlands.

There were also strategic targets in the area including oil facilities, explosives and munitions factories and other military establishments, which were actively targeted. Operational airfields in the area, such as RAF Eastchurch, RAF Gravesend and RAF Hornchurch, were attacked by the Luftwaffe. Records for heavy raids on many of the region's airfields were suppressed until after WWII.

From mid-September until the end of 1940, Essex and Kent were raided on the majority of nights. The raids continued through the early months of 1941 becoming less frequent, although often more intense.

From July 1941 the bombing campaign entered a period of relative inactivity. Raids still took place but tended to be relatively minor in severity. Manned bomber raids returned to the South East in the first four months of 1944 and, after a brief respite, were followed by the start of the V1 (Pilotless Aircraft) offensive against England in June 1944.

These weapons arrived at any time of day and caused considerable blast damage. In an attempt to prevent them from reaching London, a defence plan known as Operation Diver was devised. This involved the deployment of AA guns, barrage balloons and fighter aircraft in an attempt to intercept the V1s.

In September 1944 the V2 (Long Range Rocket) offensive began. Falling from a height of some 50 miles (80km) above the ground, these ballistic missiles caused larger craters and greater damage to underground utilities than the V1s, but their surface blast effect was generally less. Records show that in excess of 406No. V1s and 375No. V2s fell in Essex during WWII.

The counties of Essex and Kent recorded approximately 14,810No. and 24,664No. HE bombs respectively during WWII.

3.2 Strategic Targets

The presence of strategic targets significantly increased the likelihood of bombing within the local area. Airfields, docks, industrial facilities, transport infrastructure and anti-invasion defences were all targeted by Luftwaffe bombers. The inherent bombing inaccuracies at the time meant that areas surrounding the targets were often subjected to bombing.

During WWII, large parts of the Site comprised open marshland and farmland, with few significant strategic targets in close proximity.

The Site was located on Luftwaffe flight paths into London, which subsequently led to tip-and-run bombing in its immediate vicinity. Industry on the banks of the River Thames was also subjected to opportunistic attacks by bombers using it as a navigational aid.

Possible strategic targets in the vicinity of the Site are described below.

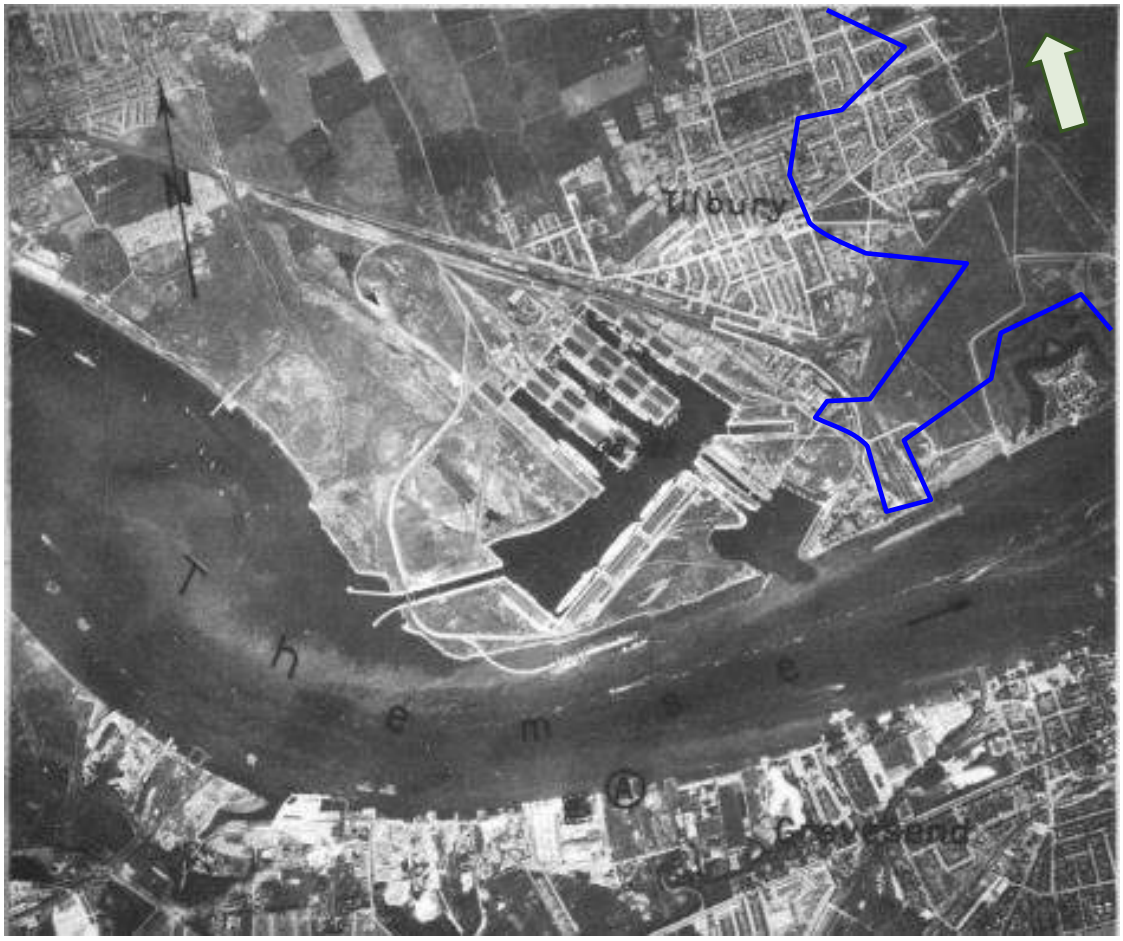
3.2.1 Tilbury Docks

Tilbury Docks (Luftwaffe Target GB 45 6), encroaching on the central part of the Site, and their associated warehouses, wharves, railway lines, factories and power stations, were principal targets of the Luftwaffe. They were widely used throughout WWII to handle military cargo and troops.

The land adjacent to Tilbury Docks was also used for the construction of the 'Pipe Line Under The Ocean' (PLUTO) and the construction of Mulberry Harbours for the D-Day landings.

Plate 3 is a Luftwaffe target photograph of Tilbury Docks, dated the 4th June 1939.

Plate 3	Luftwaffe target photograph of Tilbury Docks, 4th June 1939



Source: Clarke *Not to Scale*

3.2.2 Public Utilities

Public utilities were frequently targeted to disrupt power and water supplies to local industries.

Gas works were located in Milton, approximately 1.1km west of the southern part of the Site.

A power station and machine house, part of Bowater's Paper Mills in Gravesend, was located approximately 1.2km southwest of the central part of the Site. It has been designated as Target A in Plate 3.

3.2.3 Industrial Targets

Essex Aero Ltd, based on the Site at RAF Gravesend, produced components for aircraft and HAA guns, and manufactured magnesium alloy fuel and oil tanks for Spitfire and Sunderland aircraft.

Bowaters Paper Mill, Gravesend, approximately 2km southwest of the central part of the Site, machined and assembled Bofors 40mm Light AA guns.

At the Red Lion Wharf, Gravesend, approximately 2km southwest of the central part of the Site, the Holloway Brothers produced Maunsell Sea Forts, and W T Henley Telegraph Works were responsible for producing a range of wartime items including gas masks, mortar components, and connectors and wiring for radar installations.

3.2.4 Military Targets

Milton Range, on the Site, was used by regular Army troops and by the Home Guard for small arms and close-combat training.

RAF Gravesend, encroaching on the southern part of the Site, was used to station squadrons of Fighter Command (see Section 5.1).

Several coastal batteries were located on the Site, including Coalhouse Fort and Shornemead Fort.

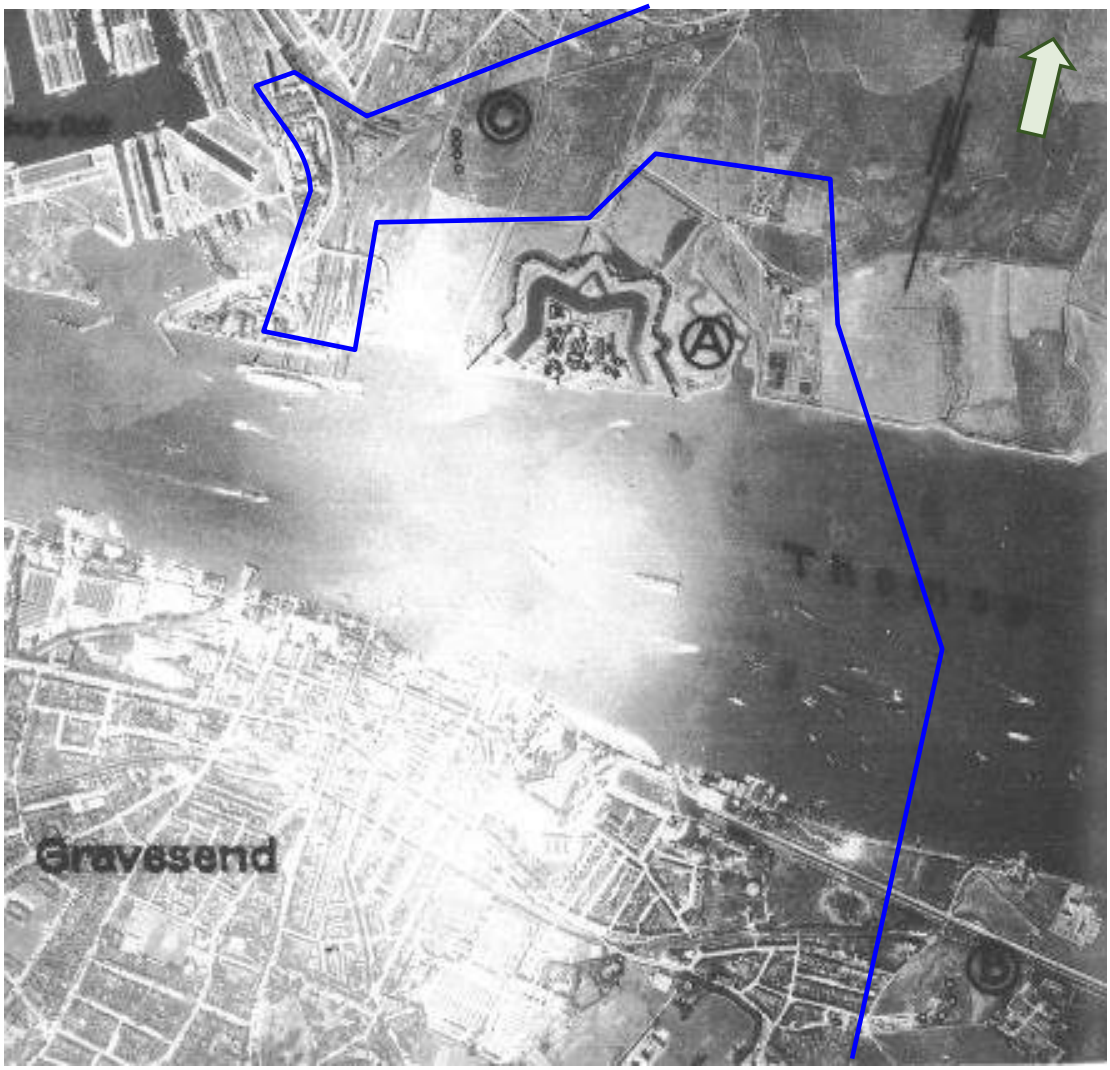
There were numerous HAA gun batteries in the vicinity of the Site, each of which had associated ammunition storage and accommodation camps. 4No. HAA batteries were located on the Site at Orsett, Buckland, North Ockendon, and Chadwell (see Section 4.2).

Tilbury Fort, approximately 0.2km south of the Site, was used to billet troops and served as an AA operations base.

Plate 4 is a Luftwaffe target photograph of Tilbury Fort (Target GB 16 23) dated the 4th June 1939.

Tilbury Fort has been designated Target A. Targets B and C respectively denote the locations of light and heavy AA gun emplacements.

Plate 4	Luftwaffe target photograph of Tilbury Fort, 4th June 1939



Source: Clarke *Not to Scale*

During the build-up to D-Day, the Allied invasions of Normandy in 1944, several Marshalling Areas for troops were established in the region. This included the construction of Orsett Camp (see Section 9.1). This formed a potential target towards the end of WWII.

RAF Hornchurch, approximately 4.5km west of the Site, was an important airfield used to station squadrons of Fighter Command engaged in the defence of London.

3.3 Bombing Density and Incidents

Table 2 gives details of the overall bombing statistics recorded for the Local Authority Districts of the Site and surrounding districts. These were categorised as Rural Districts (RD), Urban Districts (UD), Municipal Boroughs (MB) and Country Boroughs (CB).

WWII bomb density levels are defined below:

<5 bombs per 405ha is a Very Low regional bombing density.

5-30 bombs per 405ha is Low.

30-130 bombs per 405ha is Moderate.

130-330 bombs per 405ha is High.

>330 bombs per 405ha is Very High.

The Site crossed 6No. LA districts: Hornchurch UD, Thurrock UD, Northfleet UD, Brentwood UD, Gravesend MB and Strood RD.

Table 2 Bombing statistics

Area	Bombs Recorded				
	High Explosive	Parachute Mines	Other	Total	Bombs per 405ha (1,000 acres)
Northfleet UD	**364**	**3**	**7**	**374**	**99.2**
Gravesend MB	**272**	**0**	**14**	**286**	**71.3**
Hornchurch UD	**1,012**	**41**	**38**	**1,091**	**55.1**
Brentwood UD	**744**	**14**	**34**	**792**	**43.4**
Thurrock UD	**1,614**	**44**	**21**	**1,679**	**41.4**
Strood RD	**1,804**	**24**	**55**	**1,883**	**38.6**

Note that Table 2 excludes the figures for V1s (Pilotless Aircraft, also known as 'Doodlebugs'), V2s (Long Range Rockets), AA shells and IBs. Discrepancies between this list and other records, such as bomb clearance records, demonstrate that this data is likely to under-represent actual bombing.

It should be noted that during WWII, many UXB were mapped and subsequently removed as and when conditions and demands on Bomb Disposal teams allowed. Their removal was not always accurately recorded and sometimes records were later destroyed. In practice, most UXB were probably removed and only a much smaller number were actually registered as officially abandoned bombs.

The maps and aerial photographs below identify the extent of bombing across the Site. **Appendix 1** provides a list of recorded bombing incidents on the Site.

The compiled maps show the approximate locations of bomb impacts on the Site. IBs fell in such large numbers that it is not possible to plot their individual locations, only areas where significant concentrations are recorded falling.

The maps have been compiled from a number of different sources, including air raid incident reports, bomb census maps and historical aerial photographs.

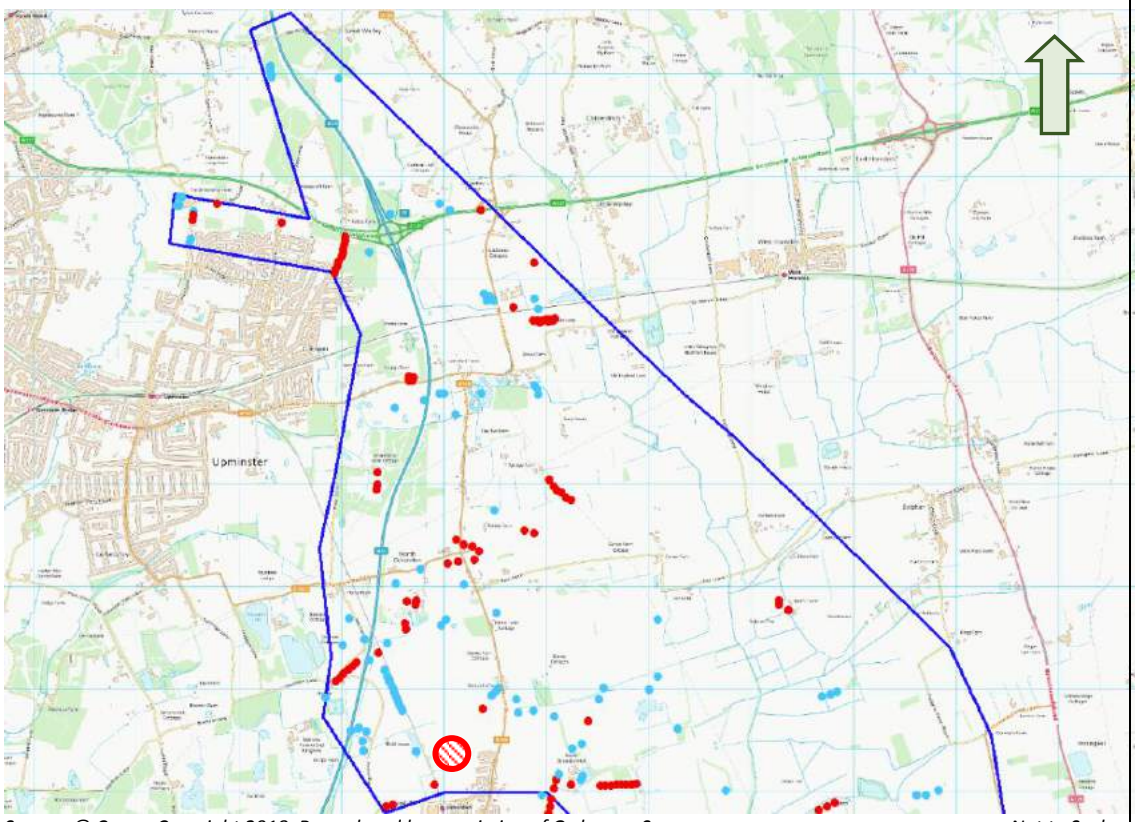
Note that air raid incident reports did not always record precise locations, often only indicating on which street, area or farm a bomb fell.

3.3.1 Northern Part of the Site

Figure 2 is a compiled bomb impact map for the northern part of the Site.

It shows that there were several incidents on the Site, including a concentration of bombing south of Great Warley and at South Ockendon, where numerous UXB are recorded falling.

Figure 2	Compiled bomb impact map for the northern part of the Site



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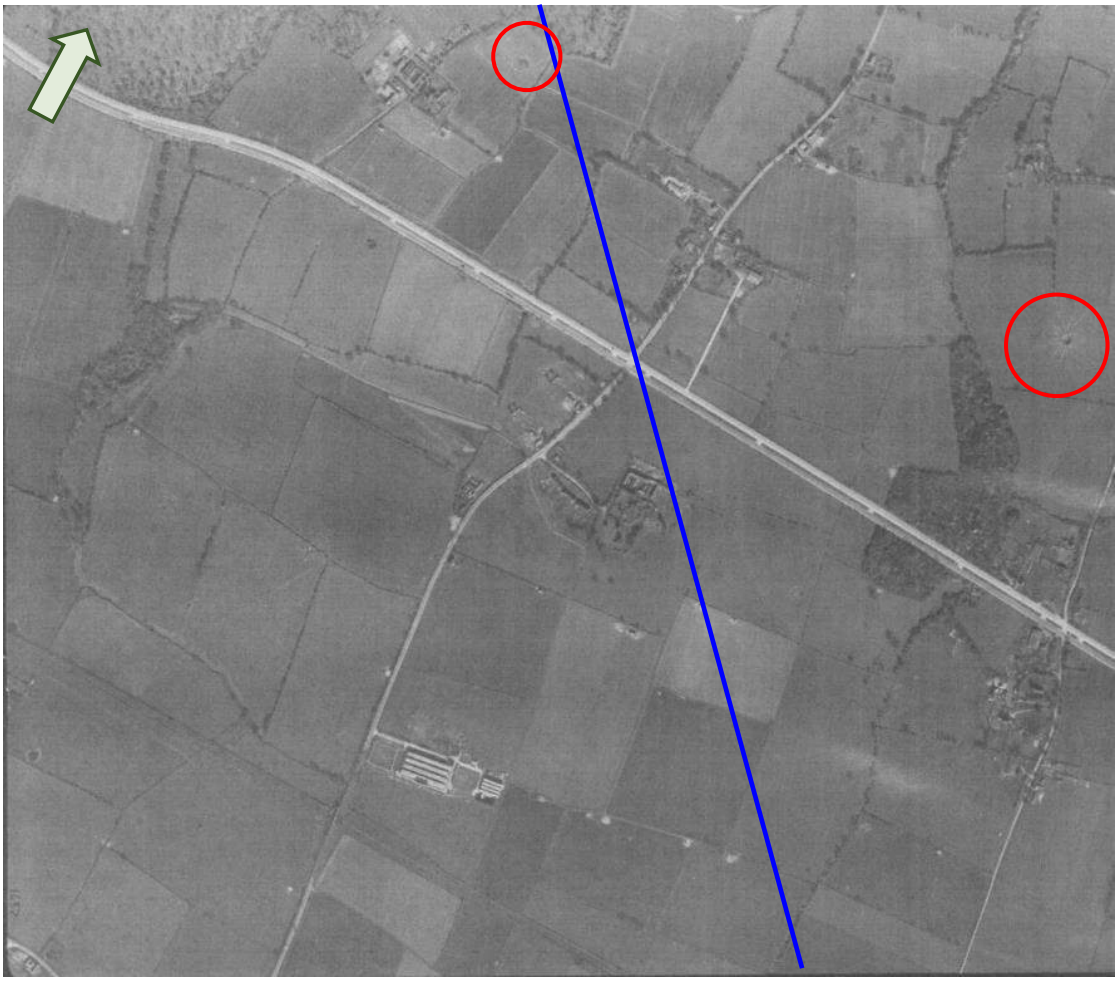
Legend	Site boundary	HE bomb	UXB	Area of IBs

Plate 5 is an aerial photograph, dated the 18th April 1944, showing the Warley Street area of the Site. Only 1No. possible bomb crater has been identified on the Site and there is no evidence of any heavy cratering.

Plate 5	Aerial photograph, 18th April 1944 (Warley Street)



Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 6 is an aerial photograph, dated the 1st May 1946, showing the Upminster area of the Site. Some possible residual bomb damage has been identified on the Site, although there is no evidence of any heavy cratering.

Plate 6	Aerial photograph, 1st May 1946 (Upminster)

Source: Historic England *Not to Scale*

Legend	Possible bomb damage ○

Plate 7 is an aerial photograph, dated the 11th October 1946, showing the Thames Chase area of the Site. Some possible bomb damage has been identified on the Site, although there is no evidence of any heavy cratering.

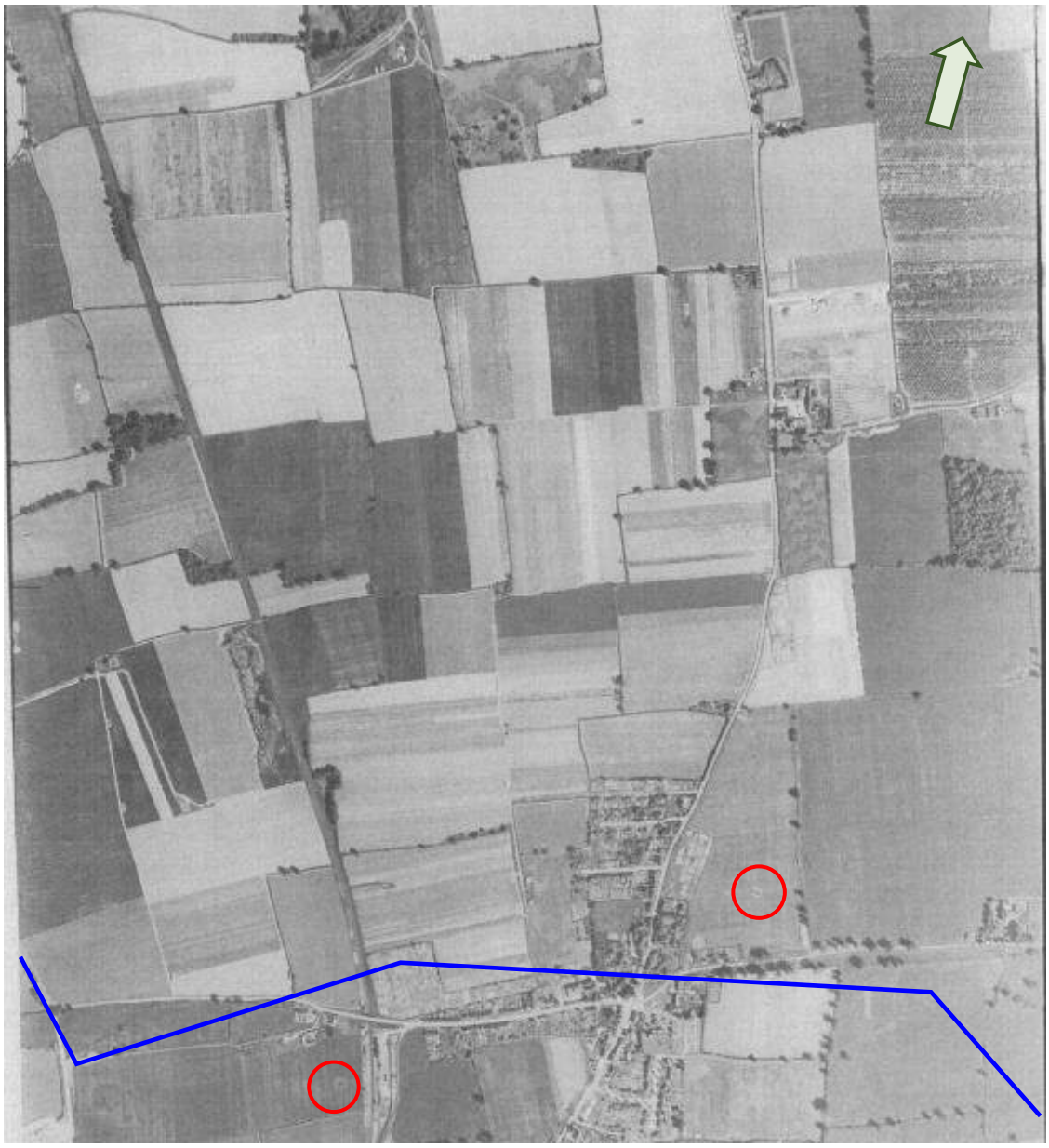
Plate 7	Aerial photograph, 11th October 1946 (Thames Chase)

Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 8 is an aerial photograph, dated the 7th June 1946, showing an area of the Site to the east of Dennis Road. 1No. possible bomb crater has been identified on the Site.

Plate 8	Aerial photograph, 7th June 1946 (East of Dennis Road)



Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 9 is an aerial photograph, dated the 1st May 1946, showing the South Ockendon area of the Site. Some possible infilled craters have been identified on the Site.

Plate 9	Aerial photograph, 1st May 1946 (South Ockendon)

Source: Historic England *Not to Scale*

Legend	Possible bomb damage ○

Potential UXO Hazard

Warley Street/St Mary's Lane

Records indicate that at least 16No. HE bombs fell in close proximity to Warley Street and St Mary's Lane. 6No. of these were recorded as UXB.

Given this elevated localised bombing density, it is considered possible that further UXB could have fallen unnoticed on this part of the Site and remained in situ.

This area is identified as M1 on **Figure 22** and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Kemps Farm

At least 16No. HE bombs fell on the Site in the vicinity of Kemps Farm, half of which were recorded as UXB.

Heavy bombing also occurred to the west and northwest of Kemps Farm due to it being on the flightpath to the strategically-important RAF Hornchurch, which was raided on numerous occasions.

Given this concentrated localised bombing density, it is considered possible that further UXB could have fallen unnoticed on this part of the Site and remained in situ.

This area is identified as M1 on **Figure 23** and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

South Ockendon area

Records indicate that at least 35No. HE bombs fell on the Site around South Ockendon. More than 50% of these were recorded as UXB, far higher than the generally accepted national average UXB rate of 10%.[2]

Given this elevated bombing density, it is considered possible that further UXB could have fallen unnoticed on this part of the Site and remained in situ.

This area is identified as M1 in **Figure 23** and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Remainder of the northern part of the Site

No significant bombing has been identified on the remainder of the northern part of the Site likely to mask the impact of a UXB.

The probability of UXB encounter in these areas is therefore considered to be low.

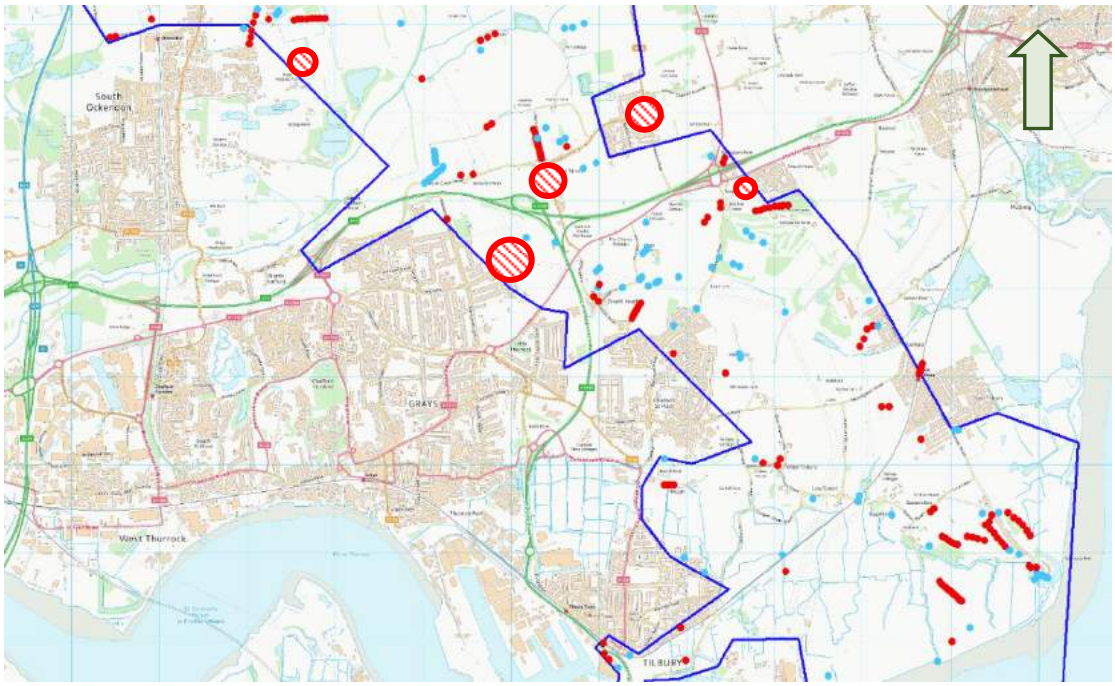
3.3.2 Central Part of the Site

Figure 3 is a compiled bomb impact map for the area surrounding Orsett and Baker Street on the central part of the Site.

This area was subjected to extensive bombing throughout WWII. This included air raids involving mixed loads of HE bombs and IBs which caused severe fire damage in the area.

[2] The reasons for elevated percentages of UXB, above the national WWII recorded MEAN figure of 10% -15%, are numerous and varied. Besides the observational intensity during and after air raids, bomb types and fuzes varied throughout WWII, as did their efficiency. Some sticks of bombs were accidentally released in the 'safe' mode, some were deliberately sabotaged and some fuzes were set for different operational release heights to those enforced by defensive AA artillery or fighter aircraft attacks. There is also the possibility that ground conditions influenced the number of UXB. The important thing to note is that these figures are collated directly from the detailed ARP and other records of the time.

Figure 3	Compiled bomb impact map for the central part of the Site (Area near Orsett)



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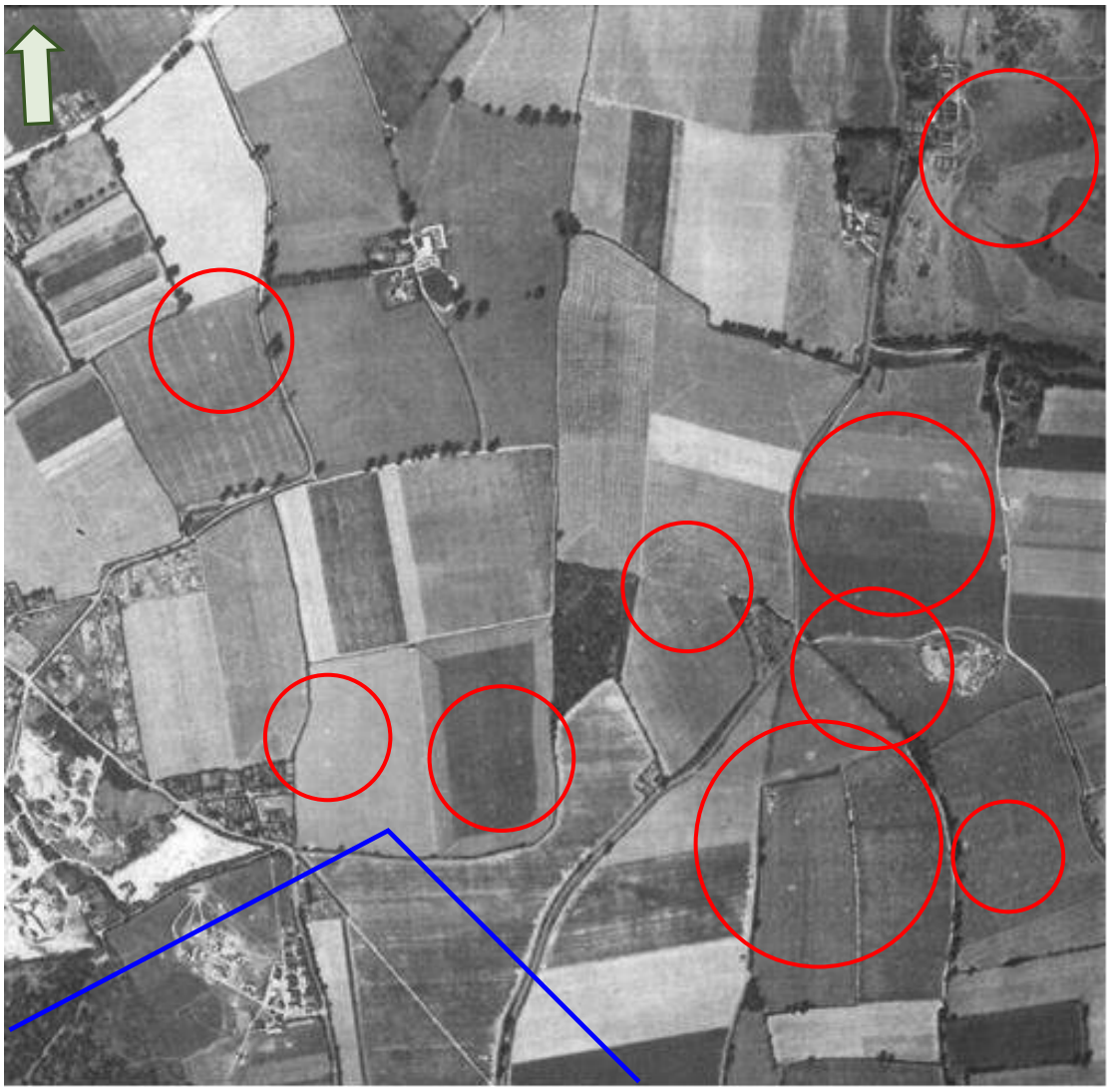
Legend	Site boundary	HE bomb	UXB	Areas of IBs

Plate 10 is an aerial photograph, dated the 4th August 1944, showing the area around Orsett Heath.

Residual bomb damage and possible infilled craters have been identified on and in close proximity to the Site.

Plate 10	Aerial photograph, 4th August 1944 (Orsett Heath)

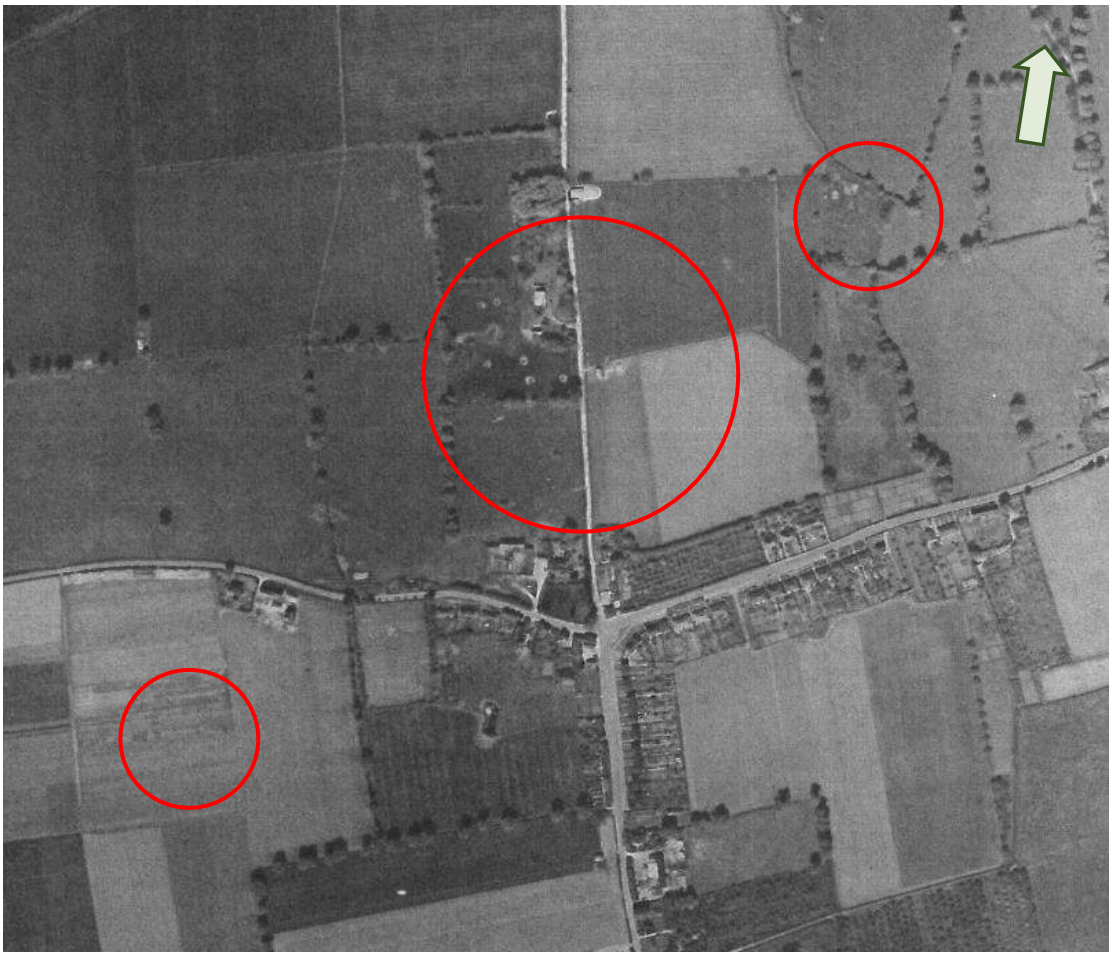


Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 11 is an aerial photograph, dated the 1st May 1946, showing the area around Baker Street. Some possible residual bomb damage has been identified on the Site.

Plate 11	Aerial photograph, 1st May 1946 (Baker Street)



Source: Historic England *Not to Scale*

Legend	Possible bomb damage ○

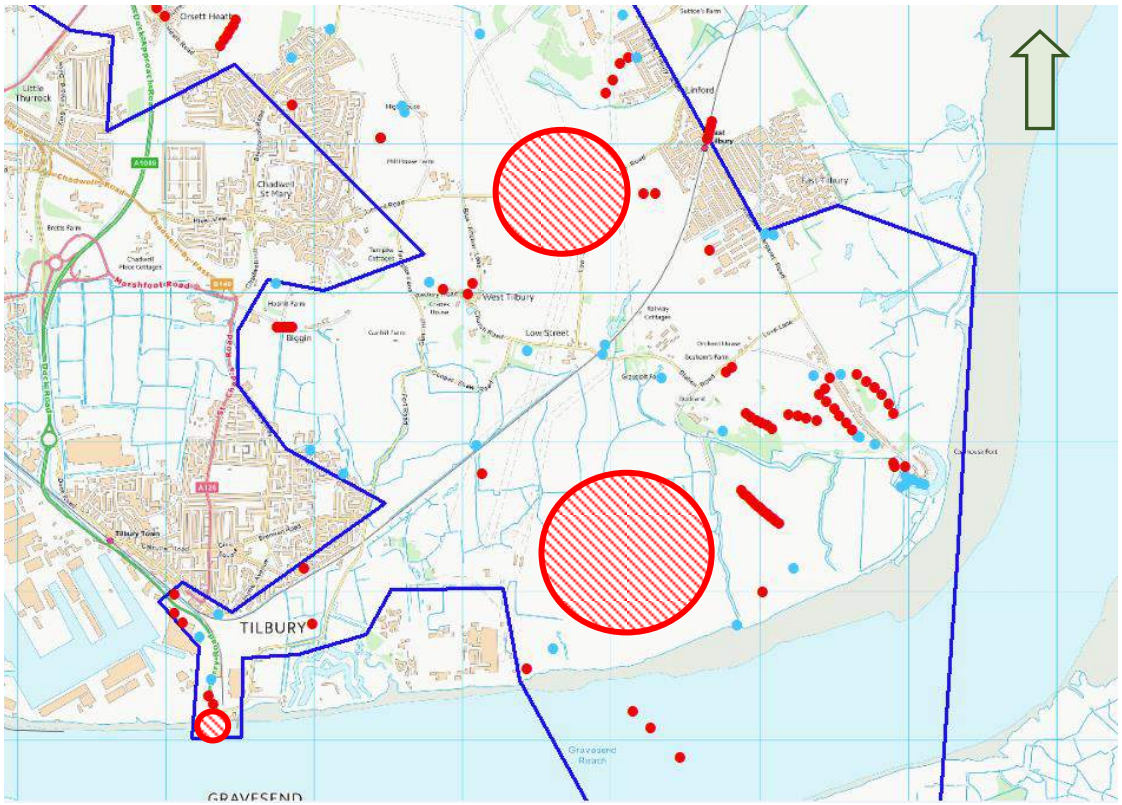
Figure 4 is a compiled bomb impact map for the area surrounding Tilbury on the central part of the Site.

In excess of 20No. HE bombs fell in the vicinity of Coalhouse Fort, East Tilbury, 6No. of which were recorded as UXB. A further 14No. HE bombs fell on the nearby saltings.

The recorded HE bombing density on Tilbury Marshes was far lower, although it should be noted that the recording of bombs falling in uninhabited marshland areas was generally less comprehensive than for more urban areas.

