BRIMSTONE

DETAILED
UXO RISK ASSESSMENT

INTEGRITY PROFESSIONALISM KNOWLEDGE

STAGE 2 DETAILED UXO RISK ASSESSMENT

Client:	IDOM
Project Ref:	IDOM95R
Site:	Swanstree Avenue, Sittingbourne
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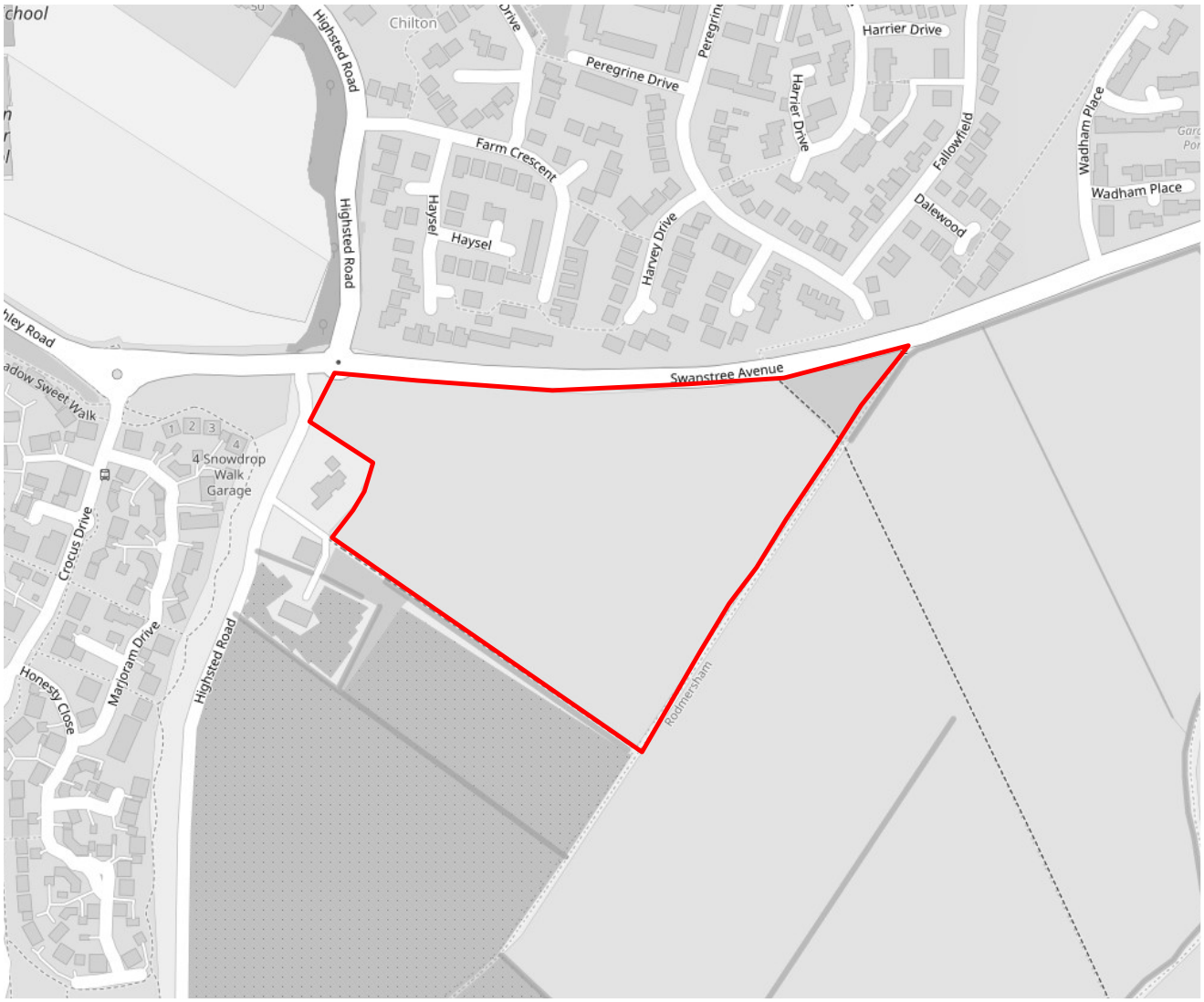

EXECUTIVE SUMMARY

RESULT: Brimstone concludes that UXO poses a **LOW RISK** to the proposed works.

THE SITE: The Site (approximately centred on the National Grid Ref: TQ 91201 62558) is located in Sittingbourne, within the county of Kent, approximately 1.3km south-east of Sittingbourne rail station. The Site is bound to the north by Swanstree Avenue, to the east and south by undeveloped agricultural ground, and to the west by structures associated with Chilton Manor Farm, undeveloped ground and Highsted Road.

The Site comprises open agricultural ground, with a gravel walkway in the north-east corner and six polytunnels in the south-east.

THE PROPOSED WORKS: At the time of writing, Brimstone was made aware that future development works will comprise residential development, however, the exact details were unknown.

Future SI works will comprise 28 windowless sampler boreholes to approximately 5m bgl, eight machine-dug trial pits to approximately 3.5m bgl, soakage testing and in situ CBR testing.

UXO RISK ASSESSMENT:

German UXO:

- During WWII, the Site was located relatively close to a Luftwaffe flightpath to London; original wartime bombing figures and mapping indicate that the study area experienced a low to moderate bombing density. However, no known or potential Luftwaffe bombing targets were present in the immediate vicinity and Sittingbourne town was never subjected to a large-scale air raid. The Site was likely therefore only vulnerable to small scale targeted 'tip and run' bombing incidents, although as aforementioned, the lack of potential targets in the vicinity reduces this likelihood.
- A collection of Kent ARP written incidents records was reviewed for this report. No bomb strikes were recorded on Site or in the surrounding area. Although the closest incident was recorded on the eastern boundary of the Site, this was a V1 strike. This rocket exploded, and as no conventional air raids occurred following this strike, there is considered to be a low likelihood of a UXB strike remaining unobserved within this area of damage.
- Historical aerial photography and OS mapping show that the Site comprised undeveloped open land and orchards during WWII. Subsequently, any potential evidence of UXO which may have fallen at this time is thought likely to have been less noticeable, with a UXB's descent into open land less obvious than through a structure or roadway, for example. As the majority of the Site comprised open ground and orchards during the war, it would have only experienced infrequent access and is highly unlikely to have been subject to post-raid specific searches for German UXBs. As such, there is a chance of a UXB falling unnoticed and remaining on Site, buried in-situ. However, the structure associated with the orchard approximately 110m north may have provided a slightly elevated level of access to the area.
- In summary, due to the very low localised bombing density, lack of recorded conventional bomb strikes on Site or in the surrounding area and lack of evidence of bomb damage, the risk of contamination from German UXBs is not considered to be elevated.

British / Allied UXO:

- 11 permanent HAA batteries were active within range of the Sites during WWII. No evidence of permanent LAA gun batteries defending vulnerable points within range of the Site was found. Luftwaffe activity was frequent over the wider area and therefore these guns are unlikely to have expended a vast quantity of ammunition. However, no evidence to suggest that AA shells struck the Site has been found.
- No evidence of historic military activity within the Site boundary has been found and it is unlikely that any has occurred historically due to the agricultural nature of the Site. Consequently, the risk from associated Allied UXO is assessed to be Low.

Likelihood of UXO Remaining and UXO Encounter:

- The Site has remained as open, undeveloped land and orchards into the present day. Agricultural work such as ploughing, and the maintenance of the orchards, are anticipated to have disturbed WWII-era soil to very shallow depths (<1m bgl). No shallow (1-2m bgl) or deep (>2m bgl) excavations of WWII-era soil are anticipated to have taken place on Site.
- The risk associated with any very shallow buried UXO on Site is considered to be partially mitigated as a result of agricultural activities such as ploughing and general maintenance of the Site. However, the risk associated with any shallow or deep buried German UXBs almost certainly remains unmitigated. Note, this is not considered to be a significant risk. Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

RECOMMENDED RISK MITIGATION MEASURES: The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings	Prior to all intrusive works commencing.

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QUALITY MANAGEMENT

Brimstone is committed to the provision of UXO risk mitigation services, including the safe removal and disposal, in the UK and overseas. Since our inception in 2016 it has been our goal to provide unsurpassed UXO risk mitigation services. Brimstone is a client-driven organisation, we aim to provide the client the services they need, to the agreed requirement, in accordance with national and international standards.

We are committed to providing a safe, cost-effective and quality service, underpinned by our three core values;

- Integrity in advice, information and the manner in which we conduct ourselves and our operations,
- Professionalism in the way we handle our operations, people and processes, and
- Knowledge in new skills and information, to ensure we remain at the forefront of innovation and strategy.

We are committed to the applicable requirements of the ISO 9001 standards. We set and review quality monitoring objectives to measure the performance of our quality management system. Brimstone wholly endorses the ethos of 'continual improvement efforts' and allocates resources to meet this requirement.

This policy applies to the whole of the Brimstone services and affects roles from the managing director down. All staff are responsible for helping manage quality, seeking improvement through constant review, and by encouraging supplier and subcontractor involvement. We are committed to achieving customer satisfaction using quality procedures, which will be operated to meet or exceed the applicable requirements of ISO 9001.

Aaron Florence
Founder and Managing Director
Brimstone

1 INTRODUCTION

1.1 Background

IDOM (the Client) has commissioned Brimstone to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the Swanstree Avenue, Sittingbourne site (the Site).

1.2 Legislation

There are no regulations that specifically govern the UXO risk mitigation industry in the UK. There are however two pieces of legislation that require consideration. It is industry best practice (and common sense) to frame your site in the context of UXO, and to put in place measures to protect people from risks. In 2009, CIRIA published Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681. This publication, though not legally binding, provides the gold-standard framework to which UXO and construction companies operate.

1.2.1 Construction Design and Management Regulations (CDM) 2015

The regulations identify the client, the CDM coordinator, the designer, and the principal contractor as responsible parties. Under the regulations, responsible parties are held accountable for the way a construction project is managed and for the health and safety of workers. Responsible parties must:

- Provide an appropriate assessment of potential UXO risks, or ensure an assessment is completed by another party.
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks.
- Ensure the preparation of an emergency response plan.

1.2.2 The Health and Safety at Work Act 1974

The Health and Safety at Work Act 1974 had a transformative impact on health and safety, saving thousands of lives since its enactment. Employers must consider their employees, workers not in their employment, and members of the public. The act places a duty on every employer 'as far as is reasonably practicable' to protect workers from risks. It also says that information must be provided about aspects of health and safety that affect their role.

1.3 Commercial Contractor and the Authorities

1.3.1 Commercial Contractors

If your site has been given a moderate or high-risk rating, then control measures will be recommended. The measures will be specific to the scope of works on site, usually in relation to the depth and extent of excavations, piling and similar activities. There are a range of different methods at Brimstone's disposal, including:

- Non-intrusive surveying (including drone surveying)
- Intrusive surveying
- Search and clear
- Watching brief
- Support to geotechnical investigations
- Target investigation
- Site-specific training packages
- Site safety briefings

Our UXO Engineers can assess suspicious items on site when they are found. This will avoid unnecessary site evacuations. If our engineer(s) decide the item is UXO, they will coordinate with the authorities, manage disruptions, and advise on control measures, such as evacuations and a cordon.

1.3.2 UK Authorities

If Brimstone is not on site and a suspicious item is found, the local police must be immediately called on the non-emergency number. Police will visit the site. They will then inform the Joint Services Explosive Ordnance Disposal (JSEOD) office, which will coordinate the callout of an army or navy response team.

A precautionary cordon will initially be put into effect, with possible evacuation of homes and businesses, road and rail closures. The cordon may be extended following the advice from JSEOD's response team.

To manage their resources, JSEOD triages incidents. A consideration of the type, size and location of the UXO is made. If an incident is not given a high priority rating, a team may not be available for up to two days following the initial report.

The use of JSEOD is under the Military Aid to Civil Authorities (MACA) framework, therefore the budget and personnel is limited, and there are no statutory obligations made of the MOD. Often the MOD will recommend involvement of a commercial UXO contractor to manage the ongoing risk – this is especially true of former airfields and training areas where contact with land service ammunition can be frequent.

