The Great Grid Upgrade

Sea Link

Sea Link

Volume 7: Other Documents

Document 7.5.3: Outline Onshore Construction Environment Management Plan

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Contents

Executive Summary 1

1. Introduction 2

1.1 Overview 2

1.2 Structure of the Outline Onshore CEMP 3

1.3 The Proposed Project 4

2. Construction Information 6

2.1 Overview 6

2.2 Construction Programme 6

2.3 Working Hours 7

2.4 Onshore Construction Site Layout and Good Housekeeping 8

3. Construction Environmental Management Principles 13

3.1 Environmental Management Systems 13

3.2 Roles and Responsibilities 13

3.3 Competence, Training and Awareness 15

3.4 Method Statements 16

3.5 Incident Procedure and Response 17

4. Communication and Consultation Strategy 19

4.1 Community Engagement and Public Information 19

5. Landscape and Visual 20

5.1 Introduction 20

5.2 Implementation of Mitigation Measures 20

6. Ecology and Biodiversity 21

6.1 Introduction 21

6.2 Implementation of Mitigation Measures 21

7. Cultural Heritage 22

7.1 Introduction 22

7.2 Implementation of Mitigation Measures 22

8. Water Environment 23

8.1 Introduction 23

8.2 Implementation of Mitigation Measures 23

9. Geology and Hydrogeology 24
9.1 Introduction 24
9.2 Implementation of Mitigation Measures 24

10. Agriculture and Soils 25
10.1 Introduction 25
10.2 Implementation of Mitigation Measures 25

11. Traffic and Transport 26
11.1 Introduction 26
11.2 Implementation of Mitigation Measures 26

12. Air Quality 27
12.1 Introduction 27
12.2 Implementation of Mitigation Measures 27

13. Noise and Vibration 28
13.1 Introduction 28
13.2 Implementation of Mitigation Measures 28

14. Socio-economics, Recreation and Tourism 29
14.1 Introduction 29
14.2 Implementation of Mitigation Measures 29

15. Health and Wellbeing 30
15.1 Introduction 30
15.2 Implementation of Mitigation Measures 30

16. Monitoring and Review 31

Executive Summary 1

1. Introduction 2
1.1 Overview 2
1.2 Structure of the Outline Onshore CEMP 3
1.3 The Proposed Project 4

2. Construction Information 6
2.1 Overview 6

2.2 Construction Programme 6
2.3 Working Hours 7
2.4 Onshore Construction Site Layout and Good Housekeeping 10

3. Construction Environmental Management Principles 15
3.1 Environmental Management Systems 15
3.2 Roles and Responsibilities 15
3.3 Competence, Training and Awareness 17
3.4 Method Statements 18
3.5 Incident Procedure and Response 19

4. Communication and Consultation Strategy 21
4.1 Community Engagement and Public Information 21

5. General Onshore Environmental Commitments and Management Measures 22

6. Landscape and Visual 28
6.1 Introduction 28
6.2 Implementation of Mitigation Measures 28

7. Ecology and Biodiversity 30
7.1 Introduction 30
7.2 Implementation of Mitigation Measures 30

8. Cultural Heritage 38
8.1 Introduction 38
8.2 Implementation of Mitigation Measures 38

9. Water Environment 40
9.1 Introduction 40
9.2 Implementation of Mitigation Measures 40

10. Geology and Hydrogeology 46
10.1 Introduction 46
10.2 Implementation of Mitigation Measures 46

11. Agriculture and Soils 50
11.1 Introduction 50
11.2 Implementation of Mitigation Measures 50

12. Traffic and Transport 53
12.1 Introduction 53
12.2 Implementation of Mitigation Measures 53

13. Air Quality 55
13.1 Introduction 55
13.2 Implementation of Mitigation Measures 55

14. Noise and Vibration 59
14.1 Introduction 59
14.2 Implementation of Mitigation Measures 59

15. Socio-economics, Recreation and Tourism 61
15.1 Introduction 61
15.2 Implementation of Mitigation Measures 61

16. Health and Wellbeing 63
16.1 Introduction 63
16.2 Implementation of Mitigation Measures 63

17. Arboriculture 64
17.1 Introduction 64
17.2 Implementation of Mitigation Measures 64

18. Monitoring and Review 66

Appendix A Detailed Unexploded Ordnance Risk Assessment 70

Table of Tables

~~Table 1.1 Structure of the Outline Onshore CEMP 3~~
~~Table 3.1 Outline roles and responsibilities 13~~
Table 1.1 Structure of the Outline Onshore CEMP 3
Table 3.1 Outline roles and responsibilities 15
Table 2.1 General onshore environmental commitments and mitigation measures 22
Table 6.1 Environmental commitments and mitigation measures relevant to landscape and visual 28
Table 6.1 Environmental commitments and mitigation measures relevant to ecology and biodiversity 30
Table 7.1 Environmental commitments and mitigations measures relevant to cultural heritage 38
Table 8.1 Environmental commitments and mitigation measures relevant to the water environment 40
Table 9.1 Environmental commitments and mitigation measures relevant to geology and hydrogeology 46
Table 10.1 Environmental commitments and mitigation measures relevant to agriculture and soils 50
Table 11.1 Environmental commitments and mitigation measures relevant to traffic and transport 53
Table 12.1 Environmental commitments and mitigation measures relevant to air quality. 55
Table 13.1 Environmental commitments and mitigation measures relevant to noise and vibration 59
Table 14.1 Environmental commitments and mitigation measures relevant to socio-economics, recreation and tourism 61
Table 16.1 Environmental commitments and mitigation measures relevant to arboriculture 64

Table of Plates

Plate 2.1 Indicative construction programme 7
Plate 2.1 Indicative construction programme 7

Version History			
Date	**Issue**	**Status**	**Description / Changes**
March 2025	A	Final	For DCO submission
September 2025	B	Final	Update to reflect S89(3) Procedural Decision from the Examining Authority
March 2026	C	Final	For Deadline 5 submission

Executive Summary

Ex1.1.1 The Outline Onshore Construction Environmental Management Plan (CEMP) has been prepared on behalf of National Grid to support the Application for a Development Consent Order (DCO).