For instance, several ARP records state that bombs fell 'on Tilbury Marshes' without specifying exactly where.

Figure 4	Compiled bomb impact map for the central part of the Site (Tilbury area)

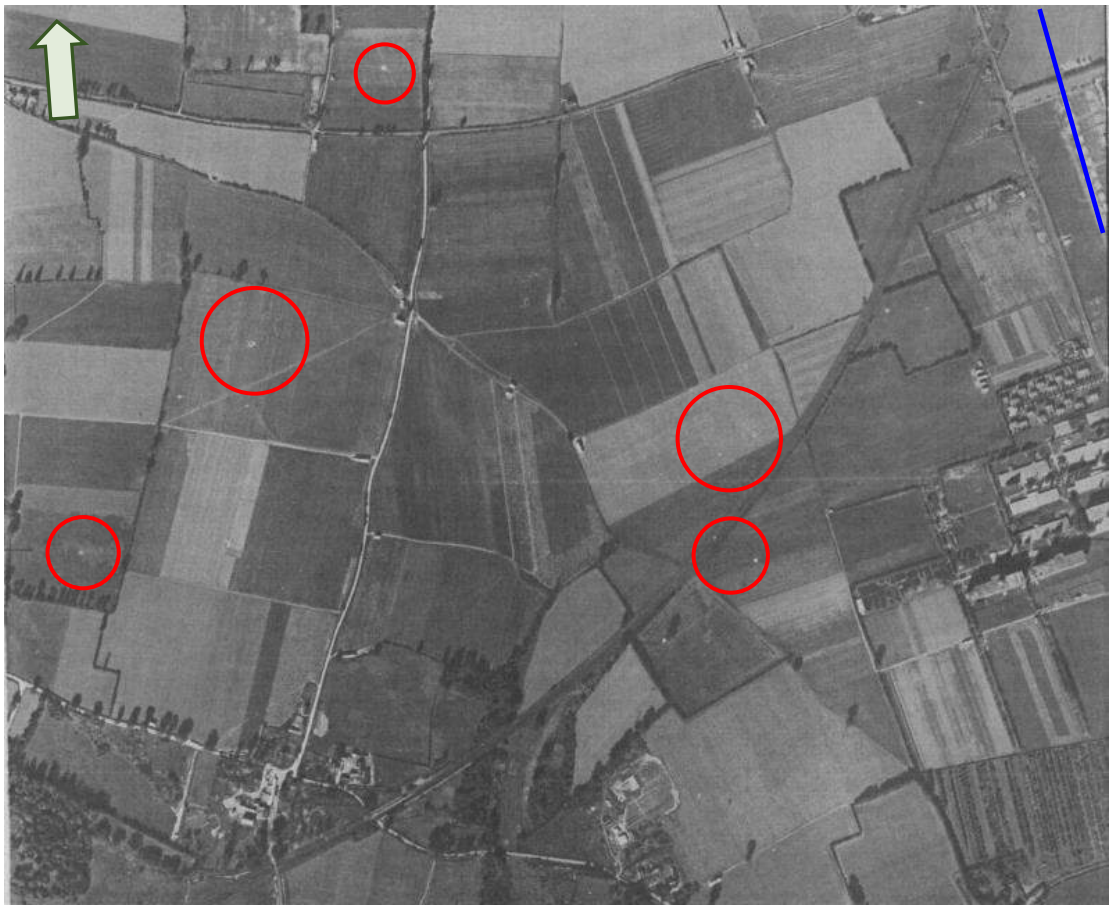


Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary	HE bomb	UXB	Areas of IBs

Plate 12, an aerial photograph dated the 11th October 1946, shows some areas of possible residual bomb damage on the Site at East Tilbury.

Plate 12	Aerial photograph, 11th October 1946 (East Tilbury)



Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 13, an aerial photograph dated the 1st May 1946, shows some possible infilled craters on the Site near Coalhouse Fort, East Tilbury.

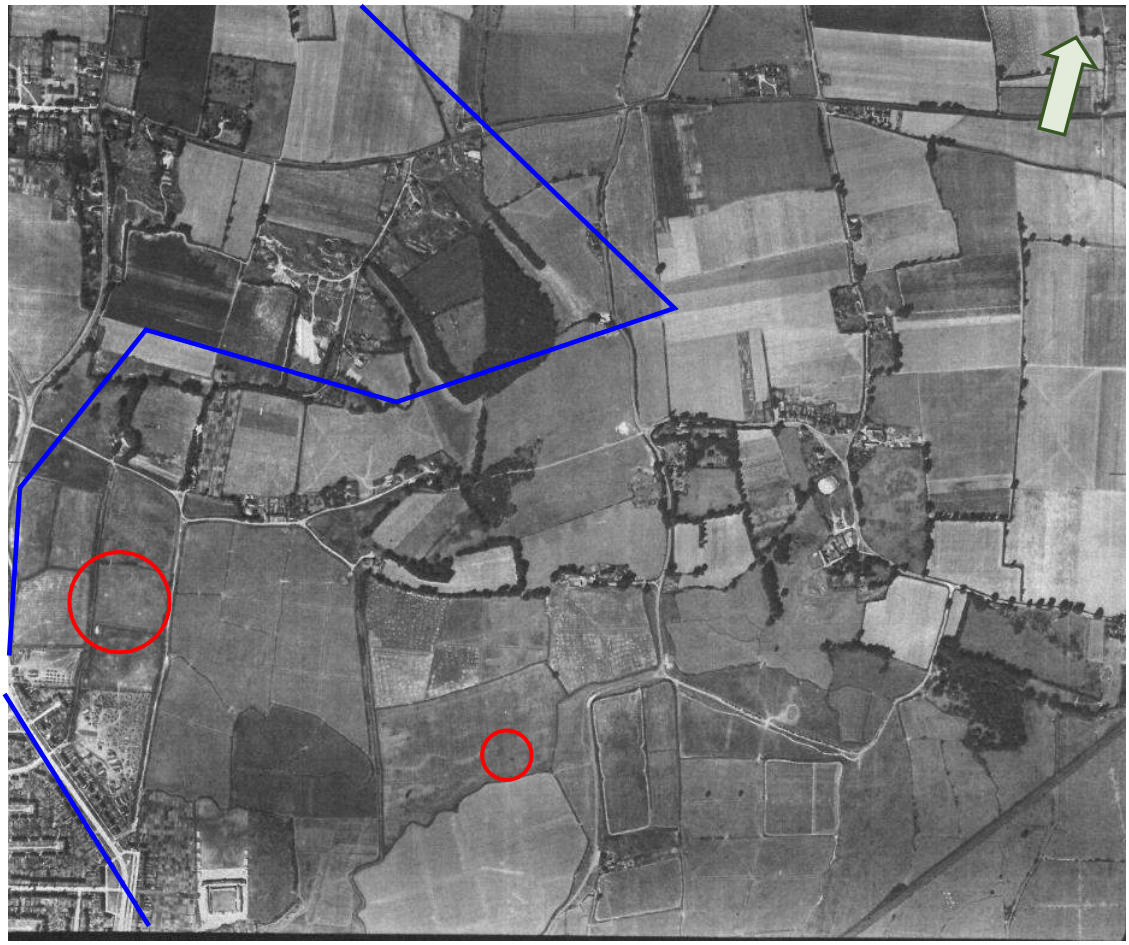
Plate 13	Aerial photograph, 1st May 1946 (Coalhouse Fort)

Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 14, an aerial photograph dated the 4th August 1944, shows some areas of possible residual bomb damage on the Site at West Tilbury. No areas of heavy cratering are evident.

Plate 14	Aerial photograph, 4th August 1944 (West Tilbury)

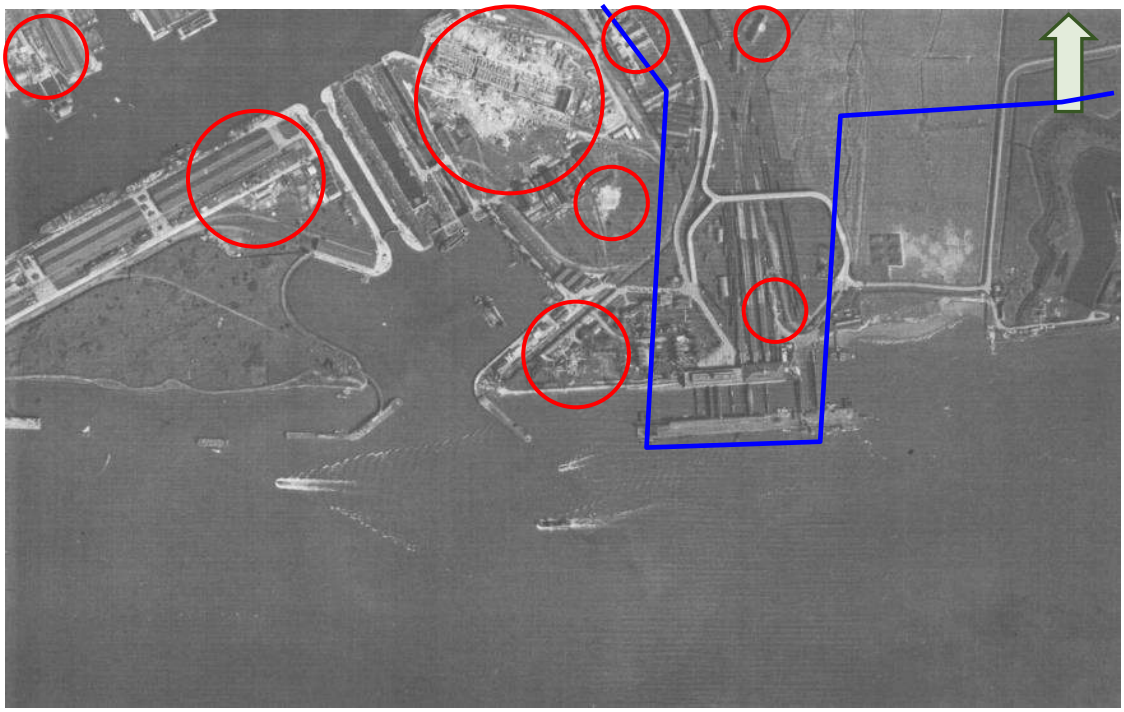


Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 15, an aerial photograph dated the 18th April 1944, shows some areas of possible residual bomb damage on the Site and in the surrounding area at Tilbury Docks, which sustained damage during several air raids.

Plate 15	Aerial photograph, 18th April 1944 (Tilbury Docks)



Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Records indicate that most of the bombing on Tilbury Marshes involved IBs. For instance, during a raid in December 1940, more than 1,000No. IBs fell across the marshland, setting fire to extensive areas of vegetation.

Plate 16, an aerial photograph dated the 6th July 1944, shows some evidence of scarring on and in the vicinity of the Site at Tilbury Marshes consistent with IB fire damage.

Plate 16	Aerial photograph, 6th July 1944 (Tilbury Marshes)

Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Potential UXO Hazard

Orsett area

Records indicate that at least 51No. HE bombs fell on the Site between Baker Street and Orsett (TQ 624826 to TQ 653800). More than 50% of these were recorded as UXB, far higher than the generally accepted national average UXB rate of 10%.[3]

There are several possible reasons for the elevated concentration of bombing, including its location on the flight path to London, interception by RAF fighters and military presence such as Orsett Camp.

Given the elevated bombing density and intensity of raids in this area, it is considered possible that further UXB could have fallen unnoticed on this part of the Site and remained in situ.

This area is identified as M1 in **Figure 24**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

East Tilbury area

Records indicate that in excess of 20No. HE bombs fell on the Site in the vicinity of Coalhouse Fort, of which at least 6No. were recorded as UXB. An additional 14No. HE bombs fell on the nearby saltings. Given the elevated localised bombing density, it is considered possible that further UXB could have fallen unnoticed on this part of the Site and remained in situ.

[3] See previous footnote.

This area is identified as M1 in **Figure 25**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Tilbury Docks

During WWII in excess of 50No. HE bombs and numerous IBs fell on Tilbury Docks and the surrounding area, encroaching on the Site. This caused extensive damage to buildings on the Site, including the railway station, Tilbury Hotel and Tilbury Laundry.

Given the elevated localised bombing density, and it is considered possible that a UXB could have fallen on the Site unnoticed.

This area is identified as M1 on **Figure 25**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Tilbury Marshes

The area of the Site on Tilbury Marshes was subjected to extensive IB raids. Whilst the possibility of finding an IB at shallow depths on this part of the Site cannot be discounted, IBs were predominantly designed to ignite and burn and had a small HE content. As such, they are typically considered to provide a low UXO hazard, see Appendix **A3.8** .

Given the low recorded HE bombing density on this part of the Site, and that no significant cratering indicative of HE bombing has been identified on historical aerial photographs, the potential of encountering a UXB is considered to be low.

Remainder of the central part of the Site

No significant bombing has been identified on the remainder of the central part of the Site.

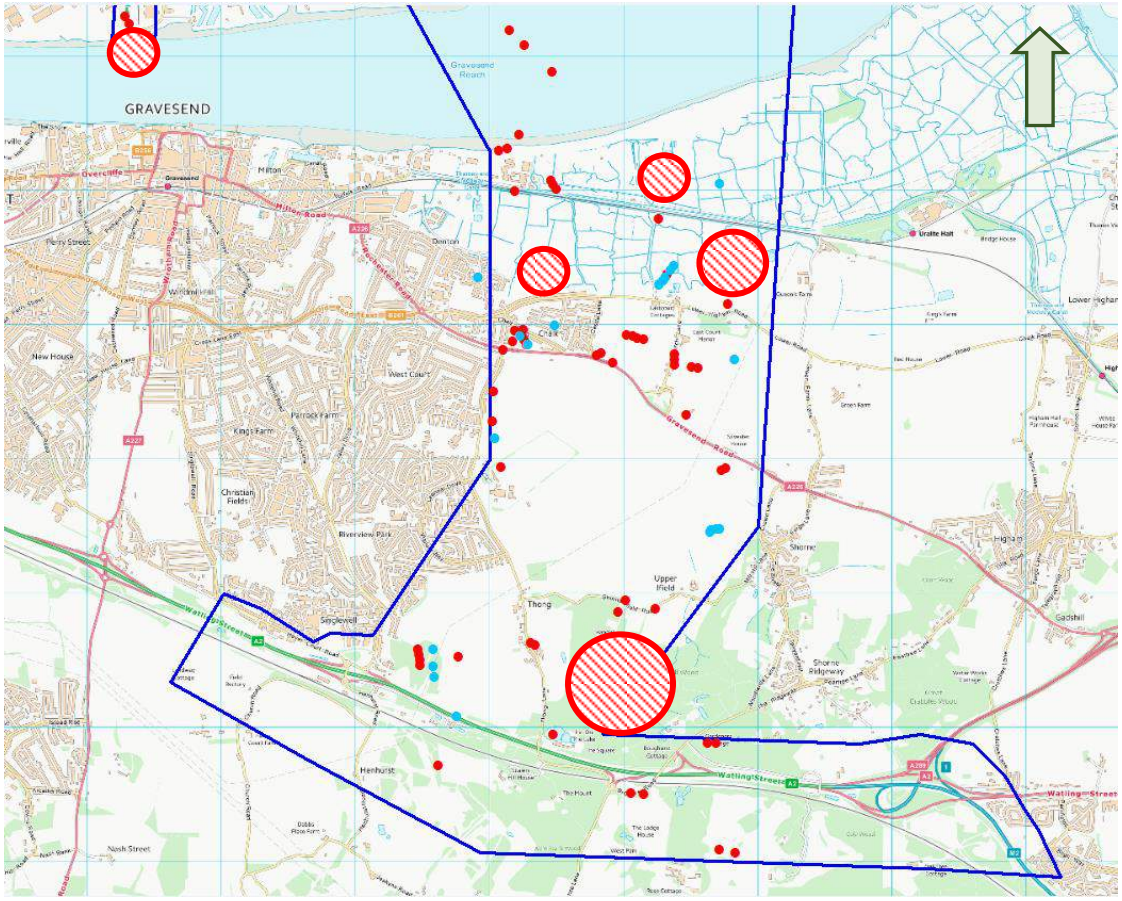
The probability of UXB encounter in these areas is therefore considered to be low.

3.3.3 Southern Part of the Site

Figure 5 is a compiled bomb impact map for the southern part of the Site.

The area around Filborough Marshes recorded several air raids, although bombing densities tended to decrease away from Gravesend and the industrialised wharves along the River Thames to the west.

Figure 5	Compiled bomb impact map for the southern part of the Site



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary	HE bomb	UXB	Areas of IBs

Plate 17 is an aerial photograph, dated the 11th October 1946, showing the Site at Filborough Marshes. Some possible isolated bomb craters have been identified on the Site.

Plate 17	Aerial photograph, 11th October 1946 (Filborough Marshes)

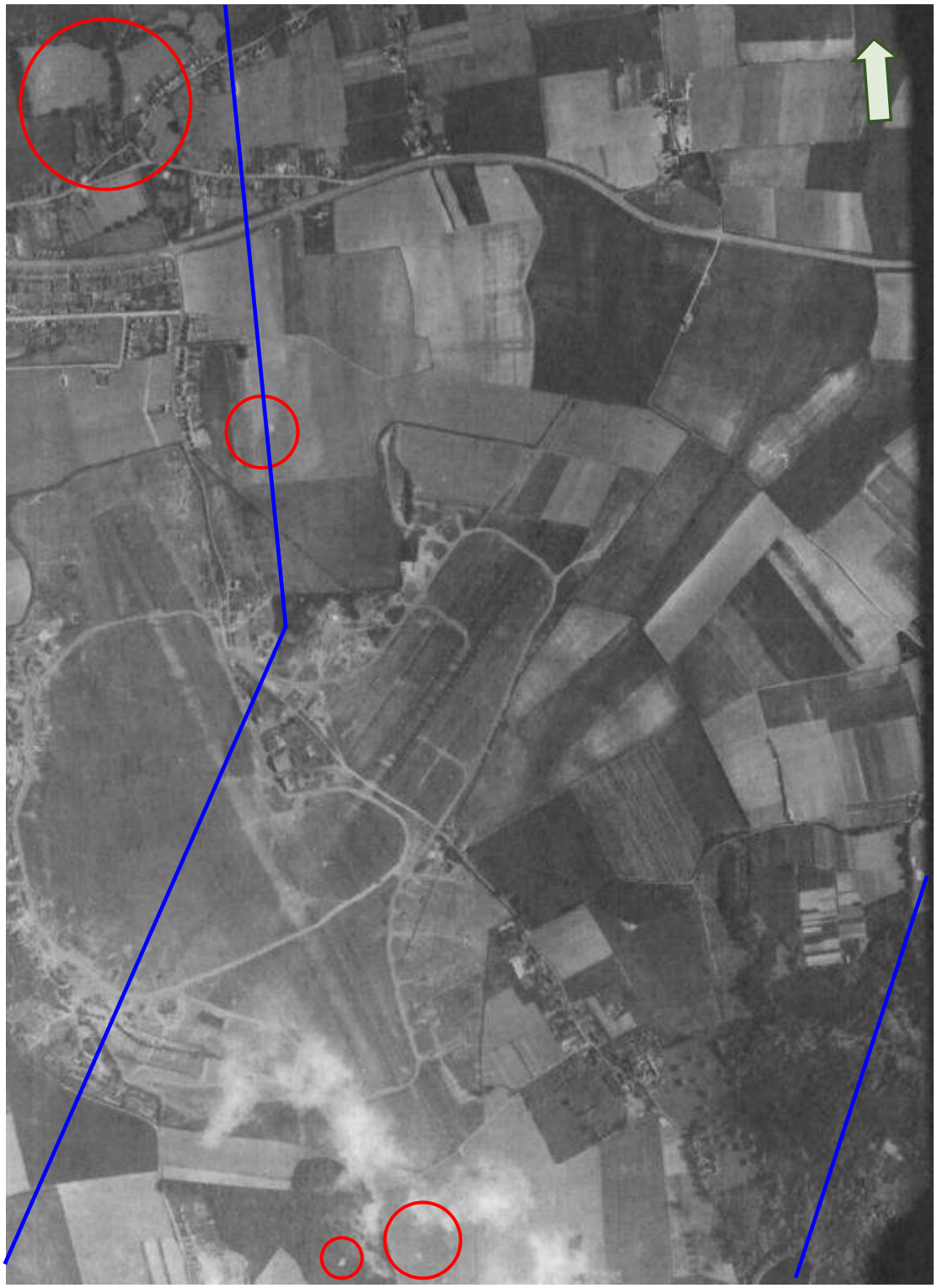
Source: Historic England *Not to Scale*

Legend	Possible bomb damage ○

Plate 18 is an aerial photograph, dated the 14th March 1948, showing the Site at Chalk.

No significant bomb damage has been identified on this part of the Site, with only a few possible infilled craters evident.

Plate 18	Aerial photograph, 14th March 1948 (Chalk)



Source: Historic England *Not to Scale*

Legend	Site boundary	Possible bomb damage

Plate 19, an aerial photograph dating from 1946, shows the Site west of Cobham.

No bomb damage has been identified on this part of the Site.

Plate 19	Aerial photograph, 1946 (west of Cobham)

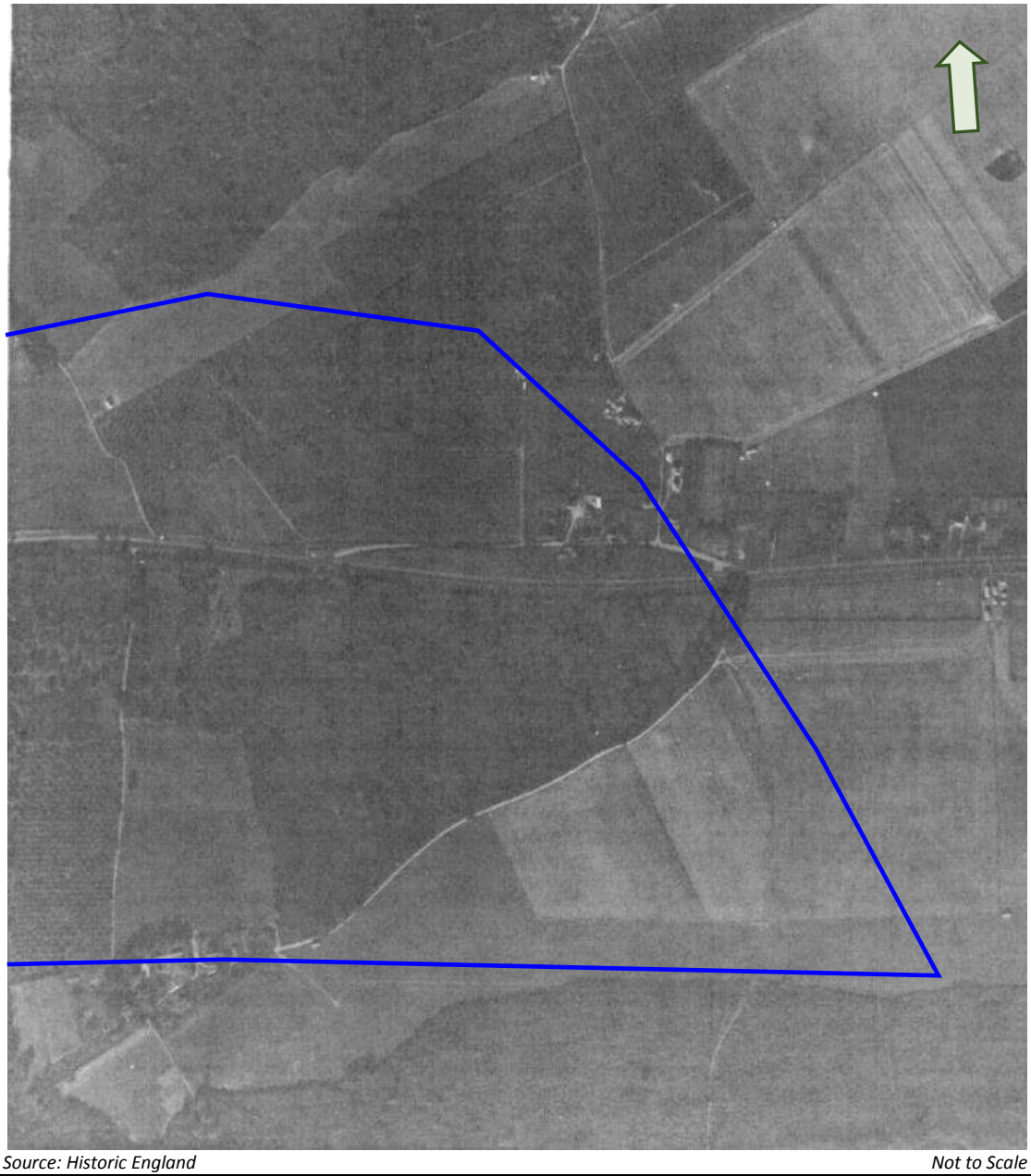
Source: Kent County Council *Not to Scale*

Legend	Site boundary

Plate 20 is an aerial photograph, dated the 11th October 1946, showing the Site to the south of Higham.

No bomb damage has been identified on this part of the Site.

Plate 20	Aerial photograph, 11th October 1946 (south of Higham)



Source: Historic England *Not to Scale*

Legend	Site boundary

Potential UXO Hazard

Filborough Marshes

Filborough Marshes sustained bombing by both HE bombs IBs. From the 7No. HE bombs recorded on on this part of the Site, 6No. were UXB.

Given the high UXB rate, and that bombs falling on uninhabited marshland were not always noticed and recorded, WWII bombing is considered to provide a possible source of UXO hazard to this part of the Site.

This area is identified as M1 in **Figure 26**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Remainder of the southern part of the Site

On the remainder of the southern part of the Site, bombing densities were generally lower and no records have been found of any extensive air raids on this part of the Site.

The probability of UXB encounter in these areas is therefore considered to be low.

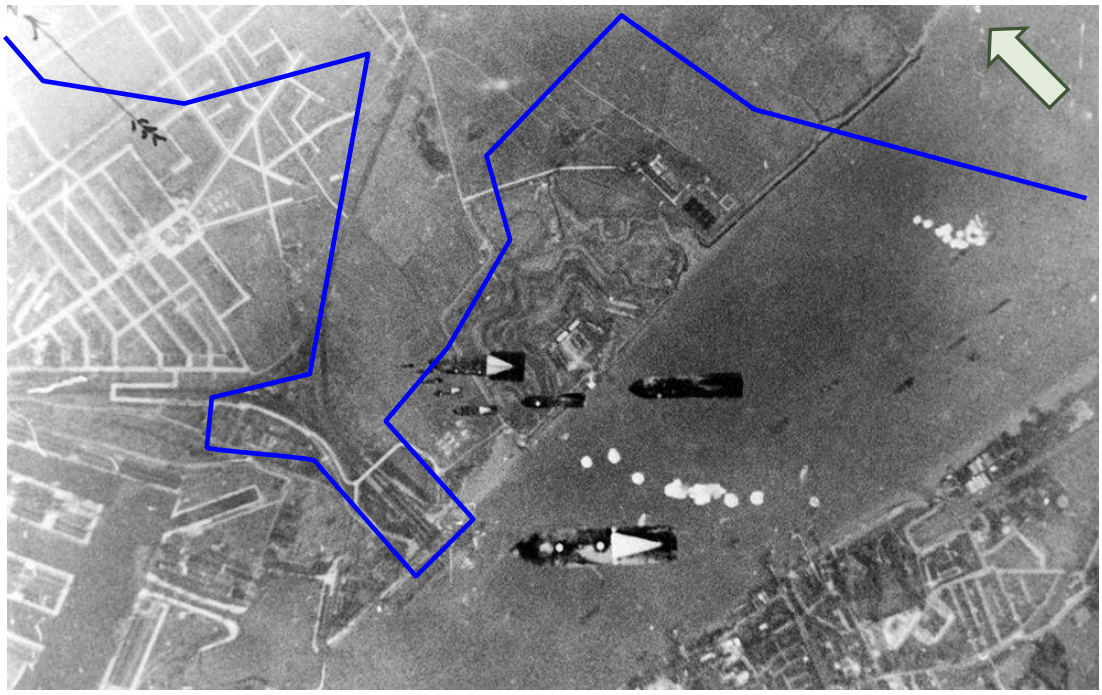
3.3.4 The River Thames

The Thames Estuary south of Tilbury was an important navigational aid for the Luftwaffe when bombing London and numerous bombs were jettisoned in the river by aircraft coming under AA fire or attacks by fighter aircraft.

Opportunistic attacks against merchant shipping in the river, in addition to industrial and military targets along its banks, increased the bombing density in this area.

Plate 21 is an aerial photograph, dating from October 1940, showing an air raid taking place against Tilbury Fort and shipping in the River Thames.

Plate 21	Aerial photograph of bombing over the River Thames at Tilbury, October 1940



Source: IWM *Not to Scale*

Legend	Site boundary

Potential UXO Hazard

There were a number of strategic targets along the River Thames in the vicinity of the Site that were bombed, and UXB falling in the river were less likely to have been accurately recorded or retrieved.

Several ARP records simply state that bombs fell 'in the river' without specifying exactly where.

Therefore it is considered that there is an elevated probability that a UXB fell unnoticed on the Site within the River Thames and remained in situ.

This area is identified as M2 in **Figure 26**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

3.4 Geology and Bomb Penetration Depths

It is important to consider the geological materials present on the Site at the time that a bomb was dropped in order to establish its maximum penetration depth. British Geological Survey (BGS) 1:50,000 Sheets 257, Romford (Solid & Drift), 271 Dartford (Solid & Drift), 272 Chatham (Drift) and Special Sheet Inner Thames Estuary (Pre-Quaternary and Quaternary Geology), based on parts of Sheets 257, 258, 259, 271, 272 & 273, as well as BGS borehole records, were consulted.

Table 3 illustrates the estimated average maximum bomb penetration depths with the assumed WWII ground conditions on the Site given as indicative lithologies and thicknesses.[4]

[4] BS 5930 Code of Practice for Site Investigations and http://www.bgs.ac.uk/data/maps/

Note that the actual depth of the bomb may be anywhere between the WWII ground surface and these indicative maximum depths due to both the 'J' curve effect (see below) and localised changes in geomaterial strength and pore water pressures.

Table 3 Estimated average maximum bomb penetration depths

Approximate Location		Bomb Weight			Summary Geology	
From	**To**	**50kg**	**500kg**	**1,000kg**	**Thickness (m)**	**Indicative Lithology**
North of Warley Road TQ 576905	Coombe Wood TQ 578900	2.5m	7.5m	9.5m	~3.0m	Stanmore Gravel Formation
					~4.0m	Bagshot Formation
					~13.0m	Claygate Member
Coombe Wood TQ 578900	Folkes Lane TQ 578896	4.5m	12.0m	13.5m	~1.0m	Head Deposits
					~13.0m	Claygate Member
					> 20.0m	London Clay
Folkes Lane TQ 578896	Hobbs Hole TQ 586861	5.0m	11.5m	13.5m	~1.0m	Head Deposits
					> 20.0m	London Clay
Hobbs Hole TQ 586861	Kemps Farm TQ 583845	2.5m	6.0m	7.0m	~1.5m	Head Deposits
					~8.0m	Boyn Hill Gravel
					> 20.0m	London Clay
Kemps Farm TQ 583845	Manor Farm TQ 584838	2.5m	9.0m	11.0m	4.0m	Lynch Hill Gravel
					> 20.0m	London Clay
Manor Farm TQ 584838	Mar Dyke TQ 614835	5.0m	12.5m	14.5m	~1.0m	Head Deposits
					> 20.0m	London Clay
Mar Dyke TQ 614835	Hobletts TQ 626828	7.0m	14.0m	15.5m	~4.0m	Alluvium
					> 20.0m	London Clay
Hobletts TQ 626828	Baker Street TQ 631814	5.0m	12.0m	14.0m	~3.0m	Head Deposits
					> 20.0m	London Clay
Baker Street TQ 631814	White Crofts TQ 641805	2.5m	6.0m	8.0m	~6.0m	Boyn Hill Gravel
					> 5.0m	Lambeth Group
White Crofts TQ 641805	High House TQ 658795	2.5m	7.0m	8.0m	~3.0m	Boyn Hill Gravel
					> 5.0m	Thanet Formation
High House TQ 658795	Muckingford Road TQ 666787	3.0m	7.5m	8.5m	> 14.0m	Thanet Formation
Muckingford Road TQ 666787	Coal Road TQ 669787	4.5m	8.5m	9.5m	~2.0m	Head Deposits
					> 10.0m	Thanet Formation
Coal Road TQ 669787	Church Road TQ 670776	2.5m	7.5m	8.5m	~5.0m	Taplow Gravel
					> 6.5m	Thanet Formation
Church Road TQ 670776	Tilbury Marshes TQ 675757	7.5m	17.0m	18.5m	~15.0m	Alluvium
					> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations

Table 3	Estimated average maximum bomb penetration depths (continued)

Approximate Location		Bomb Weight			Summary Geology	
From	To	50kg	500kg	1,000kg	Thickness (m)	Indicative Lithology
Tilbury Marshes TQ 675757	River Bank (North) TQ 675755	7.5m	17.0m	18.5m	~15.0m	Alluvium & Estuarial Tidal River Deposits
					> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
River Bank (North) TQ 675755	Gravesend Reach (North Central) TQ 675752	7.5m	17.0m	18.5m	~15.0m	Alluvial, Intertidal and Marine Deposits (Mud)
					> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
Gravesend Reach (North Central) TQ 675752	Gravesend Reach (South Central) TQ 675750	5.0m	9.5m	10.5m	> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
Gravesend Reach (South Central) TQ 675750	River Bank (South) TQ 677744	7.5m	17.0m	18.5m	>~15.0m	Alluvial, Intertidal and Marine Deposits (Mud)
					> 10.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
River Bank (South) TQ 677744	Milton Range TQ 678743	7.5m	13.0m	15.5m	~10.0m	Alluvium & Estuarial Tidal River Deposits
					> 10.0m	Seaford Chalk Formation
Milton Range TQ 678743	Lower Higham Road TQ 679732	7.5m	14.0m	15.0m	~10.0m	Alluvium
					> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
Lower Higham Road TQ 679732	East of Castle Lane TQ 679731	3.0m	7.0m	8.0m	~2.0m	Taplow Gravel
					> 10.0m	Thanet Formation
East of Castle Lane TQ 679731	North of Rochester Road TQ 679729	4.0m	8.0m	9.0m	~1.5m	Lynch Hill Gravel
					> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations

Table 3	Estimated average maximum bomb penetration depths (continued)					
Approximate Location		**Bomb Weight**			**Summary Geology**	
From	**To**	**50kg**	**500kg**	**1,000kg**	**Thickness (m)**	**Indicative Lithology**
North of Rochester Road TQ 679729	West of Thong Lane TQ 670709	4.5m	8.5m	9.5m	> 30.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
West of Thong Lane TQ 670709	West of Thong TQ 668707	3.5m	7.0m	8.0m	> 10.0m	Thanet Formation
West of Thong TQ 668707	Claylane Wood TQ 666705	4.5m	8.5m	9.5m	> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations
Claylane Wood TQ 666705	South of Watling Street TQ 670697	3.0m	6.0m	7.5m	> 15.0m	Thanet Formation
South of Watling Street TQ 670697	Rochester & Cobham Golf Course TQ 687695	3.0m	6.5m	7.5m	> 10.0m	Lambeth Group & Harwich Formation
Rochester & Cobham Golf Course TQ 687695	Harlex Haulage TQ 693695	4.0m	8.0m	9.0m	~7.0m	Thanet Formation
					>8.0m	Upper Chalk (Grade II/IV)
Harlex Haulage TQ 693695	A289 Junction TQ 704695	4.0m	9.5m	12.0m	> 20.0m	Lewes Nodular Chalk, Seaford Chalk & Newhaven Chalk Formations (Grade III –V)
A289 Junction TQ 704695	Crutches Lane TQ 709694	4.0m	8.5m	9.5m	~2.0m	Head
					~4.0m	Thanet Formation
					>15.0m	Upper Chalk (Grade II/III)

The estimated bomb penetration depths given in Table 3 are from the WWII ground level and are based on the following assumptions:

a) High level release of the bomb resulting in an impact velocity of 260m/s (>5,000m altitude).

b) A strike angle of 10 to 15 degrees to the vertical.

c) That the bomb is stable, both in flight and on penetration.

d) That no retarding units are fitted to the bomb.

e) That the soil type is homogenous.

A high altitude release of a bomb will result in ground entry at between 10° and 15° to the vertical with the bomb travelling on this trajectory until momentum is nearly lost. The bomb will then turn abruptly to the horizontal before coming to rest. The distance between the centre of the entry hole and the centre of the bomb at rest is known as the 'offset'. A marked lateral movement from the original line of entry is common.

A high altitude release of a bomb will result in ground entry at between 10° and 15° to the vertical with the bomb travelling on this trajectory until momentum is nearly lost. The bomb will then turn abruptly to the horizontal before coming to rest. The distance between the centre of the entry hole and the centre of the bomb at rest is known as the 'offset'. A marked lateral movement from the original line of entry is common.[5] [6] [7]

Low-level attacks may have an impact angle of 45° or more, which will frequently lead to a much greater amount of offset movement during soil penetration.

In low level attacks over deep water bodies, the offset distances from the point of entry at the water surface may be considerably enhanced due to hydrodynamic effects before the bomb penetrates or settles on the sea bed.

Shallow water has little effect on bomb penetration depths during high level attacks.

Note that historically, the majority of UXB have been found at less than these estimated maximum depths, with less than 1% approaching or exceeding them.

[5] Shephard R W & Cetti J, Royal Ordnance Future Systems Group Working Paper FSG/WP/47, 1987

[6] Wyatt J R, Unexploded Bombs (UXB) in the Thames Marshes, 2000

[7] Army TM5-855-1/Airforce AFPAM 32-1147(I)/Navy NAVFAC P-1080/DSWA DAHSCWEMAN-97, 1997 (reprinted 2000)

4 WWII DEFENCES

4.1 Bombing Decoys

In order to draw enemy aircraft away from towns and other strategically important targets, a series of decoys were developed between 1940 and 1941.

They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. Approximately 792No. static decoy sites were built at 593No. locations in England. In addition, numerous temporary and mobile decoys were deployed.

Several different types of decoy were devised:

- Night time dummy airfields (Q sites).
- Daytime dummy airfields (K sites).
- Diversionary fires to simulate successful bombing raids on airfields (QF sites), petroleum depots (P sites) and major towns and cities (Starfish or SF sites).
- Simulated urban lighting (QL sites).
- Dummy Heavy Anti-Aircraft (HAA) batteries, factories and buildings (C series).
- Mobile decoys representing 'hards' for troop embarkation (MQLs), tanks and other vehicles.

Machine gun emplacements and Light Anti-Aircraft (LAA) guns were used to prevent possible enemy landings at decoy airfields.

By their nature, decoy sites provide a potential risk from Unexploded Bombs (UXB), both within the decoy site boundary and in the surrounding areas.

Records indicate that a bombing decoy was located on the Site at East Tilbury (TQ 678757). An additional 9No. were located within 10km of the Site, as detailed in Table 4.

Table 4 Bombing decoys within 10km of the Site

Grid Reference	Serial No.	Location	Type	Approximate Distance and Direction from Site
TQ 678757	NC713	East Tilbury	Naval Coast MQL (NC Series)	On the Site
TQ 716788	NC703	Lower Hope Point	Naval Coast MQL (NC Series)	2.3km E
TQ 700811	P3	Thames Haven	Oil QFs (P Series)	3.6km E
TQ 688662	Q96b	Luddesdown	RAF Airfield Decoy	2.8km S
TQ 727778	Q96a	Cliffe Marshes	RAF Airfield Decoy	3.3km E
TQ 656857	Q/K43a	Bulphan	RAF Airfield Decoy	2.2km NE
TQ 529800	SF8c	Rainham Marshes	Civil Starfish (SF Series)	6.2km SW
TQ 731838	P2	Fobbing	Oil QFs (P Series)	8.8km E
TQ 779638	C102, QF223a & M1	Chatham	Civil, RAF Airfield Decoy, Dummy Airfield	8.3km SE
TQ 493938	SF8d	Lambourne End	Civil Starfish (SF series)	8.5km NW

Records show that the Luddesdown decoy was successful in drawing bombing on the 21st March 1944 and the Cliffe Marshes decoy was successful in drawing bombing on the 5th February 1944.

Plate 22 is an aerial photograph showing the locations of bombing decoys in the vicinity of the Site.

Plate 22	Aerial photograph showing the locations of bombing decoys in the vicinity of the Site

Source: Google Earth *Not to Scale*

Legend	Site boundary	Bombing decoy

1No. bombing decoy was located on the Site. This is described in the following section.

4.1.1 East Tilbury Bombing Decoy (NC713)

East Tilbury was established as a MQL Naval decoy (No. 607) in 1943. It was designed to replicate the landing craft '**Hards**' and associated lighting that had been established in Tilbury as part of the preparations for D-Day.

The decoy comprised a cluster of small buildings and a series of lighting that was operated during enemy air raids in the region.

No records have been found indicating that any raids occurred against the decoy, which was constructed late in WWII when most of the heavy bombing was finished.

Potential UXO Hazard

Given that there are no records to indicate that any of these bombing decoys were heavily bombed, they are not considered to provide a source of UXO hazard to the Site.

4.2 Anti-Aircraft Defences

Anti-Aircraft (AA) gun batteries were targeted by the Luftwaffe. They were also a source of Unexploded AA (UXAA) shells which could land up to 27km from the firing point during WWII, although more typically fell within 15km. These could be distributed over a wide area.

AA batteries present a potential source of UXO hazard as a result of the storage, use and disposal of ordnance associated with the armaments used. They may have a risk from small caches of ammunition buried locally to them. 3No. types of AA batteries existed:

- Heavy Anti-Aircraft (HAA) batteries of large guns designed to engage high flying bomber aircraft. These tended to be relatively permanent gun emplacements.
- Light Anti-Aircraft (LAA) weaponry, designed to counter low flying aircraft. These were often mobile and were moved periodically to new locations around strategic targets such as airfields.
- Rocket batteries (ZAA) firing 3" or 3.7" AA rockets with a maximum altitude of 5,800m and a ground range of 9km were also relatively permanent emplacements.

Many AA batteries were associated with searchlights and consequently 'visible' at night, providing clear targets to the Luftwaffe bombers and a potential for UXB.