1.4 UXO Risk in the UK

Fortunately, to the best of our knowledge, there has not been a single post-war incident in the UK where a construction worker has been killed or injured because of an item of UXO exploding. There have been cases in mainland Europe where UXO had been struck and then exploded, killing workers. In 2019 a WWII general purpose bomb spontaneously detonating in a field north of Frankfurt, Germany.

However, the incident in Frankfurt is not comparable to the UK, due to the way different countries manufactured ordnance. Bombs made in different countries have different associated hazards. British WWII bombs, for example, have a fuzing system which uses chemicals which makes them very unsafe. Please see **APPENDIX 1** for recent examples of UK UXO incidents.

Between 2013 and 2016 JSEOD responded to 7,500 callouts. These callouts range from falsely identified objects, inert objects, small items of UXO and large WWII German unexploded bombs (UXBs). Each year the construction industry inadvertently unearths UXO; often this goes unreported. UXO contamination comes from three main sources:

- **Enemy action:** during WWI and WWII the air forces of Germany, and to a lesser extent Italy, bombed targets throughout the UK. The German navy bombarded several coastal targets in eastern England during WWI and then in WWII German long-range artillery on the French coast bombarded parts of Kent.
- **Allied military activity:** during WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre; predominantly the US and Canada.
- **UK military activity:** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as anti-aircraft gun and rocket batteries during WWI and WWII.

1.5 UXO Detonations

A detonation is a violent chemical reaction which creates a huge volume of gas. This reaction appears to happen instantaneously – the velocity of the shockwave moving is up to 9000m per second. This chemical reaction is started using a small amount of very sensitive explosives called primary explosives. These types of explosives are highly sensitive to shock, friction, heat, and spark. As the explosive charge undergoes high order decomposition (detonation), the brisance, or shattering effect, causes the casing to splinter, projecting razor-sharp shrapnel across long distances.

The blast wave effect and the shrapnel effect can cause significant damage. Calculating safety distances is a complex process. As a rule of thumb, in open ground, a 250kg explosive charge (as would be found inside a typical 500kg bomb) would require an omnidirectional safety distance of at least 1.6km.

Bombs work by amplifying the explosive charge from the sensitive primary explosive through to the main charge or fill of the item. This process is called an explosive train, if any link in that chain is broken, the item will fail to function as intended. This can be due to mechanical, electrical, or manufacturing tolerances or faults. Amongst other reasons, detonation of UXO could occur under the following circumstances:

- **UXO body impact:** A substantial impact onto the main body of a UXO; borehole rigs, piling rigs, jack hammers and mechanical excavator buckets.
- **Fuse impact:** Environmental conditions during decades of burial can result in the primary explosives located in the fuse pocket to crystallise and become shock sensitive. It would then take a relatively small impact or friction impact to cause the fuse to function and detonate the UXO.
- **Re-starting a timer:** A small proportion of German WWII bombs used clockwork fuses. In 2002 an Army EOD Engineer reported that the clockwork fuse in a UXB re-started. Decades of burial cause substantial corrosion in WWII German UXBs and therefore an incident such as this is extremely rare.

2 ASSESSMENT METHODOLOGY

2.1 Introduction

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is a publication which originated from round table best practice discussions from industry leaders.

2.2 SPRC Risk Model

The Source, Pathway, Receptor, Consequence (SPRC) risk model can be applied to buried UXO as follows:

- **Sources:** UK and allied UXO sources include military firing ranges, bases, storage depots, munitions factories, anti-aircraft batteries, amongst others. There are many wartime causes of UXO contamination. The source for enemy contamination is overwhelmingly from WWII German air raids.
- **Pathways:** the pathway describes how the UXO reaches receptors. Usually UXO is buried and therefore pathways can be any activity which involve breaking ground. Examples include ground investigation works, site enabling works and excavations.
- **Receptors:** receptors are the people, assets and infrastructure that can be adversely affected by UXO exposure. This includes site personnel, plant, equipment, buildings, the general public, , and the environment.
- **Consequence:** the consequences of an inadvertent UXO detonation are catastrophic. They include injury and loss or life, as well as damage to property. Fortunately, the likelihood of UXO detonating is low, even when it is uncovered during works. Another consequence to consider however is delays to works, which itself can be a risk.

2.3 Assessment Structure

In accordance with CIRIA C681 this assessment addresses the following considerations in the appropriate order:

- The likelihood that the site was contaminated with UXO.
- The type of UXO that could have contaminated the site, and their associated hazards.
- The likelihood that UXO remains on the site.
- Theoretical bomb penetration depths.
- The likelihood that UXO will be uncovered during the proposed works.
- Risk rating and risk mapping (as appropriate).
- Risk mitigation recommendations.

2.4 Information Sources

To complete this risk assessment Brimstone has gathered information from a wide range of sources. Brimstone's research team has completed detailed historical research, including access of original archived records. The following is a general list of information sources that are consulted during the research process:

- The National Archives,

- Local archive centres,
- Ministry of Defence,
- The Council for British Archaeology,
- Groundsure mapping services,
- Historical aerial photography (Historic England, Britain From Above, Bluesky),
- Google open source mapping,
- The British Geological Society,
- Open sources; published book, articles, web resources,
- Site specific information supplied by the Client,
- Brimstone's library and historical database, and
- Brimstone's former armed forces employees.

2.5 ALARP Principle

The ALARP (as low as reasonably practicable) principle corresponds to the actions that should be taken to reduce risks. The term 'ALARP' is in the Health and Safety at Work Act 1974, which says that risks must be controlled in a reasonable way.

Infinite time, effort and money could be spent trying to eliminate risk entirely. HSE uses the example that spending £1m to prevent five employees bruising their knees is disproportionate, whereas spending the same amount to prevent an explosion which could kill 150 people is proportionate.

Using this principle, Brimstone aims to reduce client costs by recommending strategies that are proportionate to the assessed risks, if any elevated risk is found at all.

2.6 Risk Tolerances

The Brimstone risk assessment process divides UXO risk into two tolerances:

- **Tolerable:** negligible risk or low risk ratings are tolerable. Where the risk cannot be completely discounted, it may be a useful strategy to opt for a low-cost measure, such as a UXO safety briefing from a qualified UXO engineer.
- **Intolerable:** moderate risk or high-risk ratings are intolerable. Proactive risk mitigation measures should be put in place. Various strategies are at Brimstone's disposal to meet your project-specific needs.

2.7 Reliance and Limitations

This report has been prepared using published information and information provided by the Client. Brimstone is not liable for any information which has become available following the publication of this report. No third-party liability or duty of care is extended. Any third-party using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 The Site

The Site (approximately centred on the National Grid Ref: TQ 91201 62558) is located in Sittingbourne, within the county of Kent, approximately 1.3km south-east of Sittingbourne rail station. The Site is bound to the north by Swanstree Avenue, to the east and south by undeveloped agricultural ground and to the west by structures associated with Chilton Manor Farm, undeveloped ground and Highsted Road.

The Site comprises open agricultural ground, with a gravel walkway in the north-east corner and six polytunnels in the south-east.

FIGURE 1: Site Location Maps

3.2 The Proposed Works

At the time of writing, Brimstone was made aware that future development works will comprise residential development, however, the exact details were unknown.

Future SI works will comprise 28 windowless sampler boreholes to approximately 5m bgl, eight machine-dug trial pits to approximately 3.5m bgl, soakage testing and in situ CBR testing.

FIGURE 2: Existing Site Plan

4 SITE HISTORY

4.1 Site Introduction

Site-specific history can be assessed by reviewing historical mapping, historical aerial photography and by carrying out additional Site-specific research where appropriate. Below are descriptions of a selection of records relevant to the Site:

4.2 Mapping

Period	Map Date	Map Scale	Review
Pre-WWI	1896	1:2,500	The Site comprises open ground in the east, a section of an orchard with a stone wall in the west and a footpath in the north-eastern corner. Further orchard land and a structure associated with the orchard was located to the north, further open ground was located to the east and south and Highsted Road was located immediately west.
	1906	1:10,560	No significant changes have occurred within the Site boundary or its immediate surrounds.
Pre-WW II	1938	1:2,500	**FIGURE 3.1:** The orchards have been extended further into the east; a small area of a pit connected to the orchard encroaches within the northern boundary.
Post-WWII	1947	1:10,560	**FIGURE 3.2:** No significant changes have occurred within the Site boundary or its immediate surrounds.
	1957-67	1:10,560	No significant changes have occurred within the Site boundary or its immediate surrounds.

4.3 Photography/Aerial Photography

Period	Photo Date	Review
WWII	3rd September 1940	**FIGURE 4.1:** It must be noted that this image is of low-resolution and therefore accurate analysis of the Site is not possible. The Site appears to comprise open ground and orchards with a pathway interjecting the Site in the north-eastern corner. There does not appear to be any evidence of bombing on Site or the immediate surrounds.
Post-WWII	1st May 1946	**FIGURE 4.2:** It must be noted that the entirety of the Site is not visible within this aerial image. The majority of the Site appears to comprise orchards with some open ground in the north-eastern area. Highsted Road is visible immediately adjacent to the west. A structure associated with the orchards is visible approximately 110m north. There does not appear to be any evidence of bombing on Site or its immediate surrounds.

	17th April 1951	**FIGURE 4.3:** The full Site is visible within this aerial image. The Site comprises orchards in the east and south, with open ground in the north-east. A section of a wall/pit associated with the structure to the north encroaches within the northern Site boundary. A small hut structure appears to be visible along the southern boundary. There does not appear to be any evidence of bombing on Site or its immediate surrounds.

4.4 Additional Site-Specific History

Some sites will have been occupied by landmarks or significant buildings historically and in such cases specific written histories including significant wartime details are occasionally available in the public domain. No such information was available.

5 UXO RISK - GERMAN BOMBING

5.1 WWII Bombing History of the Site

5.1.1 Kent

In the summer and autumn of 1940, the Luftwaffe targeted the RAF's airfields and support network with the intention of achieving air supremacy prior to a planned amphibious invasion of south-east England. The resulting Battle of Britain campaign (July to October) resulted in many air raids across England, although these were mainly concentred in the south-east, especially in Sussex and Kent.

In early September 1940, the Luftwaffe changed their tactics and commenced a nine-month indiscriminate carpet-bombing campaign over London. The vast majority of the Luftwaffe units based in occupied Europe were then redeployed to the Russian front. Thousands of German aircraft sorties were flown over Kent to and from London. This resulted in many bombing incidents occurring over the county.

During 1942 and 1943, a number of small-scale fighter bomber raids were carried out against London and several towns in Kent, as well as the Baedeker Blitz occurring over Canterbury. In 1944, the Luftwaffe commenced Operation Steinboch. This campaign comprised 31 major raids against London and other southern England targets, including those in Kent, executed by inexperienced Luftwaffe crews, between January and May. However, poor navigation and improved defences resulted in unsustainable Luftwaffe losses, many formations being broken up by the RAF over the Home Counties.

Immediately following the final air raids on London, the Luftwaffe launched the V Weapons campaign, commencing in June 1944. The V1 (Flying Bomb or Doodlebug) and later the V2 (Long Range Rocket) were launched from occupied Europe. 2,419 of the former and 517 of the latter were recorded in the London Civil Defence region, with thousands more recorded in the Home Counties.

Both carried a large 1,000kg HE warhead and were constructed of thin sheet steel, rather than the thick steel used on the Luftwaffe's free fall bombs. V Weapons were designed to detonate on the surface (like parachute mines), as opposed to free fall bombs which were designed to have some penetration ability through multi-storey buildings. Consequently, any V Weapons which failed to detonate broke up on impact, resulting in an easily identifiable debris field. Although there is a negligible risk from unexploded V Weapons on land today, they caused widespread destruction throughout London and therefore, at V Weapon impact sites, the assessment of pre-1944 UXB risk can be hampered.

5.1.2 Site Specific

The nearest identified Luftwaffe target was Sittingbourne Paper Mill, located approximately 1.5km north-west of the Site. The nearest viable secondary target would have been Sittingbourne Railway Junction, approximately 2.1km north-west of the Site. Luftwaffe pilots were ordered to attack Britain's railway infrastructure as targets of opportunity if their primary targets were unavailable.

The Site is anticipated to have only been vulnerable to 'Tip and Run' bombing incidents. These were small scale and targeted attacks. Luftwaffe and corresponding RAF activity over this part of Kent was very high, especially during the autumn and summer of 1940, and therefore such incidents were commonplace.