Ex1.1.2 The purpose of the Outline Onshore CEMP is to specify the overarching principles and detailed measures to minimise as far as reasonably practicable and mitigate the effects of the construction activities associated with the Proposed Project on the surrounding environment. It will also ensure that construction activities cause minimum disruption to local residents and members of the public, by helping to create a safe and secure working environment.

Ex1.1.3 On confirmation of a contractor, this Outline Onshore CEMP will be updated to reflect specific proposed construction methods and approved by the relevant authorities. Once approved, this will become the Onshore CEMP, which will be a live document which will continue to evolve and is subject to refinement, amendment, and expansion as necessary.

Ex1.1.4 Compliance with the contents of the Onshore CEMP is secured through Requirement 6 of Schedule 3 of the draft DCO. The Onshore CEMP is intended to provide a systematic approach to environmental management so that environmental risks are identified, incorporated in all decision-making, and managed appropriately.

Ex1.1.5 The Onshore CEMP will be periodically reviewed and updated by National Grid as required, to ensure environmental risks are managed and mitigated throughout.

1. Introduction

1.1 Overview

1.1.1 The Sea Link Project (hereafter referred to as the 'Proposed Project') is a proposal by National Grid Electricity Transmission plc (hereafter referred to as National Grid) to reinforce the transmission network in the South East and East Anglia. The Proposed Project is required to accommodate additional power flows generated from renewable and low carbon generation, as well as accommodating additional new interconnection with mainland Europe.

1.1.2 National Grid owns, builds and maintains the electricity transmission network in England and Wales. Under the Electricity Act 1989, National Grid holds a transmission licence under which it is required to develop and maintain an efficient, coordinated, and economic electricity transmission system.

1.1.3 This would be achieved by reinforcing the network with a High Voltage Direct Current (HVDC) Link between the proposed Friston substation in the Sizewell area of Suffolk and the existing Richborough to Canterbury 400 kV overhead line close to Richborough in Kent.

1.1.4 National Grid is also required, under Section 38 of the Electricity Act 1989, to comply with the provisions of Schedule 9 of the Act. Schedule 9 requires licence holders, in the formulation of proposals to transmit electricity, to:

- Schedule 9(1)(a) *'…have regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest*;' and
- Schedule 9(1)(b) *'…do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects'*.

1.1.5 The purpose of a Construction Environment Management Plan (CEMP) is to specify the overarching principles and detailed measures to minimise as far as reasonably practicable and mitigate the effects of the construction activities associated with the ~~proposed~~Proposed Project on the surrounding environment. It will also ensure that construction activities cause minimum disruption to local residents and members of the public, by helping to create a safe and secure working environment. For the purpose of the Proposed Project, an Outline Onshore CEMP (this document) and Outline Offshore CEMP (**Application Document 7.5.2**) has been drafted. More specifically, the Onshore CEMP will:

- ensure that relevant mitigation measures set out in Parts 2 and 3 of the Environmental Statement (ES) as submitted in support of the Development Consent Order (DCO) application are implemented during all relevant construction activities;
- take into account relevant planning policies; and

- ensure that relevant legislation, Government and industry standards, and construction industry codes of practice and best practice standards are complied with.

1.1.6 On confirmation of a contractor, this Outline Onshore CEMP will be updated to reflect specific proposed construction methods and approved by the relevant authorities. Once approved, this will become the Onshore CEMP, which will be a live document which will continue to evolve and is subject to refinement, amendment, and expansion as necessary. Compliance with the Onshore CEMP is secured through Requirement 6 of Schedule 3 of the **draft DCO** (**Application Document 3.1**).

1.1.7 Compliance with the contents of the Onshore CEMP is intended to provide a systematic approach to environmental management so that environmental risks are identified, incorporated in all decision-making, and managed appropriately.

1.1.8 The Onshore CEMP will be periodically reviewed and updated by National Grid as required, to ensure environmental risks are managed and mitigated throughout. Any updates to the Onshore CEMP will be agreed with the relevant authority. In particular, it will be updated to take account of the following:

- changes in design;
- changes in external factors such as regulations and standards;
- any unforeseen circumstances as they arise such as new protected species or new archaeological finds and provide a mitigation framework for this;
- good construction practices and ensure these are adopted and maintained throughout;
- the results of audits and inspections; and
- learning points from environmental near misses and accidents.

1.2 Structure of the Outline Onshore CEMP

1.2.1 The structure of this Outline Onshore CEMP is set out in Table 1.1.

Table 1.1 Structure of the Outline Onshore CEMP

Chapter	Content
Chapter 1: Introduction	This chapter sets out the purpose of the Outline Onshore CEMP and how it is structured. It also provides an overview of the features of the Proposed Project.
Chapter 2: Construction Information	This chapter sets out the construction programme, working hours as well as the onshore construction site layout and good housekeeping.
Chapter 3: Construction Environmental Management Principles	This chapter sets out the construction environmental management principles.

Chapter	Content
Chapter 4: Communication and Consultation Strategy	This chapter sets out the communication strategy, including the complaints procedure.
Chapter 5-15: Topic Chapters	Chapters 5 to 15 are structured as per the environmental topic chapters of the ES. This is to aid cross reference between the assessment and the management measures listed within the Outline Onshore CEMP. Each chapter commences with a succinct summary of where relevant construction phase measures are contained and then sets out any additional information in relation to implementation of identified measures.
Chapter 16: Monitoring and Review	This chapter explains procedures in relation to site checks and reporting and how material or non-material change would be managed, if change were necessary to implement the Proposed Project.

1.3 The Proposed Project

1.3.1 The Proposed Project would comprise the following elements. Whilst a description of the Offshore Scheme is included below, this element of the Proposed Project will be covered by the Offshore CEMP (see **Application Document 7.5.2 Outline Offshore CEMP**).