During WWII the Site was within the range of guns deployed in the London and Thames & Medway Gun Defended Areas (GDAs).

Table 5 is a list of recorded HAA and ZAA batteries within 10km of the Site.

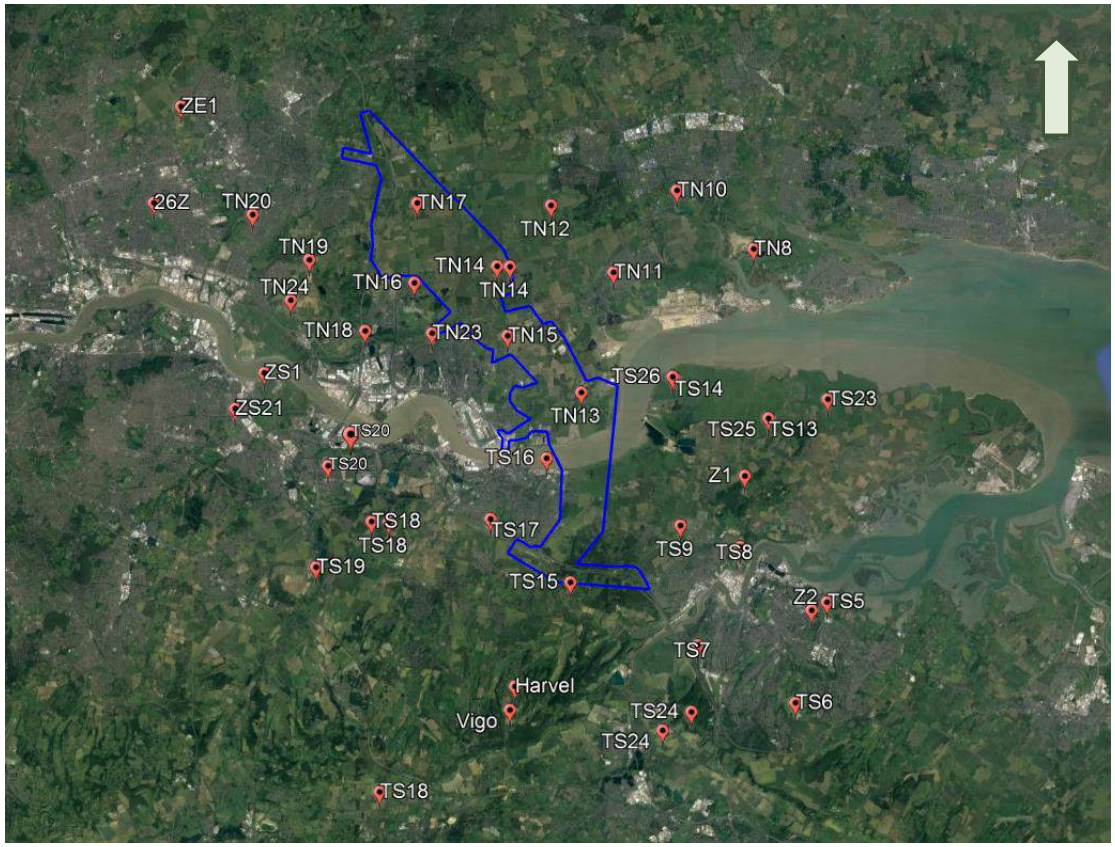
Table 5 WWII HAA and ZAA batteries within 10km of the Site

Grid Reference	Serial No.	Location	Armament	Approximate Distance and Direction from Site
TQ 679771	TN13	Buckland	4No. 3.7" then 4No. 4.5" guns	On the Site
TQ 643828	TN14	Orsett	Unknown	On the Site
TQ 643796	TN15	Chadwell	3No. 3.7" then 4No. 4.5" guns	On the Site
TQ 599856	TN17	North Ockendon	Unknown	On the Site
TQ 663740	TS16	Denton	4No. 3.7" then 4No. 4.5" guns	0.7km W
TQ 676683	TS15	Cobham	4No. 4.5" guns	0.8km S
TQ 608796	TN23	Belmont Castle	Unknown	0.8km S
TQ 599819	TN16	Buckles Farm	Unknown	0.9km SW
TQ 638711	TS17	Northumberland Bottom	4No. 3.7" guns	1.2km NW
TQ 726711	TS9	Oak Street	4No. 4.5" guns	2.3km E
TQ 661857	TN12	Laindon	Unknown	2.7km NE

Table 5	WWII HAA and ZAA batteries within 10km of the Site (continued)			
Grid Reference	**Serial No.**	**Location**	**Armament**	**Approximate Distance and Direction from Site**
TQ 720779	TS14	Lower Hope	Unknown	2.7km E
TQ 720779	TS26	-	Unknown	2.7km E
TQ 550828	TN19	Ayletts	4No. 4.5” then 4No. 5.25” guns	3.0km WSW
TQ 577796	TN18	Aveley	Unknown	3.1km WSW
TQ 691827	TN11	Abbotts Hall	4No. 3.7” guns	3.3km NE
TQ 736656	TS7	Fort Borstal	4No. 4.5” guns	3.4km SSE
TQ 754702	TS8	Tower Hill	4No. 3.7” guns	4.4km ENE
TQ 542809	TN24	Wennington	Unknown	4.7km SW
TQ 577796	TN18	Aveley	Unknown	5.2km W
TQ 523848	TN20	Dagenham	Unknown	5.6km W
TQ 652634	-	Harvel	Mobile HAA guns	5.6km SSW
TQ 591708	TS18	Green Street Green	4No. 3.7” or 4No. 4.5” guns	5.7km W
TQ 755735	Z1	Chattenden	UP rockets	6.4km NE
TQ 583708	TS18	Green Street Green	Unknown	6.6km W
TQ 572746	TS20	Littlebrook Farm	Unknown	7.1km W
TQ 734625	TS24	Burham	4No. 4.5” guns	7.1km SSE
TQ 650623	-	Vigo	Mobile HAA guns	7.2km SSW
TQ 765762	TS13	Cooling	Unknown	7.4km E
TQ 765762	TS25	-	Unknown	7.4km E
TQ 721616	TS24	Burham	4No. 4.5” guns	7.4km S
TQ 531775	ZS1	Slade’s Green	4No. 4.5” guns	7.8km SW
TQ 788674	Z2	Beatty Avenue, Gillingham	Unknown	7.9km ESE
TQ 488897	ZE1	Chadwell Heath	4No. 4.5” then 8No. 4.5” guns	8.1km WNW
TQ 562733	TS20	-	Unknown	8.2km WSW
TQ 719866	TN10	Vange	Unknown	8.3km NE
TQ 795678	TS5	Twydall	4No. 3.7”guns	8.6km ESE
TQ 755840	TN8	Northwick	Unknown	8.8km NE
TQ 792772	TS23	Decoy Farm	Unknown	9.1km E
TQ 558686	TS19	Sutton at Hone	Unknown	9.2km WSW
TQ 782631	TS6	Gibraltar Farm	4No. 4.5”guns	9.3km SE
TQ 518758	ZS21	Crayford	4No. 3.7” then 4No. 5.25”guns	9.8km SW
TQ 477852	26Z	Beacontree Heath	Unknown	9.9km W

Plate 23 is an aerial photograph showing the locations of the HAA and ZAA batteries in the vicinity of the Site.

Plate 23	Aerial photograph showing the locations of HAA and ZAA batteries in the vicinity of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary	HAA/ZAA battery

4No. HAA gun sites were located on the Site. These are described in the following sections.

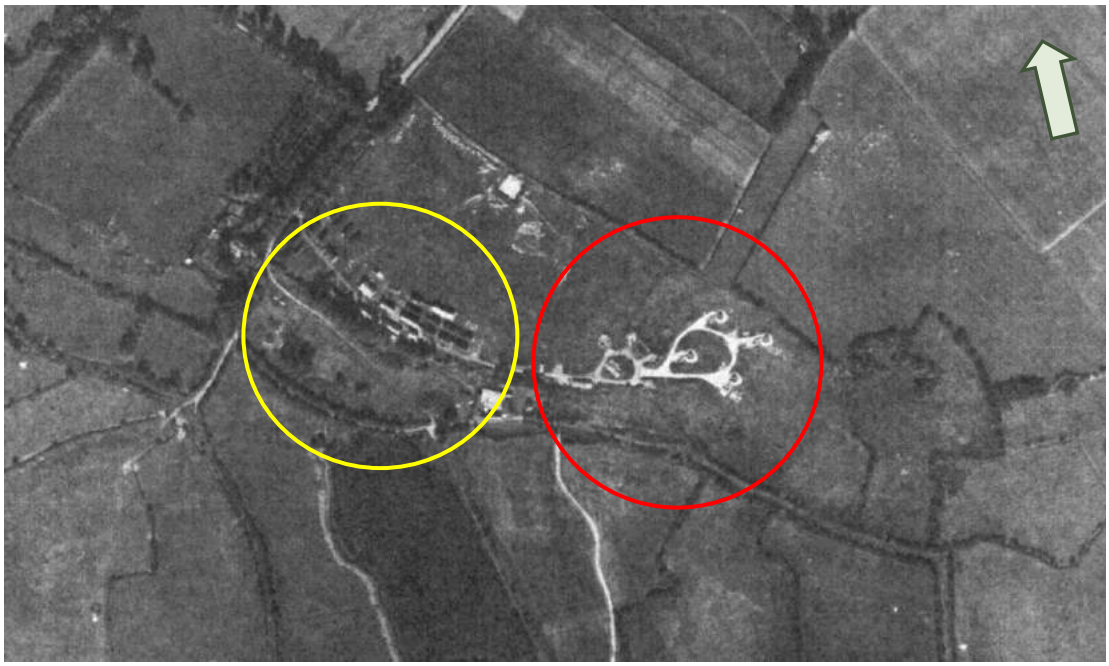
4.2.1 HAA Battery TN13, Buckland

1No. HAA battery was located on the Site at Buckland Farm, East Tilbury (TQ 678771). Established in 1940, TN13 was armed with 2No. 3.7" guns by 1942, before being upgraded to 4No. 5.25" guns by 1946.

Typically, gun emplacements had inbuilt ammunition recesses and there was a control bunker (including command post, height finder and predictor) at the centre of the battery.

Plate 24 is an aerial photograph, dated the 11th October 1946, showing the Buckland HAA battery TN13, on the Site, with associated accommodation huts and munitions stores.

Plate 24	Aerial photograph showing HAA battery TN13, Buckland, 11th October 1946



Source: Historic England *Not to Scale*

Legend	HAA Battery	Accommodation and munitions stores

The HAA gun battery at Buckland Farm was retained after WWII as an Off-Site Nucleus Battery in 1946. It is currently open ground as part of Buckland Farm.

4.2.2 HAA Battery TN14, Orsett

1No. HAA battery (TQ 643828) and an associated camp (TQ 637828) were located on the Site at Orsett. It is recorded as being unarmed in 1942.

Typically, gun emplacements had inbuilt ammunition recesses and there was a control bunker (including command post, height finder and predictor) at the centre of the battery.

Plate 25 is an aerial photograph, dated the 1st May 1946, showing the HAA battery TN14 with the associated accommodation huts and munitions stores. The photograph shows that the gun site had 4No. gun emplacements.

Plate 25	Aerial photograph showing HAA battery TN13, Orsett, 1st May 1946

Source: Historic England *Not to Scale*

Legend	HAA Battery	Accommodation and munitions stores

Historical mapping indicates that the gun emplacements had been removed by 1960 but the remnants of the camp remained. These had also been removed by the 1970s. Part of the former camp area is occupied by housing and land occupied by the gun emplacements has been returned to agriculture.

Munitions associated with the battery would typically have been removed at the end of WWII and returned to ordnance depots. The possibility that munitions were disposed of in the immediate vicinity of the battery cannot be totally discounted, although there is no evidence on aerial photographs of any potential disposal areas on the Site.

4.2.3 HAA Battery TN15, Chadwell

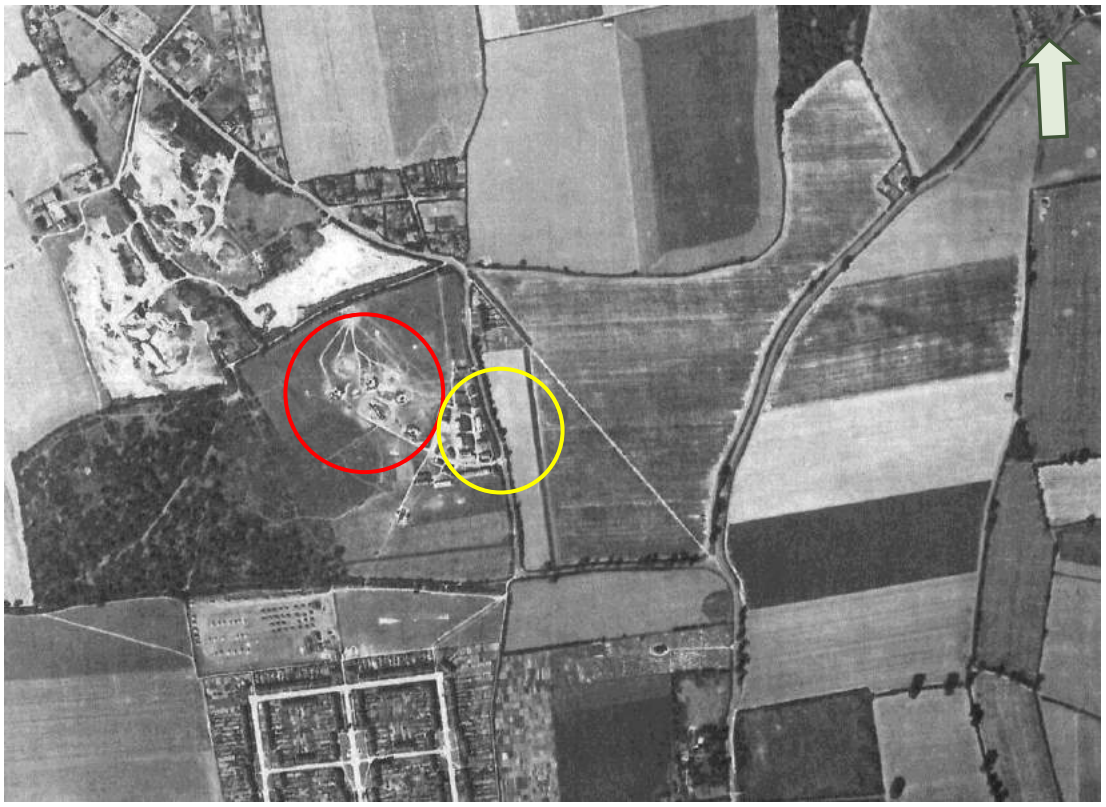
1No. HAA battery was located on the Site at Chadwell (TQ 643796). It was armed with 4No. 4.5”guns and GL Mark II radar.

Records indicate that it was manned by 8 Battery, 2nd Royal Artillery (RA) Regiment in 1942 and by 616 battery of the 184th (Mixed) RA Regiment in 1943.

Typically, gun emplacements had inbuilt ammunition recesses and there was a control bunker (including command post, height finder and predictor) at the centre of the battery.

Plate 26 is an aerial photograph, dated the 4th August 1944, showing HAA battery TN15, on the Site, with associated accommodation huts and munitions stores.

Plate 26	Aerial photograph showing HAA battery TN15, Chadwell, 4th August 1944



Source: Historic England *Not to Scale*

Legend	HAA Battery	Accommodation and munitions stores

Post-WWII it was retained as an Off-Site Nucleus Battery. Historical mapping indicates that the land occupied by the gun site and camp had been mostly redeveloped for housing by the 1960s.

Munitions associated with the battery would typically have been removed at the end of the war and returned to ordnance depots. The possibility that munitions were disposed of in the immediate vicinity of the battery cannot be totally discounted, although there is no evidence on aerial photographs of any potential disposal areas on the Site.

4.2.4 HAA Battery TN17, North Ockendon

1No. HAA battery is recorded on the Site at north of Fen Lane, North Ockendon (TQ 599856). It is recorded as being unarmed in 1942.

Typically, gun emplacements had inbuilt ammunition recesses and there was a control bunker (including command post, height finder and predictor) at the centre of the battery.

Plate 27 is an aerial photograph, dated the 11th October 1946, showing site of HAA battery TN17 and associated camp, on the Site.

No permanent gun emplacements appear to have been constructed for this HAA site and only faint remnants of their position are visible on the photograph. The camp is still present.

Plate 27	Aerial photograph showing HAA battery TN17, North Ockendon, 11th October 1946

Source: Historic England *Not to Scale*

Legend	HAA Battery	Accommodation and munitions stores

There is no evidence of the gun site or camp on post-WWII mapping and the land is currently under cultivation.

Munitions associated with the battery would typically have been removed at the end of the war and returned to ordnance depots. The possibility that munitions were disposed of in the immediate vicinity of the battery cannot be totally discounted, although there is no evidence on aerial photographs of any potential disposal areas on the Site.

Potential UXO Hazard

HAA batteries typically had associated munitions caches and stores. These stores were typically removed once the threat of invasion had passed, although the possibility that localised disposal occurred cannot be totally discounted.

This forms part of the low background risk for any similar site in the UK.

There is no positive evidence to indicate that such disposal took place on the Site and therefore HAA battery TN17 is not considered to provide a significant source of UXO hazard to the Site.

4.2.5 AA Incidents on the Site

There are several records of AA shells falling on the Site during WWII. An indicative list is given below.

Northern part of the Site

14th September 1940

1No. AA shell fell 100 yards southwest of Hall Farm, South Ockendon. It was recorded as a UXAA shell.

22nd September 1940

1No. AA shell was found in a field approximately 500yards east of Berridens.

8th December 1940

3No. UXAA shells were discovered on open ground on Ockendon Road, North Ockendon.

17th December 1940

1No. AA Shell fell 400yds southeast of Broadfields Farm. It was recorded as a UXAA shell.

20th December 1940

1No. AA shell fell 100yds west of the railway between Dennis's corner and Redcrofts. It was recorded as a UXAA shell.

24th February 1941

1No. AA shell fell 200yds north of Dennises Lane and 20yds west of Pea Lane, North Ockendon.

27th February 1941

1No. AA shell fell near Puddle Dock Farm, North Ockendon.

8th September 1941

1No. AA shell fell 600yds east of Hall Farm, South Ockendon. It was recorded as a UXAA shell.

1st April 1943

1No. UXAA shell was discovered east of Pea Lane, North Ockendon.

11th October 1943

1No. AA shell fell on Home Farm, south of St Mary's Lane.

25th October 1943

1No. AA shell fell south of Whitepost Farm, North Ockendon.

17th December 1943

1No. UXAA shell was discovered on Cranham Place Farm.

18th January 1943

1No. AA shell 300 yards south of a searchlight post near Broadfields Farm. It was recorded as a UXAA shell.

1No. AA shell 350 yards south of a searchlight post near Broadfields Farm. It was recorded as a UXAA shell.

10th February 1943

1No. AA shell fell near Chapman's Farm, Cranham.

5th March 1943

1No. AA shell fell near Clay Tye Road, North Ockendon.

1No. AA shell fell near Puddle Dock Farm, North Ockendon.

1st April 1943

1No. AA shell fell east of Pea Lane, South of Ockendon Road, North Ockendon.

14th April 1943

1No. AA shell fell northeast of Dennises Lane, North Ockendon.

15th April 1943

1No. UXAA shell was discovered northeast of Mollands Farm, South Ockendon.

19th April 1943

1No. AA shell fell south of Bay Farm, North Ockendon.

7th October 1943

1No. AA shell fell on Kemps Farm, north of West Road, South Ockendon. It was recorded as a UXAA shell.

15th January 1944

1No UXAA shell was found in a meadow, Cranham. It was removed on the 21st January 1944.

31st January 1944

1No. AA shell fell in open ground northeast of Mollands Farm. It was recorded as a UXAA shell.

2nd February 1944

1No. UXAA shell was discovered in Meadowcroft, Cranham.

14th March 1944

1No. AA shell fell on open ground east of the London, Midland and Scottish Railway (LMSR) line. It was recorded as a UXAA shell.

29th March 1944

1No. AA shell fell on open ground south of Grove Farm, South Ockendon. It was recorded as a UXAA shell.

1No. AA shell fell 200yds east of Wagstaff Wood, South Ockendon. It was recorded as a UXAA shell.

6th May 1944

1No. UXAA shell was discovered in Meadowcroft, Cranham.

10th June 1944

1No. UXAA shell was found in a potato field, near Moor Lane, Cranham.

Central part of the Site

31st August 1940

1No. AA shell fell on Grays Corner.

3rd September 1940

1No. UXAA shell was discovered in a field north of Long Lane, 300yds west of Grays Corner.

19th September 1940

1No. HE bomb and AA shells fell on Baker Street, damaging cables.

24th September 1940

1No. UXAA shell was discovered at the Bata Estate.

3rd October 1940

1No. AA shell fell on the Bata Factory, East Tilbury. It was recorded as a UXAA shell.

17th October 1940

1No. UXAA shell was removed from Fen Cottage, Orsett.

24th November 1940

1No. UXAA shell was discovered on Tilbury Marshes.

25th December 1940

1No. AA shell fell on 304 Long Lane, Stifford. It was recorded as UXB and removed.

15th March 1941

1No. AA shell fell in a field north of Northumberland Road, Linford.

19th March 1941

1No. AA shell fell near Barrington's Farm, Orsett Cock. It was recorded as a UXAA shell.

10th May 1941

1No. UXAA shell was removed from Marsh's Field, Green Lane, Orsett.

14th June 1941

1No. UXAA shell was removed from Heath Place Farm, Orsett Heath.

21st June 1942

1No. UXAA shell was discovered 40yds south of Orsett Cock.

19th August 1942

10No. AA shells were discovered near the east railway signal box, Tilbury.

14th October 1942

1No. AA shell fell approximately 30yds north of Green Lane, Baker Street. It was recorded as a UXAA shell.

18th February 1943

1No. AA shell fell in a field near Turnpike Cottages, West Tilbury.

4th March 1943

2No. AA shells fell west of Elm Farm, Orsett.

5th March 1943

1No. UXAA shell was discovered 200yds west of the Old Rectory, East Tilbury.

9th March 1943

1No. UXAA shell was discovered near the junction of Low Street Lane and Muckingford Road.

6th June 1943

1No. AA shell fell on open ground at Botny Farm. It was recorded as a UXAA shell.

17th November 1943

1No. UXAA shell was discovered on Lower Crescent, Linford.

14th February 1944

1No. AA shell exploded at the foot of the river wall near Marsh Farm, Tilbury.

26th February 1944

1No. UXAA shell was discovered 250yds north of the Thames River, on Tilbury Marshes.

29th February 1944

1No. AA shell fell 200yds north of Heath Place Farm, Orsett. It was recorded as a UXAA shell.

29th March 1944

1No. AA shell fell on open ground south of Grove Farm, South Ockendon, approximately 40m north of the Site. It was recorded as a UXAA shell.

24th August 1944

2No. AA shells fell Tilbury Riverside Railway Station.

17th November 1944

1No. UXAA shell was discovered east of Baker Street.

Southern part of the Site

4th December 1940

1No. AA shell fell near east of Church Lane, Chalk.

23rd January 1944

1No. UXAA shell was discovered on Watling Street, southwest of Claylane Woods.

4th February 1944

1No. UXAA shell was discovered near Lower Higham Road.

12th February 1944

1No. UXAA shell was discovered at Chalk, near Gravesend Road.

Potential UXO Hazard

Due to the nature and use of AA guns, shells could fall anywhere within a 27km radius of their firing point, although a smaller distance, up to 15km is more typical.

Therefore, given the number of gun batteries in the surrounding area, the potential for a UXAA shell to have fallen unnoticed on the Site cannot be entirely discounted.

This forms part of the low background risk for any similar site in the UK.

4.2.6 LAA Emplacements

Vulnerable Points (VPs) in the vicinity of the Site, such as airfields, oil installations and docks, were also protected by LAA guns. The LAA sites comprised 40mm Bofors guns, Lewis machine guns (LG) or Vickers machine guns (VM).[8]

LAA guns defended RAF Gravesend, which encroached onto the Site. These included VG2 (TQ 673718) armed with 1No. .303" Quad Lewis gun and VG3 (TQ 672712), which was armed with 1No. 40mm Bofors gun and 1No. .303" Lewis gun. Both of these were located on the Site (see Section 6.6).

1No. Quad Vickers gun was located at World's End, Tilbury (TQ 646759), on the Site, as part of the dock defences and 2No. 40mm Bofors guns were also located at Coalhouse Fort (TQ 691768), on the eastern boundary of the Site.

A further 5No. LAA guns were located within 1km of the Site.

Potential UXO Hazard

Given that there were very few LAA emplacements in the vicinity, it is considered that there is a low probability that misfired shells would have fallen on the Site and remained in situ.

Localised disposal of ammunition stored at the gun emplacements on the Site is considered unlikely but cannot be totally discounted.

4.3 Barrage Balloons and Anti-Landing Obstacles

Balloon barrages were flown in many British towns and cities to protect against air raids. Their presence deterred low flying aircraft, making it more difficult for bombs to reach their intended targets. Barrage balloon sites can be a source of UXO as they were targeted by the Luftwaffe. They also often had a small explosive charge fitted with tilt fuzes attached approximately 50m from each end of the balloon cables and designed to detonate if the cables were hit by an aircraft.

Measures were also taken to prevent enemy aircraft landing in the event of invasion. Obstructions were constructed around airfields and on other open sites deemed fit for use as landing grounds. Solid obstructions (such as concrete blocks), posts or stakes, felled trees, haystacks, scaffolding with wire and trenching were the main measures used.

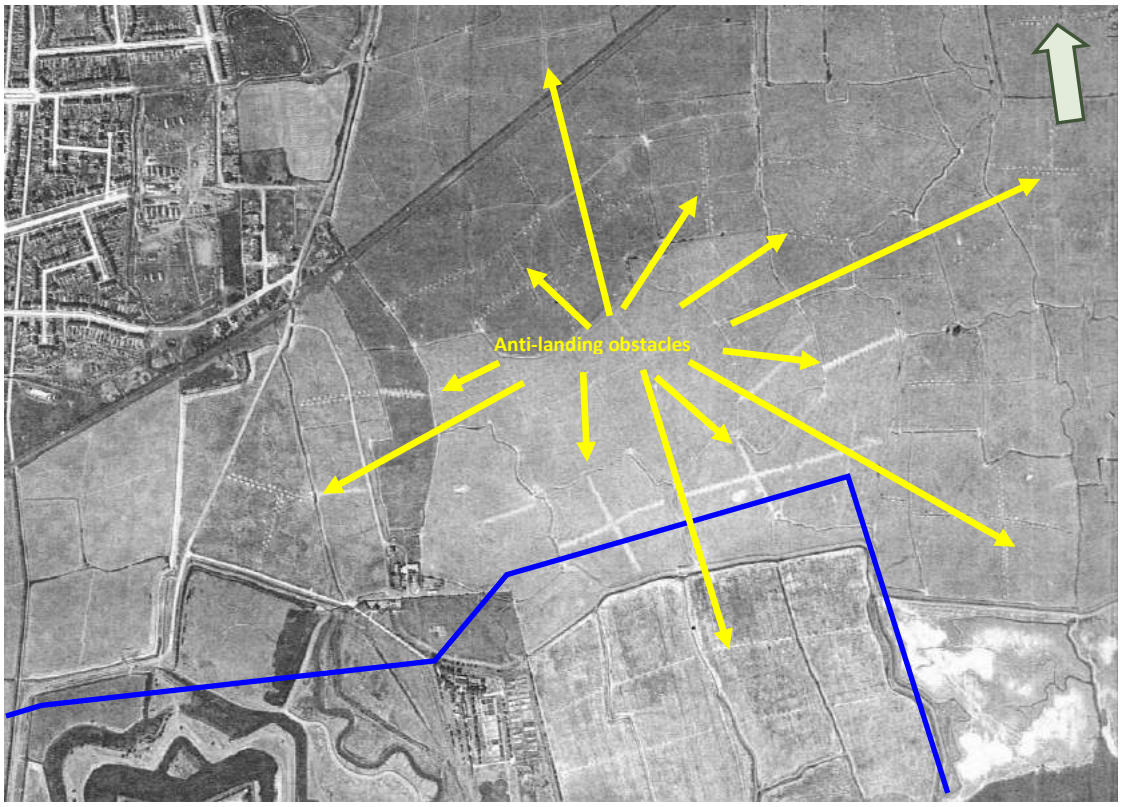
Barrage balloons were extensively deployed in the Essex and northwest Kent areas, from both onshore anchorages and floating moorings.

Records have been found indicating that 1No. barrage balloon was located on the Site. This was anchored on a submerged mooring in the River Thames, off East Court Marshes (TQ 679745).

Anti-landing obstacles were located across Tilbury Marshes, on and in close proximity to the Site. An example of this is shown in Plate 28, an aerial photograph dated the 4th August 1944.

[8] See for example, https://zeticauxo.com/wp-content/uploads/2016/07/Anti-Aircraft-Guns.pdf for more information

Plate 28	Aerial photograph showing anti-landing obstacles at Tilbury Marshes, 4th August 1944



Source: Historic England *Not to Scale*

Legend	Site boundary

Potential UXO Hazard

Barrage balloon emplacements sometimes had small explosives stores to hold the charges attached to the balloons.

Anti-landing obstacles often formed part of static defences in the region which were associated with small munitions caches (see below).

These stores would typically have been removed by the end of WWII and therefore do not provide a significant source of UXO hazard to the Site.

4.4 Anti-Invasion Defences

Defence structures are a potential source of UXB as they were especially targeted by low flying enemy aircraft, particularly during 'tip and run' raids which were common in industrialised regions. These defences may also be associated with small caches of UXO in the form of small arms, used by the troops manning the emplacement.

The rapid advance of German Troops into France, Holland and Belgium after the start of WWII prompted the War Office to review the vulnerability of the UK to invasion and a decision was taken to begin work on a national plan of anti-invasion defences. Static defences were built to interrupt and delay the progress of any invading force.

Coastal defences were strengthened (the 'Coastal Crust'). These defences included barbed wire entanglements and minefields, which were often combined to give defence in depth.

Inland, lines of defence structures were constructed along 'Stop Lines' in order to impede enemy progress for long enough to allow mobile defending forces to counter-attack.

Stop Lines included the fortification of key 'centres of resistance', such as river crossings and important road or rail junctions that could seriously hamper the enemy's advance across country. Bridges were mined for demolition and tank traps installed.

Stop Lines were further integrated into a network of fortified nodal points and 'Anti-Tank (AT) Islands'.

4.5 Pillboxes, Mortar and Gun Emplacements

Defences also included spigot mortar positions and gun emplacements.

Spigot mortars, also known as Blacker Bombards, were used primarily in an anti-tank role at road blocks or to defend airfields. Typically they fired a 20 pound (lb) HE mortar bomb. The fixed positions, in weapons pits with ammunition lockers, were frequently positioned near pillboxes.

Spigot mortar positions could be either fixed or mobile.

Records of 9No. spigot mortar emplacements on the Site have been found. Records indicate that a further 9No. were located within 1km of the Site.

Table 6 lists the spigot mortar positions on the Site.

Table 6 WWII Spigot mortar positions on the Site

Grid Reference	Location
TQ 672789	2No. located on Muckingford Road near Linford
TQ 674790	1No. located on Muckingford Road near Linford
TQ 675793	George and Dragon public house in Linford
TQ 661780	Blue Anchor Lane, West Tilbury
TQ 656779	Northwest of the junction of Gun Hill and Rectory Road, West Tilbury
TQ 662777	In bushes on the south side of Church Road, West Tilbury
TQ 661777	In a field east of St James Church, West Tilbury
TQ 645774	In grassland to the east of Chadwell Road, West Tilbury
TQ 690768	2No. at Coalhouse Fort

Pillboxes provide a potential UXO hazard both from the storage, use and disposal of ordnance associated with them and from UXB because they were targeted by enemy aircraft.

Pillboxes were common along Stop Lines, perimeters of airfields, potential land invasion sites and around important civil sites. Several different designs existed including Seagull Trenches (semi-buried structures), Alan Williams and Tett Turrets (small prefabricated pillboxes). Fortified sites, buildings or loop-holed walls also functioned as pillboxes.

Records of 1No. pillbox on the Site have been found.

This was located on the north bank of the River Thames foreshore between Tilbury Fort and Coalhouse Fort (TQ 680758).

Records indicate that a further 4No. pillboxes were located within approximately 1km of the Site.

Plate 29 is an aerial photograph showing the locations of the spigot mortars and pillbox on the Site.

Plate 29	Aerial photograph showing locations of spigot mortars and pillboxes on the Site

Source: Google Earth *Not to Scale*

Legend	Site boundary	Spigot Mortars	Pillbox

Potential UXO Hazard

Pillboxes and spigot mortar positions had associated munitions caches, often comprising SAA and close combat munitions such as grenades and mortars.

These stores were typically removed once the threat of invasion had passed, although the possibility that localised disposal occurred cannot be totally discounted.

There is no positive evidence to indicate that such disposal took place on the Site and therefore pillboxes and gun emplacements are not considered to provide a significant source of UXO hazard to the Site.

4.6 Home Guard and Auxiliary Units

Local Defence Volunteers (LDV) units, later known as the Home Guard, were located in all cities, towns and large villages.

Anti-invasion defences were to be defended by the Home Guard and regular Army troops for as long as possible in the event of an invasion. The troops were issued with 'No Withdrawal' orders.

Important elements of the ordnance supply for the use of the Home Guard included substantial supplies of Mills bombs (fragmentation grenades) and Self Igniting Phosphorus (SIP) grenades as well as machine gun and small arms ammunition.

Records of Home Guard activities and related sites are rarely preserved. Storage and disposal of munitions by the Home Guard was poorly documented and surplus supplies were either buried or dumped in lakes and ponds.

Given the irregular nature of this activity, the possibility of items of UXO being discovered at any locations occupied or used for training by the Home Guard can never be totally discounted.

In addition to the regular Home Guard, Auxiliary Units existed which were made up of guerrilla troops trained in sabotage and assassination in case of invasion. Sites used by these Units were Top Secret and many locations are still unknown.

The 3rd (Stanford le Hope), 14th (West Thurrock), and 20th (Hornchurch) Essex and the 15th (Cobham) and 16th (Gravesend) Kent Battalions Home Guard were very active in the region. Detached platoons defended VPs such as airfields, docks, factories and railway lines. Factories often had their own Home Guard units.

By May 1942, the 15th (Cobham) and 16th (Gravesend) Kent Battalions Home Guard numbered over 1,360No. men. They were armed with 43No. Blacker Bombards, 45No. Northover Projectors, more than 940No. rifles, including 68No. Anti-Tank Rifles, approximately 110No. Tommy guns and 4no. Browning machine guns.

No Home Guard or Auxiliary Unit activity or training has been identified on the Site.

4.7 Minefields and Mined Locations

Minefields were laid along the coast, in estuaries and along the banks of major rivers to deter infantry invasion. Strategic points such as bridges and gaps in cliffs were mined to impede enemy advance. Most of the mined locations in the UK have been cleared and the risk of finding UXO in these areas is considered to be low.

Possible pipe mine locations on the Site at the former RAF Gravesend are addressed in Section 6.1. No other minefields or mined locations are recorded on the Site.

There was a controlled minefield located across the River Thames near Coalhouse Fort, adjacent to the Site.

In June 1940, McNaughton and the 1st Canadian Tunnelling Company successfully demonstrated the use of pipe mines near Shornemead Fort, encroaching on the eastern boundary of the southern part of the Site.

There were approximately 85No. **Flame Fougasses** in the Gravesend area, within approximately 1.5km of the Site.

These mined locations are not considered to provide a source of UXO hazard to the Site.

5 MILITARY AIRFIELDS

Military airfields offer the potential for significant UXO hazards due to the use, storage and disposal of ordnance and as a result of enemy bombing during WWI and WWII.

Airfields active during WWII were targeted by the Luftwaffe, providing a potential source of UXB on the airfield.

As bombing accuracy was so poor during WWII, it is likely to find UXB in the surrounding areas. Aircraft crashes are also associated with operational airfields.

During WWI a number of landing grounds were established in Essex due to its proximity to both London and the European mainland.

A first class landing ground was established at Orsett (TQ 659811), encroaching upon the Site, in 1917.

It was used for home defence by Nos. 78 and 39 Squadrons of the Royal Flying Corps (RFC) until 1919. No evidence has been found to indicate that any munitions were stored at the airfield and it is therefore not considered to provide a source of UXO hazard to the Site.

During WWII, Royal Air Force (RAF) Gravesend (TQ 665720) was established on land encroaching on the southern part of the Site.

A brief operational history of the airfield is given in the Section below.

5.1 RAF Gravesend

On the 12th October 1932 a civilian airfield was established near the village of Chalk, encroaching on the southern part of the Site. The airfield was subsequently developed into Gravesend Airport London East, and was used for some limited commercial flying.

From 1937 the airfield was used by No. 20 Elementary & Refresher Training School (ERFTS) of the RAF, using Tiger Moth, Audax and Hart aircraft.

On the outbreak of WWII Gravesend was requisitioned as a Satellite Landing Ground (SLG) for RAF Biggin Hill (TQ 416610).

The airfield comprised a grass landing area with a concrete perimeter track and grass dispersals, as is shown in Plate 30, a Luftwaffe reconnaissance photograph dated the 8th November 1940.

Plate 30	Luftwaffe reconnaissance photograph of RAF Gravesend, 8th November 1940

Source: NARA *Not to Scale*

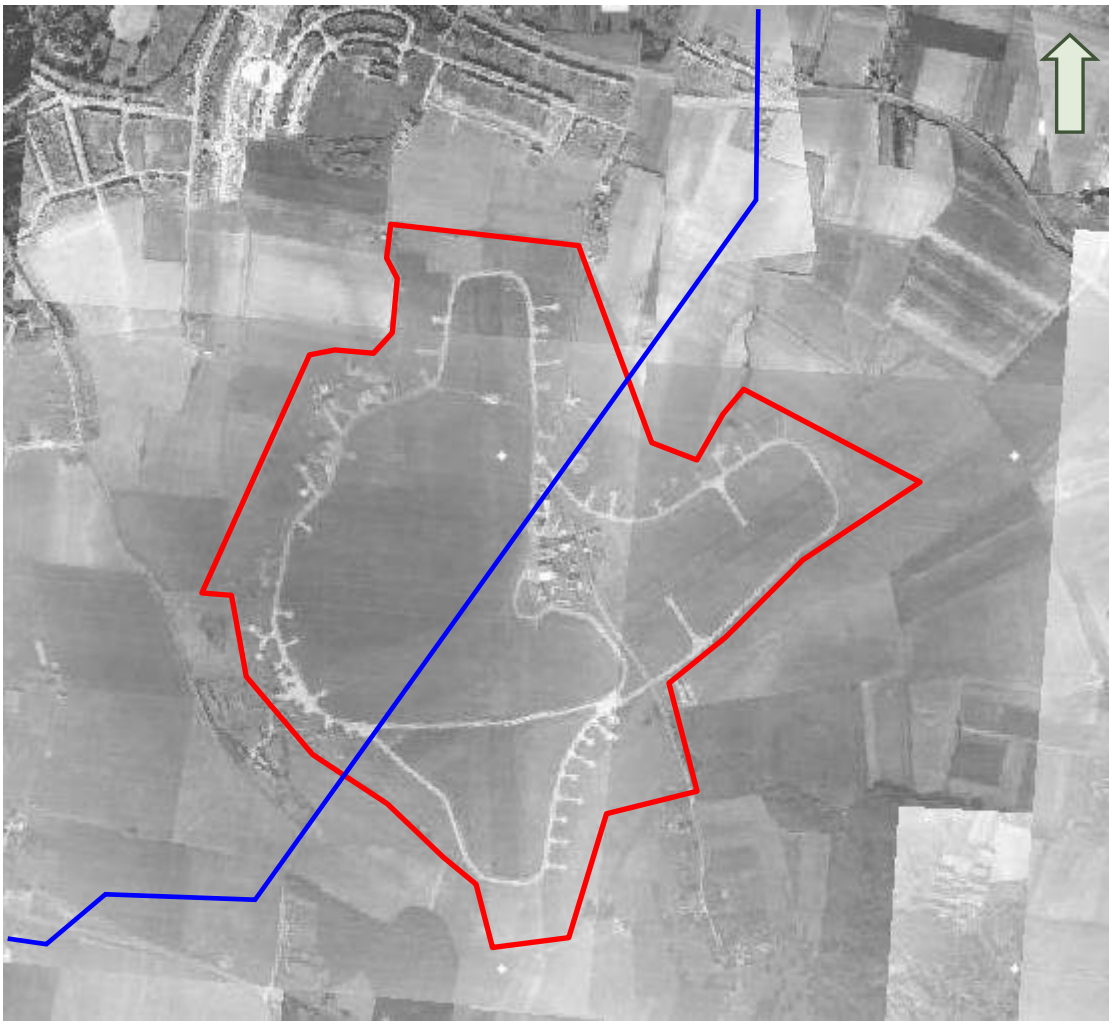
Legend	Site boundary	Airfield boundary

During the early part of WWII the airfield was used by fighter aircraft defending London and the South East, predominantly using Hawker Hurricane and Supermarine Spitfire fighter aircraft.

In 1942 and 1943 the airfield was expanded and 2No. concrete runways and new perimeter tracks were established as shown in Plate 20, an aerial photographic mosaic dating from 1946.

Individual fighter pan dispersals were located around the outside of the perimeter, some of which incorporated **Blister Hangars** for maintenance purposes. The main technical area, on the Site, also appears to have been upgraded at this time.