5.1.3 Bombing Decoy Sites

In mid-1940 bombing decoys were introduced. The decoys used either;

- A system of lighting to simulate an urban area or a military airfield's runway
- Deliberately started fires to simulate a previously bombed target
- Dummy buildings and vehicles to simulate a military facility

792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. No decoys were operational within a significant radius of the Site during WWII. The closest was approximately 9.1km to the south.

5.2 WWII Bombing Records

5.2.1 Introduction

The bomb census recorded the location and type of bomb strikes to help with intelligence gathering and planning. It was compiled using information recorded by ARP wardens. These records were gathered by the Ministry of Home Security to calculate bombing density within administrative areas.

The bomb census was unreliable in the early stages of the war, though by 1941 procedures had been standardised. The quality of the census records also depended on where in the UK the records were produced. Some records are held at the National Archives and some are held at local borough archives.

Relevant records held at the National Archives and the and the Kent History and Library Centre were obtained for this risk assessment.

5.2.2 Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Urban District of Sittingbourne and Milton. It gives a breakdown of the types of large German bombs reported and is understood to not include UXBs.

Admin Area	Sittingbourne and Milton
Area Acreage	4,935
High Explosive Bombs (all types/weights)	128
High Explosive Parachute Mines	1
Flam (Oil) Bombs	5
40kg Phosphorus Incendiary Bombs (IBs)	7
40kg 'Fire Pot' IBs	0
V1 Flying Bomb	3
V2 Long Range Rocket	0
Total (excluding V-Weapons and 1kg / 2kg IBs)	141
Bombs Per 1,000 Acres	**28.6**

1kg / 2kg incendiary bombs (IBs) and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are not included in the above figures.

5.2.3 Kent ARP Reports

Brimstone has reviewed a collection of original War Diaries; original ARP written incident reports for the Urban District of Sittingbourne and Milton produced by the local ARP organisations. These diary collections, covering the entire bombing campaign, were reviewed and the following incidents were identified in proximity to the study area. Three incidents were recorded within an approximate 1km radius of either Site. The closest recorded strikes are transcribed below;

Date	Bomb(s)	Location *(relative to the Site)*	Remarks
29th January 1944	AB 1000-R1 Cluster Bomb (Incendiary)	'Chilton Playing Fields' *Approximately 730m north*	Container found empty
	AB 500-1 Cluster Bomb (Incendiary)	'Trotts Hall Gardens' *Approximately 880m north-west*	Container found empty
	IBs	Fires at various parts of the town. *Approximately 800m north-west*	Wesleyan Church on fire.
22nd April 1944	V1 Strike	'Chalks Hole Orchard' *Eastern Site boundary*	Sheep killed and injured. Slight damage to property

5.2.4 'Where the Doodlebugs crashed in Kent'

Brimstone has reviewed an original consolidated V1 Bomb Plot Map of Kent by the Kent Messenger in 1944, held at the county archive. One V weapon strike was recorded in the approximate Site area, corroborating with the written ARP reports. Due to the large scale of the map, the accuracy cannot be relied on.

5.2.5 Abandoned Bomb Register

Due to the overstretched bomb disposal units during WW2, many bombs were intentionally left undisturbed. UXBs were triaged based on where they were and how big they were. If they didn't pose a significant risk they were 'abandoned'. The locations of these bombs were recorded on the abandoned bomb register.

The abandoned bomb register is a public record document held at the Parliamentary Archives of the House of Commons, from which Brimstone has obtained a copy. The register should not be relied on for completeness or accuracy. The closest abandoned bomb is recorded approximately 8km north-west of the Site.

5.2.6 Secondary Source / Anecdotal Evidence

A search of online resources, as well as a review of local history publications was carried out with the intention of locating any eyewitness accounts of local bombing incidents. However, no such evidence was found.

5.3 Likelihood of UXB Contamination

Where detailed bombing records exist, it is possible to predict whether any UXBs could be found on a site. This likelihood is discussed in the following table:

Density of Bombing	
Number of Air Raids in the Vicinity:	A comparison of the bombing incident records confirms that at least one air raid affected the study area. Although it must be noted that one of these incidents was not conventional, in the form of a V1 strike.
Intensity of these Air Raids:	All bombs dropped locally were likely part of small-scale raids executed by solitary aircraft. Research indicates that the study area did not experience large-scale raids during WWII.
Bomb Strike Positions	
Closest Bomb Strikes	HE bombs: 1.75km south. 1kg / 2kg IBs: 1.75km south.

Alignment of recorded Bomb Strikes:	Identifying the alignment of individual bomb-sticks is not possible with the available records as they do not record exact locations or individual bombs within a stick. Due to the lack of bomb strikes in close proximity to the Site, it is unlikely that any aircraft flew over the Site whilst dropping its bombload.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of the site:	None.
UXBs recorded in close proximity to the site:	No recorded UXB strikes within an approximate 500m radius of either Site.

5.4 Likelihood of Subsequent UXB Detection

A range of circumstances determine whether a UXB strike location would have been identified, during and after the war. This is discussed in the following table.

Historic Access
A UXB falling on a site which was frequently accessed would have had a better chance of being found. ARP Wardens actively searched for UXBs in heavily bombed residential areas. The importance of a site or nearby buildings and infrastructure was also a factor. Many industrial facilities had fire watchers tasked with extinguishing incendiary bombs and reporting UXBs.
One air raid occurred during the hours of darkness when residents and workers of structures and farms in the wider Site area would have been indoors and / or sheltering. As such there is generally a lower probability of anyone witnessing any UXB strike to the Site as it fell / occurred. NB: no evidence of fire watchers active in the vicinity (providing night-time observation) was found. The Site comprised an area of orchards and open ground. As a result, it cannot be assumed that it would have been subject to a frequent degree of access or been subject to specific post-raid searches for delayed action (DA) bombs / UXB entry holes, carried out by ARP wardens. It is conceivable therefore that any UXB dropped on Site could have fallen unnoticed. However, the structure located approximately 110m north of the Site will have provided a degree of access, although likely not to a significant level.

Bomb Damage
As the bombing campaign continued, damaged areas became vulnerable to unreported UXBs. Bomb site wreckage or soil disturbance at a bomb crater could obscure evidence of a subsequent UXB strike.
No evidence has been found to suggest that the Site sustained bomb damage. WWII-era and post-war aerial photography does not display evidence of cratering, ground disturbances etc. consistent with bombing incidents. Although, it must be noted that due to the Site comprising undeveloped land and orchards, any signs of damage would likely be less noticeable in post-WWII aerial photography as these conditions are typically less conducive to the identification of evidence bomb damage.

Ground Cover Type
A UXB which falls on open field could easily go unnoticed, whereas a UXB dropped on a hard-surfaced car park would have been easily observed.
It is conceivable that the Site, which comprised undeveloped, open ground and orchards, may have potentially been overgrown/unmaintained at times. A small UXB entry hole could easily have been obscured within such ground cover. Over time, changing environmental conditions could have caused this hole to infill, erasing any evidence of a UXB. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 20cm, creating a small easily obscured entry hole.

5.5 Bombing During WWI

During WWI, an estimated 9,000 German bombs were dropped on London, Eastern England and South-Eastern England during some 51 Zeppelin airship raids and 52 fixed-wing aircraft raids. London suffered the worst of the bombing with an estimated 250 tonnes of HE and incendiary bombs recorded across the Capital, over half of which fell on the City of London district.

The WWI bombing campaign waged by Germany was on a far smaller scale than the WWII campaign, in terms of the number of raids, the weight of ordnance dropped during each attack and the size of the bombs used. When coupled with the fact that most WWI bombed locations have since been redeveloped, German WWI UXB finds are extremely rare. Furthermore, most air raids took place during daylight hours and as it was the first time Britain had experienced strategic aerial bombardment, the raids often attracted public interest and even spectators, increasing the chances of any UXBs being reported.

Sittingbourne was raided on two separate occasions. The first occurring on the 16th April 1915[1] when an aircraft dropped five bombs; one landed in Fulston orchard, blasting an apple tree and killing a blackbird sitting in it, another fell at Crayalls Farm, and three landed at Gore Court Park (the closest occurring approximately 850m west). The second occurring on the 4/5th June 1915[2] when a zeppelin dropped four high explosive (HE) and 24 incendiary bombs on Sittingbourne and Milton Regis. The HE bombs fell in Jackson's Field, St. Paul's Street (near Pear Tree Alley), a field at Chilton Farm and on a garden wall between Unity Street and Park Road (the closest occurring approximately 300m north). The blast from this last bomb seriously damaged a number of houses and injured two people.

Neither of these raids are believed to have impacted the Site. Therefore, the associated UXB risk can be discounted.

6 WWII GERMAN BOMBS

6.1 Bombs Dropped on the UK

Nazi Germany used different types of ordnance against the UK for different effects. Some types were designed to cause fires, others for their destructive blast effect and other for their penetration capability. Each type of ordnance was fitted with at least one fuze. For some bombs multiple fuzes were used. Many different types of fuzes were available for use – each with its own set of associated hazards.

Data sheets on those bombs most likely to be encountered today are included at **APPENDIX 2**.

- **HE bombs – moderate NEQ (net explosive quantity):** the most common types of HE bombs dropped were the SC (general purpose - GP) and SD (semi-armour piercing - SAP) series of bombs. The NEQ is between 30-50%. SAP bombs are engineered to attack light fortifications, whereas GP bombs are used in a mixed destructive blast and anti-personnel fragmentation role. 70% of bombs dropped on the UK were the 50kg type.
- **HE bombs – high NEQ:** blast bombs and parachute mines have bodies made of thin steel, allowing for larger HE charges. These were designed to detonate above ground, maximising the blast effect. Parachute mines were weapons slowed by parachutes and designed to detonate without penetrating the ground. Although, in some marshland areas, partially buried parachute mines have been observed. Consequently, it is highly unlikely that any unexploded blast bombs remain buried in the UK today.
- **HE bombs – low NEQ:** The PC series were armour piercing bombs used against heavy fortifications and reinforced bunkers. They were not commonly used over the UK.
- **Small incendiary bombs:** The 1kg and 2kg incendiaries were the most dropped bomb. Up to 620 x 1kg incendiaries could be packed into the largest container unit, which opened at a pre-determined height scattering its payload over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. Variants of the 1kg and 2kg incendiary bombs contained a small HE charge designed for an anti-personnel role, and to increase its incendiary effect.

[1] https://www.iancastlezeppelin.co.uk/16-apr-1915
[2] https://www.iancastlezeppelin.co.uk/4/5-jun-1915

- **Large incendiary bombs - Thick skinned:** The C50 has a thick body and contained a mixture of incendiary liquids and white phosphorus. Another version of the C50 had a white phosphorus fill. The C50 'firepot' contained thermite incendiary containers (aka firepots) and a small HE charge.
- **Large incendiary bombs - Thin skinned:** The Flam 250 and Flam 500 models had thin steel bodies designed to break up on impact, spreading their oil-incendiary mixture, which was ignited by a small HE charge. Consequently, it is highly unlikely that any unexploded Flam bombs remain buried in the UK today. Their unreliability meant withdrawal from frontline use by January 1941.
- **Submunitions:** The SD2 'butterfly' bomb was a 2kg submunition dropped on several British cities and towns. It contained a 225gram HE charge. SD2s had no ground penetration ability so the vast majority were recovered at the time. However, SD2s are still found across Britain today.
- **V1 flying bombs and V2 rockets:** In the final year of WWII Germany began using pilotless weapons against England. Both V Weapons had 1,000kg HE warheads. Due to their light-body construction, they had no penetration ability and any impact left a noticeable debris field. As such, there is negligible risk from unexploded V weapons today.

6.2 Bomb Failures

Records from September 1940 to July 1941 show that an average of 84 UXBs were dropped on civilian targets each day. Around 8% of these were time delay bombs – designed to strike the ground and start a predetermined countdown which could last days.

There is a generally accepted 10% failure rate for WWII German HE bombs. This is estimated from records gathered by bomb disposal units. These statistics do not account for UXBs that went by unnoticed.