The Suffolk Onshore Scheme

- A connection from the existing transmission network via Friston Substation, including the substation itself. Friston Substation already has development consent as part of other third-party projects. If Friston Substation has already been constructed under another consent, only a connection into the substation would be constructed as part of the Proposed Project.
- A high voltage alternating current (HVAC) underground cable of approximately 1.9 km in length between the proposed Friston Substation and a proposed converter station (below).
- A 2 GW high voltage direct current (HVDC) converter station (including permanent access from the B1121 and a new bridge over the River Fromus) up to 26 m high plus external equipment (such as lightning protection, safety rails for maintenance works, ventilation equipment, aerials, similar small scale operational plant, or other roof treatment) near Saxmundham.
- A HVDC underground cable connection of approximately 10 km in length between the proposed converter station near Saxmundham, and a Transition Joint Bay (TJB) approximately 900 m inshore from a landfall point (below) where the cable transitions from onshore to offshore technology.
- A landfall on the Suffolk coast (between Aldeburgh and Thorpeness).

The Offshore Scheme

- Approximately 122 km of subsea HVDC cable, running between the Suffolk landfall location (between Aldeburgh and Thorpeness), and the Kent landfall location at Pegwell Bay.

The Kent Onshore Scheme

- A landfall point on the Kent coast at Pegwell Bay.
- A TJB approximately 800 m inshore to transition from offshore HVDC cable to onshore HVDC cable, before continuing underground for approximately 1.7 km to a new converter station (below).
- A 2 GW HVDC converter station (including a new permanent access off the A256), up to 28 m high plus external equipment (such as lightning protection, safety rails for maintenance works, ventilation equipment, aerials, and similar small scale operational plant) near Minster. A new substation would be located immediately adjacent.
- Removal of approximately 2.2 km of existing HVAC overhead line, and installation of two sections of new HVAC overhead line, together totalling approximately 3.5 km, each connecting from the substation near Minster and the existing Richborough to Canterbury overhead line.

1.3.2 The Proposed Project also includes modifications to sections of existing overhead lines in Suffolk (only if Friston Substation is not built pursuant to another consent) and Kent, diversions of third-party assets, and land drainage from the construction and operational footprint. It also includes opportunities for environmental mitigation and compensation. The construction phase will involve various temporary construction activities including overhead line diversions, use of temporary pylons or masts, working areas for construction equipment and machinery, site offices, parking spaces, storage, accesses, bellmouths, and haul roads, as well as watercourse crossings and the diversion of public rights of way (PRoWs) and other ancillary operations.

2. Construction Information

2.1 Overview

2.1.1 This section sets out the detail of the construction programme, proposed construction working hours and the principles for establishing the construction sites and good housekeeping.

2.1.2 Further details on the construction of the Proposed Project can be found in Section 4.6 of **Application Document 6.2.1.4 Part 1 Introduction Chapter 4 Description of the Proposed Project** of the Environmental Statement. This includes details of the anticipated methodology for construction of the Proposed Substations, Converter Stations, Overhead HVAC Connection and the Underground HVAC and HVDC Cables. As per Requirement 4(2) within Schedule 3 of the **draft DCO** (**Application Document 3.1**), construction of the Proposed Project '*may not commence until a written scheme setting out all stages of the authorised development has been submitted to the relevant planning authority*'.

2.2 Construction Programme

2.2.1 Subject to gaining development consent, construction works would be expected to start in 2026 and be functionally completed by 2031 with reinstatement potentially continuing into 2032. Certain advance works (such as archaeological trial trenching or protected species mitigation) may take place in advance of the main construction period.

2.2.2 The construction schedule will be developed as the Proposed Project progresses and will take account of seasonal constraints such as protected species breeding or hibernation seasons and reducing impacts associated with flood zones.