Plate 31	Aerial photographic mosaic of RAF Gravesend, 1946



Source: Kent County Council *Not to Scale*

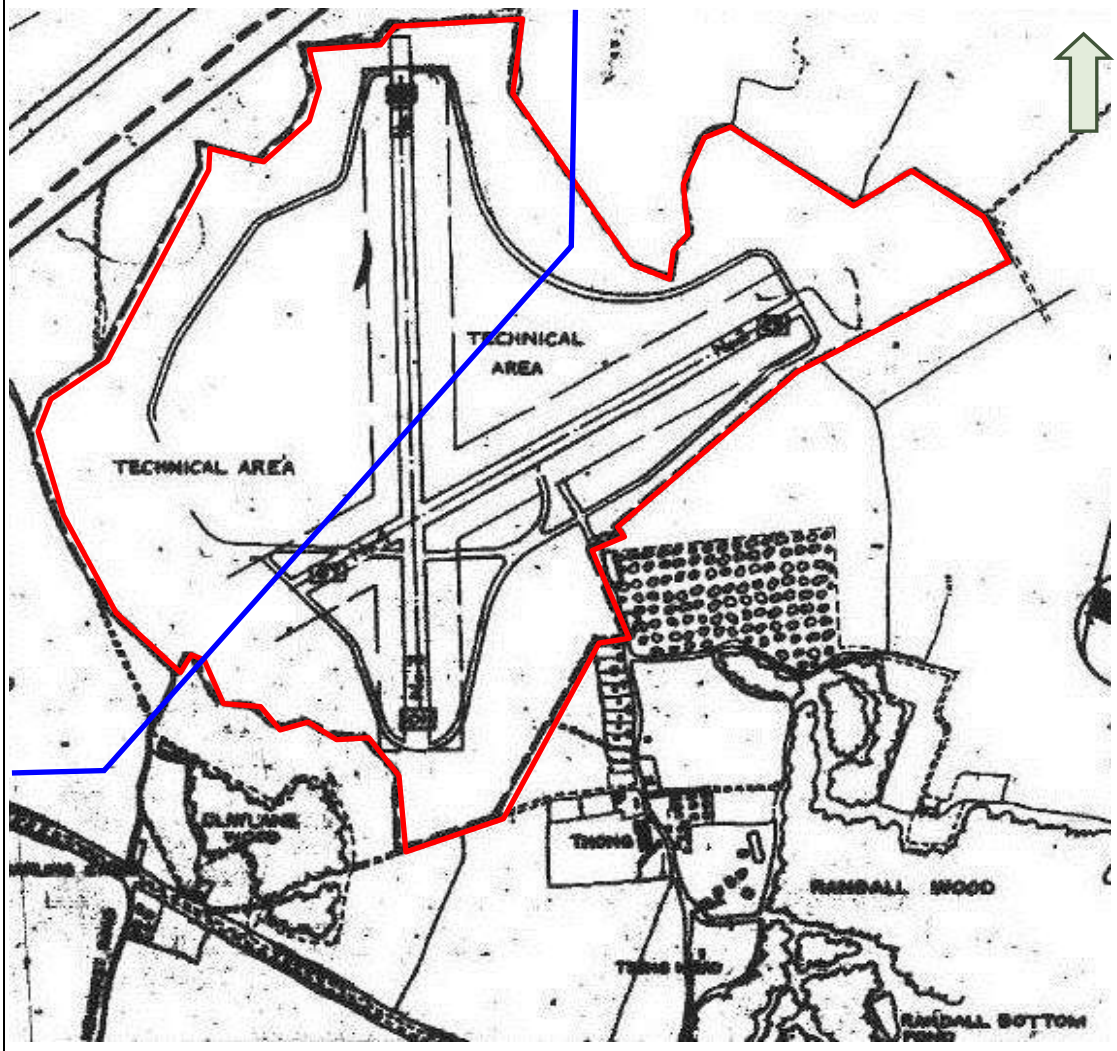
Legend	Site boundary	Airfield boundary

At the same time, the facilities at RAF Gravesend were also upgraded, which included the expansion of munitions storage for up to 650,000No. rounds of belted machine gun ammunition (see Sections 6.2 and 7.2.5 for details on munitions storage).

These upgrades allowed for 3No. RAF squadrons and, temporarily, 3No. United States Army Air Forces (USAAF) units, to be accommodated at the airfield.

The upgraded airfield layout is shown in Figure 6, a plan dating from 1945.

Figure 6	Plan of RAF Gravesend, 1945



Source: RAF Museum *Not to Scale*

Legend	Site boundary	Airfield boundary

When the V1 offensive began in 1944, RAF Gravesend was considered too close to London for the squadrons to be effective. Further, a defensive barrage balloon cordon was flown which impeded use of the airfield. The squadrons left and the airfield became No. 23 Balloon Centre controlling the deployment of barrage balloons throughout this part of Kent.

At the end of WWII RAF Gravesend was immediately put into Care & Maintenance, and most of the hangars were used for storage. The airfield was decommissioned and later sold when it was used for the manufacture of aeronautical equipment. In 1956 it was redeveloped for housing.

Details of potential sources of UXO hazard associated with activities at RAF Gravesend are given in Section 6.

5.2 Aircraft Crashes

Aircraft crash sites are a known UXO hazard. The MoD advises that if crashed aircraft are found, the safest policy is to leave them alone where possible. Unless disturbed there is no statutory requirement for the MoD to clear such sites.

Records of military aircraft crashes on and in close proximity to the Site have been found and are described below.

5.2.1 Bomber Aircraft Crashes

24th August 1940

1No. Heinkel He111H-A1+KT bomber aircraft crashed in a field at Clay Tye Hill, North Ockendon, on the Site. This aircraft was recorded as carrying a full bomb load and it is unknown whether these were cleared.

15th September 1940

1No. Heinkel He111H-2 (5120) A1+EL bomber aircraft crashed in a field at Botny Farm, Orsett, on the Site. This aircraft was recorded as carrying a full bomb load and it is unknown whether these were cleared.

4th July 1943

1No. Vickers Wellington X (HE630) bomber aircraft crashed at Henhurst Cottages, Henhurst Road, Gravesend, on the Site.

24th February 1944

1No. Junkers Ju188E-1 (260321) U5+GP bomber aircraft crashed in a field at Queen's Farm, Shorne, approximately 0.2km east of the Site.

5.2.2 Fighter Aircraft Crashes

30th August 1939

1No. Supermarine Spitfire Ia (N30314) fighter aircraft crashed in a field near Nutberry School, Nutberry Road, within approximately 300m south of the Site.

19th August 1940

1No. Supermarine Spitfire Ia (P8744) fighter aircraft crashed in a field near the Orsett Cock crossroads, southeast of Orsett, within approximately 0.1km east of the Site.

26th August 1940

1No. Hawker Hurricane I (P3157) fighter aircraft crashed in a field south of Cranham Hall, Upminster, approximately 0.5km west of the Site.

14th September 1940

1No. Supermarine Spitfire Ia (N3029) fighter aircraft crashed in a wood at Thong, on the Site.

23rd September 1940

1No. Supermarine Spitfire Ia (X4060) fighter aircraft crashed on the southeast side of RAF Gravesend, on the Site.

20th October 1940

1No. Supermarine Spitfire Ia (P7445) fighter aircraft crashed outside the main hangar at RAF Gravesend, on the Site.

16th December 1940

1No. Hawker Hurricane I (V6774) fighter aircraft crashed near Tilbury Docks, on the Site.

31st December 1943

1No. Republic Thunderbolt P-74D (42-75080) fighter aircraft crashed in a field opposite the Crown Garage, Shorne, approximately 0.2km east of the Site.

Plate 32 is a photograph showing the crash site, demonstrating a fighter aircraft wreckage that can lead to the spread of both debris and SAA over a wide area.

Plate 32	Photograph of the crash site of Republic Thunderbolt (42-75080), 1943

Source: Aircrew Remembered

28th February 1944

1No. North American Mustang III (FX996) fighter aircraft crashed in a field at Barringtons Farm, Orsett Cock, on the east-bound carriageway of the A13, on the Site.

This aircraft turned back from a mission with engine failure and it is possible that SAA is scattered at shallow depths. Records have been found indicating that the crash site was excavated in the late 1980s, potentially removing any remnant ordnance.

26th March 1945

1No. North American Mustang III (FZ117) fighter aircraft crashed on RAF Gravesend, within approximately 0.3km west of the Site.

Plate 33 is an aerial photograph showing the locations of aircraft crashes on and in the vicinity of the northern and central parts of the Site.

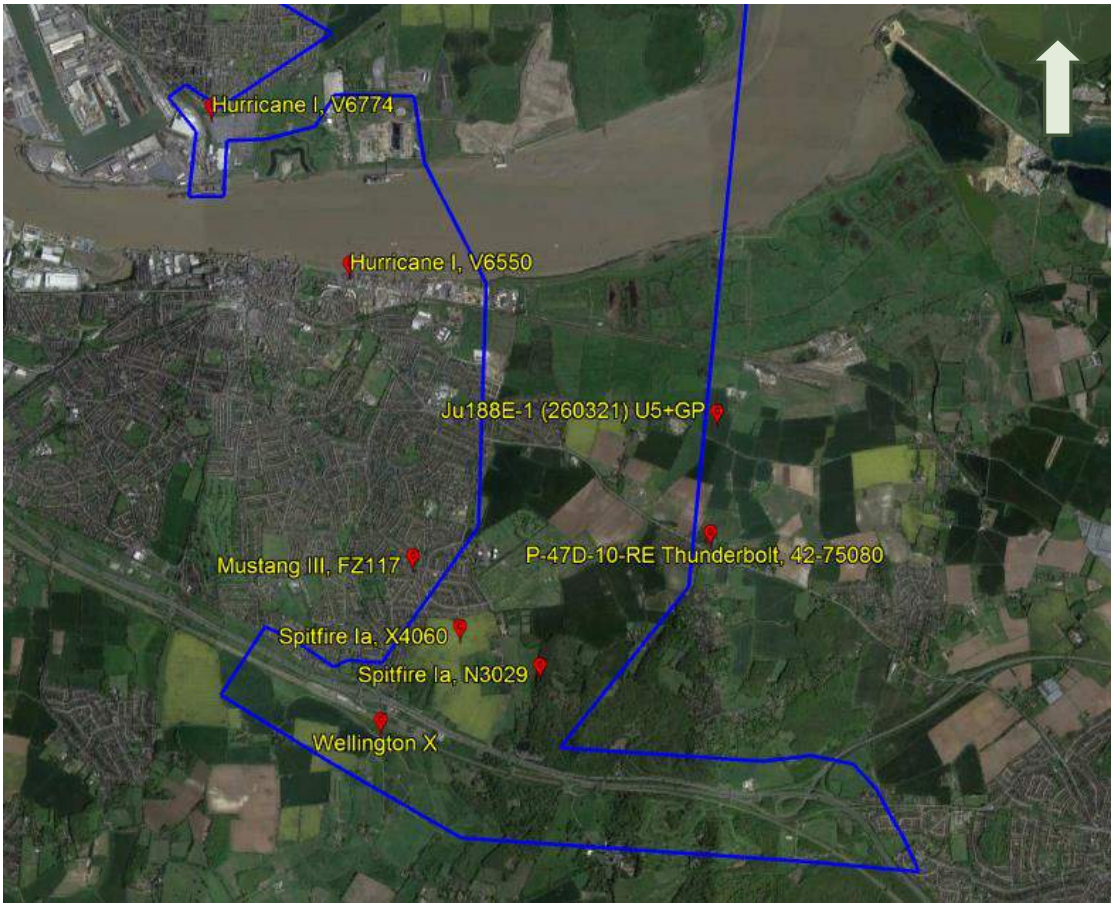
Plate 33	Aerial photograph showing the locations of aircraft crashes in the vicinity of the northern and central parts of the Site

Source: Google Earth *Not to Scale*

Legend	Site boundary	Aircraft crash

Plate 34 is aerial photograph showing the locations of aircraft crashes on and in the vicinity of the central and southern part of the Site.

Plate 34	Aerial photograph showing the locations of aircraft crashes in the vicinity of the central and southern part of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary	Aircraft crash

Potential UXO Hazard

Heinkel crashes

No records have been found to indicate whether the bombs being carried by the Heinkel He111H-2 (5120) aircraft that crashed at Botny Farm, Orsett or the Heinkel He111H-A1+KT aircraft which crashed in a field at Clay Tye Hill, North Ockendon had already been dropped, exploded on impact or were retrieved from the crash site.

It is therefore considered possible that shallow-buried UXB remain on this part of the Site.

This area is identified as M5 in **Figure 23**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Other crashes

It is considered likely that many of the crashes detailed above would have resulted in SAA from the aircraft guns being scattered across a wide area, potentially including the Site.

The potential for encountering SAA in these areas therefore cannot be discounted, although it is not typically considered to provide a significant UXO hazard, see Appendix **A3.6** .

It should also be noted that any aircraft that crashed into the River Thames is unlikely to have been recovered at the time, and some crashes may not have been recorded. If the wreckage broke up it would contribute SAA and other munitions to the marine environment which may be subject to tidal migration along the bed of the river (see Section 11).

6 AIRFIELD ACTIVITIES AT RAF GRAVESEND

Those airfields active during WWI and WWII or with long operational histories will have the greatest potential for UXO.

Practically any operational military airfield requires an ordnance disposal facility. This is usually in the form of a burning or burial pit. The amount of ordnance disposed of naturally relates to the type and amount of activity. Other sources of UXO may have resulted from practice activities on or around the airfield. Such practice would usually take place on a designated firing or bombing range.

The following Sections describe the main parts of the airfield likely to provide a source of UXO hazard to the Site.

6.1 Pipe Mines

Pipe mines laid beneath critical infrastructure such as runways were designed to be detonated in the event of an invasion to prevent enemy use of the airfield.

Records have been found indicating that pipe mines (see Appendix **A3.7**) were laid across the main landing area, the perimeter track, and sections of the technical area at RAF Gravesend by 1941. No documentation of the original layout plans of the pipe mines has been located.

Part of the Site encroached upon the south-eastern area of the original airfield (see Plate 30 above) and it is therefore considered likely that pipe mines were laid in this location.

The part of the Site encroaching upon the extended area of the airfield is unlikely to have been pipe mined as the main invasion threat had passed by the time this extension occurred.

Typically, efforts were made to remove pipe mines either when the threat of invasion had passed or when the airfield closed. No records of any WWII pipe mine clearances taking place at RAF Gravesend have been found.

Anecdotal evidence has been found indicating that empty pipe mines were removed from RAF Gravesend during the 1960s and then again later during 'Operation Crabstick' in the 1990s. This evidence indicates that the original clearance was incomplete, similar to several other airfields that were equipped with pipe mines.

For example, HMS Daedalus, Lee-on-Solent, which was subject to clearances at the end of WWII and in 'Operation Crabstick', was subject to further clearances when more pipe mines were discovered during works in 1990 and 2006.

Plate 35 is an aerial photograph giving the approximate location of the original airfield boundary in relation to the Site. This demonstrates the area in which pipe mines are likely to have been laid.

Plate 35	Recent aerial photograph showing the Site in relation to the original boundary of RAF Gravesend

Source: Google Earth *Not to Scale*

Legend	Site boundary	Airfield boundary

Potential UXO Hazard

The part of the Site likely to have been pipe mined has since been redeveloped for housing. It is possible that any remaining mines were removed during this development, although no records have been found to confirm this.

It should also be noted that pipe mines on airfields could be laid at depths up to 5.0m, beyond the typical detection capabilities of geophysical instruments of the time, and also potentially below post-WWII housing foundations.

Therefore if intrusive works are to take place in this area, it is considered prudent to undertake proactive risk mitigation to ensure that any residual risk from pipe mines is suitably mitigated.

This area is identified as M4 in **Figure 27**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

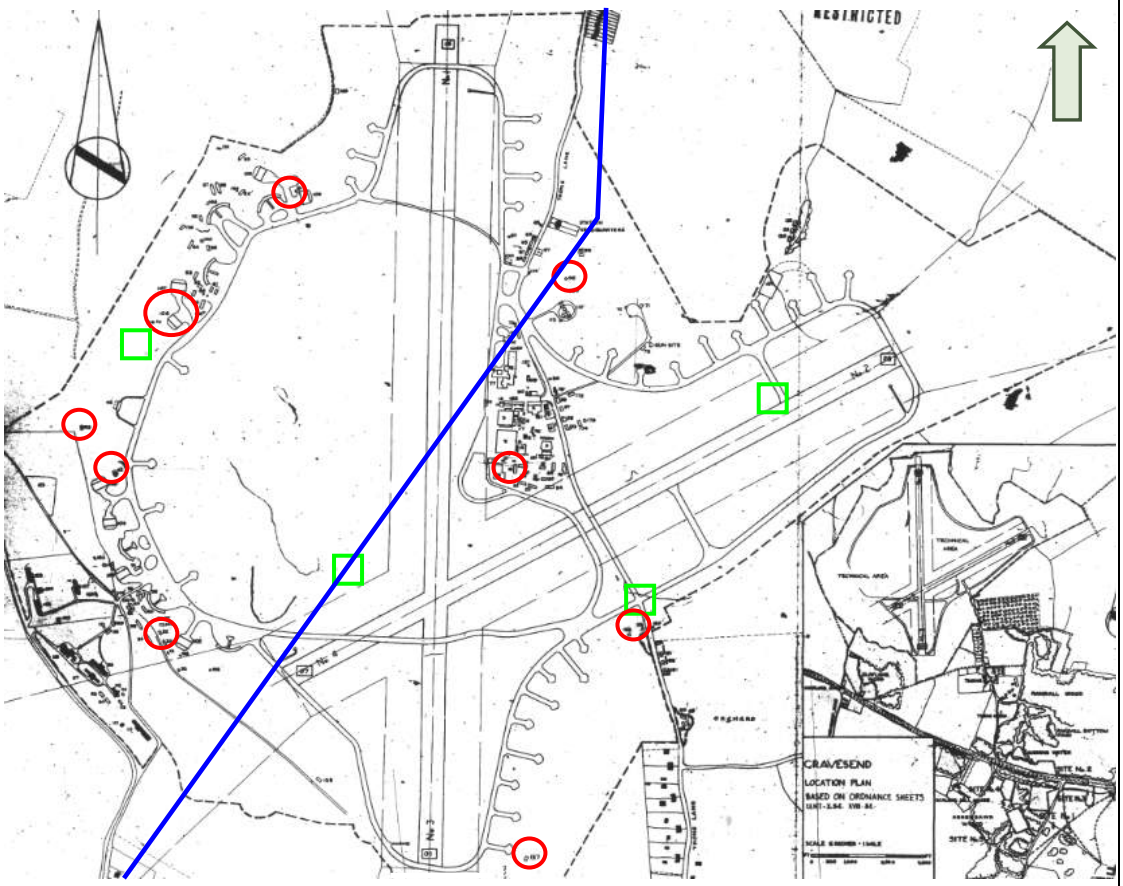
6.2 Bomb and Munitions Stores

Bomb and ammunition stores were typically constructed in a remote area of an airfield, linked to the perimeter track by a service road. Bomb stores often contained a combination of both practice and live ordnance.

During WWII, RAF Gravesend was equipped with 9No. dispersed SAA stores, of 2No. main patterns, at several locations around the airfield.

Figure 7 is a plan of RAF Gravesend highlighting the SAA stores and the station armoury together with the position of the LAA emplacements (see Section 6.6). These are likely to have had their own temporary stores associated with each emplacement.

Figure 7	Plan of RAF Gravesend with locations of SAA stores and LAA emplacements, 1945



Source: RAF Museum *Not to Scale*

Legend	Site boundary	SAA Stores/Armoury	LAA positions

Potential UXO Hazard

These stores were emptied and demolished on closure of the airfield and are therefore not considered to provide a significant source of UXO hazard to the Site.

6.3 Machine Gun Ranges & Test Butts

On an airfield, the machine gun and test butts are a designated area where aircraft test their guns. The butts are often at the end of access runways or dispersals and incorporate a mound of Made Ground or soil which is fired into.

Small arms ranges (such as rifle ranges) and close combat ranges (such as mortar and grenade ranges) are likely to provide a significant source of UXO. It should be noted that even on small arms ranges, larger munitions such as mortars or grenades cannot be discounted.

No machine gun ranges or test butts are indicated on airfield plans for RAF Gravesend.

As RAF Gravesend acted as an SLG for RAF Biggin Hill, which had harmonisation butts, it is assumed that aircraft were taken there for such operations.

6.4 Munitions Disposal Areas

Munitions disposal commonly took place in areas around the perimeter of an airfield away from aircraft operations.

No records of official munitions disposal areas at RAF Gravesend have been found.

During the course of normal operations it is likely that some munitions became unserviceable and had to be disposed of. This disposal would have been of relatively small quantities and was usually carried out in remote areas of the airfield.

Such operations would normally have involved destruction by either burning or a controlled explosion in a small destructor house. There are no indications of such facilities on airfield plans for RAF Gravesend.

Potential UXO Hazard

There is no evidence on WWII aerial photography of any areas of disturbed ground on the Site at the former RAF Gravesend which might be indicative of disposal.

As with any military airfield, particularly one used in the Battle of Britain, there is always the possibility that munitions were discarded or spilt, particularly near munitions stores or at aircraft dispersal points.

At RAF Gravesend this would typically have been SAA which would have included .303”, .5” and 20mm cannon rounds. In addition, it is possible that components such as fuzes and detonators may have been used for small bombs used in ground attacks in enemy territory.

The potential for close combat munitions (such as grenades) issued to troops defending the airfield perimeter to have been disposed of in this manner, whilst unlikely, cannot be totally discounted.

Munitions disposal at RAF Gravesend is not considered to provide a significant source of UXO hazard to the Site.

6.5 Aircraft Breaking

Specialist Maintenance Units (MU) were responsible for the modification, maintenance and repair of damaged aircraft. Those aircraft considered beyond all repair were stripped of useful and salvageable parts and disposed of in a pit or 'aircraft graveyard'. These were usually in areas around the perimeter of an airfield, adjacent to access tracks or near repair hangars.

Waste from aircraft disposal should be considered hazardous. It contains a range of conventional contaminants and potentially radioactive materials (such as radium from luminescent dials). Liquid waste from the aircraft may have been decanted into tanks.

No records of military aircraft breaking activities at RAF Gravesend have been found.

Crashed aircraft were either removed to the regional Maintenance Unit (MU) Salvage Depot at RAF Faygate in Surrey, or taken to an aircraft repair plant at Cowley in Oxford.

Essex Aero, a specialist firm in aircraft conversions, had a facility in the Technical Area at RAF Gravesend, on the Site. They worked on self-sealing fuel tanks for several aircraft types, particularly fighter aircraft.

This activity did not involve work on any aircraft carrying munitions.

6.6 Airfield Defences

Airfields were frequently given their own anti-invasion defences such as gun emplacements and pillboxes. As they often had associated caches of munitions, pillboxes and gun emplacements can provide a direct source of UXO hazard.

Records have been found indicating that gun emplacements were located on the perimeter of RAF Gravesend during WWII.

Those nearest to the Site are listed in Table 7 and shown on Figure 7 above.

Table 7 Machine gun emplacements at RAF Gravesend within 1km of the Site

Grid Reference	Location	Serial No.	Type	Approximate Distance and Direction from Site
TQ 673712	RAF Gravesend	VG3	1No. .303" Quad Lewis gun	On the Site
TQ 673718	RAF Gravesend	VG2	1No. 40mm and 1No. .303" Lewis gun	On the Site
TQ 665714	RAF Gravesend	VG4	1No. .303" Quad Lewis gun	0.1km W
TQ 661719	RAF Gravesend	VG1	1No. 40mm and 1No. .303" Lewis gun	0.7km NW

Plate 36 is an aerial photograph showing the locations of machine gun emplacements at RAF Gravesend.

Plate 36	Aerial photograph showing the locations of machine gun emplacements at former RAF Gravesend

Source: Google Earth *Not to Scale*

Legend	Site boundary	Machine gun emplacement

Potential UXO Hazard

Ammunition caches associated with these emplacements would typically have been cleared post-WWII, although the possibility that localised disposal occurred cannot be totally discounted.

There is no positive evidence to indicate that such disposal took place on the Site and therefore the machine gun emplacements at RAF Gravesend are not considered to provide a significant source of UXO hazard to the Site.

7 EXPLOSIVES AND MUNITIONS ESTABLISHMENTS AND DEPOTS

Explosives and munitions manufacturing or storage sites offer a particularly high risk from both explosive substances and UXO. Standard procedures of explosive/ordnance disposal through burial or burning means that explosive and UXO hazards will be present in some areas of such establishments.

In addition, UXB hazards may be present as a result of enemy bombing during WWI and WWII.

7.1 Explosives and Ordnance Factories

No records of any explosives or ordnance factories on or in close proximity to the Site have been found.

7.2 Munitions Stores

Local ammunition caches would have been present near to defended road blocks, pillboxes, HAA and LAA sites. Most of those associated with the anti-invasion sites are understood to have been cleared.

No records have been found indicating that any official munitions stores were located on the Site. A number of munitions stores were located at RAF Gravesend (see Section 6.3) and at the coastal batteries on the Site (see Sections 9.4 and 9.5).

Other munitions stores in the vicinity of the Site are described in the Sections below.

7.2.1 Tilbury Fort

Pre-WWI, Tilbury Fort (TQ 652755), approximately 0.2km south of the Site, was controlled by the Army Ordnance Department, specifically for storing mobilisation equipment for the 4th and 5th Divisional Horse Artillery.

During WWI the fort was re-designated as an Ordnance Depot on the 1st October 1915.

During WWII, Tilbury Fort played a relatively minor role, only housing AA guns.

Post-WWII, the fort was renovated and opened as a tourist attraction in the 1980s.

Tilbury Fort is not considered to provide a source of UXO hazard to the Site.

7.2.2 Operation Overlord Sub-Depots

In preparation for Operation Overlord, the D-Day invasions of Normandy, parts of southeast Essex were designated as Marshalling Area S (see Section 9.1). Several associated ordnance sub-depots were established within 5km of the Site.

The nearest ordnance depot was located approximately 2.1km northeast of the Site. The depots held ammunition, weapons and other supplies.

There was a Petroleum, Oils & Lubricants (POL) depot adjacent to the Site near Stubbers Wood, North Ockendon (see **Figure 9**).

Operation Overlord Ordnance depots are not considered to provide a source of UXO hazard to the Site.

7.3 Informal Munitions Depots
Informal munitions depots, often made by requisitioning roadside lay-bys or parks. Other informal munitions depots were commonly located in areas of woodland or on train wagons along sidings in marshalling yards.
No records of any informal munitions depots on or in close proximity to the Site have been found.
7.4 Munitions Disposal Areas and Bomb Cemeteries
Munitions disposal areas were often made by requisitioning open areas of land, usually away from habitation. Marshland, beaches or sand dunes were frequently used for this purpose. Disposal of munitions was carried out in many different ways, ranging from destruction to burial. Full records were not necessarily maintained for these locations, and so they can potentially be a source of UXO.
No records of any official munitions disposal areas on the Site have been found. Records indicate that during WWII, munitions disposal operations, likely to be air-dropped devices, took place at Tilbury Fort. No records have been found to indicate that this activity encroached on to the Site. Munitions disposal areas and bomb cemeteries are not considered to provide a source of UXO hazard to the Site.

8 FIRING RANGES AND MILITARY TRAINING AREAS

By their nature, firing ranges and military training areas represent a potential source of UXO due to associated training activities. The training will involve both practice and live munitions and will offer a significant risk from a very wide range of potential UXO.

8.1 Small Arms Ranges

Small arms ranges (such as rifle ranges) and close combat ranges (such as mortar and grenade ranges) are likely to provide a significant source of UXO. It should be noted that even on small arms ranges, larger munitions such as mortars or grenades cannot be discounted.

Part of the Site has encompassed Milton Range since the mid-19th century. This is described in further detail below.

8.1.1 Milton Range

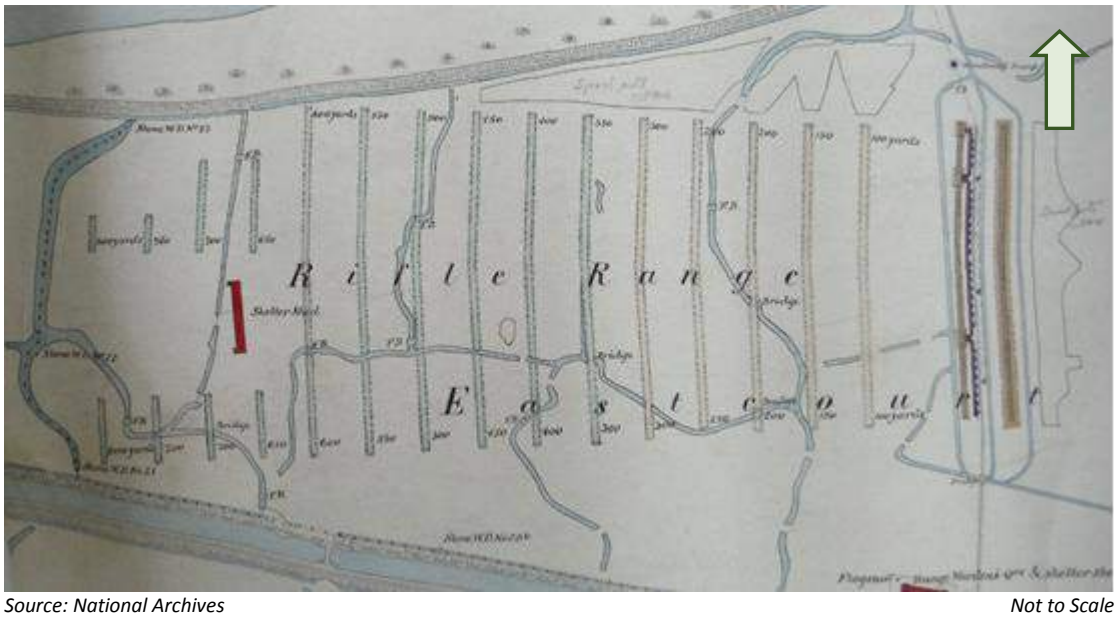
In 1862 Milton Range, a 900yd rifle range, was established on Eastcourt Marshes, between the River Thames and the Thames Medway Canal. The range comprised low earthen mound firing points every 50yds, aiming west to east towards 20No. target points located on 5No. target butts.

The range was initially used by 3No. depot battalions of Royal Marines and Royal Engineers for individual target practice, in addition to group volley and skirmish training.

In the 1890s the range was shortened to 800yds and reorganised for Lee-Metford magazine rifle training. 1No. new target butt, in addition to a series of movable target frames, was established 150yds west of the original target butts. Figure 8 is plan of Milton Range dating from 1895.

The Site completely encompassed the range.

Figure 8 Plan of Milton Range, 1895



Source: National Archives *Not to Scale*

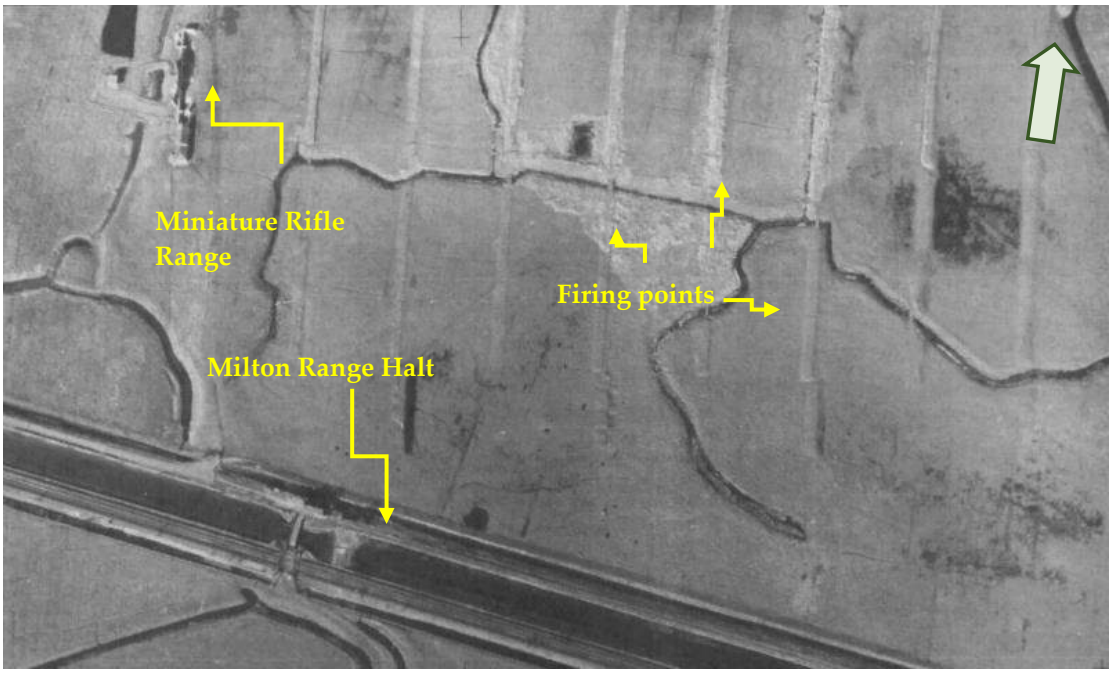
In 1906 Milton Range Railway Halt was established on the South Eastern Railway (SER) North Kent line. This was intended to render the range accessible to troops stationed in Chatham.

Milton Range was extensively used during WWI and WWII. Records have been found indicating that mortar training was undertaken on the range during WWII, and it is considered possible that other close combat munitions, such as grenades, were used during training exercises by both regular troops and the Home Guard.

Records have been found indicating that a 'gas compound' was located at Milton Range. For a short period during WWII this contained a small store of Mustard Gas, used to train troops in decontamination procedures. War diaries indicate that this compound was regularly inspected and vented before being removed.

Plate 37 is an aerial photograph, dated the 28th February 1950, showing part of Milton Range. A miniature rifle range has been identified within the range extents.

Plate 37	Aerial photograph showing Milton Range, 28th February 1950



Source: Historic England *Not to Scale*

Milton Range continued to be used as a military firing range until 1995. The range currently operates as the practice firing area for the Metropolitan Police Specialist Training Centre.

Potential UXO Hazard

Milton Range was used by the military for live firing training from 1862 to 1995. This mainly involved the use of small arms.

Concentrations of SAA are likely to be present in the immediate vicinity of the target butts. Given the possibility of spillages and accidental discharges, it is also considered that SAA will be located at shallow depths across the range.

SAA is not considered to provide a significant source of UXO, although concentrations of SAA may provide a source of metal contamination, particularly lead, antimony and zinc (see Appendix **A3.8**).

More significantly, records have been found indicating that Milton Range was used for mortar training during WWII. Given the long use of the range, it is likely that other close combat training (including grenades) has also taken place. Zetica has experience of finding such munitions on historic ranges theoretically designated for the use of small arms only.

Close combat munitions provide a more significant detonation risk than SAA and therefore further risk mitigation is recommended on this part of the Site (see Section 14).

This area is identified as M3 in **Figure 26**, and shown on HE540039-ZET-GEN-GEN-MAP-GEO-00001.

8.2 Artillery Ranges

Artillery ranges will have utilised a wide range of munitions, predominantly shells, although close combat munitions such as mortars, or larger munitions such as bombs, cannot be discounted.

No records of any artillery ranges on or in close proximity to the Site have been found.

8.3 Bombing Ranges

Bombing ranges will have primarily used bombs, although other munitions such as shells and close combat munitions such as mortars cannot be totally discounted.

No records of any bombing ranges on or in close proximity to the Site have been found.

8.4 Training Areas

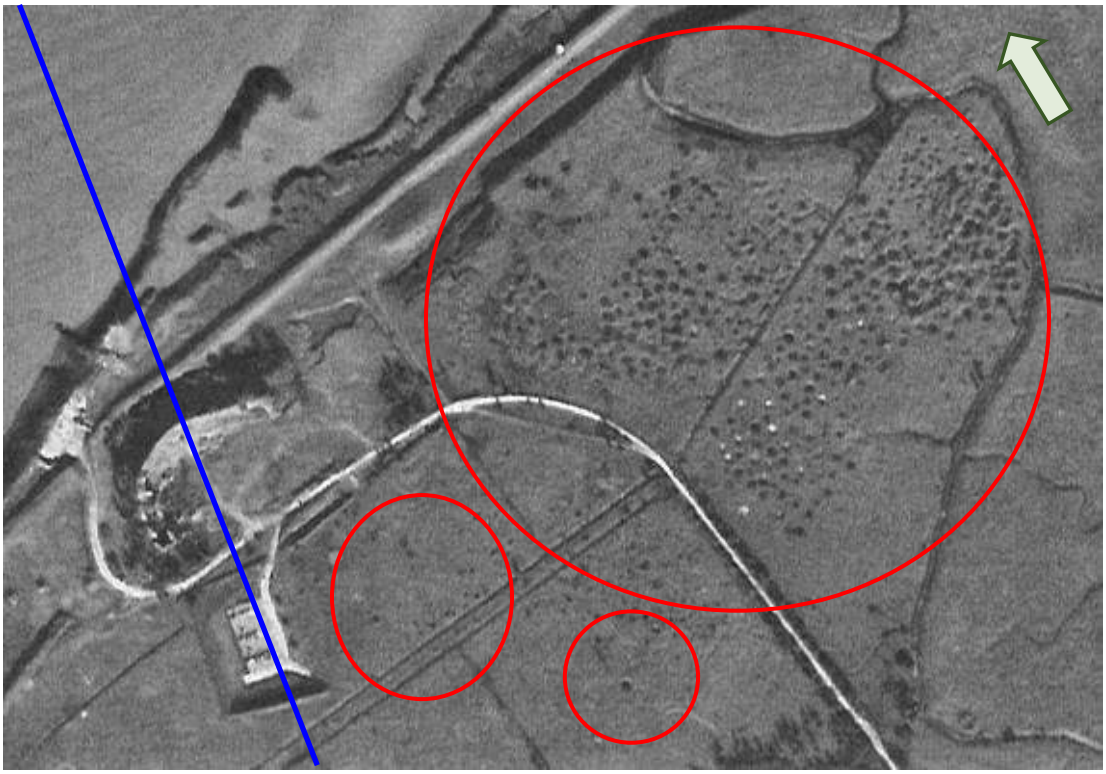
Training areas will have primarily used blank ammunition or practice shells in 'dry' areas, although live munitions such as shells and close combat munitions such as mortars cannot be discounted in any training area.

In additional to training at Milton Range described in Section 8.1.1, training also took place near Shornemead Fort, on the eastern boundary of the southern part of the Site.

Aerial photography suggests training near Shornemead Fort began in the 1950s. It is considered likely that this cratering was caused by training in close combat munitions, such as mortars and hand grenades, or during demolition or disposal exercises undertaken by the Royal Engineers.

Plate 38 is an aerial photograph dated the 19th January 1975, showing heavy cratering associated with military training exercises.

Plate 38	Aerial photograph, 19th January 1975



Source: Historic England *Not to Scale*

Legend	Site boundary	Cratering

Potential UXO Hazard

The cratering is concentrated over 0.2km east of the Site, with few craters in the immediate vicinity of the Site. Given this, it is considered unlikely that this training would have encroached on the Site.

Military training is not considered to provide a source of UXO hazard to the Site

9 OTHER ESTABLISHMENTS, MILITARY BASES AND BARRACKS

Several military establishments directly linked to the armed forces exist or have existed in the region surrounding the Site. These can provide a source of UXO hazard, although the level of risk from such hazards will depend on the nature of operations carried out.

In addition, UXB hazards may be present as a result of enemy bombing during WWI and WWII.

The nearest such establishments to the Site are described in the Sections below.

9.1 WWII Marshalling Area 'S'

In 1944, in preparation for the D-Day invasions of Normandy, a series of Marshalling Areas, used to assemble troops, vehicles and equipment, were established throughout southern England.

Marshalling Area 'S', within Eastern Command, was established on land encompassing parts of the Site.

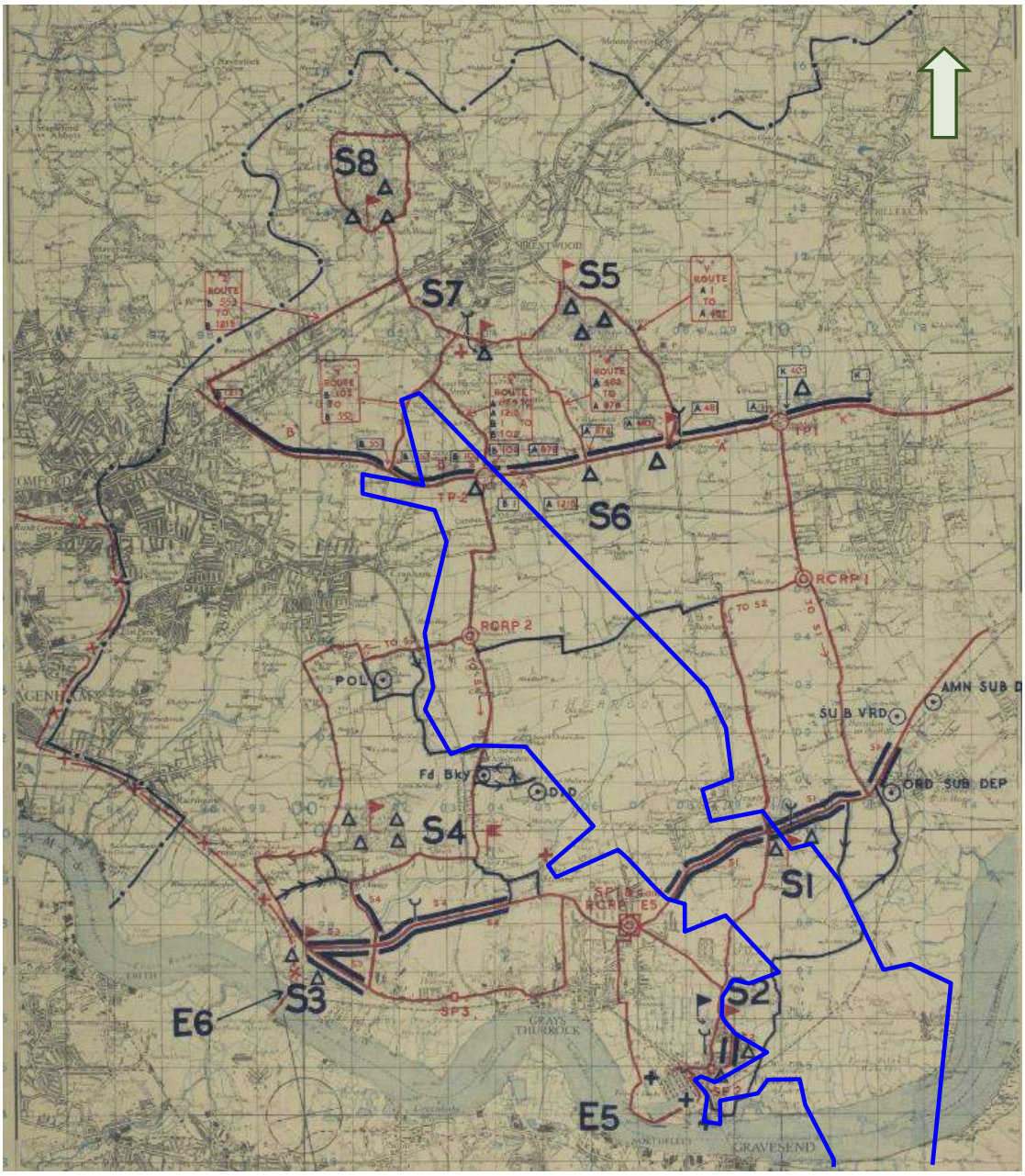
Figure 9 is a plan of Marshalling Area 'S', dated the 25th May 1944. It shows that a tented camp, designated as 'S1', was located on Orsett Golf Course, encroaching onto the Site. This was mainly used to accommodate elements of the 51st (Highland) Division, which disembarked for France on the 7th June 1944.