Failures can happen for different reasons, including:

- Equipment or human error in arming the bombs before release,
- Failure of a mechanism within the fuze (out of tolerance),
- Jettisoning payloads if the bomber was under attack or crashing, or
- Partially functioned bombs (e.g. cracks in the cast TNT)

6.3 Bomb Ground Penetration

6.3.1 Introduction

Using data gathered during WWII by the Ministry of Home Security, estimations can be made about how deep a bomb is likely to penetrate the ground. Over one thousand incidents were reported by the bomb disposal units to support this research. Further tests were carried out, dropping bombs of different sizes into chalk and measuring the depths they reached. This research is held at the National Archives. The estimates are:

Bomb weight (kg)	Ground Type (m)							
	Sand		Gravel		Chalk		Clay	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

Different layers of geology affect penetration depths. For example, 1m of made ground, then 1m of gravel before reaching clay – as is many areas of London – is not easily calculated from the data above. 12

When calculating how deep a bomb could have reached, we must make three assumptions:

- **Impact velocity:** German bombing raids were carried out at altitudes in excess of 5,000m. The velocity of impact is roughly 313ms^{-1} (not accounting for resistance). It is the same velocity regardless of mass.

- **Impact angle:** strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.
- **Bomb design:** Some larger German bombs were occasionally fitted with 'kopfrings' - a metal ring, triangular in cross section, fitted around the nose of the bomb to help prevent penetration. It must be assumed that no 'kopfrings' were fitted.

6.3.2 The J-Curve Effect

During WWII BDUs reported that most buried UXBs were found horizontal or upturned. This observation confirmed the 'J-curve effect'. As an HE bomb penetrates the ground, slightly offset from the vertical, its passage underground creates a 'J' shape.

This is relevant because the J-curve effect results in a horizontal offset between the buried UXB and its point of entry. This is distance is estimated to be one third of the theoretical penetration depth. A low altitude attack, meaning a low impact angle, could produce an even greater offset, of up to 15m.

6.3.3 Site Specific Geology

BGS Mapping	**Superficial Deposits:** Head - Clay and silt	**Bedrock Deposits:** Seaford Chalk Formation – Chalk Thanet Formation - Sand, silt and clay
SI Data	No recent SI data was provided by the Client. However, local BGS borehole logs were available. The closest BGS SI through the same mapped geology as the Site is located approximately 1.1km south-east of the Site (BGS ID: 643630). This SI (4th November 1984) encountered the following ground conditions: - 0.30m of topsoil - 2.70m of brown clay - 7.00m of rubble chalk - 28.00m of chalk and flints - 10.00m of hard bands - 26.00m of solid chalk	

6.3.4 Site Specific Maximum Bomb Penetration Depth

During WWII the Luftwaffe dropped many different types of HE bomb. The SC (general purpose) series was by far the most numerous and of this series, the SC 500 model (weighing 500kg) was the largest of the most commonly deployed and therefore this will be used as the benchmark weapon for the Site-specific bomb penetration depth calculations.

To calculate an accurate maximum bomb penetration depth, Brimstone has taken the average of the averages of the figure for the predominant Site-specific geology (clay and chalk), in the table above. This gives a maximum bomb penetration depth of 13.13m below WWII ground level for a 500kg HE bomb. However, as this borehole data is not taken directly from within the Site boundary, the bomb penetration depth may not be completely accurate.

NB: theoretically penetration depths could be greater if the UXB was larger, however, War Office statistics confirm that between October 1940 and May 1941 the majority of HE UXBs (>90%) were either 50kg or 250kg, with the 500kg bombs making up most of the remaining 10%.

7 UXO RISK - BRITISH/ALLIED ACTIVITY

7.1 Introduction

The table below lists potential sources of UXO (excluding enemy action). Those which are potentially relevant to the Site are discussed in the subsequent section(s).

Potential UXO Source	Potentially Significant
Army or RAF training areas / ranges	✗
Military bases and other installations	✗
Munitions and explosives factories	✗
Military storage depots	✗
Defensive fortifications	✗
Wartime site requisitions	✗
WWII defensive mining (landmines)	✗
WWII Home Guard activity	✗
Wartime anti-aircraft fire	✓

7.2 Potential Sources of UXO

7.2.1 Introduction

Research has not located any evidence of significant British or Allied army, RAF or Royal Navy activity specifically on Site and none is likely to have occurred historically. The only likely potential source of British UXO contamination is therefore WWII AA artillery fire.

7.2.2 WWII Anti-Aircraft Fire

Anti-Aircraft (AA) Command was a British Army command established in 1939 to defend the UK during the anticipated German bombing campaign. It controlled the Territorial Army AA artillery and searchlight units. From 1940 to 1945 BDUs dealt with 7,000 unexploded AA shells in Britain. There were three main types of AA battery used for home defence (see below). Data sheets on these AA defences are included at **APPENDIX 3**.

- **Heavy Anti-Aircraft (HAA):** large calibre guns (3.7" and 4.5") for engaging high altitude bomber formations. Hundreds of permanent batteries were constructed in and around major cities and military bases during the 1930s. Some 2,000 of these guns were available during the Blitz. Each gun could fire between 10 and 20 rounds per minute and consequently HAA batteries could expend large quantities of shells during each engagement.

  British time fuses were poorly manufactured during WWII and this led to high failure rate for HAA shells, up to 30%. Unexploded HAA shells had the potential to land up to 27km from their battery, although more typically landed within a 15km radius.

- **Light Anti-Aircraft (LAA):** smaller calibre guns for engaging dive bombers and low altitude intruders. As such they were mostly used to defend specific industrial and military targets which were subject to precision bomber attack. LAA guns were either .303" calibre machine guns or 20mm and 40mm calibre cannon. The latter were fitted with simply impact fuses and small incendiary or HE bursting charges.

  The 40mm Bofors gun could fire 120 x HE shells / minute to a ceiling of 1,800m. Each shell was designed to self-destruct if it didn't strike an aircraft, however, inevitably some failed and fell back to earth.

- **Z (Rocket) Batteries**: a Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotated Projectile (UP) rockets to a maximum altitude of 5,800m; a ground range of some 9,000m. They were deployed in cities all around the UK from 1941 and proved to be an effective addition to the existing AA guns.

  The rockets measured 0.9m (2") and 1.8m (3") in length with four stabilising fins at the base and were fitted with 3.5kg or 8.2kg HE warheads. The larger warhead had an effective airborne blast radius of up to 20m. Some variants deployed a form of aerial mine described as a "small yellow bomb" which was designed to detach from the rocket at height and descend on a parachute with the objective of becoming snagged on target aircraft and then detonating.

Unlike bombs which were designed to strike the ground, AA projectiles and rockets were designed to function in the air. Due to their shape, and centre of gravity they would often not strike the ground nose first. This coupled with the lower mass of AA UXO resulted in shallower ground penetration depths, compared to UXBs. Although, in very soft conditions, unexploded AA projectiles have been found deeper than 1.5m bgl.

11 permanent HAA batteries were active within range of the Site during WWII. No evidence of permanent LAA gun batteries defending Vulnerable Points within range of the Site was found. Luftwaffe activity was frequent over the wider area and therefore these guns are unlikely to have expended a vast quantity of ammunition. However, no evidence to suggest that AA shells struck the Site has been found.

8 UXO RISK MITIGATING CIRCUMSTANCES

8.1 Introduction

Works on a UXO contaminated site could result in the partial or complete removal of UXO risk. Construction or earthworks may have uncovered any UXO contamination, which would then have been reported and removed by the authorities. A site may have been subject to an explosive ordnance clearance (EOC) task conducted by the armed forces. EOC tasks involve surveying, subsequent target investigation and removal of UXO. Although the effectiveness of historic EOC tasks will have often been unsatisfactory.

8.2 Explosive Ordnance Clearance Tasks

The division of EOD tasks has been complex throughout British military history. It used to be the case that anything under the water level would be dealt with by navy units, and anything on land would be dealt with by army units. In recent years RAF EOD capability has been discontinued, and now only the Royal Navy and the British Army have EOD units. In the army, the Royal Logistics Corps and Royal Engineer EOD units have been amalgamated to form 29 EOD & Search Group. Often taskings are assigned to either the naval or army elements based on where in the country the threat is and the nature of the threat.

Brimstone has access to a database of historic EOC tasks. This database is only complete up until the early 2000s and therefore does not include recent EOC tasks. No such database for the RAF and Royal Navy EOD units is easily accessible. A search of this database has not resulted in any Army EOC tasks in the vicinity of the Site.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. A live WWII-era grenade was found and detonated at the Appleyard Sports Bar on the 18th April 2023, approximately 830m west of the Site. It had been found buried by the patio of the bar; the land had previously always been a sports ground.[3]

8.3 Ground Works

The Site has remained as open, undeveloped land and orchards into the present day. Agricultural work such as ploughing, and the maintenance of the orchards, are anticipated to have disturbed WWII-era soil to very shallow depths (<1m bgl). No shallow (1-2m bgl) or deep (>2m bgl) excavations of WWII-era soil are anticipated to have taken place on Site.

8.4 Deductions

The risk associated with any very shallow buried UXO on Site is considered to be partially mitigated as a result of agricultural activities such as ploughing and general maintenance of the Site. However, the risk associated with any shallow or deep buried German UXBs almost certainly remains unmitigated. Note, this is not considered to be a significant risk.

Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

[3] https://www.express.co.uk/news/uk/1759630/kent-Appleyard-Sports-Bar-Sittingbourne-live-grenade-found

9 CONCLUSION

9.1 Accuracy of Historical Records

Occasionally, the accuracy of some historical records can prove to be poor when compared with other sources of information. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the study area. No such inconsistencies were noted within the records consulted for this report.

9.2 The Risk of UXO Contamination on Site

9.2.1 Key Findings – German UXO Risk

- During WWII, the Site was located relatively close to a Luftwaffe flightpath to London; original wartime bombing figures and mapping indicate that the study area experienced a low to moderate bombing density, However, no known or potential Luftwaffe bombing targets were present in the immediate vicinity and Sittingbourne town was never subjected to a large-scale air raid. The Site was likely therefore only vulnerable to small scale targeted 'Tip and Run' bombing incidents, although as aforementioned, the lack of potential targets in the vicinity reduces this likelihood.
- A collection of Kent ARP written incidents records was reviewed for this report. No bomb strikes were recorded on Site or in the surrounding area. Although the closest incident was recorded on the eastern boundary of the Site, this was a V1 strike. This rocket exploded, and as no conventional air raids occurred following this strike, there is considered to be a low likelihood of a UXB strike remaining unobserved within this area of damage.
- Historical aerial photography and OS mapping show that the Site comprised undeveloped open land and orchards during WWII. Subsequently, any potential evidence of UXO which may have fallen at this time is thought likely to have been less noticeable, with a UXB's descent into open land less obvious than through a structure or roadway, for example. As the majority of the Site comprised open ground and orchards during the war, it would have only experienced infrequent access and is highly unlikely to have been subject to post-raid specific searches for German UXBs. As such, there is a chance of a UXB falling unnoticed and remaining on Site, buried in-situ. However, the structure associated with the orchard approximately 110m north may have provided a slightly elevated level of access to the area.
- In summary, due to the very low localised bombing density, lack of recorded conventional bomb strikes on Site or in the surrounding area and lack of evidence of bomb damage, the risk of contamination from German UXBs is not considered to be elevated.

9.2.2 Key Findings - British UXO Risk

- 11 permanent HAA batteries were active within range of the Sites during WWII. No evidence of permanent LAA gun batteries defending Vulnerable Points within range of the Site was found. Luftwaffe activity was frequent over the wider area and therefore these guns are unlikely to have expended a vast quantity of ammunition. However, no evidence to suggest that AA shells struck the Site has been found.
- No evidence of historic military activity within the Site boundary has been found and it is unlikely that any has occurred historically due to the agricultural nature of the Site. Consequently, the risk from associated Allied UXO is assessed to be Low.

9.3 Site-Specific UXO Hazards

Different types of UXO pose differing types of hazard, depending on their structural design, Net Explosive Quantity (NEQ), fill type and likely contamination depth. The table below lists the main types of UXO most often encountered on urban UK sites and their relative hazard levels.