2.2.3 An indicative construction programme for the Proposed Project is presented in Plate 2.1.

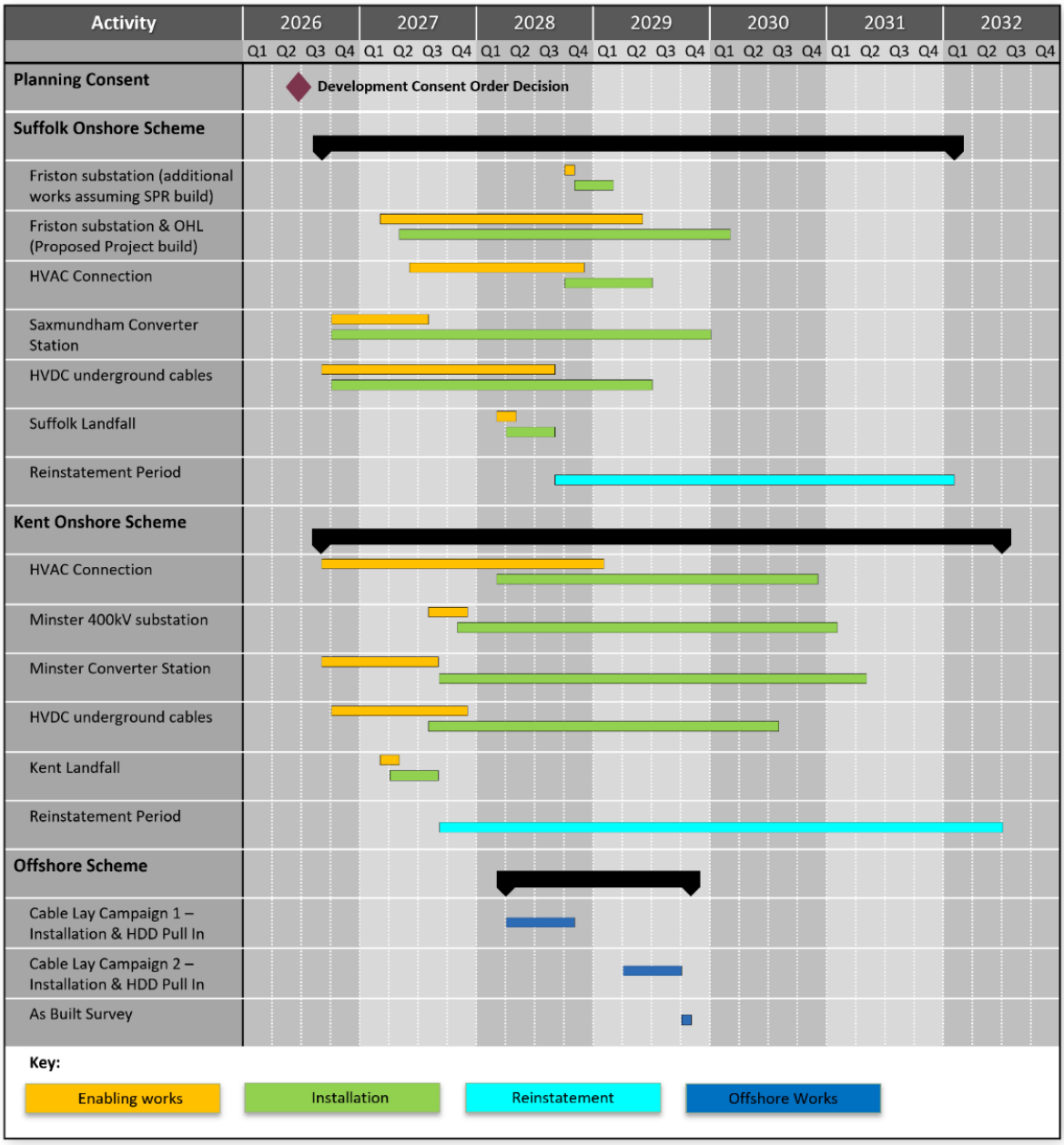


Plate 2.1 Indicative construction programme

2.3 Working Hours

2.3.1 The ~~proposed construction core~~ working hours ~~(~~will be in accordance with Requirement 7 of Schedule 3 of **the draft DCO** (**Application Document 3.1**) as follows.

~~2.3.1~~2.3.2 Subject to sub-paragraphs 2.3.2, 2.3.3, 2.3.4 and 2.3.7 onshore construction work may only take place between 0700 and 1900 Monday to Friday and between 0700 and 1700 on Saturdays, Sundays and Bank Holidays (the core working hours), unless otherwise approved by the relevant ~~Local Planning Authority)~~planning authority. There will be no working on Bank Holidays in respect of Work No. 3B, Work No. 9B, and Work No. 11, except for ~~all terrestrial~~the operations described in paragraph 2.3.4 below or with the prior agreement of the local planning authority. In respect of those works ~~in Kent and Suffolk are:~~, for Bank Holiday Mondays (meaning Easter Monday, the early May bank

holiday, the Spring bank holiday, and the summer bank holiday) there will also be no working on the preceding Saturday or Sunday in each case.

- Percussive piling works are limited to 0700 to 1900 Monday ~~–~~to Friday~~: 0700 to1900;~~ and

~~23.0.0~~2.3.3 ~~Saturday,~~ 0700 to 1700 on Saturdays and may not occur on Sundays ~~and~~or Bank Holidays~~: 0700 to 1700~~, unless otherwise approved by the relevant planning authority.

~~2.3.2 The core working hours exclude start up and close down activities up to one hour either side of the core working hours. These activities include staff arrival, briefings, checking plant, loading equipment, compound general maintenance activities, debriefing, storing equipment and plant, and staff leaving site.~~

~~2.3.3 Exceptions to the above core working hours include but are not limited to:~~

2.3.4 Subject to sub-paragraph (4), HGV deliveries are limited to 0700 to 1900 Monday to Friday and 0700 to 1700 on Saturdays and may not occur on Sundays or Bank Holidays, unless otherwise approved by the relevant highway authority.

2.3.5 The following operations may take place outside the core working hours referred to in paragraph 2.3.1—:

- (a) trenchless crossing operations including at landfalls and beneath highways, railway lines, woodlands, nature reserves, Sites of Special Scientific Interest or watercourses;
- (b) the installation and removal of conductors, pilot wires and associated protective netting across highways, railway lines or watercourses;
- (c) the jointing of underground cables;
- (d) the continuation of any work activity commenced during the core working hours to a point where they can securely and or safely be paused;
- (e) delivery to the transmission works of abnormal loads and any highway works requested by the highway authority to be undertaken outside the core working hours;
- (f) the testing or commissioning of any electrical plant installed as part of the authorised development including undertaking of any identified corrective activities;
- (g) the completion of works delayed or held up by severe weather conditions which disrupted or interrupted normal construction activities;
- (h) activity necessary in the instance of an emergency where there is a risk to persons or property;
- (i) marine works (all works below the mean high water springs line);
- (j) security monitoring;
- (k) intrusive and non-intrusive surveys;
- (l) mechanical and electrical installation works within buildings once erected and enclosed;
- (m) any highway works requested by the highway authority to be undertaken on a Saturday or Sunday or outside the core working hours; and
- (n) activity necessary in the instance of an emergency where there is a risk to persons or property.

~~2.3.4 Percussive pilling works would be limited to Monday – Friday: 0700 to 1900 and 0700 to 1700 on Saturdays and may not occur on Bank Holidays, unless otherwise approved by the local planning authority.~~

~~2.3.5 Subject to the exceptions listed in paragraph 2.3.3 above, Heavy Goods Vehicles (HGV) deliveries would be limited to Monday – Friday: 0700 to 1900 and 0700 to 1700 on Saturdays and may not occur on Bank Holidays, unless otherwise approved by the relevant highway authority.~~

~~2.3.6 The working hours will be in accordance with Requirement 7 of Schedule 3 of **the draft DCO** (**Application Document 3.1**).~~

2.3.6 The core working hours referred to in paragraph 2.3.1 exclude start-up and close down activities up to 1 hour either side of the core working hours.

2.3.7 The severe weather conditions referred to in paragraph 2.3.4(g) means any weather which prevents work from taking place during the core working hours referred to in paragraph 2.3.1 and, as the case may be, the hours referred to in paragraph 2.3.3 by reason of physical incapacity (whether for reasons of visibility, ground conditions, power availability, site access, wind or otherwise) or being contrary to safe working practices.

2.3.8 In respect of Work No.1A and Work No. 1B, construction work may only take place between 0700 hours and 1900 hours Monday to Friday and 0700 hours and 1300 hours on Saturdays, with no activity on Sundays or bank holidays, except as specified in paragraph 2.3.8.

2.3.9 Outside the hours specified in paragraph 2.3.7, construction work may be undertaken for essential activities including but not limited to:

- (a) continuous periods of operation that are required as assessed in the environmental statement, such as concrete pouring and the installation and removal of conductors, pilot wires and associated protective netting across highways or public footpaths;
- (b) internal fitting out works associated with the substation;
- (c) the completion of construction activities commenced during the approved working hours which cannot safely be stopped; (d) the testing or commissioning of any electrical plant installed as part of the authorised development; and
- (e) activity necessary in the instance of an emergency where there is a risk to persons or property.