A small military camp was also located on the Site near Great Warley Hall (TQ 593885).

The road adjacent to this part of the Site was used as a military vehicle park, serviced by a Royal Electrical and Mechanical Engineers (REME) post.

No evidence of any further military activity on the remainder of the Site is shown.

Figure 9	Extract from plan of Marshalling Area 'S', 25th May 1944



Source: Essex Record Office *Not to Scale*

Legend	Site boundary	Camp	Sub Area HQ	Vehicle Park
	Storage Depots	Port	Admin route	One way route
	REME post	Start point	Traffic point	Road Convoy Post

Potential UXO Hazard
Marshalling Area S had designated munitions stores, located to the northeast of Horndon on the Hill. While troops based at Orsett Camp are likely to have been issued with SAA which may have been discarded, this is not considered to provide a significant source of UXO hazard to the Site. Additionally, any potential any munitions that may have been present at the camp on its closure are likely to have been removed during subsequent quarrying activities. As much of Marshalling Area S was used for vehicle storage and troop movement, this is not considered to provide a source of UXO hazard to the Site.

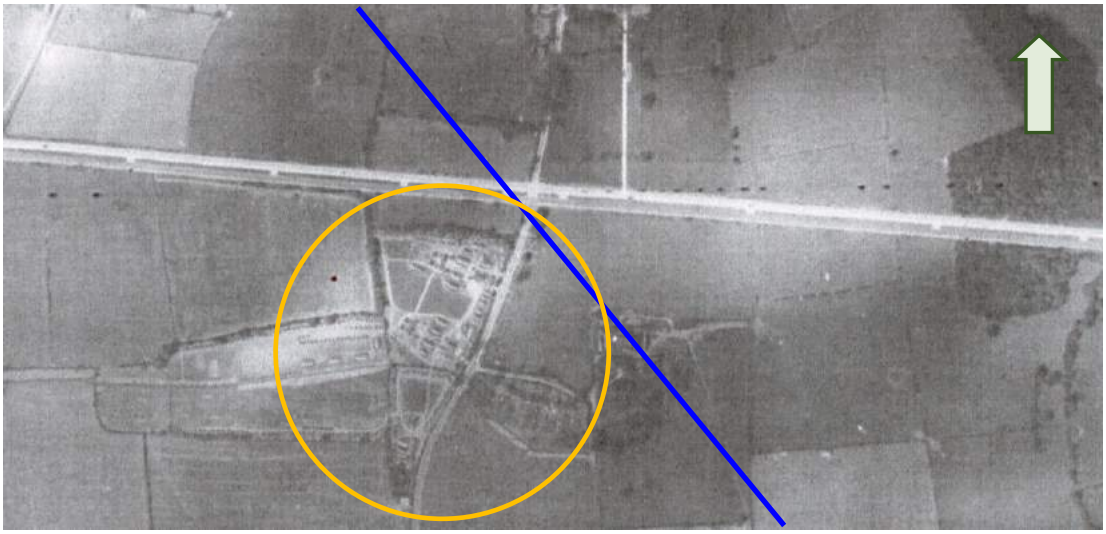
9.1.1 Great Warley Camp

Land along the Southend Arterial Road near Great Warley was requisitioned as Marshalling Area (MA) S6. 4,500No. military personnel were accommodated in tented camps in surrounding fields, one of which was on the northern part of the Site (TQ 593885). The units camped here included the 51st (Highland) Division.

MA S6 also had storage capacity for 2,450No. military vehicles. Many of these were parked on any suitable open ground along the Arterial Road, partially on the Site.

Plate 39 is an aerial photograph dated the 6th July 1944, showing the location of the camp on the Site.

Plate 39	Aerial photograph showing Great Warley Camp, circa 1946



Source: Historic England *Not to Scale*

Legend	Site boundary	Camp

Post-WWII, the camp was closed and the land reverted to agriculture.

Great Warley Camp is not conisdered to provide a source of UXO hazard to the Site.

Potential UXO Hazard

During WWII Great Warley Camp was used to accommodate troops before disembarkation to mainland Europe. Although Marshalling Area S had designated munitions stores, located to the northeast of Horndon on the Hill, it is likely that British troops would have used the surrounding fields and woods as a training area, with the possibility of leaving behind both inert, blank and live munitions.

This forms part of the low background risk for any former military site in the UK.

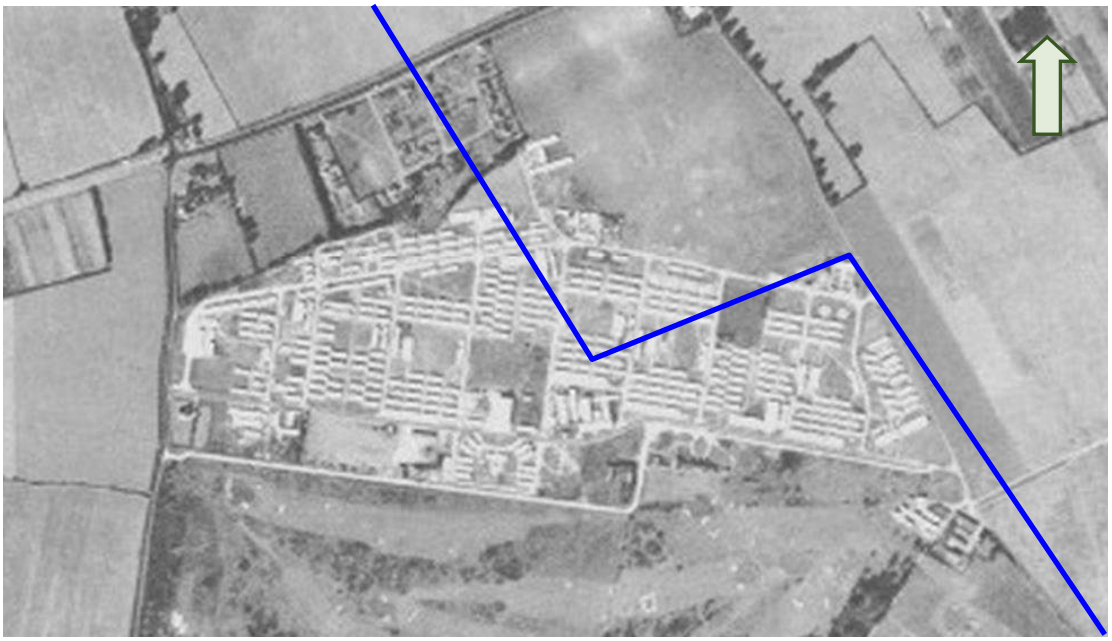
Great Warley Camp is not considered to provide a significant source of UXO hazard to the Site.

9.2 Orsett Camp

In 1945, the tented MA camp on Orsett Golf Course (see Section 9.1) was redeveloped as a British Army transit camp, comprising approximately 300No. brick buildings.

Plate 40 is an aerial photograph dating from circa 1946, showing the layout of Orsett Camp.

Plate 40	Aerial photograph showing Orsett Camp, circa 1946



Source: Historic England *Not to Scale*

Legend	Site boundary

During the late 1940s Orsett Camp accommodated a series of units, including the 6th Company (Motor Transport) Royal Army Service Corps (RASC) and elements of the Royal Corps of Signals. Throughout the 1950s the camp was mainly used to accommodate the 57th HAA Regiment Royal Artillery.

The camp remained largely unchanged during this time, as is shown in Figure 10, the historical map of 1960.

Figure 10	Historical map of 1960 showing Orsett Camp

Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary

By the 1970s the camp had been closed, and the land was given over for use as a quarry.

Potential UXO Hazard

During WWII, Orsett Camp was primarily used as a transit camp before troops embarked for mainland Europe.

No evidence has been found indicating that Orsett Camp was used for military training, and no designated munition stores have been identified on the Site.

Any munitions that may have been present at the camp on its closure are likely to have been removed during subsequent quarrying activities.

Orsett Camp is not considered to provide a source of UXO hazard to the Site.

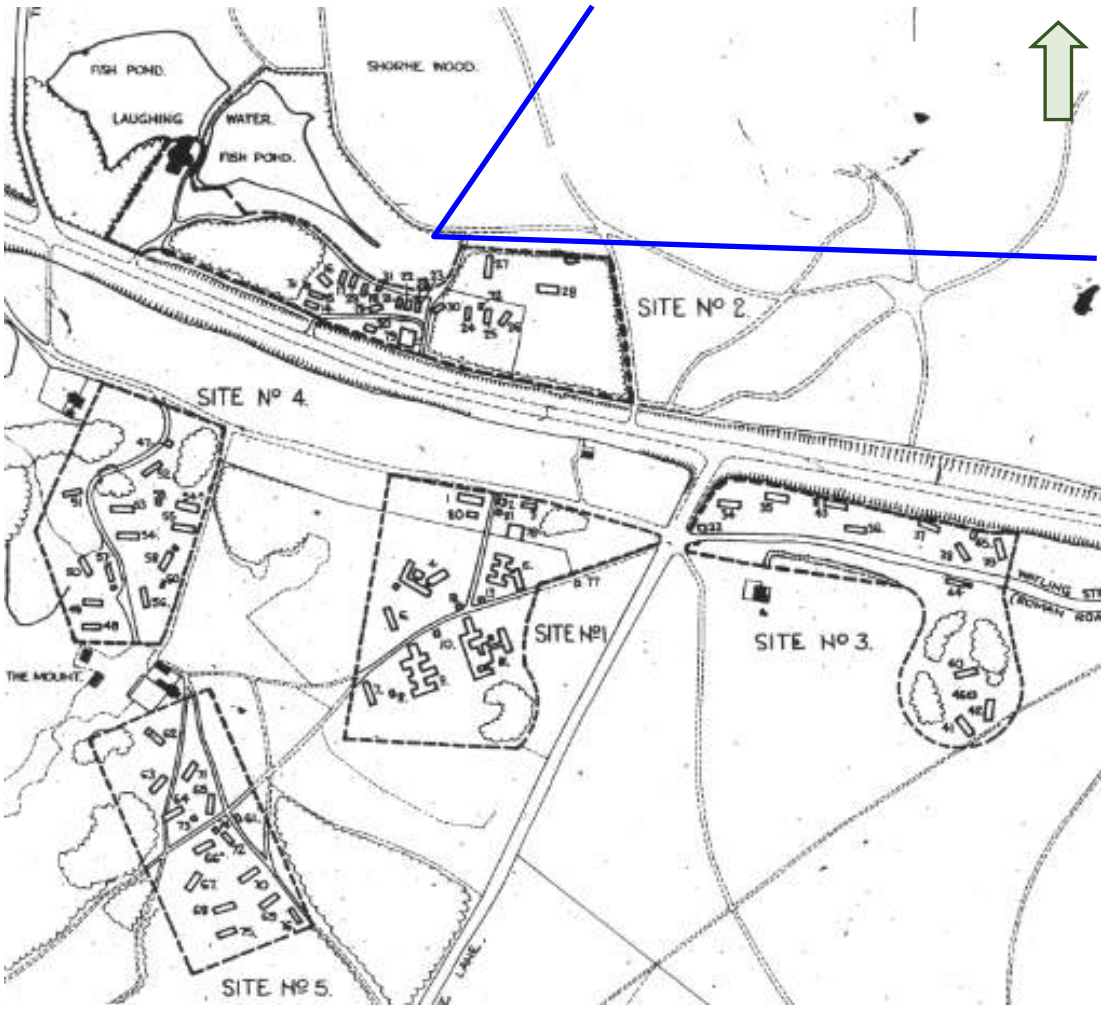
9.3 Ashenbank Wood Camp

During WWII land surrounding Watling Street, north of Cobham, was used to accommodate troops stationed at RAF Gravesend. Three dispersed camps were located at TQ 674696, TQ 677695 and TQ 675693.

It was also used briefly as a Royal Navy (RN) training establishment. 2No. additional dispersed accommodation sites were located at Laughing Water (TQ 677697 and TQ 681695), on the Site.

Figure 11 is a 1945 plan of the dispersed accommodation camps located near Ashenbank Wood.

Figure 11	Plan of dispersed accommodation, RAF Gravesend, 1945



Source: RAF Museum *Not to Scale*

Legend	Site boundary

Post-WWII, the buildings on the Site were used as civilian accommodation until the mid-1950s when the majority of the buildings were demolished to their foundations, with the exception of a small number of air raid shelters that remain extant.

Potential UXO Hazard

During WWII Ashenbank Wood Camp was used to station troops based at RAF Gravesend.

No evidence has been found indicating that this area was used for military training, and no designated munition stores have been identified.

Any munitions that may have been present at the camp on its closure are likely to have been removed when the camp was demolished.

Ashenbank Wood Camp is not considered to provide a source of UXO hazard to the Site.

9.4 Coalhouse Fort

In the 1860s Coalhouse Fort was constructed on the Site (TQ 690767) for the defence of the River Thames at East Tilbury.

In 1893 East Tilbury Battery was constructed in close proximity to the Fort and armed with 2No. 6pdr guns. It was decommissioned and sold in 1913. It remains private land.

The Wing (Quick Firing) Battery, to the south of the Fort, was armed with 1No. 6-pdr gun for engaging small vessels. The Wing Battery fell into disuse from 1902, being replaced with guns at Coalhouse Fort itself. Coalhouse Fort was regularly rearmed and modernised during this time.

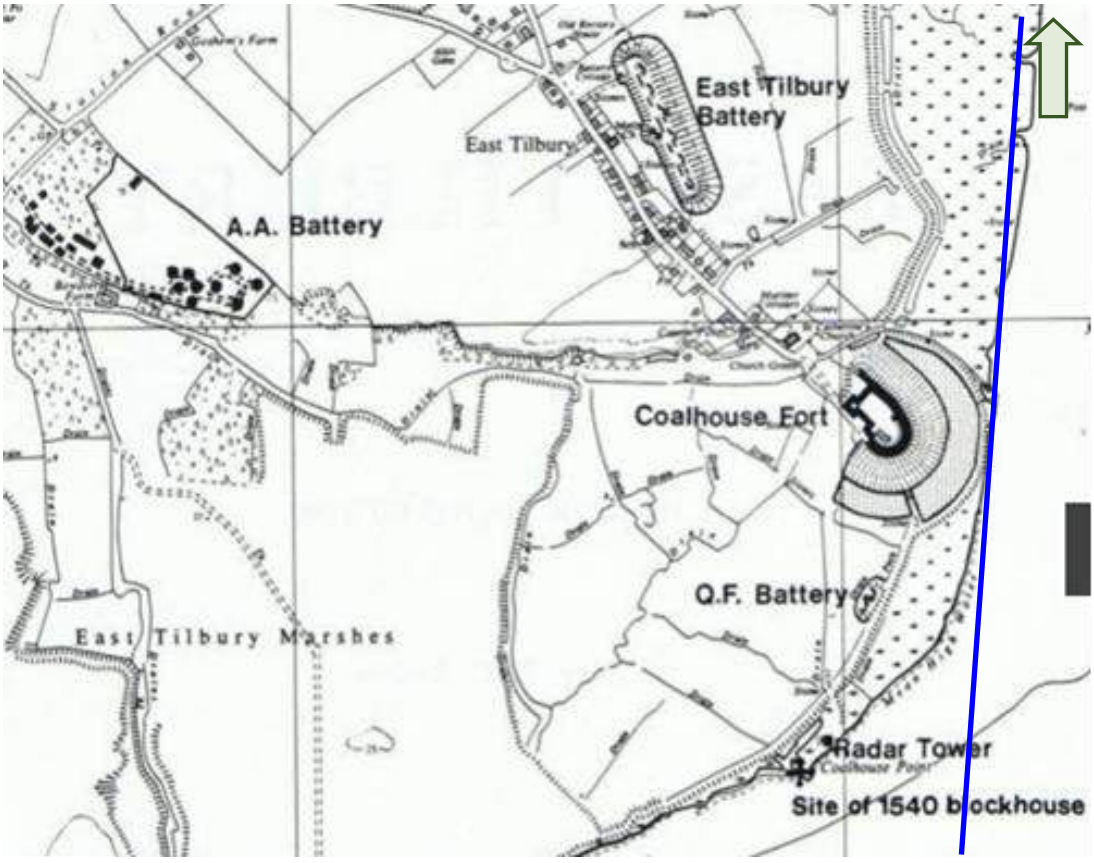
During WWII Coalhouse Fort was again rearmed with a variety of armaments, including 2No. 5.5" naval guns and 1No. Bofors gun, and several designated munitions storage areas were constructed within the fort.

Additionally, a concrete observation tower was constructed north of the fort to control electrically detonated mines in the River Thames. This worked in conjunction with a radar station to the south of the fort. This radar station was occupied by naval forces, covering the approach to the minefield.

In 1944 Coalhouse Fort was transferred to the Home Guard's Coastal Battery detachment.

Figure 12 is a plan of WWII defences at East Tilbury.

Figure 12	Plan of WWII defences at East Tilbury



Source: Derelictplaces.co.uk *Not to Scale*

Legend	Site boundary

The Fort was decommissioned in 1949 and used as a storage facility. In 1962 the fort became a scheduled monument and was partially restored.

Potential UXO Hazard

Since its construction Coalhouse Fort has been regularly rearmed and modernised, and several munitions storage areas were located in the fort.

It is considered likely that these munitions were cleared when, post-WWII, the fort became a scheduled monument and opened to the public.

Coalhouse Fort is not considered to provide a source of UXO hazard to the Site.

9.5 Shornemead Fort

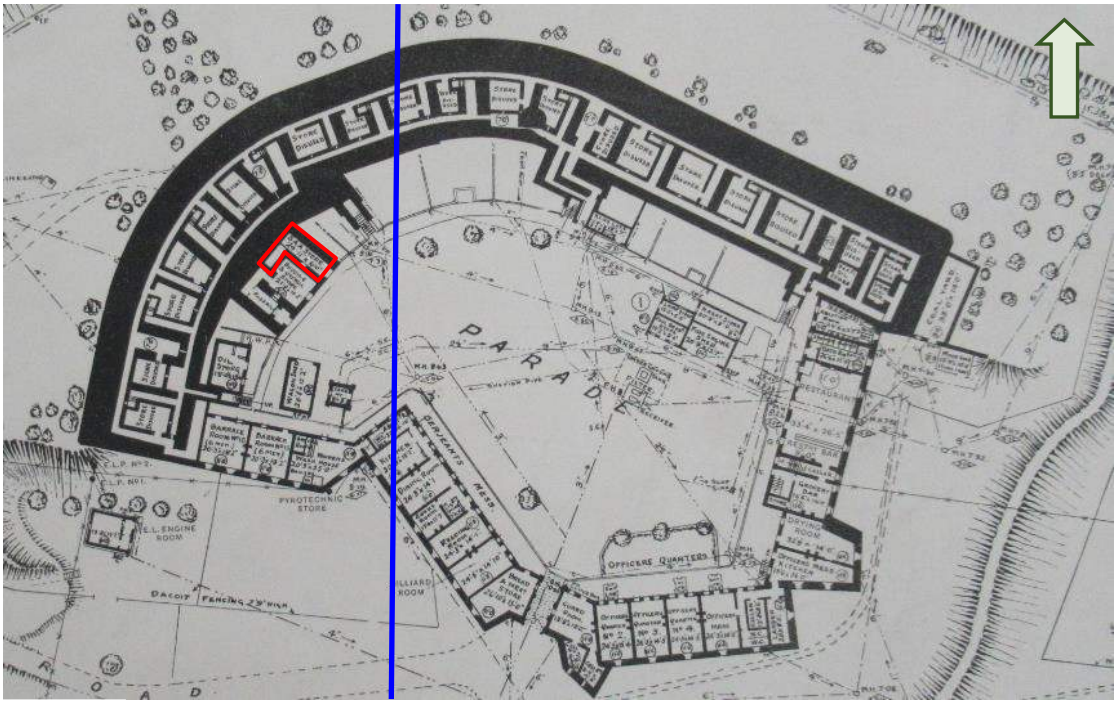
In the 1860s Shornemead Fort was constructed on land encroaching on to the Site for the defence of the River Thames.

Although initially equipped with 11No. 11" Rifled Muzzled-Loading (RML) guns in the 1870s, the fort was soon disarmed and used as a training facility by the Royal Engineers. A submarine mining depot was also established to the west of the fort during the 1870s, consisting of mine stores and mine servicing areas. This facility was removed during or shortly before WWI.

Shornemead Fort was rearmed during WWI with 2No. 12-pdr guns.

Figure 13 is a plan of Shornemead Fort dating from 1930. The casemates are marked as disused stores and the majority of the fort was used as barracks. An SAA store was located on the Site.

Figure 13 Plan of Shornemead Fort, 1930



Source: National Archives *Not to Scale*

Legend	Site boundary	SAA stores

During WWII, the fort was designated as an emergency battery and rearmed with 2No. 5.5" naval guns, as well as a landing hard for the embarkation of troops. The fort was also used to station troops training at the nearby Milton Range.

Post-WWII Shornemead Fort was decommissioned and during the 1960s was used by the Royal Engineers demolition squad for explosives practice, which destroyed the barracks at the rear of the fort (See Section 8.4).

Potential UXO Hazard

During WWII Shornemead Fort was armed with 2No. naval guns and included SAA stores on the Site. It is likely that the fort would have had storage for shells, connected to the firing points with lifts.

It is considered likely that these munitions were removed once the fort was decommissioned. Any remnant munitions are likely to be at the surface or shallow depths. This forms part of the low background risk for any military site in the UK.

Shornemead Fort is not considered to provide a source of UXO hazard to the Site.

10 MARINE ORDNANCE HAZARDS

Both wartime and peace time military and naval activities provide numerous sources of UXO within the offshore environment. The principal sources of UXO hazards are from ordnance disposal at sea, WWII aerial laid mines, mines laid as beach defences, air raids on shipping, crashed aircraft and wrecks containing ordnance.

Clearance certification for UXO within a marine environment may be valid only for a limited period as storms, tides and general current movement can cause UXO to migrate into an area that may have been cleared of UXO only hours before. This also makes it very difficult to accurately predict where UXO may be found.

UXO is most likely to be concentrated on and immediately around the principal sources of the UXO hazard. These are typically ordnance disposal sites at sea, WWII mines, marine ranges and wrecks containing ordnance.

10.1 Coastal Gun Batteries

Strategic targets, such as harbours, together with vulnerable sections of the coastline were protected by a number of gun emplacements. Some were sites that had been used during WWI or earlier, others were newly constructed to give added protection.

During WWII the approaches to the Thames Estuary were heavily defended by a series of coastal batteries.

Table 8 lists the recorded coastal batteries within 5km of the Site. Those on the north bank of the River Thames were manned by units of the East Tilbury Home Guard from 1943.

Table 8 Coastal batteries within 5km of the Site

Grid Reference	Location	Armament	Approximate Distance and Direction from Site
TQ 687774	East Tilbury Battery	4No. 12-pdr guns	On the Site
TQ 691768	Coalhouse Fort	2No. 5.5” naval guns	On the Site
TQ 693748	Shornemead Fort	2No. 5.5” naval guns	On the Site
TQ 652755	Tilbury Fort	2No. 6” guns and 4No. 12-pdr guns	0.2km S
TQ 653742	New Tavern Fort	2No. 6” naval guns	1.1km SE
TQ 707768	Cliffe Fort	Unknown	1.3km E

These coastal batteries had associated searchlight emplacements, often using the sites of the Defence Electric Lights (DEL) of the 1900s. This included those at Coalhouse Fort and Shornemead Fort which were originally used for lighting the boom defences across the River Thames.

Plate 41 is an aerial photograph showing the locations of coastal batteries in the vicinity of the Site.

Plate 41	Aerial photograph showing the locations of coastal batteries in the vicinity of the Site

Source: Google Earth *Not to Scale*

Legend	Site boundary	Coastal Batteries

Potential UXO Hazard

As with HAA gun bateries (see Section 4.2), the potential for misfired or unexploded shells from coastal batteries falling on the Site cannot be totally discounted

This forms part of the low background risk for any similar site in the UK.

It should also be noted that the coastal batteries are likely to have contributed to UXO in the marine environment in the vicinity of the Site.

10.2 Marine Ranges

No records have been found indicating that marine ranges were located on or in close proximity to the Site.

The nearest identified WWII offshore marine range was Range N25, approximately 17km east of the Site. This was used for HAA and LAA gunnery practice by the Chatham Military School. Defensively Equipped Merchant Ships (DEMS) also practiced on Range N25.

The location of the range is shown in Figure 14. The Shoeburyness Artillery Test Range (A81), the Yanlett Zone Coast Artillery Range (A83) and the Sheerness and Grain Coast Artillery Range (A85) have also been identified.

Figure 14	Extract of plan showing marine ranges in the vicinity of the Site, 1945

Source: National Archives *Not to Scale*

Legend	Site boundary

Given their distance from the Site and the tidal patterns in the area, marine ranges are not considered to provide a source of UXO hazard to the Site.

10.3 Marine Mines

During WWI, approximately 128,000No. mines were laid in the sea around the coast of the UK. At the beginning of WWII, the Admiralty ordered the laying of further extensive minefields around the coast of England. This included both defensive mines on beaches in order to prevent enemy landings, as well as approximately 100,000No. marine mines laid at sea to destroy enemy ships.

Known marine minefields were cleared at the end of WWII using the original layout plans, although less than 30% of the total number of sea mines were cleared as many were moved from their original positions by tidal currents. As a result there is a possibility that some remain in the marine environment and a mine can be washed up on a beach or found drifting in the water around any part of the UK's coastline.

Marine mines typically carried 100lbs to 500lbs (50kg to 250kg) of explosive. The initiating mechanisms in these mines have often deteriorated but the explosive charges will not have significantly altered unless the mine has split and the explosives have migrated and dispersed in the marine environment.

No records have been found indicating that marine mines were laid on the Site.

Records indicate that marine mines were laid in the River Thames during at least 25No. Luftwaffe raids between November 1939 and November 1941. These were effective in sinking vessels in the Thames Estuary on a number of occasions.

Marine mines are considered unlikely to provide a source of UXO hazard to the Site.

As with any similar area in the UK, the possibility that a buoyant mine is washed up or found drifting on the Site, albeit unlikely, cannot be totally discounted.

10.4 Attacks on Shipping

During WWI, ships were attacked by U-boats, German E-boats or Luftwaffe aircraft and were often bombed, mined or torpedoed.

The importance of the sea lanes in the River Thames and Thames Estuary meant that they were regularly attacked by Luftwaffe aircraft dropping ordnance including armour piercing bombs, mines and torpedoes. There are no records of the total numbers of these but, as an example, in two raids on the 11th August 1940, 100No. aircraft attacked ships mustering for a convoy in the Thames Estuary.

Many other attacks on vessels, both underway and at anchorage in the river Thames, occurred throughout WWII.

Evidence has been found indicating that enemy air raids on shipping took place in close proximity to the Site (see Section 3).

Further examples of offshore bombing incidents in the vicinity of the Site are given below.

2nd November 1940

HMT Deanbrook was sunk by aerial bombing involving influence mines at Tilbury, approximately 2.5km west of the Site.

HMT Lea was sunk by aerial bombing involving influence mines at Tilbury, approximately 2.5km west of the Site.

Aerial bombing is considered to provide a possible source of UXO hazard to the River Thames part of the Site (see Section 3.3.4 and Section 11.4).

10.5 Wrecks Containing UXO

No records have been found indicating that any live wrecks likely to contain a source of UXO hazard are located on the Site.

4No. lighter barges, typically used to transport goods and people, are shown as live wrecks on the Site.

The nearest military wreck is detailed below.

Wreck No. 69972

The 19th century three-masted training ship *HMS Cornwall* was bombed and sunk at its moorings near Clubbs Jetty, approximately 0.2km west of the Site, on the 6th July 1942. It was broken up and removed during the 1970s, with the remnants moved onshore, approximately 0.3km west of the Site.

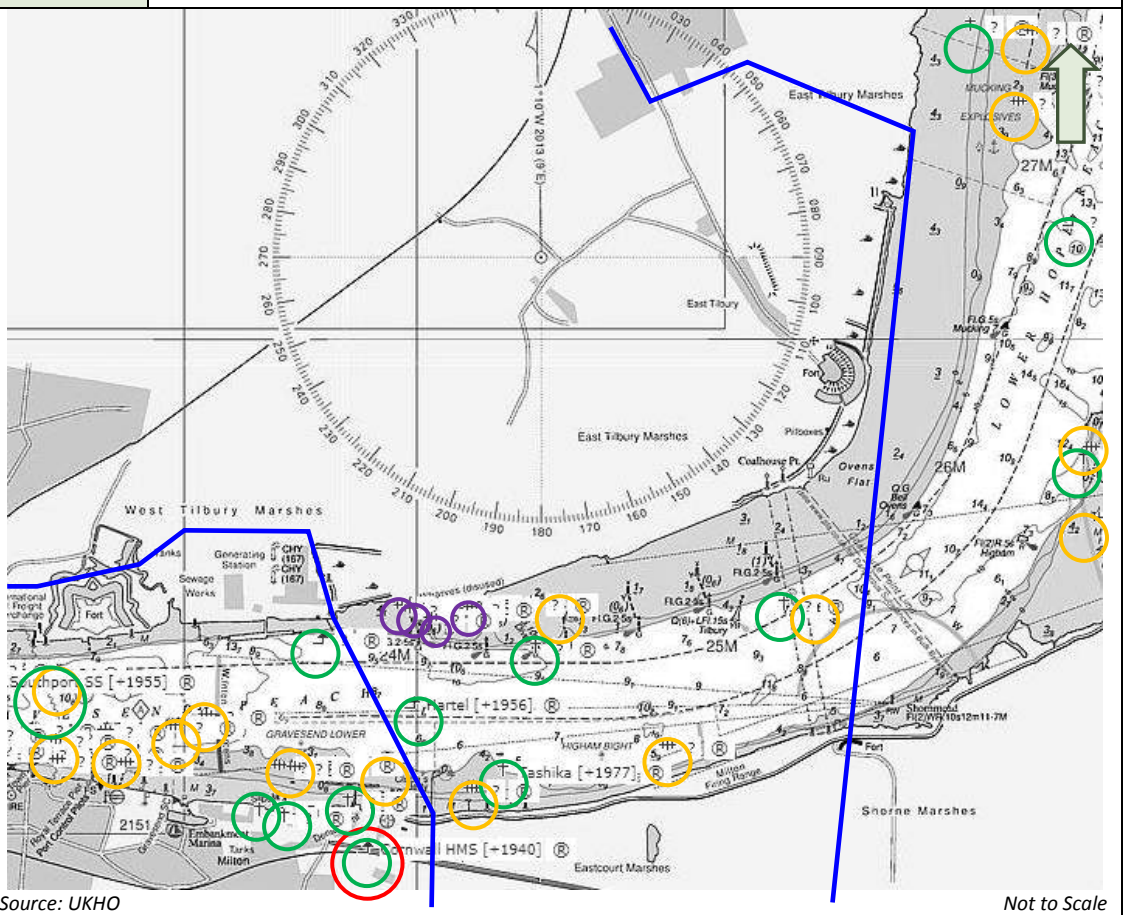
The nearest wreck known to have contained explosives is detailed below.

Wreck No. 12908

The wreck of a powder hulk is recorded off Mucking Flats, approximately 2.2km northeast of the Site.

Figure 12 is an extract from the Admiralty chart showing the wrecks and obstructions in the vicinity of the Site. *HMS Cornwall* is circled in red and the live wrecks (lighter barges) on the Site are circled in purple.

Figure 15	Admiralty chart showing wrecks in the vicinity of the Site [9]



Source: UKHO *Not to Scale*

Legend	Site boundary	Dead or lifted wrecks	Other obstructions[10]
	HMS Cornwall	Lighter barges	

No wrecks likely to contain explosives have been identified on the Site and wrecks are not considered to provide a source of UXO hazard to the Site.

10.6 Offshore Munitions Disposal

No records have been found indicating that offshore munitions disposal occurred on or in close proximity to the Site.

The 'Mucking Explosives' anchorage for vessels with cargoes of explosives is shown on Admiralty charts, adjacent to the northeast of the Site.

This is not considered to provide a source of UXO hazard to the Site.

[9] http://www.wrecksite.eu/Wrecksite.aspx

[10] Ibid. Marked as 'foul' - ground tackle remaining on the riverbed following the removal of PLA marine services mooring buoys.

11 OFFSHORE CURRENTS AND UXO

In most cases, because of mass, the largest items of UXO are unlikely to be transported very far from their original locations in the majority of marine environments. It is more likely that any large UXO on the river or sea bed will be periodically exposed by scour and then reburied by migrating sediment.

An exception to this would be buoyant or semi-buoyant UXO, as may be the case with some marine mines; smaller, lighter items of UXO, such as small shells and Small Arms Ammunition (SAA); or UXO with neutral buoyancy which could roll as bed load particles.

The following factors influence the likely migration of UXO in the fluvial and estuarial environment in the proximity of the Site.

11.1 Tidal Currents

The Thames Estuary in the vicinity of the Site has a tidal range exceeding 6m during spring tides, with correspondingly strong offshore tidal currents.[11] Tidal water levels are enhanced by a storm surge component, which may raise the tide levels by as much as 4m at high water.

There is an increasing tidal range upstream due to the funnelling effect of the estuary. The tidal current pattern is controlled by the funnelling effect. Tidal currents become increasingly flood-dominated in an upstream direction.

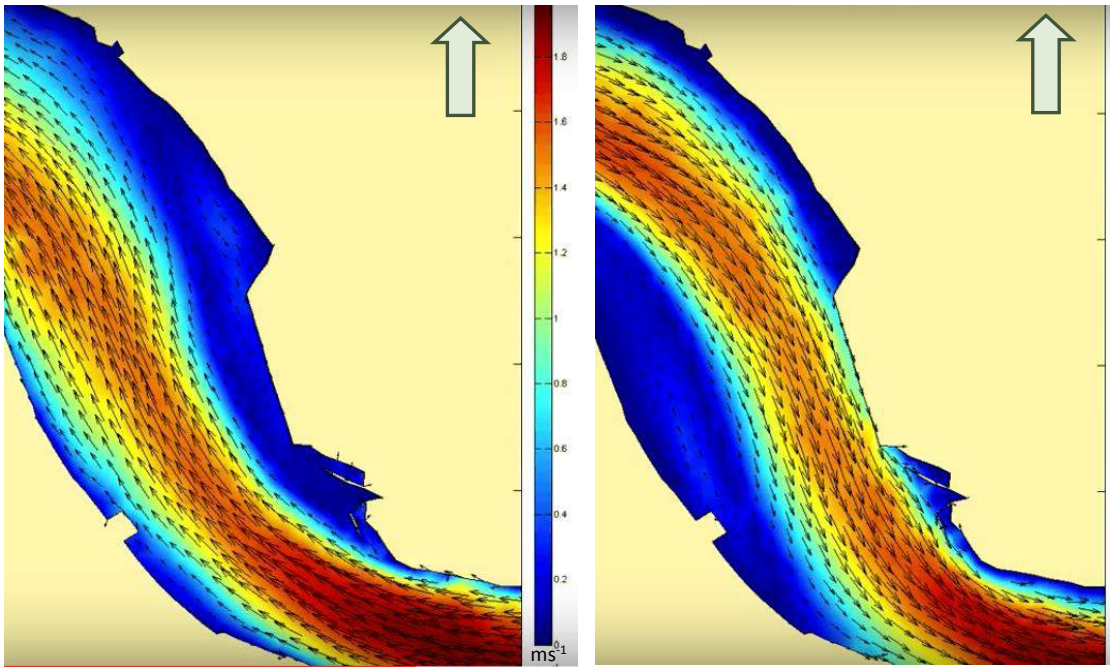
Between Sheerness and Gravesend, maximum ebb current velocities are in excess of the flood, upstream of Gravesend the flood current velocities are in excess of the ebb. [12]

The main freshwater input to the Thames Estuary has an average flow rate of 90 m^3s^{-1}. Major fluvial events occurred in 1947 (714 m^3s^{-1}) and 2003 (461 m^3s^{-1}). Average freshwater inputs are small compared to tidal discharge in the estuary. Tidal discharges of up to 15,000 m^3s^{-1} on both flood and ebb tides have been recorded.

Typical tidal streams in the vicinity of the Site with maximum velocities of up to $2m^{-s}$ are shown in Figure 16.

[11] https://pla.co.uk/Safety/Tidal-information
[12] http://www.visitmyharbour.com/articles/3172/hourly-tidal-streams-in-the-thames-estuary

Figure 16 Typical tidal streams in the vicinity of the Site at Tilburyness



FLOOD **EBB**

Source: https://pla.co.uk/Safety/Tidal-information *Not to Scale*

Tidal streams may exceed 2.5ms^{-1} in the central channel. Elsewhere the currents are controlled mostly by channel geomorphology and water depth. Peak near and offshore velocities are highest in deeper water, but for spring tides they are generally less than 2ms^{-1}.

Bed stresses created by these tidal currents may sweep the deeper channel clean of finer sediments.[13]

Near shore, in the vicinity of the Site, they are insufficient to entrain anything more than fine sediments, but they act in conjunction with waves to transport other material both onshore and offshore, as described in the following sections.

11.2 Wave Action

Wave data demonstrates that the wave environment within the estuary is predominantly wind driven. The prevailing wave direction offshore is from the east and southeast but fetches are dramatically reduced within the estuary in the vicinity of the Site, where intertidal areas and river bends protect the foreshores.

In the Lower Gravesend Reach, significant wave heights are 1.5m for 1 in 50 year winds and under 0.7m for 10 times a year winds.

The passage of large vessels also generates significant waves, which may influence sediment mobilisation and net direction of transport.

[13] Soulsby R & Clark S, Bed shear-stresses under combined waves and currents on smooth and rough beds, HR Wallingford Report TR137, 2006

Strong flood and ebb flows also interact with waves, leading to wave blocking in some locations and at some states of tide.

The generally low energy wave action dominates the near shore and intertidal sediment transport on the mudflats and shoals in the vicinity of the Site.

11.3 Sediment Pathways

The tidal current ebb- or flood-dominance has implications for sediment, and therefore UXO, transport in the Thames Estuary. Flood-dominance will tend to favour net movement of sediment into the estuary, whereas ebb-dominance will favour net export of sediment. The combined influences of wave action and tidal currents create a dynamic environment which continually moves fine sediments around the estuary.

The River Thames carries some 300,000 tonnes of sediment a year, much of which goes to build up the mud flats and sand banks in the estuary.[14] Approximately 20,000 tonnes of sediment is carried per tide but much of it is carried back on the following tide so the net effect is small.[15]

The river bed material is generally dominated by fine-medium gravel, overlain by alluvium.

Channel dredging in the River Thames and flood prevention schemes have influenced sediment supply to the estuarine parts of the system, including in the vicinity of the Site.

Maintenance dredging since 1928 has periodically removed shoals or sediments from existing navigational channels, berths and moorings to maintain an appropriate safe depth of water for navigation, construction or operational purposes. [16]

Annual dredging returns for the River Thames for the period 1928 to 1956 were 1,860,000m^3. Approximately 50% of this dredging originated in the Mud, Gravesend and Lower Hope Reaches.

Located upstream of Coalhouse Point, Diver Shoal (Sandbank), on the Site, has historically provided the limiting depth for the river as it impinges on the deep water channel.

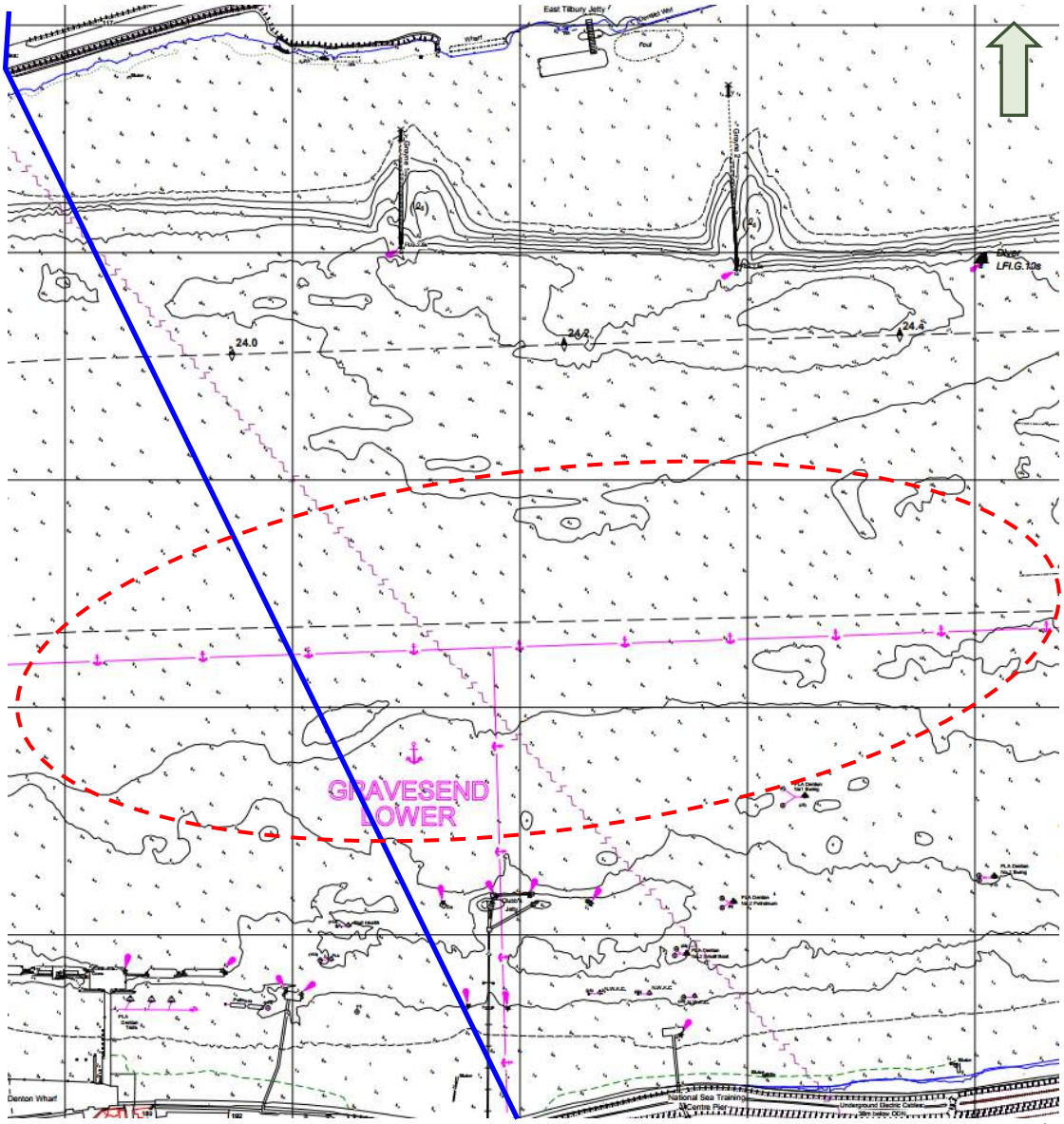
From 1965 there has been a significant reduction in maintenance dredging from the Gravesend Reach/Diver Shoal. Within the vicinity of the Site, dredging was approximately in balance with annual rates of sedimentation between 1977 and 1997, suggesting a sedimentation rate of 37,000 tonnes per annum.