UXO Type	NEQ (NEQ Range)	Likely Burial Depth	Hazard Posed
WWII German General Purpose HE Bombs	25kg - 220kg (most commonly deployed bomb weights)	Likely deep burial (>2m)	HIGH RISK
WWII British Heavy Anti-Aircraft Shells	1.1kg - 1.7kg	Shallow burial (1-2m)	MODERATE-HIGH RISK
WWII British Land Service Ammunition	<2kg	Shallow burial (1-2m)	
WWII German 2kg Incendiary / HE Bombs	680g incendiary hazard + ~500g explosive hazard	Shallow burial (1-2m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (1-2m)	MODERATE RISK
WWII British Light Anti-Aircraft Shells	4g - 70g	Very shallow burial (<1m)	LOW-MODERATE RISK
Small Arms Ammunition	<1g	Very shallow burial (<1m)	LOW RISK
Inert/Practise Item	0g	Very shallow burial (<1m)	

9.4 The Likelihood of UXO Encounter

9.4.1 Introduction

This report assesses the risk of UXO in relation to the proposed works, not simply the risk that UXO remains buried on site. The likelihood of UXO encounter during intrusive ground works will vary depending on the type of UXO and the type of construction methods employed during the project. With increased soil disturbance i.e. more excavations, the likelihood of encountering UXO increases.

Within an area of elevated UXO contamination likelihood, the sub-surface volume of potential UXO contamination will comprise the natural soil / geology in between WWII ground level and the maximum bomb penetration depth. Therefore, any intrusions into this layer will be at risk of UXO encounter.

Any post-WWII fill material deposited on a site is unlikely to be contaminated with UXO and therefore the risk of encountering UXO on such a site could vary with depth.

In the wake of the initial nine-month Blitz, many cities and towns were left with vast quantities of bomb site rubble that required removal and relocation. This material was put to use for in a variety of ways, for example >750,000 tons of London's rubble was used to build runways for new RAF and USAAF airfields and much of Liverpool's rubble was used to create and maintain sea / flood defences throughout Merseyside.

It is quite possible that unexploded British AA projectiles and German 1kg incendiaries were overlooked during removal, resulting in UXO contaminated fill material ending up on otherwise low UXO risk sites, possibly many miles from any high bombing density areas.

9.4.2 German UXBs

Although most German UXBs came to rest several metres below WWII ground level, these weapons can be found at any level between just below WWII ground level and the maximum bomb penetration depth. There are a number of reasons why these heavy bombs might be found at surprisingly shallow depths.

- **Tip and run:** When enemy aircraft had to take evasive action to escape RAF fighter intercepts or AA defences, they often dropped their bomb loads from a reduced height, potentially resulting in extreme J-curve effect.
- **Deflection:** the shape of German bomb nose sections meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hardstanding.
- **Aircraft Crash Site:** if an aircraft was unable to dump its bomb load before impacting the ground, due to mechanical fault, any externally fitted bombs could have become buried on impact.

German 1kg / 2kg incendiaries were cylindrical and approximately 50mm in diameter. They had tail sections, and so landed nose first. Within soft ground this could result in full penetration of the bomb below the surface. Such UXBs are usually found close to the surface.

9.4.3 British / Allied UXO

The nature of British/Allied military activity involving LSA and SAA and the smaller size of these munitions (in relation to German HE bombs) indicates that any resulting UXO contamination on a site will be limited to shallow depths, usually within 1.5m of the surface, notwithstanding added material to raise the ground level.

Domestic military LSA and SAA contamination will either be the result of expending blinds (dud ammunition) which bury into the ground on impact or munitions purposefully buried, for a number of reasons. Either way, these types of UXO are all found at shallow depth.

9.4.4 Deductions

It is conceivable that a UXB could be encountered during any mechanical excavations beneath the existing ground level in this location given the lack of significant post-WWII redevelopment occurring on Site. However, the likelihood of such an incidence occurring is considered insignificant.

10 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating the Site, remaining within the Site up to the present day and being encountered during the proposed works, inform the overall risk rating. The UXO risk to the proposed works has been assessed as **Low.**

Risk Table: Low Risk				
UXO TYPE (ASSOCIATED HAZARD)	LIKELIHOOD OF UXO CONTAMINATION	LIKELIHOOD OF UXO REMAINING	LIKELIHOOD OF ENCOUNTER	OVERALL RISK RATING
WWII German 'Iron' Bombs	Low	n/a		LOW
WWII British Heavy Anti-Aircraft Shells	Low	n/a		
WWII British Land Service Ammunition	Low	n/a		
illWWII German 2kg Incendiary / HE Bombs	Low	n/a		
WWII German 1kg Incendiary Bombs	Low	n/a		
WWII British Light Anti-Aircraft Shells	Low	n/a		
WWII British Small Arms Ammunition	Low	n/a		

11 RISK MITIGATION RECOMMENDATIONS

Brimstone has not identified an elevated UXO risk to the proposed works. The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on Site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Prior to all intrusive works commencing.

FIGURES: 1 - 4

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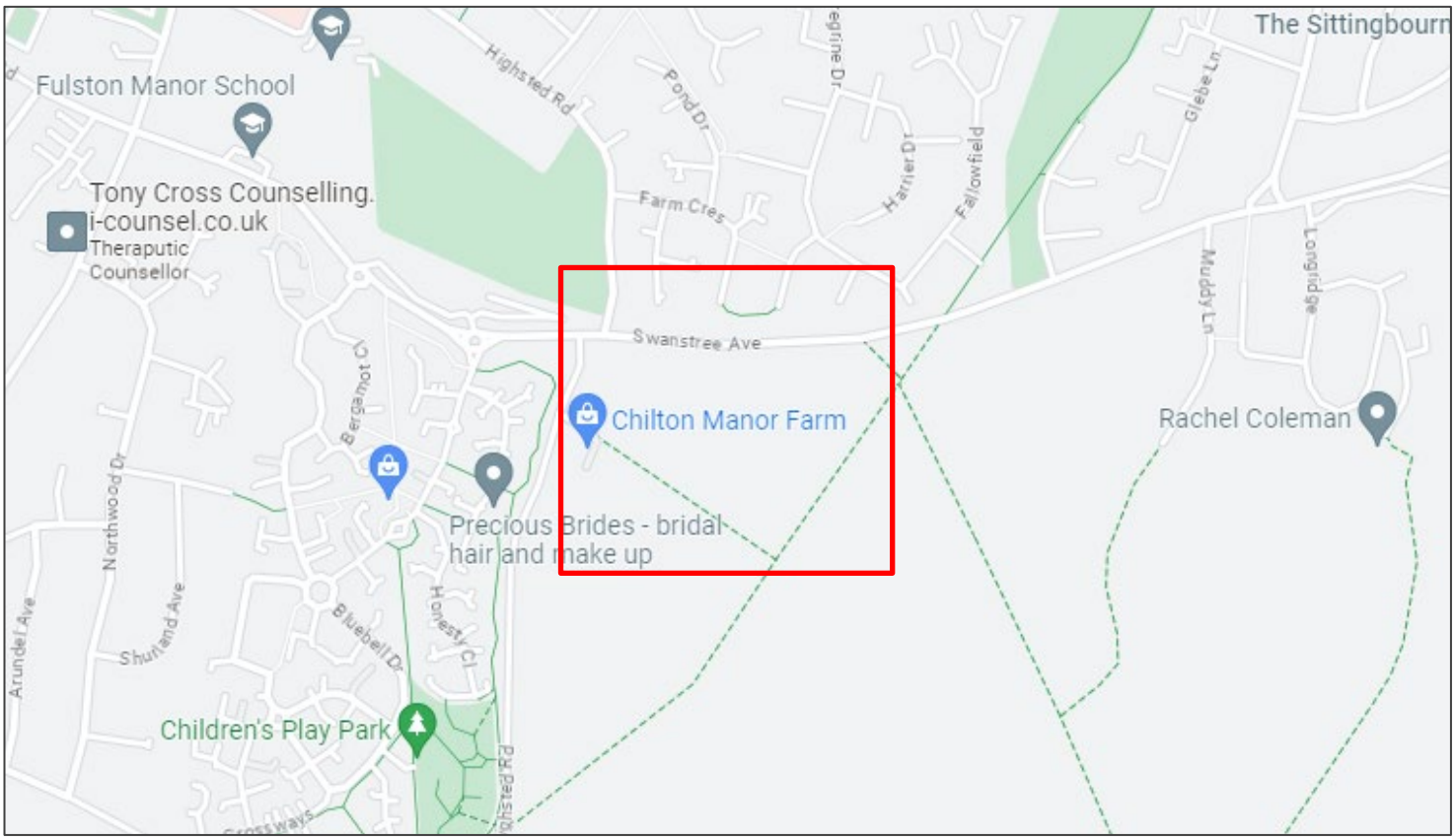
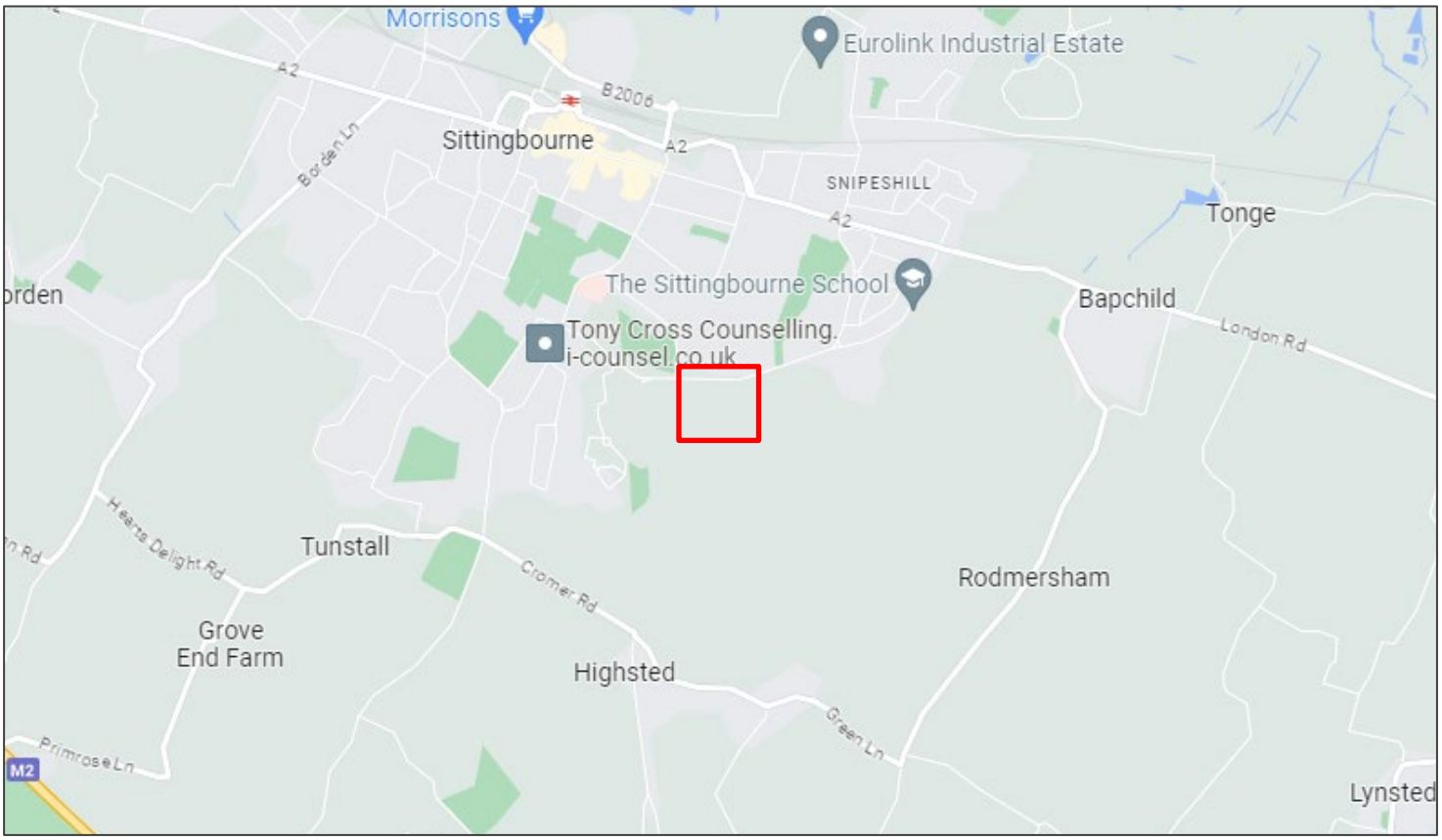
N	**Title:**	**Site Location Maps**	**FIGURE: 1**





Project:	**Swanstree Avenue, Sittingbourne**		
Client:	**IDOM**		
Report Ref:	**DRA-23-1577**		
General Site Location:		Info Source:	Google (open-source)