2.3.10 With the exception of activities undertaken in accordance with paragraph 2.3.8(e), the timing and duration of construction work undertaken in accordance with paragraph 2.3.8 and, where works do not fall within paragraphs 2.8.3(a) to 2.8.3(e), whether such works are essential, must be approved by the relevant planning authority in writing in advance, and must be carried out within the approved time.

2.4 Onshore Construction Site Layout and Good Housekeeping

2.4.1 The layout, appearance and operation of the construction site, site offices and compounds will be detailed prior to construction commencing and will comply with the ~~commitments in the Outline Code of Construction Practice (CoCP) (see **Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**).~~control and management measures set out within this document.

2.4.2 Good housekeeping practice will be applied at all times and all working areas will be inspected as required using a site audit programme. A written report on compliance will be provided to National Grid on a monthly basis.

Site Establishment

2.4.3 Site layout and appearance will be designed according to the following principles (further detail provided below):

- installation of fencing where appropriate to secure working areas;

- storage sites, temporary offices, fixed plant, machinery and equipment must be located to minimise environmental impacts, having due regard to neighbouring residential properties and the constraints of each work site;
- noise generating activities must be sited away from noise sensitive receptors or screened; and
- the site layout must also consider and minimise potential impacts from restricting natural light to adjacent residential properties or ecological receptors.

Fencing

2.4.4 Where necessary, working areas will be appropriately fenced off from members of the public and to prevent animals from straying onto a working area. National Grid will ensure, as far as reasonably practicable, that the visual intrusion of the construction site fencing is contained and limited, through limiting fencing to that which is essential for the safety of the public, site personnel and private assets.

2.4.5 Fencing and other means of enclosure, including those required for mitigating effects on protected species, will be inspected daily initially and then regularly as appropriate (protected species fencing is likely to remain as daily), repaired and repainted as necessary. Any temporary fencing will be removed as soon as reasonably practicable after completion of the works.

Lighting and visual intrusion

2.4.6 Construction compounds will not be lit at night outside of the working hours identified for the particular activity (noting that there are exceptions listed in paragraph 2.3.3 which could be undertaken outside of core working hours and during nighttime), except for welfare and site security cabins, which will include low level lighting. Motion sensor lighting will be used in areas of high security risk.

2.4.7 Site or welfare cabins, equipment and lighting will be sited so as to minimise visual intrusion insofar as is consistent with the safe and efficient operation of the work site. Site lighting will be positioned and directed to minimise glare and nuisance to residents and walkers, and to minimise distractions or confusion to passing drivers on railways or adjoining public highways.

2.4.8 Winter working may require task-specific lighting due to the short day lengths when lighting will be required at the beginning and end of the day. Lighting will be used only when required during working hours for particular activities, unless otherwise stated and will comprise lighting of work areas and access and egress with low level directional lighting.

2.4.9 On land where cable jointing is required, there will be a need for 24/7 lighting inside the covered structures that will surround the cable jointing bays. Motion sensor lighting will be required outside the covered structures for security and access and egress purposes.

2.4.10 When lighting is necessary, appropriate lighting and luminaires will be used to minimise the impact of lighting on ecological resources, including nocturnal species. Lighting will be designed to minimise spillage into surrounding habitats, such as sensitive watercourses, to avoid disturbance to wildlife.

Security

2.4.11 Temporary construction compounds including offices will be adequately secured to protect the public and prevent unauthorised entry to or exit from the site. Access to the temporary construction compounds will be limited to specified entry points only and personnel entries/exits will be recorded and monitored for both security and health and safety purposes.

2.4.12 Site-specific assessments of the security and trespass risk will be undertaken at each site and appropriate control measures implemented. In addition, security units and/or remote cameras will be used to monitor sites.

Public rights of way

2.4.13 Parts of both the Suffolk and Kent Onshore Schemes cross a number of Public Rights of Way (PRoW).

2.4.14 **Application Document 7.5.9.1 Outline Public Rights of Way Management Plan – Suffolk** and **Application Document 7.5.9.2 Outline Public Rights of Way Management Plan – Kent** set out the agreed approach to any PRoW diversions or other mitigation required and will be submitted with the DCO application.

2.4.15 The Proposed Project would cross the existing PRoW network. The works which would be required at these locations can be classified into four categories. These are:

- Provisions – at these locations a diversion would not be required. However, safety measures would be put in place to maintain access during the construction period. The installation of safety measures is likely to require short term closures or the control of users using stop go boards or similar, to allow for the installation of fences, gates or overhead netting as required.
- Long term temporary diversion – at these locations a diversion route would be provided for the duration of the construction works.
- Short term temporary diversion – at these locations, the impact on the PRoW is caused by isolated construction activities, so a diversion would only be required for a reduced period of time. These diversions would be implemented within the Order Limits locally to the PRoW affected. For example during the installation of haul roads or ducts across the PRoW, the route would be temporarily diverted 50-100m along the alignment of the Order Limits to cross a section already installed or an area not yet reached by the works.
- Permanent diversion – at these locations the route of the existing PRoW would be impacted by the permanent assets. A permanent diversion route would therefore be required.

2.4.16 In Suffolk, there are 21 locations where the proposed works would impact the existing PRoW network identified in **Application Document 6.3.1.4.A ES Appendix 1.4.A Crossing Schedules** and presented in **Figure 6.4.1.4.5 PRoW, Highway and Railway Crossings** of **Application Document 6.4.1.4 Description of the Proposed Project**.

2.4.17 In Kent, there are 16 locations where the proposed works would impact the existing PRoW network identified in **Application Document 6.3.1.4.A ES Appendix 1.4.A Crossing Schedules** and presented in **Figure 6.4.1.4.5 PRoW, Highway and Railway Crossings** of **Application Document 6.4.1.4 Description of the Proposed Project**.

Welfare

2.4.18 Onsite welfare facilities will be provided for all site workers and visitors. Welfare facilities will be kept clean and tidy.

2.4.19 Where portable generators are used to provide electricity for welfare units, industry best practice will be followed to minimise noise and pollution from such generators.