Groynes and training works implemented on the northern side of the channel in 1995 successfully generated higher currents in the channel itself, while allowing accretion on the northern foreshore. This considerably reduced, although did not eliminate, the shoal's maintenance dredging requirements. Maintenance of depth was undertaken by water injection dredging and, less frequently, mechanical dredging to remove coarser materials.

Although approximately 75% of the granular bed load is transient and does not accumulate on the river bed, since 1997 bed elevations have increased slightly in response to the lack of dredging, as shown in Figures 17 to 20, extracts from the PLA hydrographic survey charts dated January to March 2016, showing the Site and Diver Shoal.

[14] https://www.pla.co.uk/Safety/PLA-Hydrographic-Service-Published-Surveys
[15] Tomes I M, Harmar O P & Thorne C R, Sediment Impact Analysis for the Lower Thames Flood Strategy, 2006
[16] https://www.pla.co.uk/Environment/Historic-Dredging.

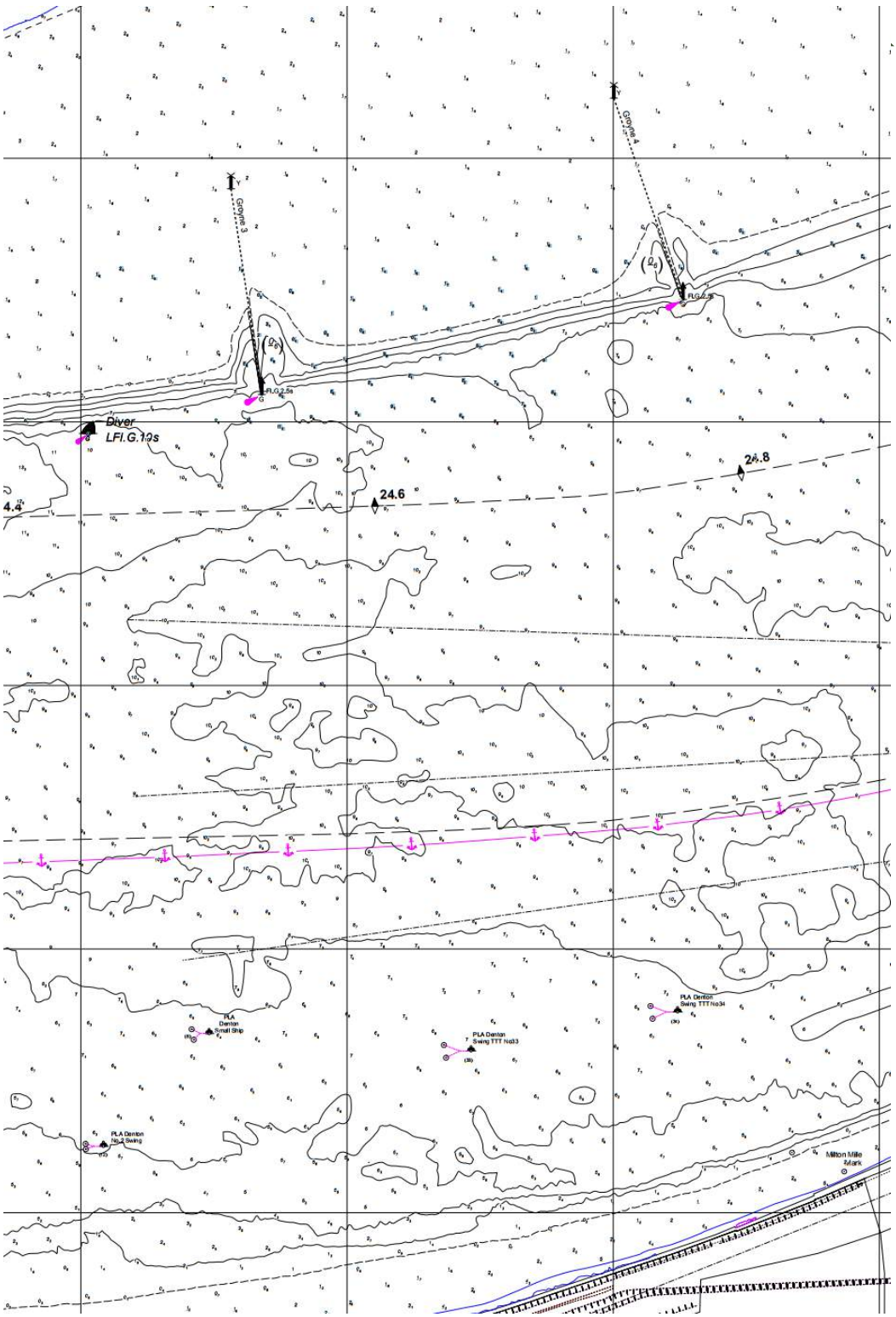
Figure 17	Extract from PLA hydrographic survey chart dated January to March 2016 (western)



Source: PLA *Not to Scale*

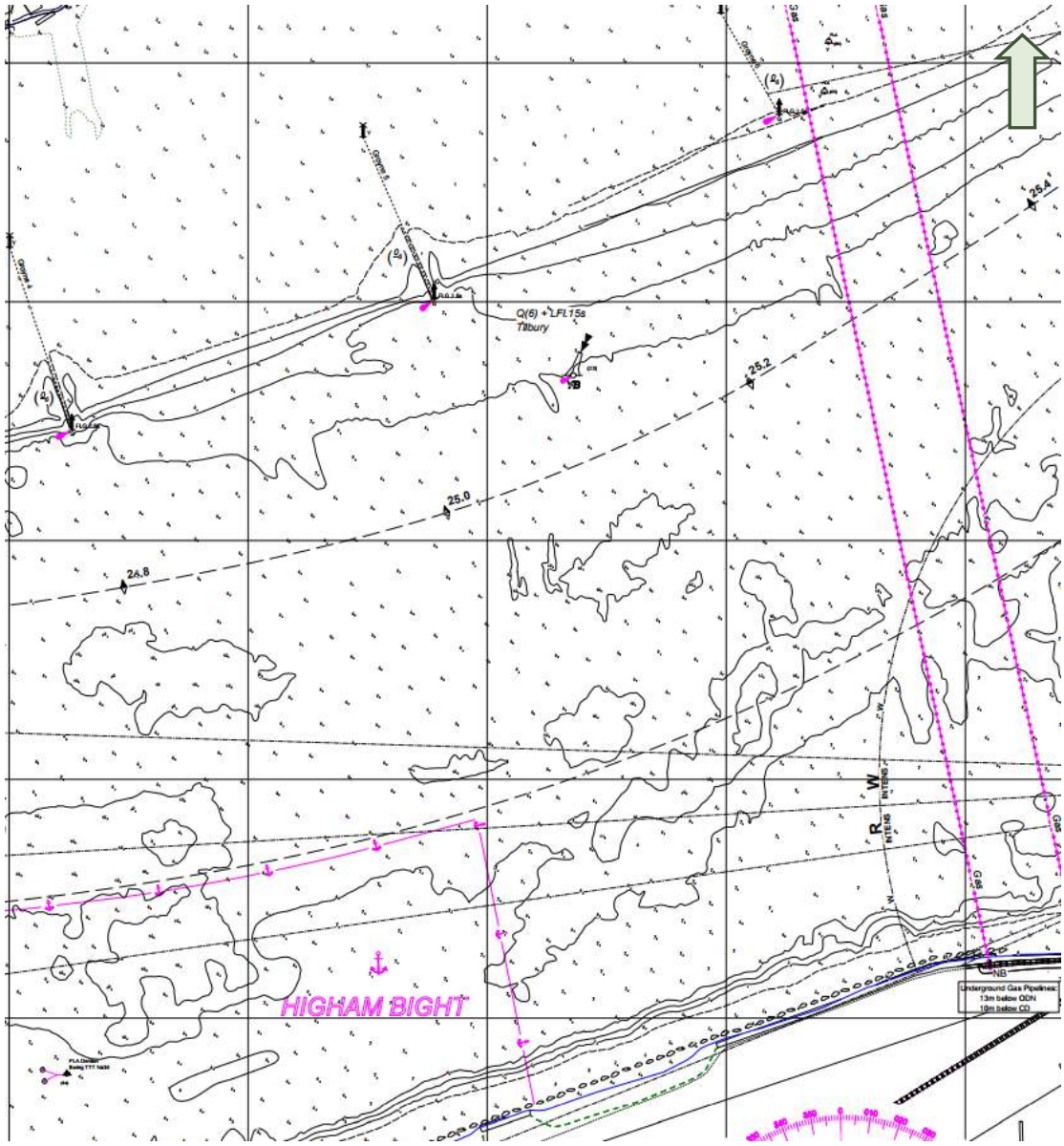
Legend	Site boundary	Diver Shoal

Figure 18	Extract from PLA hydrographic survey chart dated January to March 2016 (west central)



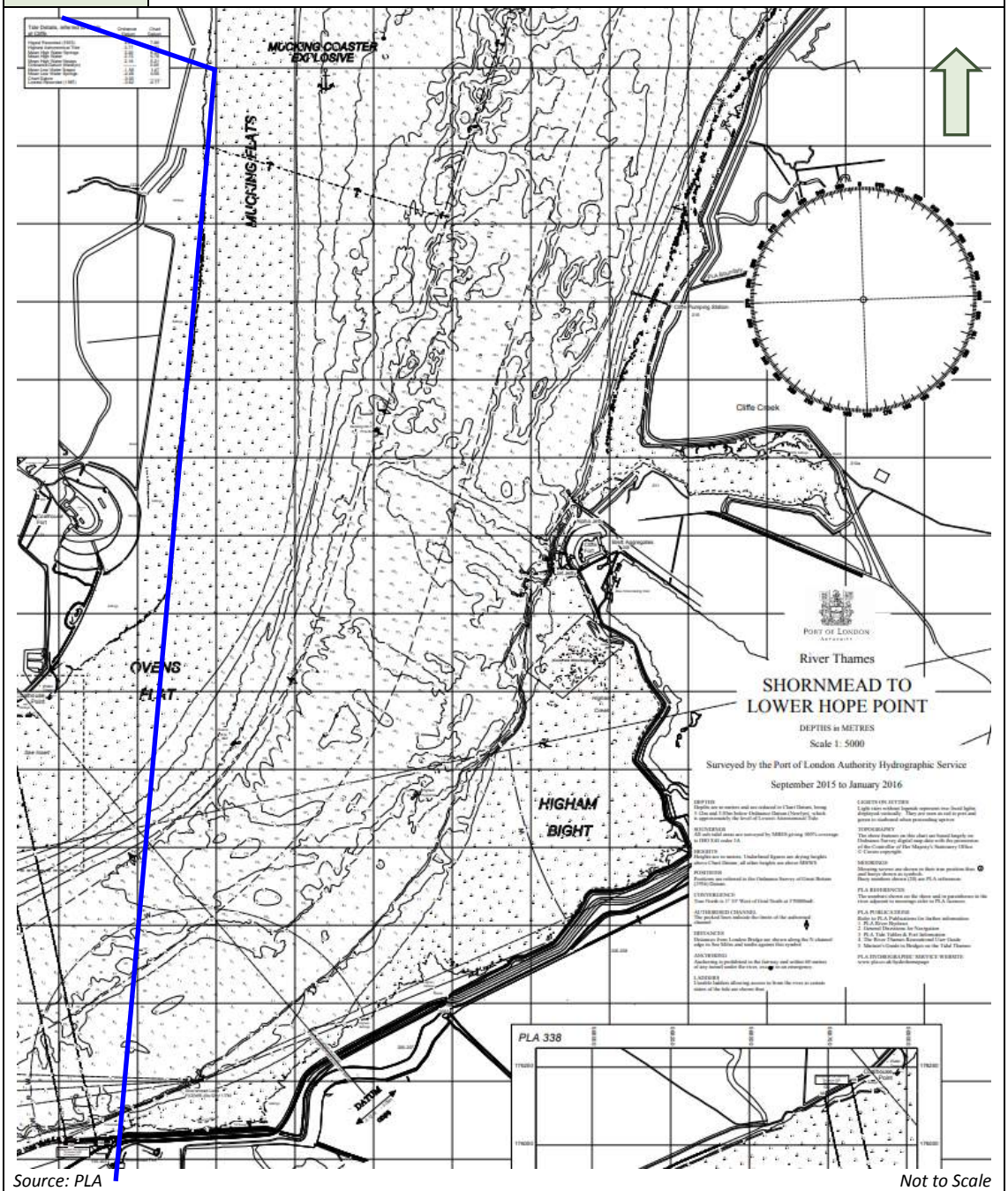
Source: PLA *Not to Scale*

Figure 19	Extract from PLA hydrographic survey chart dated January to March 2016 (east central)



Source: PLA *Not to Scale*

Figure 20	Extract from PLA hydrographic survey chart dated January 2016 (eastern)



Source: PLA *Not to Scale*

Legend	Site boundary

More recently the navigable depth, approximately 9.1m CD, of the Diver Shoal which impinges on the deep water channel in the vicinity of the Site, has been maintained by dredging every three to six months.

Approximately 6,000 m^3 of fine sand and silt, with little gravel but some debris, is regularly moved by water injection dredging. The debris accumulating on the river bed is removed by mechanical plant. The excavated material comprises coarser gravels, with additional waste materials such as tyres and steel debris.

11.4 UXO Migration

Given the river flow, tidal streams, wave action, pattern of sediment movement and dredging in the vicinity of the Site, as detailed above in Sections 11.1 to 11.3, it is considered that large UXO items in the marine environment are unlikely to be transported on to the Site.[17]

More likely is for large UXO (such as UXB and AA shells) to have fallen directly on the Site and penetrated the river bed at an estimated maximum depth of 19m for UXB and 2.5m for 4.5" UXAA shells.

It is considered that buoyant UXO (as may be the case with some marine mines), smaller, lighter items of UXO (such as small and medium sized shells) and SAA could roll as bed load particles during high river flow, flood, storm or tidal surge conditions.

Such conditions may provide a pathway for UXO migration onto the Site. However this is considered to present no more than a low background risk (as in any other such offshore environment in the UK).

[17] CIRIA C754, Assessment and Management of Unexploded Ordnance Risk in the Marine Environment, 2016, p.27

12 EXPLOSIVE ORDNANCE CLEARANCE ACTIVITIES

Official UK bombing statistics have been compiled from both British and German sources. There were differences in the way the figures were originally reported and collated which has led to discrepancies in the summary data.

Based on data from 1939 to 1945, War Office statistics indicate that 200,195No. HE bombs exploded within Great Britain. Additionally, 25,195No. HE bombs (representing 11%) were recorded as UXBs. However, records from the Royal Engineers who were responsible for bomb disposal at the time indicate that as of 27th February 1946 upwards of 45,000No. UXBs were disposed of.

On average 8.5% UXBs later self-exploded. In some cases the bombs had delayed action fuzes or were never intended to explode, their purpose being to cause inconvenience and fear.

Given the discrepancy in records and the fact that UXBs are still being found unexpectedly, it is clear that the original figures are understated and provide only an approximation of the number of potential UXBs in the UK.

War Office statistics also show that between October 1940 and May 1941 most of the UXBs (93%) were either 50kg or 250kg. It should be noted that details of the recovery and the size of the UXB were not always accurately reported.

The larger WWII UXBs are often difficult to recover due to both penetration depths and the presence of two or more fuzes, combined with more sensitive fillings of explosive mixtures including Amatol and Trialen.

12.1 Abandoned Bombs

Zetica holds the following record of a previously abandoned bomb on the Site.

15th September 1945

1No. 1,000kg bomb was abandoned at East Tilbury (TQ 688770). This bomb was removed at 20 feet (ft), approximately 6.1m, on the 10th October 1950.

No other officially recorded abandoned bombs are on the Site.

12.2 EOC Tasks

Zetica Ltd holds records of the following post-WWII EOC tasks being undertaken in the vicinity of the Site.

Undated

1No. 250kg HE bomb was discovered at an electricity sub-station in Wychelm, Hornchurch, approximately 1.1km west of the northern part of the Site.

1st May 1952

1No. 250kg HE bomb was discovered in a sandpit in Meesons Lane, Grays, approximately 2.8km southwest of the central part of the Site.

8th September 1955

1No. 50kg SC bomb was found on a beach at Tilbury, within approximately 0.4km south of the central part of the Site.

10th January 1956

1No. UXIB was found in Great Crabbles Wood, Shorne, approximately 2.1km east of the southern part of the Site. It was removed.

19th April 1962

1No. 250kg HE bomb was discovered in a sandpit in Meesons Lane, Grays, approximately 3km southwest of the central part of the Site.

1966

Live WWII ammunition was found in Laughing Water Lake, Cobham, on the southern part of the Site, previously used to station troops from RAF Gravesend.

10th June 1984

28No. 105mm MI HE shells (US), 21No. **Schermuly Flares**, 3No. 37mm AP rounds (US), were discovered at Columbia Wharf, Tilbury Docks, approximately 3km southwest of the central part of the Site. They were removed.

26th June 1984

9,830No. 2lb shells, 19,176No. 20mm shells, 10No. 105mm **MI High Explosive (HE) Shells** (US), 1No. 6" shell, 1No. 25lb carrier, 2No. 4.2" mortar shells, 1No. No. 36 Mills grenade, 5No. 57mm ammunition, 416No. 37mm ammunition and 1No. Mortar (unknown), were discovered at Columbia Wharf, Tilbury Docks, approximately 3km southwest of the central part of the Site. They were removed.

18th January 2001

1No. hand grenade was found on rail track near Stanbrook Road bridge, approximately 3.4km west of the southern part of the Site.

31st January 2007

1No. unexploded hand grenade was discovered in a rubbish bin in Thurrock, within approximately 0.5km southwest of the central part of the Site. It was removed.

29th April 2008

1No. UX hand grenade was found at an address in Salisbury Avenue, Stanford-le-Hope, approximately 2.5km northeast of the central part of the Site. It was removed to a local site for demolition.

4th September 2009

WWII era .303" live rounds and cartridges together with live 9mm rounds were discovered at Bramble Tree Wharf, Borstal, Rochester, approximately 2.1km south-southeast of the southern end of the Site. They were removed.

20th March 2012

22No. shells was discovered at Sacred Heart of Mary School, Upminster, approximately 2.4km west of the northern part of the Site. They were removed.

10th April 2012

1No. shell was discovered at Sacred Heart of Mary School, Upminster, approximately 2.4km west of the northern part of the Site. It was removed.

26th February 2013

1No. shell was discovered at the Waste Recycling Centre, Buckingham Hill Road, Thurrock, approximately 0.6km northeast of the central part of the Site. It was removed and found to be empty.

7th May 2015

1No. unexploded artillery shell was found near Gordon Promenade, Gravesend, between the cafe and Gravesend Sailing Club, approximately 1.8km west of the southern part of the Site.

17th May 2016

1No. UXAA shell was found on Trinity Road, Gravesend, approximately 1.8km west of the southern part of the Site.

27th May 2016

1No. UX WWII item was found in the back of a car parked in St. Mary's Close, Gravesend, approximately 1.7km west of the southern part of the Site.

The MoD has provided no additional information on official EOC tasks on the Site.

13 UXO HAZARD ASSESSMENT

13.1 UXO Hazard Level

The definitions for the levels of UXO hazard are provided below.

Definitions of UXO Hazard Level for a Site	
Hazard Level	**Definition**
Very Low	There is positive evidence that UXO is not present, e.g. through physical constraints or removal.
Low	There is no positive evidence that UXO is present, but its occurrence cannot be totally discounted.
Moderate	There is positive evidence that ordnance was present and that other uncharted ordnance may be present as UXO.
High	There is positive evidence that UXO is present.
Very High	As high, but requires immediate or special attention due to the potential hazard.

5No. potentially significant sources of UXO hazard have been identified on the Site and several parts of the Site have subsequently been assigned a moderate UXO hazard level.

Each Hazard Zone is identified by a code (M1-M5) relating to the anticipated hazard in that area. These are described below, with their extents shown in the figures on the following pages and on the accompanying UXO hazard zone plan, HE540039-ZET-GEN-GEN-MAP-GEO-00001:

WWII Bombing (M1)

Records indicate that during WWII in excess of 440No. **HE** bombs fell on the Site. At least 175No. of these were recorded as **UXB**.

It is considered prudent to assign a moderate UXO hazard level to 8No. parts of the Site where an elevated bombing density and high percentage of UXB were recorded.

Estimated bomb penetration depths in these areas vary between 1m and 19.0m depending on the weight of the bomb and the underlying geological materials (see **Table 3**).

River Thames (M2)

Several potential sources of UXO hazard have been identified on the part of the Site encompassing the River Thames.

The main anticipated ordnance hazard is from air-dropped UXB due to the heavy WWII raids in the region and UXAA **Shells** fired from the numerous gun batteries in the vicinity of the Site.

This part of the Site is therefore assigned a moderate UXO hazard level.

Milton Range (M3)

Part of the Site encompasses Milton Range, which has been in use from the 19th century until the present day.

In addition to training with **SAA**, records indicate that the range was used for mortar practice during WWII, providing a potentially significant hazard.

This part of the Site is assigned a moderate UXO hazard level due to the potential presence of **Mortars** (and other **Close Combat Munitions** such as **Hand Grenades**) at shallow depths.

Pipe Mines at RAF Gravesend (M4)

Canadian Pipe Mines were laid under the runways and perimeter track at Royal Air Force (RAF) Gravesend at the beginning of WWII so that the airfield could be destroyed in the event of a German invasion.

Part of the Site encroached upon the area that was pipe mined and records suggest that not all of the mines were removed during WWII and post-WWII clearances.

Therefore, it is considered prudent to assign this part of the Site a moderate UXO hazard level to account for the possibility that pipe mines remain in situ.

Bomber aircraft crashes (M5)

There are records of 2No. WWII bomber aircraft crashes on the Site at Botny Farm, near Orsett, and at Clay Tye Hill, near North Ockendon. No records have been found to indicate whether the bombs being carried by this aircraft had already been dropped, exploded on impact, or were retrieved from the crash site.

It is therefore considered prudent to assign these parts of the Site a moderate UXO hazard level at shallow depths to account for the possibility that UXB are present.

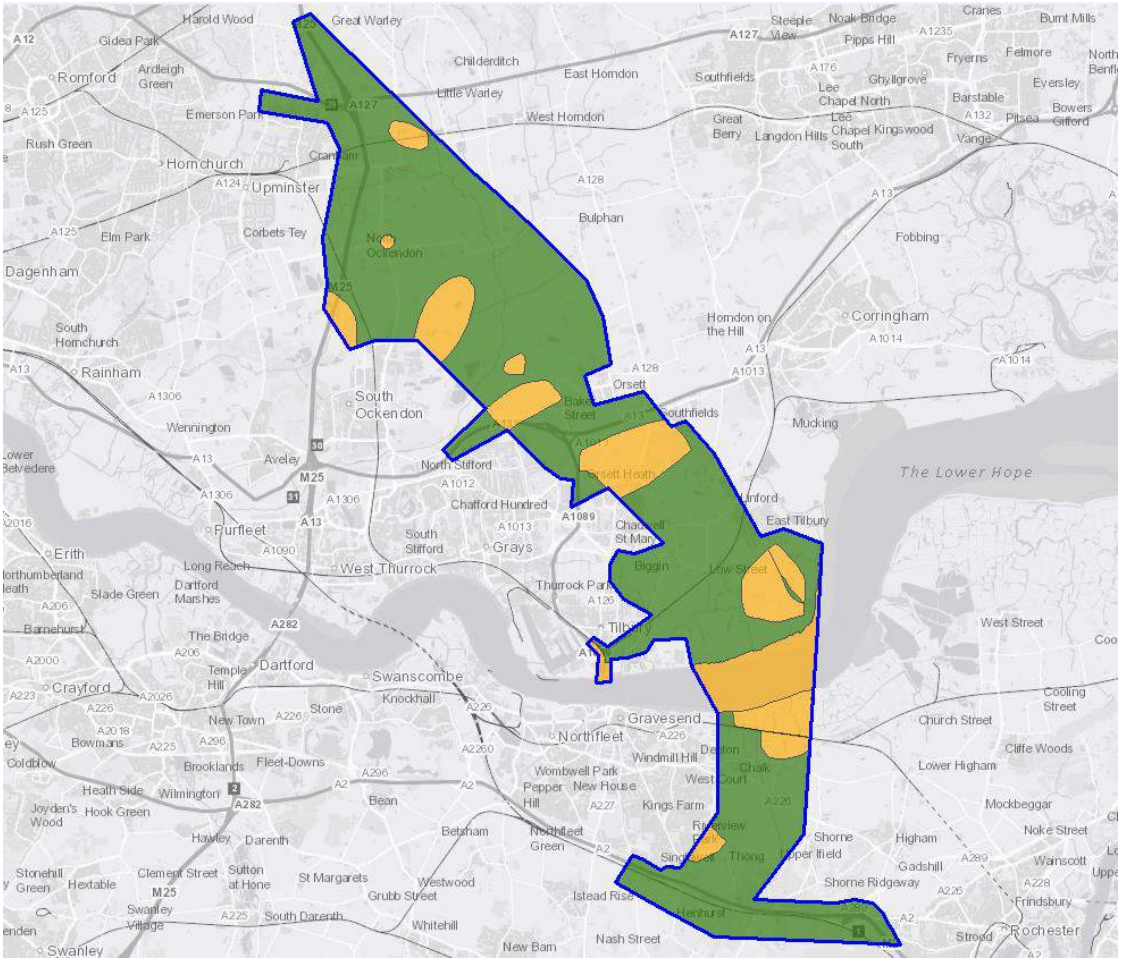
Remainder of the Site

No records of any significant bombing or other sources of UXO hazard have been identified on the remainder of the Site, which is assigned a low UXO hazard level.

It is therefore considered that the UXO hazard level on the Site can be zoned from low to moderate, as shown in Figure 21 below.

The definitive hazard plan is given in the accompanying, HE540039-ZET-GEN-GEN-MAP-GEO-00001.

Figure 21	UXO hazard zone plan of the Site

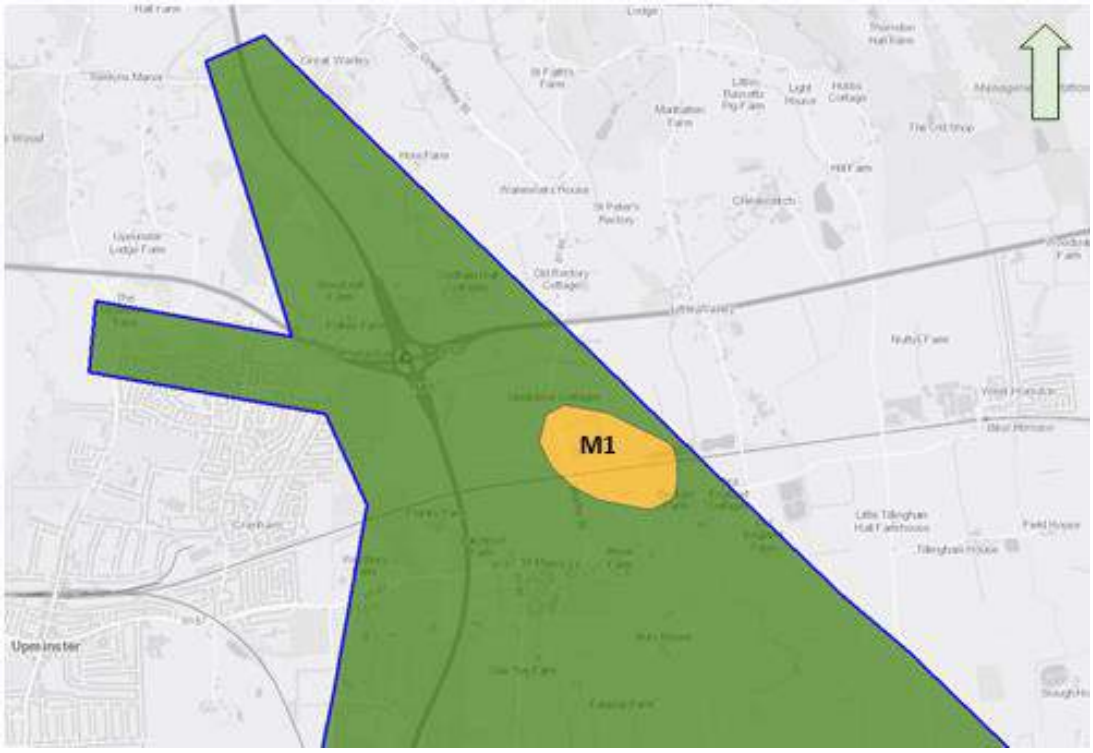


Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figures 22 to 27 provide more detailed extracts of the moderate UXO hazard level zones on the Site.

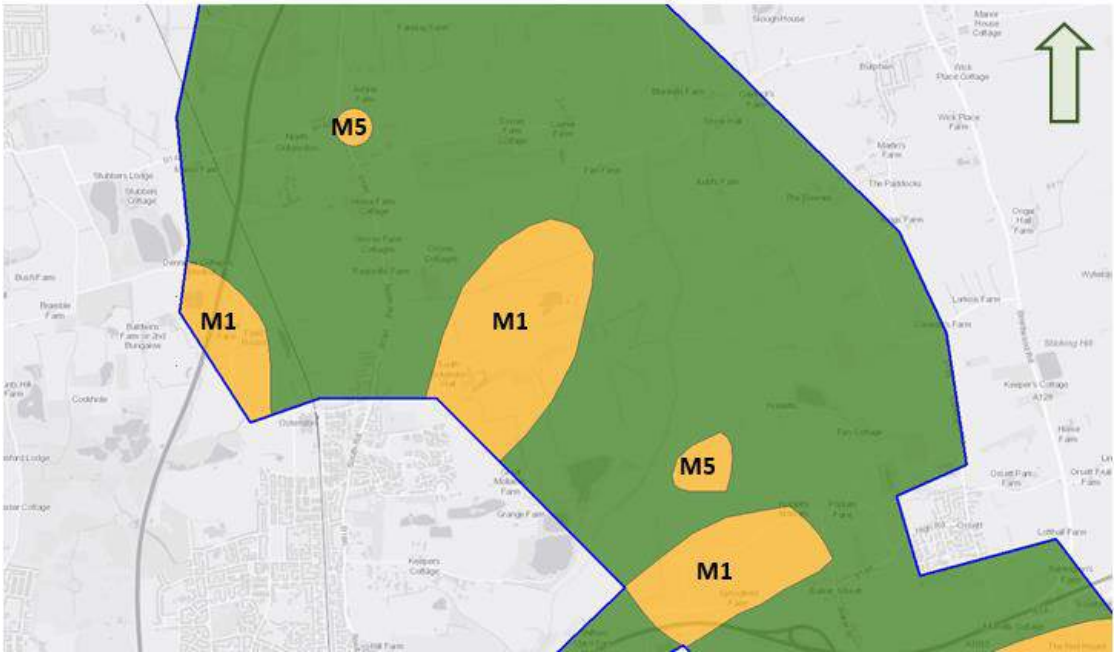
Figure 22	UXO hazard zone plan of the Site (Great Warley to Upminster)



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

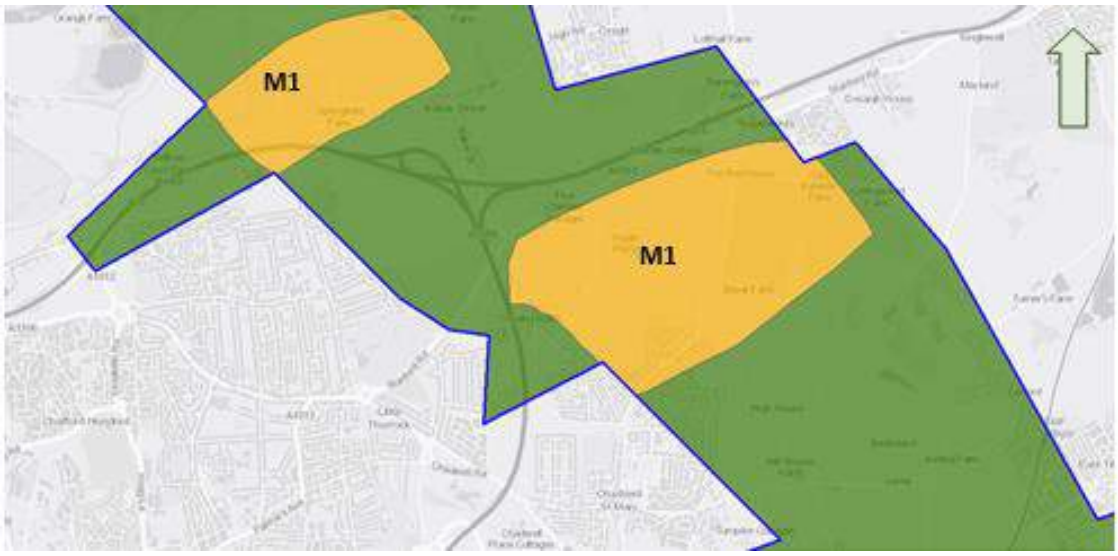
Figure 23	UXO hazard zone plan of the Site (North Ockendon to Baker Street)



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

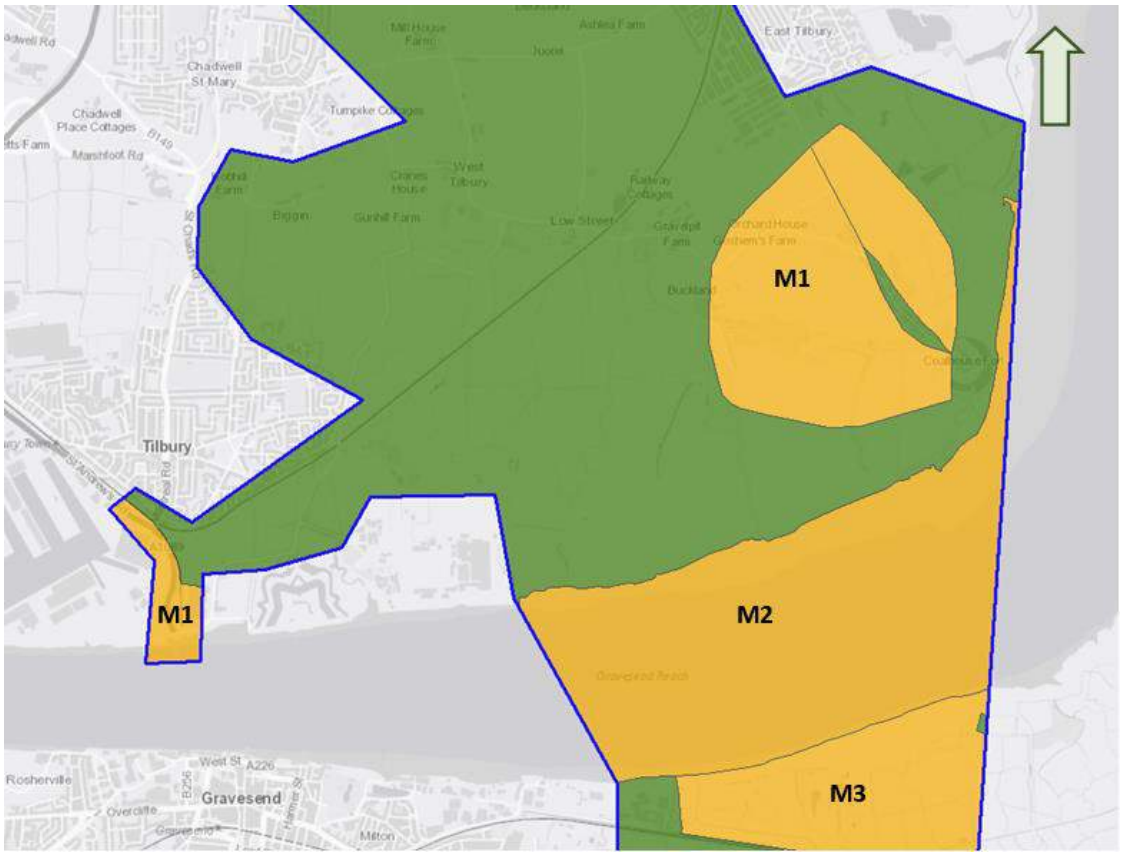
Figure 24	UXO hazard zone plan of the Site (Baker Street to Linford)



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate	
	High		Very High		Site boundary	

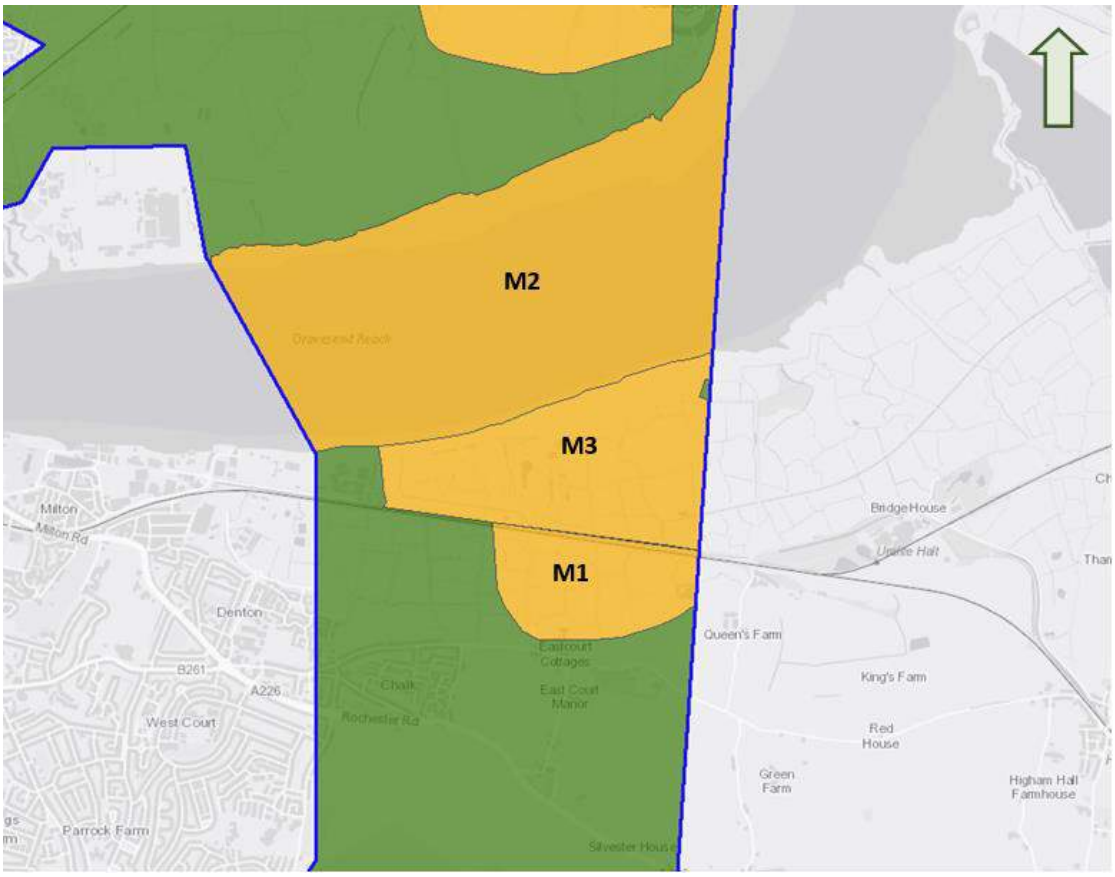
Figure 25	UXO hazard zone plan of the Site (Tilbury)



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure 26	UXO hazard zone plan of the Site (River Thames and Milton Range)



Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

Figure 27	UXO hazard zone plan of the Site (Chalk and Thong)

Source: © Crown Copyright 2018. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend					
	Very Low		Low		Moderate
	High		Very High		Site boundary

14 UXO RISK ASSESSMENT

14.1 UXO Risk Level

A UXO risk assessment has been undertaken for the proposed works, taking into consideration the identified UXO hazard.

Firstly, the probability of encountering UXO (PE) has been considered and rated for the different construction techniques, as detailed below.

Probability of Encounter (PE)	Rating
Frequent, highly likely, almost certain.	5
Probable, more likely to happen than not.	4
Occasional, increased chance or probability.	3
Remote, unlikely to happen but could.	2
Improbable, highly unlikely.	1
Impossible	0

Secondly, the probability of detonating a UXO (PD) has been considered and rated for the different construction techniques, as detailed below.