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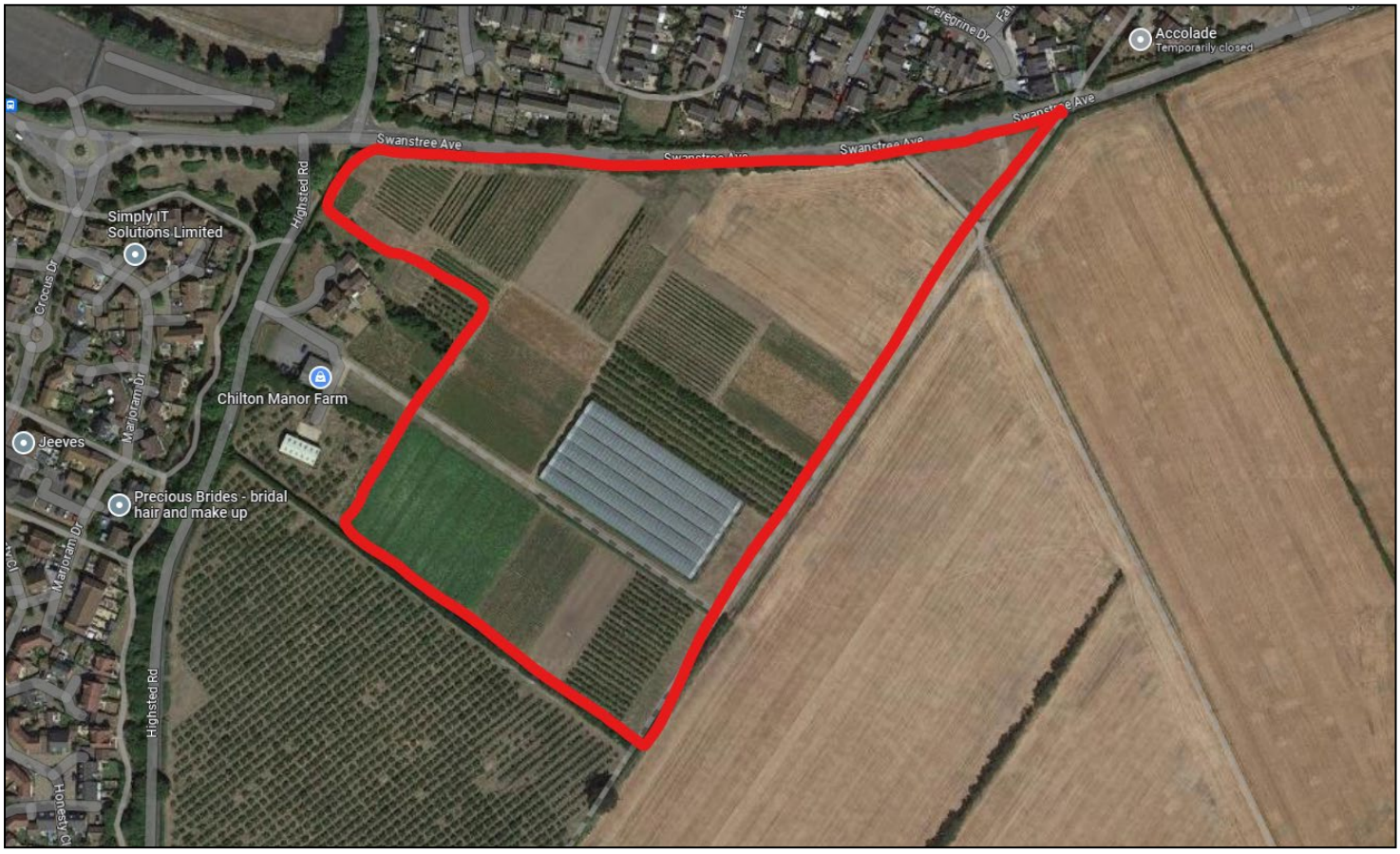
N	Title:	Existing Site Plan	FIGURE: 2



Project:	Swanstree Avenue, Sittingbourne
Client:	IDOM
Report Ref:	DRA-23-1577
Site Boundary:	Info Source: IDOM

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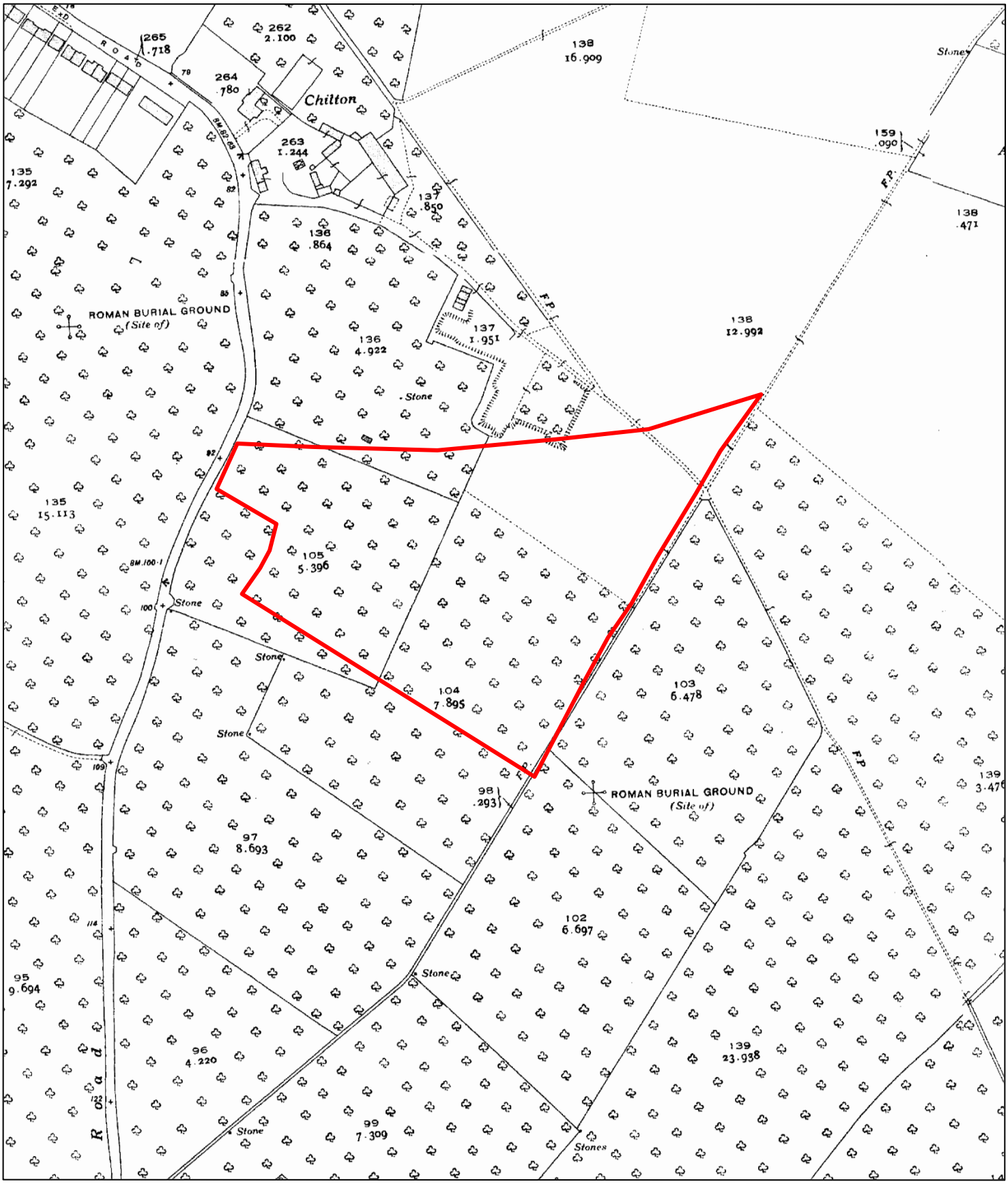
N	**Title:**	**Historical OS Mapping – 1938**

FIGURE: 3.1



Project:	**Swanstree Avenue, Sittingbourne**
Client:	**IDOM**
Report Ref:	**DRA-23-1577**
Approx. Site Boundary:	Info Source: ProMaps

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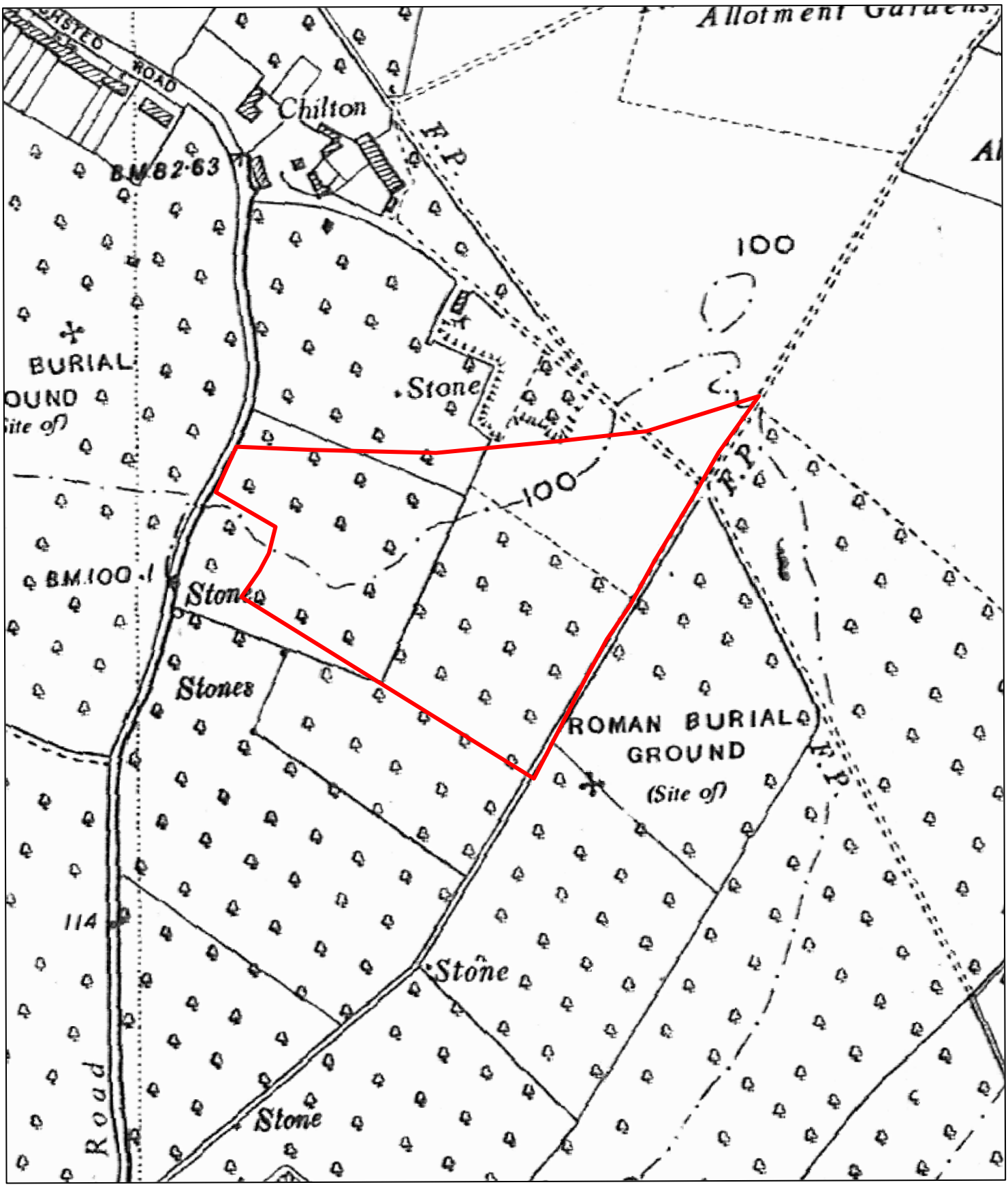
Title:	Historical OS Mapping - 1947	FIGURE: 3.2



Project:	Swanstree Avenue, Sittingbourne
Client:	IDOM
Report Ref:	DRA-23-1577
Approx. Site Boundary:	Info Source: ProMaps