Waste management

2.4.20 ~~A~~Outline Material and Waste Management ~~Plan will be~~Plans have been produced ~~prior to construction which sets~~ setting out the framework for the management of wastes generated during the construction of the Proposed Project~~. The~~ (see **Application Document 9.115.1 Outline Materials and Waste Management Plan – Suffolk** and **Application Document 9.115.2 Outline Materials and Waste Management Plan – Kent**). The contractor will produce final MWMPs, in accordance with the outline MWMPs prior to construction. The MWP document will set out the decisions taken during the planning and design stages to minimise construction waste and set objectives and targets for the main waste types. The document will also identify the following:

- responsibilities within the construction team for waste management;
- the types of waste (including invasive plant material) and the quantities likely to be generated;
- measures to be adopted during construction to minimise waste generated;
- opportunities for recycling and/or reuse;
- proposed treatment and disposal sites together with details of their Environmental Permit; and
- provisions for staff training and use of the Material and Waste Management Plan.

2.4.21 The aim of the Material and Waste Management Plan is to minimise the volume of waste generated and maximise resource efficiency by applying the waste hierarchy (reduce – reuse – recycle – energy recovery - responsible disposal).

2.4.22 Provision will be made for the recycling of wastes including scrap metal, timber, paper, cardboard, plastics, toner cartridges, batteries in addition to waste oils from equipment and machinery where local schemes are available.

2.4.23 Wastes of different types will be segregated on site through the use of labelled skips, containers or bays indicating the types of waste each may accept and also the European Waste Code. Waste containers shall be in good condition and covered to prevent leachate spillage, waste escaping or ingress of rainwater as appropriate.

2.4.24 Waste disposal will be carried out in accordance with the Waste (England and Wales) Regulations 2011 and Waste: Duty of Care – A Code of Practice (2016), as appropriate to current legislation.

2.4.25 Provision will be made for the correct storage and disposal of Hazardous Wastes as defined by and in accordance with the Hazardous Waste (England and Wales) Regulations 2005 and amendments. The site will be registered as a producer of hazardous waste prior to any transfer of hazardous waste from site and a Hazardous Waste Consignment Note will accompany every transfer. In accordance with the Waste Acceptance Criteria (WAC) hazardous waste may need to be treated, and then tested, before disposal.

2.4.26 Appropriate site investigation and materials testing will be undertaken by specialist consultants prior to construction commencing to identify any 'hazardous waste' as defined in The Hazardous Waste (England and Wales) Regulations 2005 as amended and The List of Waste Regulations 2005 (as amended) so that it can be appropriately managed and disposed of.

Drainage

2.4.27 A Drainage Management Plan (DMP) will be prepared by the contractor prior to the commencement of works. The DMP will demonstrate how the contractor will manage surface water runoff across the worksite during the construction phase, including details of how offsite impacts will be managed and mitigated. This will be developed following detailed drainage investigations and hydrological assessments, which will determine potential location specific risks in relation to the water and natural environment and identify appropriate control measures to reduce the risks.

2.4.28 A phased approach may be taken to the development of the DMP to reflect the phasing of the construction programme and the different elements of the Proposed Project.

Clearance of Site on Completion

2.4.29 All temporary working areas and accesses will be removed when construction has been completed. Plant, temporary cabins and vehicles will be removed from the site.

2.4.30 All temporary land, including highways and public rights of way crossed by the works or other land temporarily occupied will be made good to the satisfaction of landowners and/or the relevant highways authority.

2.4.31 To facilitate reinstatement, a full photographic/aerial footage and descriptive record of condition (pre-condition survey) will be carried out of the working areas that may be affected by the construction activities prior to these works commencing. This record will be available for comparison following completion of reinstatement works to ensure that the standard of reinstatement at least meets that recorded in the pre-condition survey, or as agreed in **Application Document 7.5.7.1 Outline Landscape and Ecological Management Plan – Suffolk** and the **Application Document 7.5.7.2 Outline Landscape and Ecological Management Plan - Kent** or if the DCO provides otherwise, then in accordance with the DCO.

2.4.32 Reinstatement details are provided in **Application Document 7.5.7.1 Outline Landscape and Ecological Management Plan – Suffolk** and the **Application Document 7.5.7.2 Outline Landscape and Ecological Management Plan - Kent**.

3. Construction Environmental Management Principles

3.1 Environmental Management Systems

3.1.1 National Grid will implement management processes and briefings so that the works are carried out in accordance with current legislation and guidance. This will be achieved by application of well-established work processes that apply the recognised British Standard (BS) EN ISO 14001:2015 or equivalent.

3.1.2 The contractor will have an Environmental Policy that meets the requirements of ISO 14001 or equivalent, through their internal Business Management System procedures. The policy statement will be displayed on the site notice boards, publicised to all site staff and operatives, and made available to interested parties upon request.

3.2 Roles and Responsibilities

3.2.1 Envisaged roles with defined environmental responsibilities are detailed below. The Onshore CEMP will provide details of all roles relevant to environmental management. An organogram depicting environmental management roles and arrangements will also be provided in the Onshore CEMP.

3.2.2 It is the responsibility of all staff involved with the Proposed Project to ensure the correct implementation of the Onshore CEMP and the environmental mitigation contained within. The Onshore CEMP will include details on roles and responsibilities, however, during the construction phase of the Proposed Project the key environmental responsibilities are likely to be held by the following:

Table 3.1 Outline roles and responsibilities

Role	Responsibilities
Project Manager / Director	Overall environmental management of the Proposed Project, ensuring that all works are carried out in accordance with the Onshore CEMP.
Environmental ~~Advisor /~~ Manager	Work with programme planners and project managers to ensure consents are embedded within the programme. Monitor submission of consent applications and ensure their timely delivery. Provide input to consultation with consent granting bodies, commitment holders and other third parties. Co-ordinate and manage all required scheduled consents. Ensure environmental consents are obtained in line with the programme. Monitor and report progress on consents and commitments.