Probability of Detonation (PD)	Rating
Frequent, highly likely, almost certain.	5
Probable, more likely to happen than not.	4
Occasional, increased chance or probability.	3
Remote, unlikely to happen but could.	2
Improbable, highly unlikely.	1
Impossible	0

Next, the probability of encountering and detonating the UXO (PE x PD) have been used to generate an overall likelihood rating (P).

P = PE x PD	LIKELIHOOD of Encounter and Detonation	Rating
21 to 25	Frequent, highly likely, almost certain.	5
16 to 20	Probable, more likely to happen than not.	4
6 to 15	Occasional, increased chance or probability.	3
2 to 5	Remote, unlikely to happen but could.	2
1	Improbable, highly unlikely.	1
0	Impossible	0

P ranges from 25, a certainty of UXO being encountered and detonated on the Site by engineering activity, to 0, a certainty that UXO does not occur on the Site and will not be detonated by engineering activity.

The likelihood of encountering and detonating UXO during site works is multiplied by the severity of such an event occurring (P x S), in order to provide a risk level using the following matrix.

Severity (S)	Rating
Multiple fatalities	5
Major injury, long term health issues, single fatality.	4
Minor injury, short term health issues, no fatalities.	3
First aid case but no lost time or ill health.	2
Minor injuries, no first aid.	1
No injuries.	0

UXO Risk Matrix

		SEVERITY (S)					
		5	4	3	2	1	0
LIKELIHOOD (P)	5	25	20	15	10	5	0
	4	20	16	12	8	4	0
	3	15	12	9	6	3	0
	2	10	8	6	4	2	0
	1	5	4	3	2	1	0
	0	0	0	0	0	0	0

The final risk assessment for the Site is given in Table 9.

Table 9 UXO risk assessment for the Site

Hazard Zone	Potential UXO Hazard	Anticipated Works	PE	PD	P = PE x PD	Likelihood	Severity	Risk Rating	UXO Risk
M1	UXB	Shallow Excavations	2	3	6	3	5	15	Moderate
		Deep Excavations	3	3	9	3	5	15	Moderate
		Boreholes/CPT	2	4	8	3	4	12	Moderate
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	Low
		Deep Excavations	1	1	1	1	4	4	Low
		Boreholes/CPT	1	1	1	1	3	3	Low
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	Low
		Deep Excavations	1	1	1	1	4	4	Low
		Boreholes/CPT	1	1	1	1	3	3	Low
	SAA[18]	Shallow Excavations	2	1	2	2	2	4	Low
		Deep Excavations	2	1	2	2	2	4	Low
		Boreholes/CPT	1	1	1	1	2	2	Low

UXB – Unexploded Bomb; **UXAA –** Unexploded Anti-Aircraft; **SAA –** Small Arms Ammunition; **Close Combat Munitions**– see **Appendix 3**.

[18] For further information, see for example Prugh R W, The Effects of Explosive Blast on Structures and Personnel; Process Safety Progress (Vol 18 No. 1), 1999

Table 9	UXO risk assessment for the Site (continued)								
Hazard Zone	**Potential UXO Hazard**	**Anticipated Works**	**PE**	**PD**	**P = PE x PD**	**Likelihood**	**Severity**	**Risk Rating**	**UXO Risk**
M2	UXB	Boreholes/CPT	3	4	12	3	4	12	**Moderate**
	UXAA Shells	Boreholes/CPT	2	4	8	3	3	9	**Moderate**
	Close Combat Munitions	Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Boreholes/CPT	2	1	2	1	2	4	**Low**
M3	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	3	3	9	3	4	12	**Moderate**
		Deep Excavations	3	3	9	3	4	12	**Moderate**
		Boreholes/CPT	2	4	8	3	3	9	**Moderate**
	SAA	Shallow Excavations	4	1	4	2	2	4	**Low**
		Deep Excavations	4	1	4	2	2	4	**Low**
		Boreholes/CPT	2	1	2	2	2	2	**Low**
M4	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	2	1	2	2	2	4	**Low**
		Deep Excavations	2	1	2	2	2	4	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**
	Pipe Mines	Shallow Excavations	2	5	10	3	4	12	**Moderate**
		Deep Excavations	3	2	6	3	4	12	**Moderate**
		Boreholes/CPT	2	3	6	3	3	9	**Moderate**
M5	UXB	Shallow Excavations	2	3	6	3	5	15	**Moderate**
		Deep Excavations	3	3	9	3	5	15	**Moderate**
		Boreholes/CPT	2	4	8	3	4	12	**Moderate**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	2	1	2	2	2	4	**Low**
		Deep Excavations	2	1	2	2	2	4	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**

UXB – Unexploded Bomb; **UXAA –** Unexploded Anti-Aircraft; **SAA –** Small Arms Ammunition; **Close Combat Munitions**– see **Appendix 3**.

Table 9	UXO risk assessment for the Site (continued)								
Hazard Zone	**Potential UXO Hazard**	**Anticipated Works**	**PE**	**PD**	**P = PE x PD**	**Likelihood**	**Severity**	**Risk Rating**	**UXO Risk**
Low	UXB	Shallow Excavations	1	1	1	1	5	5	**Low**
		Deep Excavations	1	1	1	1	5	5	**Low**
		Boreholes/CPT	1	1	1	1	4	4	**Low**
	UXAA Shells	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	Close Combat Munitions	Shallow Excavations	1	1	1	1	4	4	**Low**
		Deep Excavations	1	1	1	1	4	4	**Low**
		Boreholes/CPT	1	1	1	1	3	3	**Low**
	SAA	Shallow Excavations	1	1	1	1	2	2	**Low**
		Deep Excavations	1	1	1	1	2	2	**Low**
		Boreholes/CPT	1	1	1	1	2	2	**Low**

PE (Probability of Encounter), PD (Probability of Detonation), P (Overall Probability)

Shallow excavations defined as <1.0m below ground level (bgl).

UXB – Unexploded Bomb; **UXAA** – Unexploded Anti-Aircraft; **SAA**– Small Arms Ammunition; **Close Combat Munitions**– see **Appendix 3**.

UXO Risk	Matrix Rating	Definition
Very Low	0-1	Little action is required by the client provided that suitable records and procedures are in place to ensure appropriate action is undertaken should the UXO risk level change.
Low	2-5	Tolerable to the client as engineering activity need not alter if UXO related procedures and controls are strictly adhered to.
Moderate	6-15	May be tolerable for the client, but it is prudent to reduce the risk where cost effective and reasonably practicable.
High	16-20	Tolerable to the client only where further risk reduction is impracticable or disproportionate to the risk involved. Essential that all practicable measures are taken to reduce the level of risk.
Very High	21-25	Unacceptable to the client except in extraordinary circumstances. Imperative that all control measures are taken.

14.2 Risk Mitigation Recommendations

To ensure that the UXO risk is reduced to As Low As Reasonably Practicable (ALARP) the following mitigation is advised:

Ground Investigation Works (Land)

Low Risk

Excavations

Where a low risk of UXO encounter is anticipated, industry good practice is simply to raise the awareness of those involved in excavations so that in the unlikely event that a suspect item is discovered, appropriate action is taken.

This awareness is to be provided through formal UXO awareness inductions. Typically ~1hour in duration, these briefings will be expected to provide site workers with:-

• Background to the potential UXO hazards that could be encountered.

• Awareness of how the UXO hazard could present a risk.

• Knowledge of what to do in the event that a suspect item is encountered.

The UXO awareness induction is to be provided along with back-up materials such as UXO awareness posters, emergency contacts numbers and other background information to assist site workers in becoming familiar with what potential UXO can look like. The materials can also be used by key staff to cascade out the salient points of the induction to others who visit or work on the Site.

By providing the UXO awareness induction, it ensures that in the unlikely event that UXO is encountered:-

• All site staff take appropriate action.

• The likelihood of harm to persons or property is reduced.

• Delays in works can be minimised.

It is the responsibility of the contractor to ensure that all staff have received an appropriate UXO awareness induction. A combination of identification badges and helmet stickers can be used to provide confirmation that staff onsite have undergone such an induction.

Boreholes/CPT

Clearance certification for borehole or CPT locations is considered prudent only if a zero tolerance to risk is adopted. Zero tolerance is commonly adopted for sites that have safety critical infrastructure such as nuclear establishments and oil refineries.

Moderate Risk (Hazard Zone M1)

Excavations

UXO awareness

It is considered essential to raise the awareness of those involved in excavations as per low risk.

Non-intrusive UXO detection

Where a potential UXO hazard has been identified at a shallow depth, a non-intrusive UXO detection survey is considered appropriate.

Ferrous targets (such as UXB) should be detected using a magnetometer.

As part of the procedure for the survey, at least 2No. inert ordnance-sized items should be temporarily buried on the Site at 0.5m depth.

The UXO contractor should then undertake surveys over these targets in order to provide practical (rather than just theoretical) references for target selection for the burial setting of the Site.

After surveying, identified anomalies can be modelled against the typical responses of the anticipated UXO type by an experienced and competent geophysicist. A list of targets which may be UXO can then be compiled.

Where excavations are proposed that are deeper than the instrument detection range, the above technique can be employed in ~2.0m layers to achieve the required detection depth.

Target investigation

Where the survey has identified targets that may be UXO, an intrusive investigation should be undertaken by an experienced Explosive Ordnance Clearance (EOC) team.

Typically all excavation works are conducted by hand. Where the ground proves too hard to economically hand excavate, a mechanical excavator and operator may be required.

The EOC Engineer will carry out a visual assessment on any suspect items and classify them as potential UXO or other material. If an item of UXO is identified, the UXO contractor should oversee and manage the disposal process.

After the investigation of all targets, a clearance report should be produced, detailing the detectability of anticipated targets, results of the target investigation, and the reduction of the UXO risk.

EOC Engineer supervision

As an alternative to prior detection and removal of UXO, an EOC Engineer can be used to supervise during excavation works.

This option is typically employed where UXO detection is not feasible due to ground conditions (such as excessive geophysical noise limiting detection of individual targets) or restricted access.

The EOC Engineer will carry out a visual assessment on any suspect items uncovered during the excavation task and classify them as potential UXO or other material.

Boreholes/CPT

Where deep (>3.0m) UXB detection is required, a magnetometer should be advanced into the ground at the proposed location of a borehole or CPT position. This technique enables detection of ferrous metal targets such as UXB.

The MagCone or MagDrill UXB technique can be used depending on the encountered geology, the MagDrill specifically where a more robust drilling technique is required.

MagDrill - this is a system that is suitable for working with ground investigation drillers. It allows a magnetometer to be lowered into the borehole to ensure the route is clear of potential UXB. This saves the mobilisation of a separate drilling or probing rig. Typical radius of detection should be approximately 1.0m for a 50kg bomb.

MagCone - this is a CPT based system that facilitates the pushing of a magnetometer into the ground at the proposed GI location. MagCone is suitable for cohesive/loose soils and has a much higher speed of operation compared to drilling based techniques. Typical radius of detection should be approximately 1.0m for a 50kg bomb.

Assuming no objects comparable to the UXB detection range are identified, then the borehole or CPT position can be considered clear of UXB.

Moderate Risk (Hazard Zones M3 & M5)

Excavations

UXO awareness

It is considered essential to raise the awareness of those involved in excavations as per low risk.

Non-intrusive UXO detection

Where practical, non-intrusive UXO detection techniques (as detailed above) should be employed to detect shallow-buried UXO.

Note that where non-ferrous targets are anticipated (such as some grenades and mortars), an electromagnetic survey technique is appropriate.

EOC Engineer supervision

As an alternative to prior detection and removal of UXO, an EOC Engineer can be used to supervise during excavation works (as detailed above).

Boreholes/CPT

Non-intrusive UXO detection and intrusive investigation of identified targets in advance of drilling or CPT is recommended.

As the anticipated UXO hazards in these areas are at shallow depths, deep UXB detection (MagDrill or MagCone) is not appropriate.

Moderate Risk (Hazard Zone M4)

It is understood that no GI works will take place in Hazard Zone M4, where there is a possibility of encountering pipe mines. If this changes, then a proactive approach to mitigation is essential due to the increased risk of an accidental detonation.

A surface non-intrusive geophysical scan, using a magnetometer, should be undertaken over a <50m by 50m square area centred on each GI location within this hazard zone.

This will provide a map of shallow-buried below ground features where, subject to ground conditions, linear features such as pipe mines will be more readily identifiable.

Rather than targeting potential pipe mines, the aim of each scan is to allow for the avoidance of potential shallow-buried UXO at the proposed locations.

Ground Investigation Works (Marine)

Moderate Risk (Hazard Zone M2)

Jackup Equipment for GI Work

Non-intrusive UXO detection

Non-intrusive UXO detection methods and either avoidance of or intrusive investigation of identified targets is recommended where practical. The aim of such surveying is to locate or make an area free of UXO for the safe deployment of jackup equipment for borehole and CPT investigations. See below for further considerations relating to the actual borehole and CPT investigation works.

The Client is understood to be planning a marine geophysical survey on the Site to detect potential buried UXO. Such a survey should achieve complete coverage of:

- The area of any proposed jackup equipment
- Additional extent allowing for possible repositioning of the jackup equipment
- An additional 5m radius to allow the jackup rig to be positioned with an exclusion zone from any potential UXO.

Based on the findings of this desk study, the main anticipated UXO types on the Site in the River Thames comprise air-dropped UXB and UXAA shells. These are likely to be located between the river bed and the maximum bomb penetration depth, and are unlikely to be relocated by tidal currents between the times of the survey and construction.

Either a total magnetic field strength or a vertical magnetic gradient system would be considered appropriate, but it is noted that survey altitudes typically need to be lower for vertical gradient systems to achieve the same detectability limits.

To detect the above items, it is recommended that the survey has an altitude of no more than 2m and a survey line spacing of no more than 1m. A 1m line spacing may be achieved by the use of an array of sensors, and an appropriate swath spacing to achieve full coverage at 1m intervals.

The minimum survey altitude is controlled by:-

- Survey noise levels (depending on the magnetometer system used, the geology and the amount of scrap metal on the Site; a system/site with low noise levels will allow detection of an anomaly from a higher survey altitude).

The survey line spacing in a survey is controlled by:-

- Survey altitude (at higher altitude, anomalies become smaller).
- Survey noise levels (a system/site with low noise levels will allow detection of an anomaly at lower amplitudes where the anomaly will be wider).
- The anticipated anomaly width of the UXO items anticipated (a UXAA shell will typically have an anomaly width of <2m).

Our recommendations are based on experience with a range of data quality levels. Based on modelled anomaly amplitudes, and assuming data quality and site conditions are consistent with our past experience, the anticipated UXO items would be detectable at up to 2 to 3m from the magnetometer. A recommendation to survey at a higher altitude should be supported by a surrogate item trial (SIT) survey.

The effectiveness of the marine geophysical survey should also be verified and demonstrated through the use of an SIT survey. An SIT survey uses one or more surrogate items, which should have similar material properties and dimensions to the UXO object of concern. Where possible, the items should be degaussed to remove any permanent magnetisation. The surrogate item should be deployed on the river bed in an area free of other ferrous anomalies (a pre-deployment survey is typically used to select a location for the surrogate item). The SIT survey should be conducted with the same equipment and survey configuration proposed for the main survey to verify detection capabilities. If practical, the SIT should also include surveys of the surrogate items at different survey altitudes to enable a depth limit of detection to be determined.

Review of contractor proposals and/or survey results can be provided by Zetica on request.

Boreholes/CPT

As described above, a marine geophysical survey will only be capable of detecting the anticipated UXO items (UXB and UXAA shells) to a distance of 2 to 3m below the magnetometer sensors. The anticipated items could be located anywhere from river bed and the maximum theoretical bomb penetration depth (19.0m).

Clearance certification for any borehole or CPT location is considered essential.

This can be achieved by advancing a magnetometer into the ground at the location in order to provide detection of ferrous metal targets such as UXB (as detailed above).

Assuming no objects comparable to the UXB detection range are identified, then the position can be considered clear of UXB.

Given the changing morphology of the seabed, there is potential for items of UXO to be buried or uncovered. Therefore marine geophysical surveys have a limited shelf life and due consideration should be given to the timing of the survey and the subsequent construction, as stated in CIRIA C754 'Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment'.

Future Works

This desk study should help inform any future works on the Site and, if required, Zetica can be consulted prior to any such works taking place to confirm that the risk mitigation being employed is appropriate for the anticipated hazard and the proposed work activity.

The report can be updated and refined as a more detailed construction plan becomes available.

Risk Mitigation Plan

It is recommended that a detailed risk mitigation plan is devised based on the information provided in this desk study and risk assessment, the proposed construction methodology, and the requirements of any planning conditions.

This should outline the recommended risk mitigation techniques in relation to the identified UXO hazards, proposed construction methods, and intended phase of works.

These risk mitigation measures are to be discussed and confirmed with the client to ensure that the level of proposed mitigation is appropriate for the intended use and the client's risk tolerance, and carefully addresses the often emotive issue surrounding UXO and development.

Outline Explosive Ordnance Disposal (EOD) proposals are also to be detailed to account for the type of UXO anticipated.

The contents and structure of any risk mitigation plan can be discussed with Zetica prior to compilation.

Table ***9***10, below, gives recommended actions in relation to the potential UXO risk level and the anticipated Site activity.

Table 10	Risk mitigation for assumed Site activities			
Risk Level	**Typical Future Activity on the Site**			
	None	**Shallow Excavations (<1.0m)**	**Deep Excavations (>1.0m)**	**Boreholes/CPT**
Very low	Ensure suitable records and procedures are in place to highlight the risk should future development be planned.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.
Low	**As very low.**	**As very low.** **+ It is considered prudent to include some UXO awareness training in site inductions.**	**As very low.** **+ It is considered prudent to include some UXO awareness training in site inductions.**	**As very low.** **+Clearance certification for borehole or CPT locations would be considered prudent only if a zero tolerance to risk is adopted.** **Zero tolerance is commonly adopted for sites that have safety critical infrastructure such as nuclear establishments and oil refineries.**
Moderate	**As very low.**	**As low.** **+Non-intrusive investigation methods considered prudent where practical.** **+Alternatively, EOC Engineer supervision is considered prudent.**	**As low.** **+Non-intrusive investigation methods considered prudent where practical.** **+Alternatively, EOC Engineer supervision is considered prudent.**	**As low.** **+Clearance certification for borehole or CPT locations is considered essential.**
High	As very low.	As moderate. +Non-intrusive investigation methods considered essential where practical. + Alternatively, EOC Engineer supervision is considered essential.	As moderate. +Non-intrusive investigation methods considered essential where practical. + Alternatively, EOC Engineer supervision is considered essential.	As moderate.
Very High	Requires immediate or special attention.	Requires immediate or special attention.	Requires immediate or special attention.	Requires immediate or special attention.
The above table is for guidance only.				

APPENDICES

Appendix 1 WWII Bombing Incident List

This appendix outlines WWII bombing incidents on the Site. To aid the reader, the Site has been divided into three parts, northern, central and southern.

Northern Part of the Site

26th July 1940

HE bombs (number unspecified) bombs fell between Brentwood and North Ockendon, including the Site.

1st August 1940

1No. UXB was discovered in a field east of Clay Tye Hill, North Ockendon.

24th August 1940

1No. UXB was discovered in a field northwest of the junction of the B186 and the Southend arterial road, on the eastern site boundary.

29th August 1940

HE bombs (unspecified number) fell on North Ockendon.

4th September 1940

IBs fell on North Ockendon.

9th September 1940

UXBs (unspecified number) were located in North Ockendon.

10th September 1940

HE bombs (unspecified number) fell on Broadfields Farm.

1No. HE bomb fell on Poole's Farm, Hall Lane, Upminster.

11th September 1940

1No. HE bomb fell on North Ockendon. It was recorded as UXB.

16th September 1940

2No. OBs and 100NO. IBs fell half a mile east of Ockendon Road, north of Fen Lane, North Ockendon.

18th September 1940

1No. HE bomb fell on Ockendon Road, leading to the White House Inn, North Ockendon. It was recorded as UXB.

18th-19th September 1940

1No. HE bomb fell to the west of the junction of Warley Street and the A127.

21st September 1940

1No. HE bomb fell 100yds north of the footpath on Front Lane, Cranham. It was removed.

23rd September 1940

9No. HE bombs fell between the LMSR railway line, on the Site, and Dennis's Corner. They were all recorded as UXB.

1No. HE bomb fell on Kemps Farm. It was recorded as UXB.

25th September 1940

1No. PM fell near Monks Farm, west of Cranham.

HE bombs fell on Harold Wood, Tye Lane and Hornchurch, including the Site.

26th September 1940

HE bombs (number unspecified) fell on Broadfields Farm.

4th October 1940

1No. HE bomb fell on open fields at North Ockendon Hall Farm.

7th October 1940

1No. OB fell in field near the junction of St Marys Lane and Warley Street.

9th October 1940

1No. HE bomb fell on Kemps Farm. It was recorded as UXB.

13th October 1940

1No. HE bomb fell on the railway line near South Ockendon.

14th October 1940

4No. DAB fell north of Dennises Lane.

16th October 1940

1No. HE bomb fell on Brookman's Farm, Front Lane, Cranham, on the Site.

10No. HE bombs fell between Fairholme Gardens, Moor Lane and the A127, Cranham.

17th October 1940

1No. HE bomb fell 350 yards south of Ockendon Road and 20 yards west of Pea Lane. It was recorded as UXB.

20th October 1940

2No. HE bombs fell north of the junction of Hall Lane and Bird Lane, Cranham. They were recorded as UXB and removed. (west of hall lane)

1No. HE bomb fell west of Hall Lane and south of Bird Lane, Cranham. It was recorded as UXB and removed.

25th October 1940

1No. Delayed Action Bomb (DAB) south of Dennis's Cottages, Dennises Lane, exploded during disposal operations.

3No. HE bombs fell 400yds north of Berry Farm, North Ockendon, on the Site. They were recorded as UXB and removed.

26th October 1940

1No. HE bomb fell 500yds south of Bird Lane, 50yds east of Hall Lane, Cranham. It was recorded as UXB and removed the next day.

28th October 1940

8No. HE bombs fell on open ground at Manor Farm, North Ockendon.

4th November 1940

2No. UXBs were removed from a field west of Hall Lane, near the junction with Bird Lane, Cranham.

5th November 1940

4No. HE bombs fell on and near the CWS factory, Warley Street. They were recorded as UXB and removed.

23rd November 1940

6No. HE bombs fell on fields between Hall Farm and South Ockendon Mental Hospital, including the Site. 1No. of these was a Delayed Action Bomb (DAB) and exploded the next day.

24th November 1940

1No. HE bomb fell near Hall Farm, South Ockendon. It was recorded as UXB.

27th November 1940

9No. HE bombs and 1No. OB fell on the north side of St Mary's Lane, North Ockendon.

29th November 1940

1No. HE bomb fell in a field behind Cranham Place Farm. No exact location was given. It was recorded as UXB.

1No. HE bomb fell on North Ockendon Hall Farm.

10th December 1940

1No. HE bomb fell 200yds east of Home Farm Cottages, North Ockendon. It was recorded as UXB.

29th December 1940

18No. UXIBs were discovered between Puddledock Wood and Berry Farm, North Ockendon.

31st December 1940

1No. HE bomb fell on Pea Lane. It was recorded as UXB.

13th January 1941

IBs fell on Great Warley, between Great Warley Street and Moor Lane.

19th January 1941

2No. HE bombs fell on Broadfields Farm.

23rd January 1941

1No. HE bomb fell 250 yards west of Pea Lane and 300 yards north of Dennises Lane. It was recorded as UXB.

19th March 1941

4No. HE bombs fell 1 mile east of Wantz Bridge, St Mary's Lane, Cranham.

20th March 1941

1No. HE bomb fell 500yds north of South Ockendon and west of North Road.

4th April 1941

2No. HE bombs fell east of North Road and south of Groves Farm. They were both recorded as UXB.

9th April 1941

1No. UXB was located 650 yards west of the junction of the B186 and A127.

17th April 1941

2No. HE bombs fell between Chapman Hall and Chapman Cottages, Hall Lane, Upminster.

19th April 1941

2No. HE bombs fell on Kemps Farm. They were both recorded as UXB.

14th August 1941

1No. HE bomb fell 600 yards north of The Hall, South Ockendon. It was recorded as UXB.

9th September 1941

1No. HE bomb fell 400 yards northeast of The Hall, South Ockendon. It was recorded as UXB.

4th March 1943

8No. HE bombs fell in a stick from open ground on North Ockendon Hall Farm, to open ground south of Dennises Lane.1No. of which was recorded as UXB.

1No. HE bomb fell south of South Ockendon Hall. It was recorded as UXB.

8th March 1943

1No. V1 exploded in the air between Hall Lane and Front Lane, Cranham.

5th May 1943

1No. UXB was removed from a field east of Moor Lane, Upminster.

9th October 1943

1No. HE bomb fell on the ALMA factory, Warley Street.

21st October 1943

1No. HE bomb fell between St Marys Lane and the arterial road, east of Great Warley Street. 16No. additional craters were identified. On and adjacent to the eastern boundary of the Site. Damage was recorded at Codham Hall.

23rd October 1943

1No. HE bomb fell near the CWS factory, Warley. It was recorded as UXB and removed.

21st January 1944

1No. PhIB fell on open ground north of Bullen Farm, North Ockendon. It was recorded as UXPhIB and removed.

22nd January 1944

2No. HE bombs fell near St Mary's Church, North Ockendon.

8No. HE bombs fell near Codham Hall. It was recorded as UXB.

29th January 1944

1No. HE bomb fell on Codham Hall Wood. It was recorded as UXB.

1No. PhIB fell on open ground east of Berry Farm, North Ockendon. It was recorded as UXPhIB and removed.

1No. V1 fell south of St Mary's Lane, Cranham, on the Site boundary.

30th January 1944

1No. HE bomb and 1No. Phosphorous Incendiary bomb (PhIB) fell on Kemps Farm. The HE bomb was recorded as UXB.

20th February 1944

3No. HE bombs fell north of Hall Farm, South Ockendon. 2No. were recorded as UXB.

1No. HE bomb fell northeast of Hall Farm, South Ockendon. It was recorded as UXB.

1No. HE bomb fell 300 yards east of Whitestaffs Wood.

2No. HE bombs fell southwest of Middle Farm.

21st February 1944

8No. HE bombs fell 200yds east of Hall Farm, South Ockendon.

18th March 1944

5No. UXB were discovered in a woodland near Woodside Cottage, Stoney Hill.

22nd March 1944

IBs fell on North Ockendon.

17th June 1944

1No. V1 fell 200 yards south of St Mary's Lane.

3rd August 1944

1No. V1 fell in a field west of Folkes Lane, Cranham.

11th October 1944

1No. V1 fell on Fen Lane, North Ockendon.

11th November 1944

1No. V1 fell near Codham Hall.

26th November 1944

1No. V2 fell on Cranham, on the Site boundary.

Central Part of the Site
23rd July 1940
2No. HE bombs fell 500yds west of South Ockendon Railway Station.
1st August 1940
At least 2No. HE bombs fell in the River Thames between Coalhouse Fort and Tilbury Fort.
3rd August 1940
Approximately 40No. IBs fell on Anchor Lane and Condovers Farm.
2No. HE bombs fell northwest of Baker Street, Orsett.
18th August 1940
1No. HE bomb fell north of the railway line near London Road, Tilbury.
26th August 1940
1No. UXB was located near Low Street Station, East Tilbury.
29th August 1940
IBs were reported at Low Street Station and Tilbury Station.
31st August 1940
IBs fell on the dust chute at Tilbury.
1st September 1940
1No. HE bomb fell on Tilbury Dock Railway Station.
2nd September 1940
1No. HE bomb fell 150yds from Grove Road. It was recorded as UXB.
3rd September 1940
2No. HE bombs fell southwest of Coalhouse Fort. They were recorded as UXB.
1No. UXB was discovered on Ferry Road, Tilbury.
5th September 1940
200No. IBs fell across Heath Place Farm, Orsett Heath.
A large number of IBs fell between the Orsett and Buckles Farm AA gun sites.
3No. HE bombs fell on Grove Farm, South Ockendon. They were all recorded as UXB.
6No. HE bombs fell near Buckland Farm.
IBs fell on Tilbury Marshes.
IBs fell on Tilbury, including the Site.
1No. HE bomb fell near the sea wall, Tilbury.
1No. UXB was discovered at Railway Cottages, Tilbury.
1No. HE bomb fell on the Co-operative Laundry, Tilbury.

6th September 1940

6No. HE bombs fell near the gun battery, Chadwell St Mary.

1No. UXB was discovered at Bull Hall Cottages, Chadwell St Mary.

6No. HE bombs fell on Biggins Hill, Chadwell St Mary.

8th September 1940

IBs fell on South Ockendon and Orsett.

HE bombs (number unspecified) fell on Orsett and Orsett Heath.

10th September 1940

1No. HE bomb fell on Botny Farm. It was recorded as UXB.

1No. HE bomb fell on Surridges Dust Chute, East Tilbury Marshes.

1No. HE bomb or AA shell fell near the road between Orsett and Baker Street.

IBs fell on Fielding Avenue, on and adjacent to the Site.

13th September 1940

IBs and HE bombs (number unspecified) fell on Orsett Heath and Baker Street, including the Site.

1No. HE bomb fell 350yds southeast of Heath Place Farm, Orsett Heath.

1No. HE bomb fell on Seaborough Hall. It was recorded as UXB.

2No. HE bombs fell southeast of Heath Place Farm, Orsett Heath. They were recorded as UXB.

1No. HE bomb fell 250yds of Bucklands Farm.

HE bombs (number unspecified) fell on Lower Crescent, Linford.

2No. HE bombs fell on Orsett Golf Course, encroaching on the Site. They were recorded as UXB.

HE bombs (number unspecified) fell on Lower Crescent, Linford.

HE bombs (number unspecified) fell on Somerset Crescent, Linford.

1No. HE bomb fell north of the junction of Northumberland Road and Stanford Road. It was recorded as UXB.

4No. HE bombs fell near the barrack wall of Coalhouse Fort. These were recorded as UXB and removed.

2No. HE bombs fell to the southwest of Coalhouse Fort. They were removed as UXB and removed.

14th September 1940

There was widespread IB and HE bombing across southeast Essex, including the Site.

1No. HE bomb fell on the front lawn of the Rectory, Orsett. It was recorded as UXB.

Approximately 40No. IBs fell near the gun battery, Chadwell St Mary.

1No. HE bomb fell near the sea wall at Tilbury.

15th September 1940

1No. HE bomb fell 200yds east of Seaborough Hall. It was recorded as UXB.

2No. HE bombs fell on East Tilbury, near Coalhouse Point.

16th September 1940

1No. OB and 1No. HE fell on East Tilbury.

4No. HE bombs fell on Tilbury Marshes. No exact locations were given.

17th September 1940

2No. HE bombs fell on the dust chute at East Tilbury.

1No. HE bomb fell on Hill House Farm, Orsett. It was recorded as UXB.

1No. HE bomb fell 200yds south of the farmhouse at Poplars Farm, Orsett. It was recorded as UXB.

18th September 1940

Enemy action caused widespread damage across Essex, including the Site.

4No. HE bombs fell on Tilbury Marshes. No exact locations were given.

IBs fell on West Tilbury.

2No. HE bombs fell near the gun battery, Chadwell St Mary.

1No. HE bomb fell in a field near Parker's Avenue, Tilbury. It was recorded as UXB and removed the same day.

1No. HE bomb fell near the east signal box, Tilbury. It was recorded as UXB and removed the same day.

19th September 1940

1No. HE bomb and AA shells fell on Baker Street.

IBs fell on West Tilbury.

1No. HE bomb fell in a field near Mill House, Baker Street. It was recorded as UXB.

HE bombs fell on Tilbury Docks, on and adjacent to the Site. No exact locations were given.

HE bombs fell on the Railway Cottages, Tilbury.

1No. HE bomb fell on the Laundry at Tilbury.

20th September 1940

3No. HE bombs fell near Heath Place Farm, Orsett Heath. They were recorded as UXB.

14No. HE bombs fell on the saltings at East Tilbury.

1No. HE bomb fell near hairpin Bridge, between Ferry Road and Dock Road, Tilbury, on the Site.

21st September 1940

1No. HE bomb fell near High House Farm, Chadwell St Mary. It was recorded as UXB.

23rd September 1940

Damage was recorded on the railway at Dennis' Corner, South Ockendon.

24th September 1940

1No. HE bomb fell 300yds east of Marsh Farm Bungalow on Tilbury Marshes.

1No. HE bomb fell on West Tilbury.

25th September 1940

2No. HE bombs fell on Hall Farm, South Ockendon. They were recorded as UXB.

1No. HE bomb fell 1 mile east of Hall Farm, South Ockendon.

1No. UXB was removed south of Fen Lane Corner, Bulphan.

26th September 1940

IBs fell on South Ockendon, including the Site.

28th September 1940

1No. PM fell on Orsett Golf Course.

29th September 1940

1No. HE bomb fell 300yds east of Seaborough Hall. It was recorded as UXB.

1No. PM fell 100yds south of the club house, Orsett Golf Course.

1No. HE bomb fell near Potash Hill, Orsett Heath Place. It was recorded as UXB.

2nd October 1940

1No. HE bomb fell on Brentwood Road, Chadwell St Mary.

4th October 1940

1No. HE bomb fell on Low Street Station, East Tilbury.

5th October 1940

1No. HE bomb fell on Barrington's Farm, Orsett. It was recorded as UXB.

IBs fell on East Tilbury.

1No. HE bomb fell on Hall Farm, South Ockendon. It was recorded as UXB and removed.

1No. HE bomb fell southwest of Bull Hall Cottages, Sandy lane, Chadwell. It was recorded as UXB and removed.

6th October 1940

1No. HE bomb fell on Hall Farm. It was recorded as UXB.

9th October 1940

IBs fell on South Ockendon and Orsett Heath.

100No. IBs fell near the gun battery, Chadwell St Mary.

HE bombs (unspecified number) and IBs fell on South Ockendon, within approximately 2km of the Site.

13th October 1940

HE bombs (unspecified number) fell on South Ockendon near the railway line to Upminster.

15th October 1940

1No. HE bomb fell 200yds east of the Bata Shoe Factory, East Tilbury.

15th-16th October 1940

Widespread bombing was reported at Orsett, South Ockendon and West Tilbury

1No. HE bomb fell on Sandy Lane, Chadwell St Mary. It was recorded as UXB and removed.

1No. HE bomb fell to the north of the allotments near Gun Hill, West Tilbury. It was recorded as UXB.

17th October 1940

1No. HE bomb fell near the road between West Tilbury and Low Street. It was recorded as UXB and removed.

18th October 1940

HE bombs fell on West Tilbury.

1No. HE bomb fell on the northern end of Blackshots Lane, Grays.

20th October 1940

1No. HE bomb fell on Barrington's Farm, Orsett.

1No. HE bomb fell southeast of Parker Avenue, West Tilbury. It was recorded as UXB and removed.

23rd October 1940

1No. HE bomb fell on West Tilbury.

24th October 1940

3No. HE bombs fell southwest of Middle Farm, South Ockendon.

25th October 1940

UXB exploded south of Dennis Cottages during excavations.

1st November 1940

3No. HE bombs fell near Castle Farm, Bulphan. They were recorded as UXB and removed.

2nd November 1940

1No. HE bomb fell in Battery Field, East Tilbury. It was recorded as UXB.

4th November 1940

1No. HE bomb fell in open ground near Chadwell St Mary.

1No. HE bomb fell east of Brentwood Road, near Alexandra Cottage, Chadwell St Mary. It was recorded as UXB and removed.

5th November 1940

HE bombs (unspecified number) and IBs fell on East Tilbury.

IBs fell on Orsett Heath.

7th November 1940

HE bombs (unspecified number) fell on South Ockendon near Hall Lane.

8th November 1940

8No. HE bombs and 1No. OB fell on Heathfields Farm, Buckingham Hill, Muckingford.

12th November 1940

1No. HE fell on the fairway, 300yds east of the Road, Orsett Golf Course. It was recorded as UXB.

13th November 1940

4No. HE bombs fell on Green Lane. They were recorded as UXB.

UXBs (number unspecified) were removed from the Lighteridge and Dredger dust chute, 0.75 miles east of Tilbury Fort.

24th November 1940

1No. HE bomb fell on Hall Farm, South Ockendon. It was recorded as UXB.

25th November 1940

2No. HE bombs fell on Castle Farm, Bulphan.

29th November 1940

2No. HE bombs fell on West Tilbury.

1No. HE bomb fell on Castle Farm, Bulphan.

9th December 1940

1,000No. IBs fell between Mucking and West Tilbury, including the Site.

IBs fell between East and West Tilbury, including on the Site.

1No. UXIB was located on East Tilbury Marshes.

10th November 1940

2No. HE bombs fell to the northeast of a roundabout on the A13, Baker Street. They were recorded as UXB and removed.

12th December 1940

3No. HE bombs fell on open ground at Botny Farm and Hobletts Farm.

9No. HE bombs fell north of Baker Street.

1No. HE bomb fell 300yds south of Heath Place Farm.

16th December 1940

1No. HE bomb fell near High House Farm. It was recorded as UXB.

17th December 1940

1No. HE bomb fell on Rainbow Shaw, Linford. It was recorded as UXB.

20th December 1940

1No. UXB was removed from Orsett Heath.

4th January 1941

1No. HE bomb fell on open ground near Heath Place Farm, Orsett Heath.

2No. HE bombs fell 700yds northeast of Heath Place Farm.

2No. HE bombs fell on Orsett Heath.

9th January 1941

HE bombs fell on fields in West Tilbury.

12th January 1941

HE bombs (number unspecified) fell near Orsett Camp. No exact locations were specified.

1No. OB and 1No. HE bomb fell on Fairfield Avenue, Little Thurrock.

1No. HE bomb fell in a labour compound 10yds south of St Andrews Road, Tilbury. It was recorded as UXB and removed.

17th January 1941

1No. HE bomb fell 200yds northwest of Heath Place Farm, Orsett Heath. It was recorded as UXB.

19th January 1941

1No. UXB was removed from allotments near St Andrews Road, Tilbury.

25th January 1941

1No. HE bomb fell 400yds south of Heath Place Farm, Orsett Heath.

5th February 1941

IBs fell on Orsett Heath.

IBs at Grays Corner.

6th February 1941

100No. IBs fell been Orsett Heath and Orsett Golf Course, including the Site.

10th February 1941

IBs fell on Orsett.

IBs fell on Hall Farm, South Ockendon.

IBs fell on South Ockendon.

11th February 1941

2No. HE bombs fell on Green Lane, Baker Street. No exact locations were specified.

12th February 1941

1No. HE bomb fell on the Bata Shoe Factory, East Tilbury.

15th February 1941

1No. HE bomb fell on Hill Farm, Orsett. It was recorded as UXB.

4th March 1941

16No. HE bombs fell on East Tilbury, 4No. of which fell near the gun battery at Buckland Farm.

2No. HE bombs fell near South Hall Farm, East Tilbury. They were recorded as UXB.

5th March 1941

1No. HE bomb fell on Bowaters Farm, East Tilbury.

1No. HE bomb fell west of East Tilbury Vicarage. It was recorded as UXB.

8th March 1941

4No. HE bombs fell north of Barrington's Farm, Orsett. They were recorded as UXB.

9th March 1941

1No. HE bomb fell to the rear of the mill, Orsett. It was recorded as UXB.

12th March 1941

2No. HE bombs fell on Surridges Marshes between Golden Gate, Mucking and East Tilbury Fort.

15th March 1941

IBs (number unspecified) fell in fields west of Orsett, including the Site.

IBs fell on south of Stifford Clays, including the Site.

2No. HE bombs fell west of Carters Cottages. They were recorded as UXB.

2No. HE bombs fell on Carters Cottages, Heath Road, Orsett Heath.

1No. HE bomb fell on the Shaw, Orsett Heath. It was recorded as UXB and removed.

19th March 1941

HE bombs (unspecified number) fell in a field north of South Ockendon.

7th April 1941

1No. UXB was removed from Windmill Cottages, Baker Street.

9th April 1941

1No. HE bomb fell on Surridge's Dust Chute, East Tilbury Marshes. It was recorded as UXB.

16th April 1941

9No. UXBs were removed from Green Lane, near Stifford Clays Road.

17th April 1941

2No. PMs fell on Hall Farm.

19th April 1941

HE bombs (unspecified number) fell on Hall Farm.

HE bombs fell between Tilbury Laundry, on the Site and Ferry Road, Tilbury.

1No. HE bomb fell south of Grove Farm, South Ockendon. It was recorded as UXB.

20th April 1941

IBs fell on East Tilbury Marshes, including the Site.

2No. HE bombs fell north of West Street, South Ockendon. They were recorded as UXB.

IBs fell on South Ockendon.

1No. HE bomb fell 500yds north of South Ockendon Railway Station.

23rd June 1941

1No. HE fell on Grays Corner. It was recorded as UXB and removed.

30th July 1942

3No. UXBs were removed from a field north of Orsett Camp.

23rd December 1942

1No. UXB was discovered near the Old Rectory, East Tilbury.

4th January 1943

1No. HE bomb fell on the Bata Shoe Factory. It was recorded as UXB.

4th March 1943

1No. UX anti-personnel bomb was located 100yds southeast of Potash Cottages.

1No. HE bomb fell 250yds north of Black Cottages, Hornsby Lane, Orsett Heath. It was recorded as UXB.

1No. Anti-Personnel Bomb (APB) and IBs fell on Whitecrofts Farm, Orsett. It was recorded as unexploded and removed.

1No. APB fell in a field north of Long Lane, near Grays Corner. It was recorded as a UXAPB and removed.

3No. APBs fell south of Grays Corner. They were recorded as Unexploded APBs (UXAPB) and removed.

9th March 1943

1No. UXAPB was located 50yds north of Baker Street.

1No. UXAPB was removed from Baker Street, Orsett.

2nd April 1943

1No. APB 100yds west of Orsett Heath.

3rd April 1943

1No. HE bomb fell 300yds south of the entrance to Heath Place Farm, Orsett Heath.

5th April 1943

2No. Armour-Piercing Incendiary (API) bombs and 1No. HE fell 75yds west of Grays Corner. They were recorded as UXB and removed.

17th April 1943

1No. HE bomb fell on the Old Rectory, Fen lane.

8th May 1943

5No. Firepots of IBs fell on Orsett Heath.