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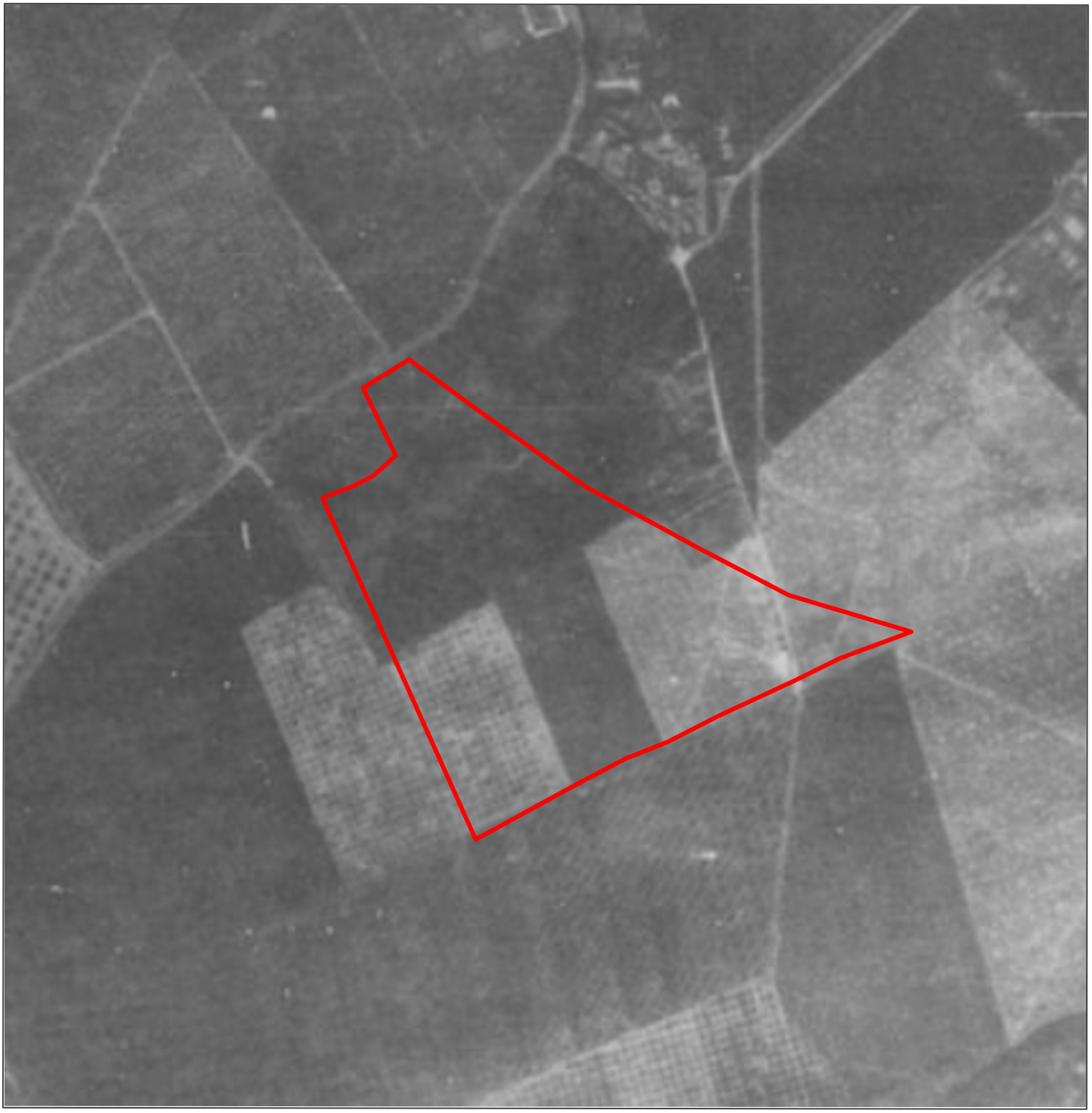
Title:	Historical Aerial Photography – 3rd September 1940	FIGURE: 4.1



Project:	Swanstree Avenue, Sittingbourne
Client:	IDOM
Report Ref:	DRA-23-1577
Approx. Site Boundary:	Info Source: NCAP

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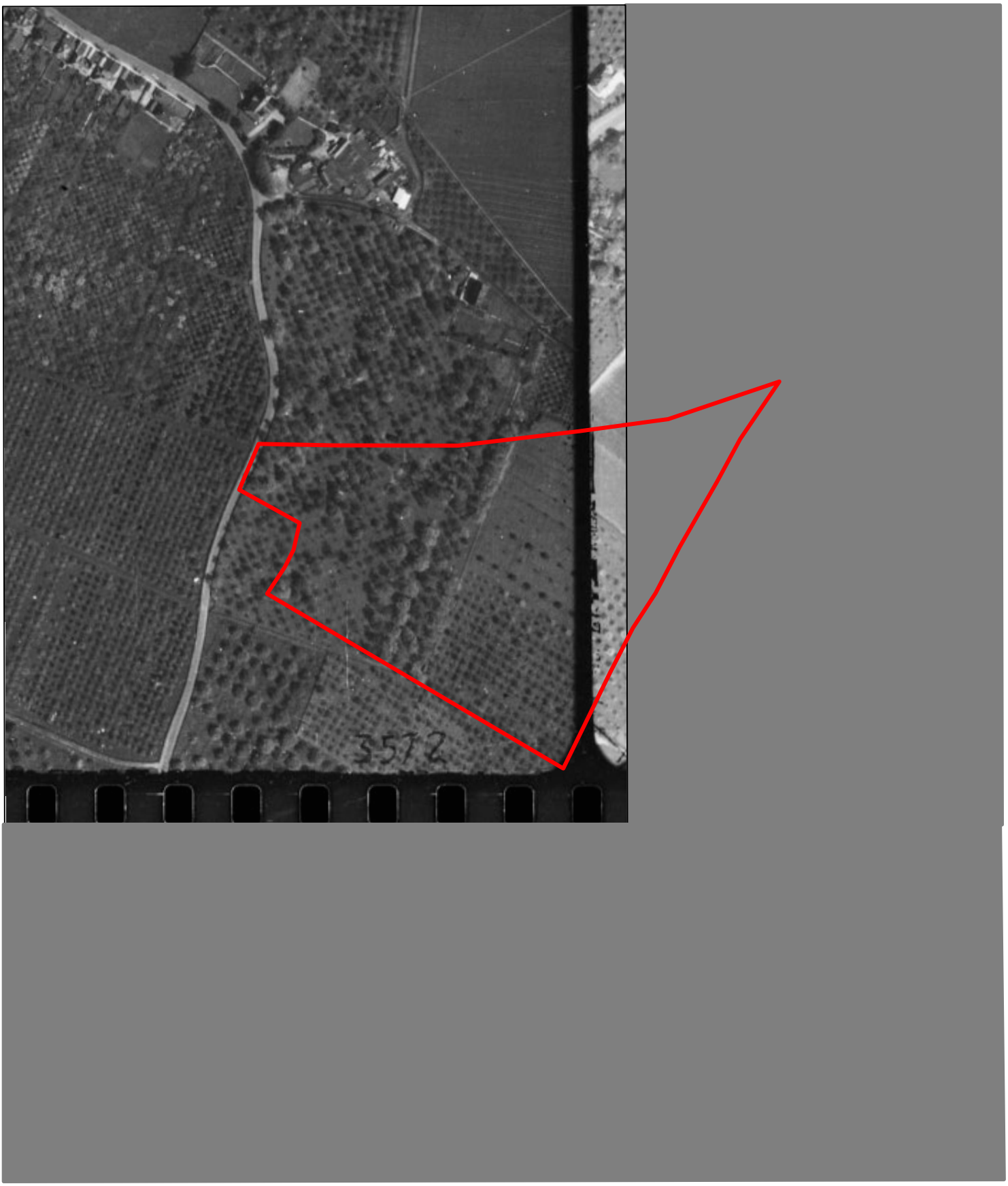
N	**Title:** Historical Aerial Photography – 1st May 1946	**FIGURE: 4.2**



Project:	**Swanstree Avenue, Sittingbourne**
Client:	**IDOM**
Report Ref:	**DRA-23-1577**
Approx. Site Boundary:	Info Source: Historic England

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Title:	Historical Aerial Photography – 17th April 1951	FIGURE: 4.3

Project:	Swanstree Avenue, Sittingbourne
Client:	IDOM
Report Ref:	DRA-23-1577
Approx. Site Boundary:	Info Source: Historic England

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APPENDICES: 1 - 5

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Recent German UXB Finds in the UK + Historical Analysis

- ***23rd May 2019*** - An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Kingston upon Thames, London. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest approximately 3 to 4m bgl.*
- ***15th May 2017 -*** An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Aston, Birmingham. *Historical Analysis: The UXB landed in a small back garden belonging to a terraced house, part of a row. It J-Curved under a neighbouring garden and came to rest at just 1.4m bgl. NB: These houses had not sustained bomb damage.*
- ***2nd March 2017 -*** A 250kg HE bomb was found during deep excavations at a building site in Brondesbury Park, London. *Historical Analysis: UXB landed in a large residential back garden. A single storey building was built on top of the UXB post-WWII.*
- ***19th January 2017 -*** An SD50 (semi-armour piercing 50kg HE bomb) was dredged from the Thames during barge dredging works near Westminster Bridge, London.
- ***12th May 2016 -*** A 500kg HE bomb was found buried just 1m below the playground of the former Royal High Junior School in Bath. *Historical Analysis: The UXB landed in a plot of neglected, unmaintained vegetation in between the school gym and main school building.*
- ***23rd September 2015 -*** A 1,000kg HE bomb was encountered by a mechanical excavator on a building site in Paradise Street, Coventry. *Historical Analysis: the UXB landed in a large residential back garden occupied by dense vegetation. A two storey building was built on top of the UXB post-WWII.*
- ***10th August 2015 -*** A 250kg HE bomb was found immediately beneath a basement floor during refurbishment works in Temple Street, Bethnal Green (London). *Historical Analysis: The UXB struck a house that had been damaged beyond repair during a previous air raid. The existing house was then built on top of UXB post-WWII.*
- ***21st May 2015 -*** An SC50 (general purpose 50kg HE bomb) was found during deep excavations at a construction site in Wembley, London. *Historical Analysis: UXB landed in a large residential back garden.*
- ***23rd March 2015 -*** A 250kg HE bomb was found during deep excavations at a building site in Grange Walk, Bermondsey (London). *Historical Analysis: inconclusive - reported UXB position is likely inaccurate.*

NB: Domestic UXO finds in the UK are too numerous to list. Between 2006 and 2009, over 15,000 items of British / Allied UXO (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Initiation of WWII Allied Bombs

- ***6th January 2014 -*** Mechanical excavator stuck a WWII bomb in Euskirchen (Germany) causing it to explode, killing the operator and injuring 13 more, two critically. The explosion was so large it damaged buildings 400m away.
- ***1st March 2013 -*** During piling at a construction site in Ludwigshafen (Germany) a small buried WWII bomb exploded, injuring one worker.
- ***2nd June 2010 -*** A British 500kg bomb detonated whilst being defused, killing three EOD engineers in Goettingen, Germany. The bomb was found as builders dug the foundations for a new sports hall. Several houses had their fronts blown off by the blast.
- ***19th September 2008 -*** Seventeen people were injured and buildings were damaged when an excavator apparently drove over and set off a 250kg American bomb at a construction site in Hattingen, Germany.
- ***23rd October 2006 -*** A construction worker breaking up tarmac at the side of a highway near the south-western German town of Aschaffenburg was killed when his machine struck and detonated a WWII bomb. In addition, the blast injured several motorists who were driving past.
- ***2006 -*** A piling rig and dump truck were destroyed when a piling rig struck an Allied bomb on a construction site in Austria.
- ***2003 -*** In the Austrian city of Salzburg, two people were killed while attempting to defuse a 250kg Allied bomb.
- ***1994 -*** At a central Berlin construction site a piling rig struck a large WWII Allied bomb. 3 were killed and 14 more were injured. Dozens of cars in a 250m radius were wrecked, the top 10 floors of neighbouring office building collapsed and human remains were found 100m away.
- ***1990*** - In Wetzlar (Germany) two EOD engineers were blown up as they removed the detonator of an allied WWII UXB.