Role	Responsibilities
	Monitoring construction works for compliance against Environmental Risk Assessment and method statement control measures. Co-ordination of all environmental documentation. Monitoring environmental training, consultation and implementation of contractor procedures. Attending HSE committee meetings. Monitoring of all environmental incidents and ensuring they are reported and investigated. Undertaking audits/inspections, monitor and advise on compliance with duty of care, the Material and Waste Management Plan or any permits and/or exemptions. Monitoring and measurement of waste. Communicate sustainability good practice, innovation and targets to the project team and supply chain. Keep a record of key performance indicators. Act as the main point of contact on environmental matters relating to the Proposed Project.
Environmental Clerk of Works	A qualified and experienced Environmental Clerk of Works (ECoW) will be available during the construction phase to advise, supervise and report on the delivery of the mitigation methods and controls outlined in the CEMP. The ECoW will monitor that the works proceed in accordance with relevant environmental DCO requirements and adhere to the required good practice and mitigation measures. The ECoW will be supported as necessary by appropriate specialists.
Community Relations Agency / Public Relations Officer	To advise on dissemination of project material to the public. To track complaints from members of the public and respond within reasonable time frames. To liaise with members of the public regarding issues such as any specific anticipated nuisance.
Engineering Manager	Ensure environmental issues and constraints are included in individual designs, in accordance with environmental design procedures.
Construction Manager	Advising contractor representative on the implementation of the Onshore CEMP. Monitoring construction works for compliance against Environmental Risk Assessment and any method statement control measures. Monitoring environmental training, consultation and implementation of contractor procedures. Accompanying Environment Inspections where required and any environmental authority inspections.

Role	Responsibilities
	Attending Environmental co-ordination meetings.
Works Supervisors	Ensuring that all work is carried out in accordance with project requirements. Ensure that staff under their supervision are aware of their environmental responsibilities. Ensure key risks are identified and brief operatives on environmental topics. Carry out inspections to identify any environmental issues.
General Operatives	Ensuring environmental mitigation measures are carried out during the course of their duties, in line with project requirements. Working considerately with a good working ethic in order to minimise adverse environmental impacts and follow all requirements communicated during briefings and project training sessions. Informing relevant persons of any environmental issues, so that these can be communicated to the project management team for further investigation. Attending the project induction prior to commencing work where details of the environmental requirements will be provided.

3.3 Competence, Training and Awareness

3.3.1 National Grid will have a system in place to ensure that contractors are competent to perform their scope of work.

3.3.2 Contractors shall identify the training needs of their employees and subcontractors so that they can implement the requirements of this Outline Onshore CEMP (and the Onshore CEMP once agreed) into briefings and construction method statements.

3.3.3 Specific training needs will be developed for individuals to reflect the work to be carried out on the Proposed Project and the significant risks and opportunities identified.

3.3.4 All personnel will be aware of their general environmental management responsibilities, and for those whose work may cause, or have the potential to cause, a significant impact on the environment, to receive specific environmental awareness briefings. Environmental awareness will be reinforced through information, such as poster campaigns, environmental/sustainability performance indicator reports and environmental alerts.

3.3.5 All contractors are responsible for ensuring the competency of their environmental staff. In the event that environmental training is needed for staff, a contractor is responsible for ensuring this requirement is fulfilled. Any training provided to members of the project team will be logged by the project administrator and any certification documents will be produced by the relevant members of staff as evidence that they hold the required competencies.

Toolbox Talks and Training

3.3.6 To provide on-going reinforcement and awareness training, the below topics, along with any other environmental issues which arise, will be discussed at regular toolbox talks. Where applicable to the works the following topics will be included in the induction:

- waste management;
- pollution prevention and control;
- biosecurity;
- environmental measures;
- archaeology; and
- emergency response procedures.

3.3.7 Additional toolbox talks shall be added as required based on circumstances such as unforeseen risks, repeated observation of bad practices, perceived lack of awareness, pollution event, etc.

3.3.8 Records of all toolbox talks and their attendees shall be maintained and recorded.

Health and Safety

3.3.9 National Grid are committed to ensuring the health and safety of persons working on projects is maintained in accordance with the Construction (Design and Management) Regulations 2015 (CDM) and the principles and philosophy behind them.

3.3.10 The contractors will prepare a construction phase Safety Health and Environment (SHE) Plan prior to construction works commencing. A construction phase SHE Plan will be prepared by the contractors for each element of the Proposed Project. The Plan will ensure that adequate arrangements and welfare facilities are in place to cover:

- the safety of construction staff;
- the safety of all other people working at or visiting the construction site;
- the protection of the public in the vicinity of the construction site;
- compliance with the Construction (Design and Management) Regulations 2015 and associated Health and Safety Executive (HSE) guidance documents;
- emergency procedures being defined and adopted; and
- appropriate training and information being provided to personnel.

3.3.11 The contractors' Construction Phase SHE Plan will be reviewed and approved by National Grid prior to construction commencing.

3.3.12 All staff, site visitors and delivery drivers will receive the relevant level of project induction from the contractor to ensure they are aware of site hazards and health, safety and environmental management requirements. Site staff will be briefed daily by the contractor prior to work commencing. Site-specific risk assessments will be carried out to ensure the risk strategy of the frequently changing workplace remains relevant. The contractors will be required to carry out audits and inspections.

3.4 Method Statements

3.4.1 The implementation of Method Statements for the different activities of the Proposed Project works shall be completed by the relevant contractor(s) by trained staff or other appropriate experienced personnel, in consultation with specialists. Their production shall include a review of the environmental/ health and safety risks and commitments, so that appropriate control measures are developed and included within the construction process.

3.4.2 Method Statements will be reviewed by the contractor's Project Manager and, where necessary, by an appropriate environmental specialist. Where appropriate~~, and if required or necessary~~, method statements will be submitted to the relevant regulatory authorities.

3.4.3 Method statements must contain as a minimum:

- location and duration of the activity;
- work to be undertaken and methods of construction;
- plant and materials to be used;
- labour and supervision requirements;
- health, safety and environmental considerations (including relevant control measures); and
- permit or consent requirements.

3.4.4 Deviation from approved method statements (where this is a statutory requirement) will be permitted only with prior approval from relevant parties. This will be facilitated by formal review before any deviation is undertaken.

3.5 Incident Procedure and Response

3.5.1 Contractors will develop and implement an Incident Response Plan which will detail their response in the event of any incident or non-conformance with the Onshore CEMP on site.