13th May 1943

1No. HE bomb fell in a wheatfield 300yds east of Health Place Farm. It was recorded as UXB.

17th May 1943

1No. HE bomb fell on East Tilbury.

6th June 1943

1No. HE bomb on open ground at Botny Farm.

7th October 1943

1No HE bomb fell on the carriage sidings at Tilbury Riverside Station.

18th October 1943

2No. HE bombs fell on Orsett Heath.

23rd October 1943

1No. HE bomb fell on Hall Farm, South Ockendon.

25th October 1943

2No. HE bombs fell near Goshems Farm, East Tilbury.

2nd November 1943

1No. HE bomb fell on Chantry Farm.

1No. HE bomb fell on Springfield Farm, Baker Street.

HE bombs (unspecified number) fell on East Tilbury.

3rd November 1943

HE bombs fell over a widespread area, including East Tilbury and Orsett, including the Site.

22nd January 1944

702No. IBs fell on Orsett Golf Course. In excess of 100No. of these were recorded as UXIB.

29th January 1944

1No. UXPhIB was discovered 60yds northeast of the Gatekeeper's Cottage at Bata Halt, East Tilbury.

30th January 1944

IBs fell on Orsett Heath, including the Site.

1No. HE fell to the southeast of a signal box, Tilbury.

1No. HE bomb and several IBs fell on Coalhouse Fort, East Tilbury.

4th February 1944

IBs fell on Tilbury Hotel, on the Site, causing extensive damage.

1No. HE bomb fell on Fort Road (exact location unspecified), Tilbury.

21st February 1944

HE bombs and IBs fell on South Ockendon and Tilbury, within approximately 2km of the Site.

23rd February 1944

1No. Phosphorous Incendiary bomb (PhIB) fell 250 yards southeast of the windmill, South Ockendon. It was recorded as UXPhIB.

18th March 1944

1No. HE bomb fell 130yds southwest of Linford Police House. It was recorded as UXB.

1No. HE bomb landed in a wheatfield, East Tilbury. It was recorded as UXB.

19th April 1944

5No. HE bombs fell at the Halt, East Tilbury.

16th June 1944

1No. V1 fell 300yds north of Orsett Cock and 200yds west of Brentwood Road.

16th August 1944

1No. V1 fell on East Tilbury Marshes.

8th October 1944

1No. V1 fell on open ground near Linford.

24th October 1944

1No. V1 fell near Castle Farm, Bulphan.

15th November 1944

1No. V2 fell in the River Thames, near Surridges Jetty. It was record as a UXV2.

17th November 1944

1No. V1 fell on Orsett Fen.

4th December 1944

1No. V2 fell on the sidings, east of Tilbury Riverside Station, on the Site boundary.

9th January 1945

1No. V2 fell north of Mollands Lane.

13th January 1945

1No. V2 fell on open ground in Low Street.

21st February 1945

1No. V2 fell 800 yards north of Grange Farm.

10th March 1945

1No. V2 fell southwest of Middle Farm.

17th March 1945

1No. UXB was discovered on Fairplay Field, east of Clay Tye Road, North Ockendon.

Southern Part of the Site

9th September 1940

IBs fell on open country in Gravesend.

11th September 1940

1No. HE bomb fell in a field south of Chalk Road. It was recorded as UXB.

20th September 1940

2No. HE bombs fell on Cobham Golf Course.

21st September 1940

2No. HE bombs fell on a field to the east of the junction of Castle Road and Rochester Road, Gravesend.

1No. HE bomb fell on Rochester Road, Gravesend.

24th September 1940

1No. HE bomb is recorded falling in the Thames River, north of the Isolation Hospital, Gravesend, on the Site.

1No. HE bomb fell south of the railway, east of Milton Range.

4No. HE bombs fell northwest of Shorne, on the Site. They were recorded as UXB and removed.

29th September 1940

4No. OBs fell on a field, south of Bourne Road, Gravesend.

2nd October 1940

1No. HE bomb fell north of London Road, Thong. It was recorded as UXB and removed.

3rd October 1940

Approximately 100No. IBs fell on Filborough Marshes and East Court Farm, Gravesend.

6th October 1940

2No. HE bombs fell on fields east of the Isolation Hospital, Gravesend.

8th October 1940

50No. IBs fell on the marshes between the sandpit of Lower Higham Road and the River. No exact locations were given.

1No. HE bomb fell 100yds east of Milton Range Halt.

11th October 1940

3No. OBs fell on the landing ground of RAF Gravesend.

15th October 1940

HE bombs fell south of Watling Street, Thong.

16th October 1940

Several IBs fell to the east of Thong.

21st October 1940

1No. HE bomb fell north of Watling Street, Thong. It was recorded as UXB and removed.

22nd October 1940

4No. HE bombs and 1No. OB fell on Claylane Woods.

23rd October 1940

1No. HE bomb fell near RAF Gravesend.

HE bombs are recorded falling on Chalk.

1st November 1940

3No. HE bombs fell north of Chalk.

5th November 1940

2No. HE bombs fell on Cheney's Farm, Thong Lane.

3No. HE bombs fell near the Isolation Hospital, Gravesend.

15th November 1940

2No. HE bombs fell on Cheney's Farm, Thong Lane.

20th November 1940

6No. HE bombs fell on Filborough Marshes. 5No. of these were recorded as UXB.

23rd November 1940

4No. HE bombs fell on Lower Shorne, north of Gravesend Road.

8th December 1940

IBs fell on Lower Shorne.

IBs fell between Higham and Cliffe, encompassing the eastern tip of the southern part of the Site.

9th December 1940

IBs fell on Chalk.

11th January 1941

2No. HE bombs fell north of Cobham.

15th March 1941

1No. HE bomb fell near the junction of Thong Lane and Rochester Road, Gravesend.

1No. HE bomb fell near Chalk Vicarage.

2No. HE bombs fell near Thong Lane.

1No. HE bomb fell to the rear of 58 Chalk Road. It was recorded as UXB.

1No. HE bomb fell on a field north of Chalk Road.

1No. HE bomb fell on Chalk Vicarage.

1No. HE bomb fell on a garden in Chalk Road. It was recorded as UXB.

1No. HE bomb fell near the junction of Thong Lane and the A225.

1No. HE bomb fell on a field adjoining the White Hart Hotel.

16th March 1941

HE bombs and IBs fell to the south of Shorne.

19th April 1941

1No. HE bomb fell in a field adjacent to Thong Lane.

20th April 1941

3No. HE bombs fell on Church Lane, Gravesend.

2No. HE bombs fell to the east of Church Lane, Gravesend.

1No. HE bomb fell on open ground, Thong Lane.

21st April 1941

1No. HE bomb fell in open ground south of the railway.

2No. HE bombs fell on open ground to the northwest of Shorne.

1No. HE bomb fell on open ground to the northwest of Shorne.

IBs fell on Lower Shorne.

26th April 1941

2No. HE bombs fell south of Brewers Road, Shorne.

5th June 1941

Damage was recorded to Watling Street.

26th June 1941

1No. HE bomb fell in Laughing Lake, Cobham.

21st October 1943

3No. HE bombs fell west of the Shorne.

2nd November 1943

HE bombs are recorded falling on Chalk Road and Lower Higham Road.

4th February 1944

IBs are recorded falling on Denton, Chalk and Old Road East.

18th June 1944

1No. HE bomb fell on Claylane Woods. It was recorded as UXB.

21st June 1944

1No. HE bomb fell on Claylane Woods. It was recorded as UXB.

1No. HE bomb fell on Claylane Woods. It was recorded as UXB.

3rd August 1944

1No. HE bomb fell near RAF Gravesend. It was recorded as UXB.

17th August 1944

1No. UXB was removed from the eastern side of Eastcourt Marshes.

1No. V1 fell in the River Thames.

21st August 1944

1No. HE bomb fell on Lower Higham Road. It was recorded as UXB.

Appendix 2 Glossary & Definitions	
Anti-Aircraft (AA) Shell	Shells are a projectile containing an explosive charge designed to burst the casing that can contain High Explosives, pyrotechnic compounds or other chemicals. Most commonly used AA shells were 3.7" and 4.5"HE shells, although they ranged from 2" to 5.25" calibre. The 3.7" shell weighed 12.96kg and the 4.5" AA shell was 24.97kg.
Air Raid Precautions (ARP)	ARP was a civil defence organisation dedicated to protect civilians against aerial bombardment. This included the employment of Air Raid Wardens and the issuing of gas masks.
Anti-Personnel (AP) Rounds	Anti-Personnel rounds are used to incapacitate people and usually fragment on firing.
Billet	A place, usually a civilian house, where soldiers are temporarily lodged.
Blister Hangar	An arched, portable aircraft hangar.
Calibre	The diameter of a bullet or shell, or the internal diameter of a gun barrel.
Camouflet	The type of cavity produced when a charge explodes underground without breaking the surface of the earth to form a crater.
Clearance Certification	A clearance certification is issued by the MoD and other organisation. 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.
Close Combat Munitions	Close combat (sometimes known as land service) munitions include grenades, mortars and shells. They contain larger amounts of explosives, often with sensitive fuze mechanisms, and so may be easier to detonate. Further details on these munitions can be found in Appendix 2 and at https://zeticauxo.com
Detonation	The high-speed chemical breakdown of an energetic material producing heat, pressure, flame and a shock wave.
Device	This term is used for any component, sub-assembly or completed ordnance, which may or may not have an explosive risk. It can apply to detonators, primers, gaines, fuzes, shells or bombs.
Explosive	The term explosive refers to compounds forming energetic materials that under certain conditions chemically react, rapidly producing gas, heat and pressure. Obviously, these are extremely dangerous and should only be handled by qualified professionals.

Explosive Ordnance (EO)	Explosive Ordnance is 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, small arms ammunition, mines, torpedoes, depth charges, pyrotechnics, cluster bombs & dispensers, cartridge & propellant actuated devices, electro-explosive devices, clandestine & improvised explosive devices, and all similar or related items or components explosive in nature.
Explosive Ordnance Clearance (EOC)	Explosive Ordnance Clearance is a term used to describe the operation of ordnance detection, investigation, identification and removal, with EOD being a separate operation.
Explosive Ordnance Disposal (EOD)	Explosive Ordnance Disposal is the detection, identification, on-site evaluation, rendering safe, recovery and final disposal of unexploded explosive ordnance.
Flame Fougasse	40 gallon oil drums concealed by roadsides with built-in explosive charges designed to blast the flaming barrel onto the road in the path of oncoming enemy vehicles.
Fuze	A fuze is the part of an explosive device that initiates the main explosive charge to function. In common usage, the word fuze is used indiscriminately, but when being specific (and in particular in a military context), fuze is used to mean a more complicated device, such as a device within military ordnance.
Gaine	Small explosive charge that is sometimes placed between the detonator and the main charge to ensure ignition.
Gotha Bomber Aircraft	Gotha bombers were heavy bomber aircraft used by the Luftstreitkräfte, the Imperial German air force, during WWI.
Hard	A road leading to a foreshore. Hards were constructed to the embarkation and disembarkation of troops.
High Explosive	Secondary explosives (commonly known as High Explosives (HE) make up the main charge or filling of an ordnance device. They are usually less sensitive than primary explosives. Examples of secondary explosives are: Nitro glycerine (NG), Trinitrotoluene (TNT), AMATOL (Ammonia nitrate + TNT), Gunpowder (GP), and Cyclotrimethylenetrinitramine (RDX).
Low Explosive	Historically, Low Explosives, such as gunpowder or black powder, were designed to burn to liberate propellant gases. High Explosives are designed to detonate, typically at velocities between approximately 1500 to 7500m/s. Modern classifications include explosive densities and often a TNT-equivalent value to relate the explosive energy and damage potential. Boundaries are blurred, for example guncotton or nitrocelluose can be a propellant or a high explosive.

MI High Explosive (HE) Shell	MI HE Shells are shells used in Howitzer MI artillery.
Munition	Munition is the complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological or chemical material for use in military operations, including demolitions. This includes those munitions that have been suitably modified for use in training, ceremonial or non-operational purposes. These fall into three distinct categories:- • inert - contain no explosives whatsoever. • live - contain explosives and have not been fired. • blind - have fired but failed to function as intended.
Pipe Mine	Sections of metal tubing filled with high explosive and fitted with a detonation device.
Primary Explosive	Primary explosives are usually extremely sensitive to friction, heat, and pressure. These are used to initiate less sensitive explosives. Examples of primary explosives are: Lead Azide, Lead Styphnate, and Mercury Fulminate. Primary explosive are commonly found in detonators.
Propellants	Propellants provide ordnance with the ability to travel in a controlled manner and deliver the ordnance to a predetermined target. Propellants burn rapidly producing gas, pressure and flame. Although usually in solid form they can be produced in liquid form. Examples of propellants are: Ballistite often found in a flake form and Cordite used in small arms ammunition.
Pyrotechnic	A pyrotechnic is an explosive article or substance designed to produce an effect by heat, light, sound, gas or smoke, or a combination of any of these, as a result of non-detonative, self-sustaining, exothermic chemical reactions.
Schermuly Flare	A pyrotechnic device used to signal and illuminate location.
Small Arms Ammunition (SAA)	SAA includes projectiles around 12mm or less in calibre and no longer than approximately 100mm. They are fired from a variety of weapons, including rifles, pistols, shotguns and machine guns.
Stick	Stick refers to a line of bombs dropped by a single aircraft.
Target Butt	A backstop, possibly a mound or bank, for catching missiles shot at a target.
Unexploded Anti-Aircraft (UXAA) Shell	UXAA shells are army ordnance commonly containing HE, though they can also contain pyrotechnic compounds that produce smoke. Most commonly shells were 3.7” and 4.5” HE shells, although they ranged from 2” to 5.25” calibre.
Unexploded Bomb (UXB)	UXB is a common term for unexploded air-dropped munitions.

Unexploded Ordnance (UXO)	UXO is explosive ordnance that has been either primed, fuzed, armed or prepared for use and has been subsequently fired, dropped, launched, projected or placed in such a manner as to present a hazard to operations, persons or objects and remains unexploded either by malfunction or design.
Zeppelin airship	The term Zeppelin refers to rigid dirigibles used to conduct bombing raids during WWI.

Appendix 3 UXO Hazard and Ordnance Types

When assessing the risk from UXO including UXB, it is important to be aware of ordnance type and function. The following Section briefly describes the more common types of UXO. More data on these can be found at http://zeticauxo.com/downloads-and-resources/ordnance-data-sheets.

A3.1 German High Explosive (HE) Bombs

Probably the most common and certainly most publicised UXOs to be found in the UK are bombs. Air dropped bombs, as a result of WWII enemy action, are found on a relatively frequent basis as UXO. They tend to be highly publicised (at least on a local basis) due to the common disruption where an evacuation of the potentially affected area is put in place.

The amount of High Explosive and the potential for a fuze to still be activated means that these devices have the prospect of causing some of the most widespread damage. WWII bombs were particularly sophisticated for their time, with anti-tamper fuzes.

Many German bombs were designed to not explode on impact and instead to cause disruption as a UXB. Some fuzes were set with a delay time of over 70 hours. During this time, an anti-tamper fuze could also be activated to detonate should it be disturbed.

The most commonly used bombs during WWII were the 50kg and 250kg sized general purpose bombs. Less frequently, the 500kg bomb was also used. Larger bombs were used, but so infrequently that any assessment of hazard is more typically based on bombs ranging up to 500kg only. It should be noted that the June 2008 find of a 1000kg bomb in London, does demonstrate that larger bombs can be found and any risk mitigation measures should consider this.

The Plate below shows the variety of UXB recovered by the Civil Defence during WWII.

Plate	Photograph of a variety of UXB recovered by the Civil Defence during WWII

Source: Imperial War Museum

A3.2 Shells

Shells are a projectile containing an explosive charge designed to burst the casing that can contain High Explosives, pyrotechnic compounds or other chemicals.

Shells can be found in a range of sizes, from <20mm to several times this size. The most likely shells to be found on the Site are Small Arms Ammunition (SAA) or UXAA shells that have fallen back to the ground unexploded.

Most commonly used Anti-Aircraft (AA) shells were 3.7" and 4.5"HE shells, although they ranged from 2" to 5.25" calibre. The 3.7" shell weighed 12.96kg and the 4.5" AA shell was 24.97kg. Maximum penetrations of these AA shells would typically be less than 1.5m to 2m from the ground surface, although in very soft ground the 5.25" could penetrate up to 3m.

The 3.7" and 4.5" AA shells were filled with approximately 1kg and 1.7kg of HE, respectively.

The Plate below is a photograph of a 3.7" UXAA shell found in Camberwell, London.

Plate	Photograph of a recently excavated 3.7" AA shell

Source: Zetica Ltd

Coastal batteries were also armed with anti-aircraft artillery and naval guns, typically firing 3", 5.5" and 6" shells, filled with a combination of cordite, lyddite, amatol or TNT.

If fired and found as UXO, shells can offer a hazard from accidental detonation as they can have sensitive fuze mechanisms. A fuze is a device which incorporates mechanical, electrical, chemical or hydrostatic components to initiate a train of fire or detonation.

A3.3 Hand Grenades

Hand grenades can be filled with explosives or chemicals and have 3No. main parts, a body, a fuze with a pull ring and a safety-clip assembly. Fragmentation grenades are the most common and have a metal or plastic body filled with an explosive. Most use a burning delay fuze that functions for 3 to 5 seconds after the safety lever is released.

Some, such as smoke grenades, are activated instantly when the lever is released. The Plate below illustrates the typical character and condition of No. 36 hand grenades (Mills Bombs) that have been excavated from a site.

Plate	Photographs of a typical and an excavated WWII No. 36 hand grenades

Source: Google Images

Source: Zetica Ltd

A3.4 Projected Grenades

Projected grenades are among the most commonly found UXO items, particularly the 40mm type. These contain high explosives and use a variety of fuzes, including some of the most sensitive internal impact-fuzing systems. They are extremely dangerous and can explode if moved or handled.

A3.5 Mortars

A mortar is a short tube designed to fire a projectile at a steep angle. Mortars can range from approximately 50mm to 280mm in diameter and can be filled with explosives, toxic chemicals, white phosphorous or illumination flares. They generally have a thinner metal casing than projectiles, but use the same types of fuzing and stabilisation.

During WWII there are records that the target areas of RAF practice bombing ranges were occasionally used for mortar training.

The Plate below shows a typical 2-inch mortar bomb found (left) and a demonstration 3-inch mortar bomb (right).

Plate	Photographs of WWII 2-inch and 3-inch mortars

Source: Daily Mail

Source: Zetica Ltd

A3.6 Small Arms Ammunition

Small Arms Ammunition (SAA) is one of the more recognisable categories of ordnance which is primarily designed for anti-personnel use. SAA include items such as bullets, generally up to a calibre (diameter) of 20mm. Larger calibre small arms munitions can contain fuze mechanisms and high explosives or pyrotechnic fillings and may have been used for anti-aircraft or anti-vehicle purposes.

Generally small arms ordnance has a relatively low risk as UXO due to the small amount of explosive and its lack of sensitivity, although the larger calibre categories may have the same detonation risk as larger high explosive ordnance. SAA is often associated with discarded ammunition boxes around firing practice ranges. The Plate below illustrates some common SAA.

Plate	Photograph of typical WWII small arms ammunition

Source: Google Images

A3.7 Canadian Pipe Mines

Often crudely made, pipe mines were pipes approximately 100mm in diameter and up to 55m long bored roughly horizontal beneath critical infrastructure such as airfield run ways, or angled between ten and thirty degrees into river banks in places were invasion forces may land.

The pipes were filled with explosives and usually a sensitive fuzing mechanism. With nitro-glycerine or Polar Blasting Gelignite (PBG) being the primary component, over time, these devices can become increasingly unstable.

Pipe mines were not usually installed individually. The preferred method was to overlap them, usually in a grid pattern at intervals, at different depths of anything up to 5m below ground level (bgl), or to insert several parallel, closely spaced tubes.

By the 31st May 1941, Southern Command had installed a total of 12,200' (approximately 3,800m) length of Canadian pipe 'obstacles' using approximately 26,880' (approximately 8,300m) of pipes and 33 tons of Blasting Gelatine.

In mid-1941, it was discovered that the in some cases the conditions of burial caused early deterioration of the explosive charge due to moisture and alike. A maintenance cycle was put in place to initially inspect the pipe mine cartridges every 12 months. Thereafter, the inspection was carried out every 3 months for the Blasting Gelatin but every month for the other explosives.

The Nitroglycerine within the charge was also potentially very hazardous due to its instability when it becomes frozen at temperatures of <14°C. As such removal of pipe mines is undertaken with extreme caution.

Where pipe mines needed replacing, typically new pipe mines were installed to avoid the hazards when removing an existing mine.

Towards the end of 1941, if deterioration of the original explosives was discovered, they were removed by a specially designed pronged spear or corkscrew rod and a water flush technique and then burnt. In most cases the pipe mines were recharged with a new explosive mix. This was undertaken during 1941-42.

The fuze was usually a length of cordtex, capped with a No. 3 tube fuze, in a vertical drain pipe fitted with a cover flush with the ground. The initiator was a half-hour time pencil fitted with a No. 27 detonator and covered with a primer. A glass ampoule was broken to initiate the time pencil.

After WWII, most remaining Canadian pipe mine installations were removed. Due to the method and speed of placement of many of them during 1940-41, detailed plans and maps were sometimes not available and a small number were missed.

For example, in April 2006, 20No. unexploded pipe mines were discovered at the former Royal Navy air base HMS Daedulus in Hampshire. The original 265No. pipe mines were each approximately 18m long. The 20No. unexploded pipe mines contained approximately 1,100kg of HE. The mines were destroyed by controlled explosion.

Left undisturbed, it is unlikely that these devices will detonate and in this case, the road has been used for in excess of 70 years without incident.

Today, disposal of pipe mines is taken with extreme caution due to the probability of accidental detonation as a result of the instability of its Nitroglycerine content. The process typically involves identifying the extent of the pipe mines, where possible using non-intrusive geophysical techniques.

Significant blast protection is placed over the suspected pipe mine location. Careful excavation by hand is used to expose one end of the pipe mine allowing a donor charge to be placed on the pipe. The blast protection then permits a safe detonation of the pipe mine in situ.

Plate	Photographs of typical pipe mines ex-situ and in-situ




Source: Royal Engineers (EOD Branch)

A3.8 Incendiary Bombs

Incendiary Bombs (IBs) ranged from small 1kg and 2kg thermite filled, magnesium bodied bombs to a 250kg 'Oil Bomb' (OB) and a 500kg 'C300' IB. The C300 bombs were similar in appearance to 500kg HE bombs. In some cases the IBs were fitted with a very small High Explosive (HE) bursting charge. This exploded after the bomb had been alight for a few minutes causing burning debris to be scattered over a greater area.

By far the most common air dropped incendiary devices across the UK during WWII were small Brandbomben 1kg Elektron (B-1E) IBs.

B1-E IBs consisted of a cylinder of magnesium alloy (Elektron) with an incendiary filling of 680 grammes (g) of thermite, an incendiary mixture of 24% aluminium and 76% iron (III) oxide, occasionally with additional barium nitrate or boric acid. The thermite was ignited by a very small percussion charge in the nose which fired on impact.

Later B-1E Zusatz (B-1E Z) versions with an explosive charge in the nose or tail were introduced in the bomb loads. The explosive charge, ignited by heat (B-1E ZA) or a small delayed action device (B-1E ZB), usually consisted of small amounts, typically less than 15g, of Penta-erythritol-tetranitrate (Nitropenta or PETN). Less than 5% of the IBs which fell in the vicinity of the Site had explosive charges.

Later, the 2.2kg steel nosed B-2E was deployed.

In most cases the B-1E IBs, which actually weighed approximately 0.83kg and were 50mm in diameter and 350mm long, were unlikely to have penetrated more than 0.5m.

The small amount of HE and the almost negligible potential for B-1E or B-1EZ IBs to remain active after more than 70 years in the ground means that these items have very little prospect of causing damage. In the majority of cases if IBs are found in the ground, the incendiary materials have deteriorated to such an extent that they are considered to provide a low UXO hazard level.

However, since magnesium and phosphorus were common components in IBs, some localised chemical contamination may occur where the contents have leached out of the IB into the surrounding soil.

The Plate below shows fragmentary remains of IBs and an intact example.

Plate	Photographs of typical fragmentary remains of IBs and a UXIB

Source: Swansea Museum

Source: Museum of London

Detonation

In the very unlikely event that a UXIB is encountered on the Site, it is likely to be at depth (>1.0m). Given the negligible amount of HE within these devices, a detonation is considered unlikely. If a detonation does occur, given the overburden it is extremely unlikely to cause any harm to people or property. A possible outcome of such a detonation may be for an operative of a piling rig to see a small trail of smoke caused by the deflagration of the IB contents.

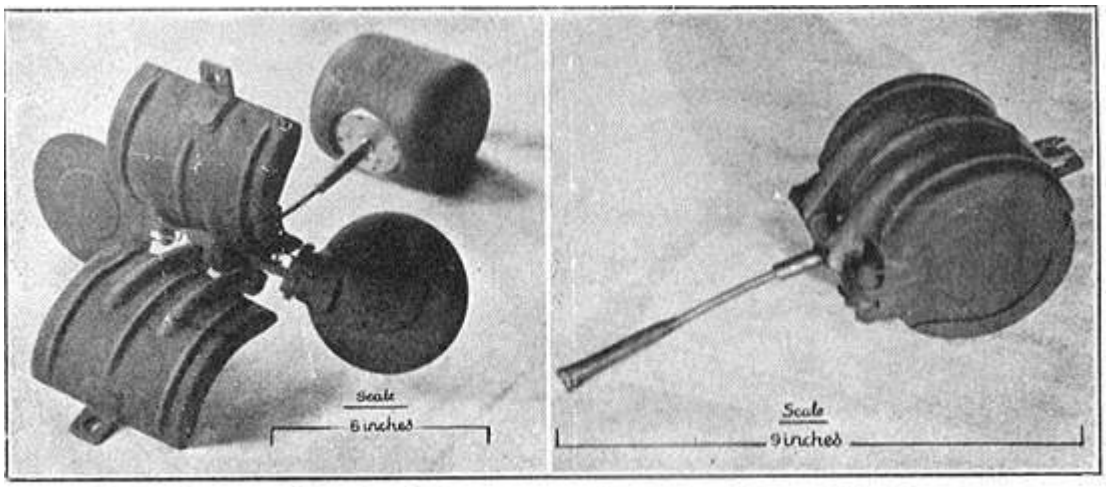
A3.9 Anti-Personnel Bombs

2No. types of Anti-Personnel (AP) bombs were in common use, the 2kg and the 12kg bomb. The 2kg bomb could inflict injury across an area up to 150m away from the impact, within 25m of this, death or fatal injury could occur.

In the majority of cases WWII AP bombs were so sensitive to disturbance that none have been found since WWII as UXAPB and it is considered very unlikely that such an item would be found buried as a UXAPB.

The Plate below shows typical AP ('Butterfly') bombs recovered by the Civil Defence during WWII.

Plate	Photographs of typical AP ('Butterfly') bombs



Source: Smith

A3.10 Practice Bombs

Practice bombs were typically used on inland bombing ranges. 11.5lb practice bombs contained a small explosive charge and produced a coloured powder plume for daylight operations and a light flash for night operations. The Plate below shows a recovered 25lb practice bomb head and a complete 25lb WWII practice bomb.

Plate	Photographs of 25lb WWII practice bomb head and practice bomb

Source: Zetica Ltd

Source: BOCN

A3.11 Magnetic Mines

Magnetic mines are designed to lie at the bottom of relatively shallow water and explode when the earth's magnetic field become distorted by any large metal object such as a ship coming within range.

Luftwaffe aircraft laying mines on tidal rivers are known to have accidentally dropped magnetic mines on to land. It is unlikely that magnetic mines would remain in the ground as unexploded ordnance as they were approximately 2m long, normally dropped by parachute and were unlikely to penetrate the ground because of this. The same is true for other parachute mines.

The Plate below is a photograph of a typical WWII buoyant marine mine.

Plate	Photograph of buoyant marine mine

Source: www.warhistoryonline

A3.12 Land Mines

Wartime activities provide numerous sources of UXO within the land environment. Whilst efforts have been made to clear the known British minefields, it was common for mines to become lost for a variety of reasons and so not recovered. Additionally, such munitions might have been disposed of on an unofficial basis and so no records were kept.

Most of the mined beaches and other land areas in the UK have been cleared by the MoD. Occasionally, wave action or activities such as bombing caused mines to become displaced and these were missed as part of any past clearance activities.

A3.13 Home Guard Weapons

Initially, the Home Guard's armoury was largely second-hand and much of it was of WWI vintage. Personal weapons (such as shotguns) and home-made devices were also employed.

By the end of WWII, some units were well equipped with a wide variety of small arms and munitions.

These included .32, .38 and .455 revolvers, .303 P14, .300 P17 and .303 Canadian Ross rifles, anti-tank rifles and a variety of Sub- Machine Guns (SMG) such as the .45 Thompson and 9mm Sten Guns.

Other heavier Machine Guns (MG) at their disposal included Browning, Hotchkiss, Lewis, Vickers and Marlin MG. Sub-artillery weapons were developed for them, including grenade throwers (the Northover Projector) and spigot mortars (the Blacker Bombard). 2-pdr anti-tank guns and Projector, Infantry Anti-Tank (PIAT) weapons were in circulation amongst some units, and the Home Guard also manned AA guns later in WWII.

Explosives were available to some Home Guard units and were used and stored by all Auxiliary Unit patrols. Flame fougasse were 40 gallon oil drums concealed by roadsides with built-in explosive charges designed to blast the flaming barrel onto the road in the path of oncoming enemy vehicles. The barrels were filled with oil and petrol, and a fulminate of mercury detonator was placed in the explosive charge.

As well as the hand grenades detailed in this Appendix, the Home Guard had stocks of Molotov Cocktails, Sticky Bombs and SIP grenades.

In October 2006 a cache of 76No. SIP grenades was found in a garden at Seend, Wiltshire. In October 2008, a further 26No. SIP grenades were discovered in a garden in Wimborne, Dorset.

Similar caches were discovered in October 2009 in Hove, Sussex and during May 2010 in Halesowen in the West Midlands, and a further cache of 20No. was uncovered on a construction site at Birdlip, Gloucestershire, in July 2010. Also in July 2010, a box of 24No. SIP grenades was found on Cogden Beach, Dorset. In April 2012, more than 8No. SIP grenades were found on a construction site in Banbury and destroyed by members of the Army Royal Logistic Corps (RLC).

In March 2015, 80No. SIP grenades were found at a building site in Eastbourne, some of which exploded before they could be made safe by a Bomb Disposal Unit (BDU).

In May 2016, 1No. No. 76 SIP grenade was found during excavation at Chapel Point, Lincolnshire forcing works to be delayed. During WWII, the site was occupied by a pillbox and gun emplacement associated with the heavily-defended 'Coastal Crust', manned by Home Guard units. The device was removed safely.

Also in May 2016, 49No. SIP grenades were found at a building site in Washington, Sunderland and were made safe by an RAF BDU.

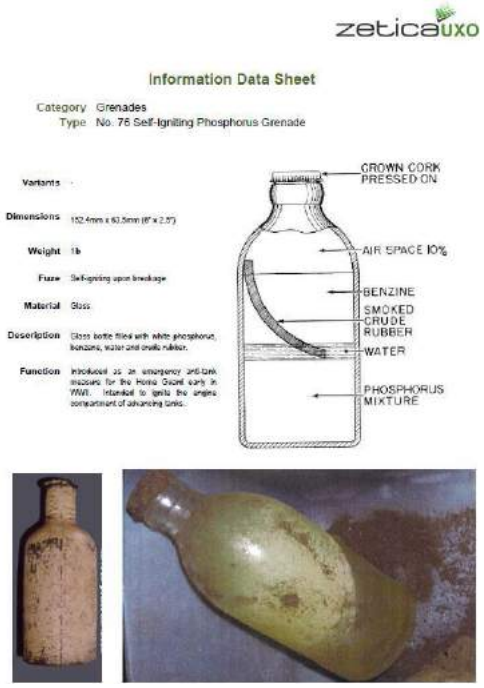
In January 2017, a cache of 24No. SIP grenades was discovered at Derriford, Plymouth and made safe by a Royal Navy Bomb Disposal Unit.

In February 2017, a cache of SIP grenades were uncovered on a building site at Trowbridge, Wiltshire. They were safely detonated by an Army Bomb Squad.

In all these cases, the bottles were in good condition and most exploded in flames when broken.

The Plate below is a photograph of a No. 76 SIP grenade (LHS) with an explanatory leaflet produced by ZeticaUXO for site staff (RHS).

Plate	Photograph of the No. 76 SIP grenade



Source: Zetica Ltd

Given the irregular nature of Home Guard activity, the possibility of items of UXO or weapons being discovered at any locations occupied or used for training by them can never be totally discounted.

A3.14 UXO Migration

It is possible for explosive material, UXO or ordnance scrap to migrate to a site during landfill or dredging operations or other ground works which import Made Ground or natural materials already containing UXO. It is important to understand the nature and age of such landfill or dredging operations when assessing the potential UXO hazard level on the site.

A3.15 Fluvial, Marine and Coastal UXO Hazards

Wartime activities provide numerous sources of UXO within the fluvial and marine environment. There were extensive minefields laid by the British to protect the approaches to the ports around the coast and convoys using the shipping lanes, as well as offshore anti-invasion barriers. There were also many German air and ship raids to lay mines in the coastal shipping lanes.

Clearance certification for UXO within a marine environment may be valid only for a limited period because storms, tides and general current movement can cause UXO to migrate into an area that may have been cleared of UXO only hours before. This also makes it very difficult to accurately predict where UXO may be found.

A3.16 Effects and Consequences

There have been a limited number of recorded incidents in the UK since WWII where bombs have detonated during engineering works, though a significant number of bombs have been discovered. Incidents involving smaller ordnance are, however, relatively common in the UK.

In the UK, there are no recorded incidents since the decade after WWII, of a UXB accidentally detonating. In recent years, bombs have been found that have fuze mechanisms that have started to operate indicating that given the right conditions a UXB may still function.

In June 2008 the UXB uncovered in the Lea Valley caused difficulty to No. 33 Regiment (Explosive Ordnance Disposal) Royal Engineers because the fuze mechanism started to operate.

The 1,000kg 'Hermann' bomb, the first of this size to be found in over 30 years, took 5 days to deactivate. This demonstrates that larger bombs can be found and any risk mitigation measures should provide the option to deal with this size of device. Since WWII, UXBs have been found on a regular basis in London.

Since WWII, UXBs have been found on a regular basis throughout Britain. Some of the most recent cases are described below.

In May 2009 1No. 50kg WWII bomb was found on a building site in Bexhill-on-Sea, Sussex, and on the 16th August 2009, 1No. 250kg WWII bomb was found near Ebberston, North Yorkshire. Both of these were destroyed in controlled explosions by Bomb Disposal Units.

On the 8th March 2010 1No. 500kg WWII bomb was found at Bowers Marsh in Essex by Zetica EOC operatives following a Zetica desk study concluding a high risk of UXB on the site. The bomb was demolished in situ by members of the Army Royal Logistics Corps (RLC).

The Plate below is a photograph of the bomb in situ.

Plate	Photograph of the 500kg WWII UXB at Bowers Marsh, 8th March 2010

Source: Zetica Ltd

On the 23rd February 2011, 1No. WWII UXB was found on a building site in Notte Street in Plymouth City centre. The bomb was removed by EOD personnel and demolished at sea.

On the 22nd July 2012, a landslip in the cliffs at Mappleton in the East Riding of Yorkshire exposed over 1,000No. UXO items, including practice bombs, mortars, rockets, shells and grenades. The cliff was part of a former bombing and artillery range, used during WWII and until the 1970s.

UXO items were removed by Explosive Ordnance Disposal (EOD) officers from Catterick and MoD staff from Leconfield. 15No. controlled explosions were undertaken by the Royal Engineers (RE) to detonate the more volatile items in situ, while other less hazardous UXO devices were left in place to be dealt with at a later date.

1No. WWI bomb (shown in the Plate below) was found on the Isle of Sheppey on the 2nd August 2012 during a geophysical survey following desk study research by Zetica Ltd which had established that a previously unknown WWI bombing range existed on the site. A further WWI bomb was found in the same location in August 2015.

Plate	Photograph of WWI bomb, Isle of Sheppey, 2nd August 2012

Source: Zetica Ltd

On the 23rd March 2015, 1No. WWII 500kg UXB was found on a building site in The Grange, Bermondsey. The bomb was made safe by EOD personnel and removed for demolition.

On the 21st May 2015, 1No. 50kg UXB was found on a building site near Wembley Stadium, London Borough of Brent. The bomb was made safe by EOD personnel and removed for demolition.

On the 10th August 2015, 1No. 250kg UXB was found under the basement of a building site at Bethnal Green, London Borough of Tower Hamlets. It was made safe and removed by an EOD team from the RLC.

On the 21st September 2015, 1No. UXB was uncovered on a construction site in Cheylesmore, Coventry, by the operator of a mechanical digger. It was destroyed in situ by an EOD team from the RLC.

In January 2016, Zetica discovered 3No. 500lb British UXB at a former airfield in Cambridgeshire. These were destroyed in controlled explosions. The Plate below is a photograph of one of the bombs.

Plate	Photograph of a recently excavated WWII British 500lb GP bomb

Source: Zetica Ltd

On the 12th May 2016, 1No. 250kg UXB was found on a building site in Bath. It was made safe and then taken to a local quarry for demolition,

In September 2016 1No. 500kg UXB and 1No. torpedo were discovered during dredging works in Portsmouth Harbour. An additional 250kg HE bomb was discovered on the 16th November 2016. These devices were towed out to sea and destroyed in controlled explosions.

The Plate below is a photograph of an unexploded German SD 50kg bomb, a small armour-piercing bomb used against shipping, found in the River Thames near Waterloo Bridge on the 19th January 2017.

Plate	Photograph of an unexploded SD 50kg bomb dredged from the River Thames, 2017

Source: BBC News

On the 12th May 2016, 1No. 250kg UXB was found on a building site in Bath. It was made safe and then taken to a local quarry for demolition.

On the 19th January 2017, 1No. 50kg UXB was found during dredging works along the River Thames Victoria Embankment in Central London. The device was towed to Tilbury in Essex where it was destroyed in a controlled explosion.

On the 25th January 2017, 1No. 500lb British UXB and 1No. mortar shell were found in King's Forest, Thetford. They were destroyed in a controlled explosion.

On the 2nd March 2017, 1No. 250kg German UXB was found on a building site in Brondesbury Park in the London Borough of Brent. It was defuzed by an EOD team and removed to a safe location where it was destroyed in a controlled explosion.

On the 15th May 2017, 1No. suspected 250kg German UXB was found on a building site in Aston, Birmingham. Due to the corrosion of the fuzes, the UXB was destroyed in situ on the 17th May 2017.

On the 23rd August 2017, 1No. UXO item was found at Lombard Wall, near Greenwich Shopping Park. It was removed.

On the 4th September 2017, 1No. 50kg UXB was found in a ragstone quarry at Kings Hill near West Malling in Kent. It was destroyed in situ in a controlled explosion by an EOD team.

On the 11th February 2018, 1No. 500kg UXB was found in King George V Dock in London, resulting in the temporary closure of the adjacent London City Airport. The UXB was freed from a silt bed and towed along the River Thames to Shoeburyness where it was destroyed in a controlled explosion on the 14th February 2018.

On the 26th February 2018, an EOD team destroyed numerous items of ordnance including shells and 20mm ammunition which had been exposed by storms on Selsey Beach.

On the 3rd April 2018, 1No. WWI shell was found in Steeton near Bradford. It was destroyed in a controlled explosion after being made safe and moved to a nearby field.

On the 9th Jue 2018, 1No. WWII shell was found in Winchester. It was detonated in situ.

On the 29th August 2018, 1No. WWII shell was found on Church Manorway in Erith. It was removed for disarmament.

Overseas Incidents

The discovery and detonation of UXBs overseas, particuarly in Germany, is more common than in the UK, namely due to the sensitive fuzing mechanism in Allied HE bombs and the greater number dropped. There is a long list of incidents during construction work in Germany that in some cases have led to the deaths of workers.

In June 2010, 3No. members of a bomb disposal team were killed, and 6No. others injured, whilst attempting to defuze an unexploded WWII bomb in Goettingen, Central Germany.

The bomb, the second found in Goettingen in the space of a few days, was unearthed at a depth of 7.5m during excavations for a sports stadium.

In September 2008, 17No. people were injured and considerable damage occurred to adjacent buildings when a bomb exploded on a construction site in Hattingen, Germany.

In October 2006 during road works on a motorway near Aschaffenburg in Bavaria, southern Germany, a bomb was struck by a machine and detonated. The plant driver was killed and 5No. others injured, including passing motorists.

In a similar incident in October 2004 in Linz, Austria a bomb exploded injuring 3No. workers and causing considerable damage to plant. In the same month, a WWII bomb under a back garden in Vienna, Austria, was detonated without warning by a minor earth tremor, after remaining undiscovered for over 60 years.

Incidents involving UXO are also reported from the marine areas around the North Sea. For example, on 6th April 2005, 3No. Dutch fishermen were killed when they accidentally trawled up a WWII UX bomb which exploded when it hit the deck.

More recently, an unexploded HE bomb was trawled from the sea floor off South Shields on the 25th February 2015 but caused no damage.

Further details of similar finds can be found at http://zeticauxo.com/news/.

The effects of a partial or full detonation of ordnance are usually shock, blast, heat and shrapnel damage. A 50kg buried bomb can damage brick / concrete structures up to a distance of approximately 16m away.[19] Unprotected personnel on the surface up to 70m away from the blast could also be seriously injured. Larger ordnance would obviously be more destructive.

Explosives rarely lose effectiveness with age, although over time mechanisms such as fuzes and gaines can become more sensitive and therefore more prone to detonation, regardless of whether the device has been submersed in water or embedded in silt, clay or similar materials.

The effects of a detonation of explosive ordnance are usually extremely fast, often catastrophic and invariably traumatic to any personnel involved.

[19] Prugh R W, The Effects of Explosive Blast on Structures and Personnel; Process Safety Progress (Vol 18 No. 1) 1999: Smith P, Blast Effect on Buildings, 2009. Further information on the consequences of detonation can be found at https://zeticauxo.com

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