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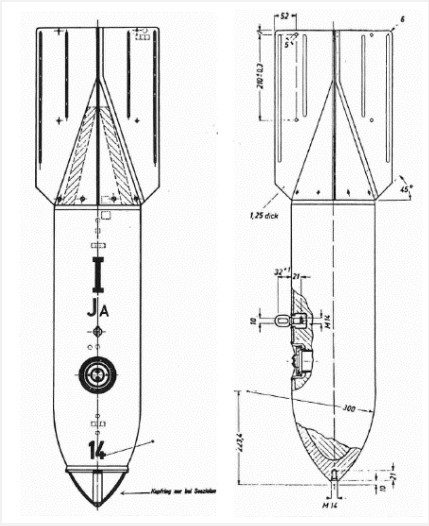
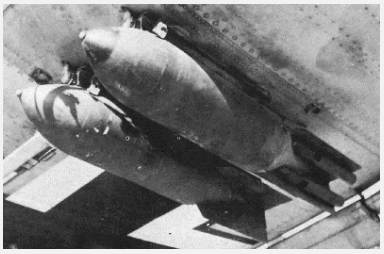
Title: German WWII Air-Delivered Munitions - Most Commonly Deployed High Explosive

APPENDIX: 2.1

SC 50

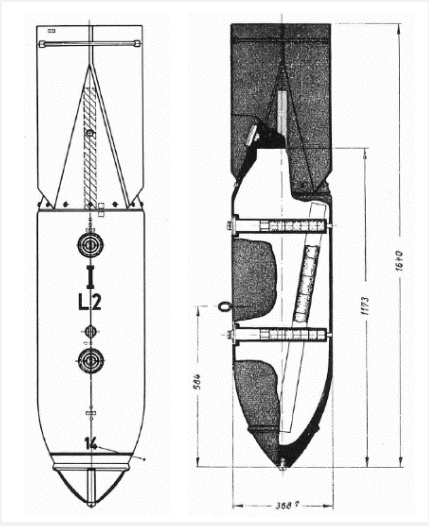
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Additional fittings: Kopfring nose for limited penetration and Stabbo nose for dive-bombing.





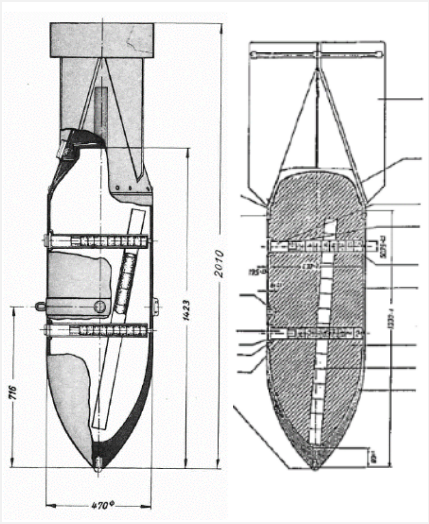
SC 250

Bomb Weight:	245-256kg (540-564lb)
Explosive Weight:	125-130kg (276-287lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	1 or 2 electrical impact fuse(s) or mechanical delayed action fuse(s)
Body Dimensions:	1,173mm length x 368mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Kopfring nose for limited penetration. Stabbo nose for dive-bombing.



SC 500

Bomb Weight:	480-520kg (1,058-1,146lb)
Explosive Weight:	220kg (485lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	2 electrical impact fuses or mechanical delayed action fuses
Body Dimensions:	1,423mm length x 470mm diameter
Appearance:	Bomb body and tail painted grey/green or buff with a yellow stripe on the tail unit. Steel construction.
Variants:	3 x variants. Kopfring nose for limited penetration.



Project:	**Swanstree Avenue, Sittingbourne**
Client:	**IDOM**
Report Ref:	**DRA-23-1577**
Info Source:	*W, Ramsey.1988 / various news sources*

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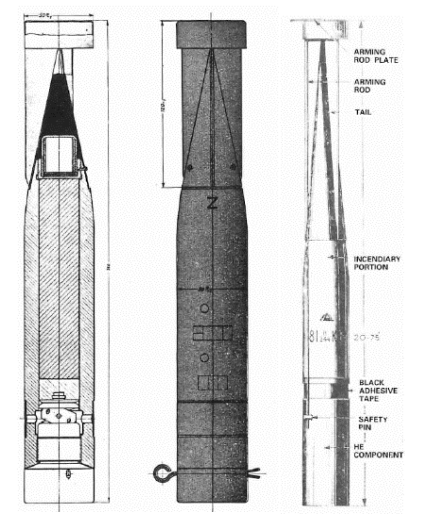
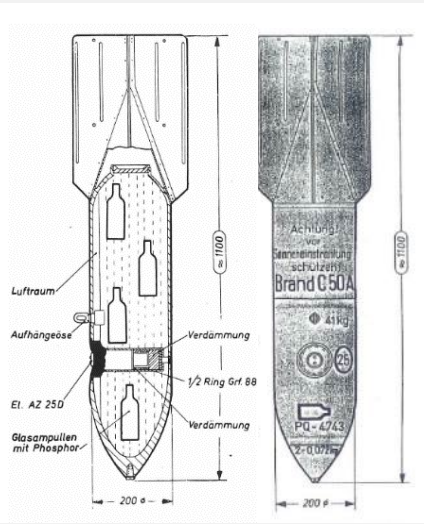
B-1E Sub-Munition

Bomb Weight: 1-1.3kg (2.2-2.87lb)
Incendiary Weight: 680g (1.4lb)
Filling: Thermite
Fuse Type: Simple impact fuse
Body Dimensions: 247mm length x 50mm diameter
Appearance: Grey body and dark green painted tail unit. Magnesium alloy case.
Operation: Small percussion charge ignites Thermite (>1,000°C burn).
Variants: Most common variant: B 2EZ (2kg) included a small HE charge
Remarks: Drop containers varied in size. The smallest cluster bomb held 36 x B-1Es and the largest 620 x B-1Es.



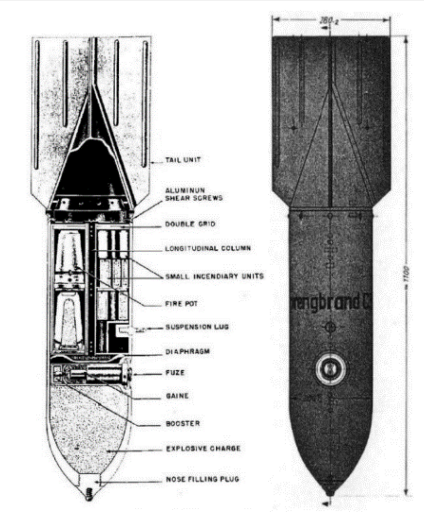
Brand C50

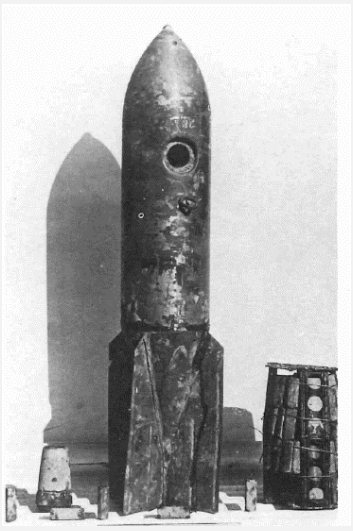
Bomb Weight: 41kg (90.4lb)
Incendiary Weight: 13kg (30lb)
Filling: Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type: 1 x electrical impact fuse
Bomb Dimensions: 762mm length x 203mm diameter
Appearance: bomb body and tail painted grey or green with the rear of the bomb painted red and a red band around the centre of the body.
Variants: C 50 B: 77% White Phos fill
C 250 A: 87.7% Petroleum, 11.7% Polystyrene, 0.5% White Phos (185kg version)



Spreng-Brand C50 - *Fire Pot*

Bomb Weight: 34kg (75lb)
Explosive Weight: 9kg (20lb)
Filling: TNT burster charge, 6 x Thermite containers (fire pots) and 67 x small triangular incendiary elements.
Fuse Type: 1 x electrical impact fuses or aerial burst fuse
Bomb Dimensions: 711mm length x 203mm diameter
Appearance: Bomb body and tail painted grey/green or pale blue with red base plug and red or green incendiary markings. Steel construction.
Operation: A charge blows off the base plate, firing a plume of incendiary mixture 100 yds. Approx 1 second later the HE charge detonates.





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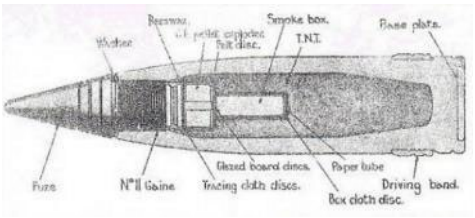
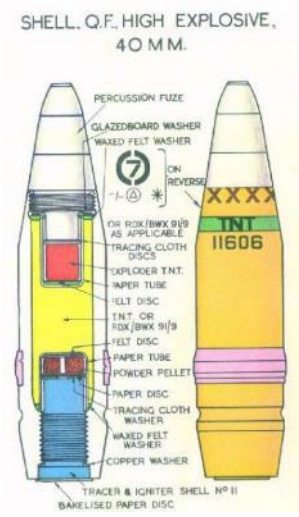
HAA Battery - 3.7" QF Shell

Shell Weight:	12.7kg
Shell Dimensions:	94mm x 438mm
Fill Weight:	1.1kg
Fill Type:	TNT
Fuse Type:	Mechanical Time Delay fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	10 - 20 rpm
Ceiling:	9,000 - 18,000m
Variants:	HE or shrapnel shells. Note, the 4.5" gun was also used in an HAA role throughout the UK.



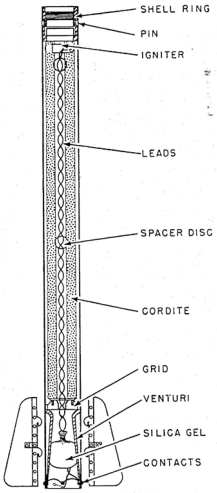
LAA Battery - 40mm Bofors Shell

Shell Weight:	0.84kg
Shell Dimensions:	40mm x 180mm
Fill Weight:	70g
Fill Type:	TNT
Fuse Type:	Impact fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	120 rpm
Ceiling:	7,000m
Variants:	HE or AP shells. Both with rear tracer compartment



Z Battery - 3" U.P Rocket

Rocket Weight:	24.5kg
Warhead Weight:	1.94kg
Filling:	TNT warhead. Black Powder solid fuel rocket motor.
Fuse Type:	Mechanical Time Delay fuse
Rocket Dimensions:	1,930mm x 76mm
Ceiling:	6,770m
Operation:	Fired from single, tandem and (later) 36 x rail launchers (Z Batteries). Limited use throughout the UK.



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AA	*Anti-Aircraft (defences)*
AFS	*Auxiliary Fire Service*
AP	*Anti-Personnel*
ARP	*Air Raid Precautions*
ASW	*Anti-Submarine Warfare*
BDU	*Bomb Disposal Unit (historic term for EOD)*
Bgl	*Below Ground Level*
EOC	*Explosive Ordnance Clearance*
EOD	*Explosive Ordnance Disposal*
FP	*Fire Pot (German bomb)*
GI	*Ground Investigation*
HAA	*Heavy Anti-Air (gun battery)*
Ha	*Hectare (10,000m2)*
HE	*High Explosive*
IB	*Incendiary Bomb*
Kg	*Kilogram*
LAA	*Light Anti Air (gun battery)*
LCC	*London County Council*
LRRB	*Long Range Rocket Bomb (V2)*
LSA	*Land Service Ammunition*
Luftwaffe	*German Air Force*
OB	*Oil Bomb (German bomb)*
PM	*Parachute Mine (German bomb)*
RAF	*Royal Air Force*
RFC	*Royal Flying Corps*
RN	*Royal Navy (British)*
RNAS	*Royal Naval Air Service*
ROF	*Royal Ordnance Factory*
SAA	*Small Arms Ammunition*
SD2	*2kg AP bomb (German bomb)*
SI	*Site Investigation*
U/C	*Unclassified (German) bomb*
UP	*Unrotating Projectile (British 3" AA rocket)*
USAAF	*United States Army Air Force*
UX	*Unexploded*
UXB	*Unexploded Bomb*
UXO	*Unexploded Ordnance*
V1	*German Flying (pilotless) bomb - "Doodlebug"*
V2	*German LRRB - "Big Ben"*
WAAF	*Women's Auxiliary Air Force*
WWI	*World War One*
WWII	*World War Two*

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