3.5.2 The Incident Response Plan will:

- describe the procedure to be followed in the event of an incident (in accordance with the 'Incident Response' procedure below);
- describe the procedure for the notification of appropriate emergency services, authorities and personnel on the construction site;
- describe the procedure for the notification of relevant statutory bodies, environmental regulatory bodies, local authorities and local water and sewer providers;
- provide maps showing the locations of local emergency services facilities such as police stations, fire authorities, medical facilities, other relevant authorities, such as the Environment Agency, and also the address and contact details for each service and authority provide contact details for the persons responsible on the construction site for pollution incident response;
- provide contact details of a competent spill response company which can be contacted at short notice for an immediate response;

- ensure that site drainage plans and flood risk management plans are available on site and are kept up-to-date; and
- ensure staff competence and awareness in implementing plans and using pollution response kit.

3.5.3 All incidents associated with the construction of the Proposed Project, will be reported and investigated using the Incident Response Plan (unless stated differently in other Management Plans).

3.5.4 The following procedure will be followed in the event of an incident or non-conformance with the Onshore CEMP and will be detailed further in the Incident Response Plan.

- works will stop when it is safe to do so;
- the Environmental Manager and Safety, Health, Environment and Quality assurance (SHEQ) Manager will be contacted;
- the scale of the incident will be assessed:
  - if the incident is controllable by staff on Site, remedial action will be taken immediately in accordance with the Plan;
  - if the incident cannot be controlled by the staff on Site, emergency assistance will be sought;
- the appropriate enforcing authority will be contacted and informed, including:
  - the Environmental Agency for incidents affecting rivers, groundwater and major emissions to atmosphere;
  - the East of England Ambulance Service;
  - the local sewerage undertaker for incidents affecting sewers;
  - the Local Authority Environmental Health Department for incidents that could affect the public;
  - the Food Standards Agency for incidents that have the potential to affect food through deposition on crops or land used for grazing livestock;
- an investigation panel will be set up which may include the Senior Project Manager and SHESQ Manager to instigate an investigation into the occurrence of the incident;
- the findings will be sent to the appropriate enforcing authority where necessary; and
- an action plan will be prepared to determine why the incident occurred and whether any modifications to working practices are required to prevent a recurrence. If necessary, the Onshore CEMP and SHE Plan will be updated (and any other plans as appropriate) and all workers will be notified.

3.5.5 The Environment Agency must be notified of a significant pollution incident as soon as possible to allow assessment and remediation measures to be taken. The notifications must be made in the first instance to the Environment Agency incident hotline (0800 80 70 60).

4. Communication and Consultation Strategy

4.1 Community Engagement and Public Information

4.1.1 A community relations agency will be appointed to engage with local residents and provide dedicated community relations and external communications support. The community relations agency will work with the internal established communications team at National Grid.

4.1.2 A free telephone hotline will be available, and a project website will be established and managed by the community relations team. The project helpline number and website URL details will be visible on boards placed around the perimeter of the construction site in appropriate locations where they would be visible to the public. The telephone number and project website details will also be provided to the local authorities.

Complaints Procedure

4.1.3 Any complaints associated with the construction of the proposed development, including non-conformance with ~~the CoCP~~this Outline CEMP and other management plans, will be reported, recorded and investigated using a detailed complaints procedure developed by the contractor in consultation with the community relations team.

4.1.4 The detailed complaints procedure (including but not limited to complaints relating to noise, dust, vibration, pollution and construction traffic) will set out:

- how and to whom complaints can be made;
- a reasonable timeframe for responding to complaints;
- the potential remedies available to address complaints; and
- who to contact in the event that the complainant is not satisfied with the outcome.

4.1.5 Primarily any minor issues or complaints relating to site incidents will be dealt with by the contractor. For the escalation of these issues or for more serious issues these will be dealt with by National Grid project team.

4.1.6 The community relations team will ensure the details of any complaints are recorded and all complaints are appropriately managed. Complaints will be investigated, and appropriate action will be taken.

4.1.7 In addition to the project telephone helpline and project website, complaints from an external party may also be received via a number of other communication routes, for example via written correspondence. Any such communications will also be passed to the community relations team.

4.1.8 Where a person from a community local to the works makes a complaint, it will be passed initially to the community relations team. The community relations team will liaise with the other members of the project team to investigate the complaint. Appropriate action will be taken by the project construction team and both the complaint, and the action taken in response, will be recorded.

5. General Onshore Environmental Commitments and Management Measures

5.1.1 This section sets out the general project-wide environmental commitments and mitigation measures to be adopted during construction, as presented in Table 5.1. Topic-specific environmental commitments and mitigation measures are detailed in the relevant subsequent sections of this document. National Grid will ensure that all sub-contractors adhere to the environmental good practice guidelines for implementation during work activities.

Table 5.1 General onshore environmental commitments and mitigation measures

REAC Ref	Commitment
GG01	The Proposed Project will be delivered and operated in compliance with all relevant legislation, consents and permits.
GG03	The CEMP shall include measures to manage dust, waste, water, noise, vibration and soil during construction. The contractor(s) shall undertake daily site inspections to check conformance to the Management Plans. The title and contact number of person(s) accountable for issues relating to dust, waste, water, noise, vibration and soil will be displayed at site boundary.
GG04	A suitably experienced Environmental Manager will be appointed for the duration of the construction phase. In addition, a qualified and experienced Environmental Clerk of Works (ECoW) will be available during the construction phase to advise, supervise and report on the delivery of the mitigation methods and controls outlined in the CEMP. The ECoW will monitor that the works proceed in accordance with relevant environmental DCO requirements and adhere to the required good practice and mitigation measures. The ECoW will be supported as necessary by appropriate specialists, including ecologists, soil scientists, landscape architects and arboriculturists.
GG05	Construction workers and maintenance staff will undergo training to increase their awareness of environmental issues as applicable to their role on the project. Topics will include but not be limited to: • pollution prevention and pollution incident response; • dust management and control measures; • location and protection of sensitive environmental sites and features;

REAC Ref	Commitment
	• adherence to protected environmental areas around sensitive features; • working hours and noise and vibration reduction measures; • working with potentially contaminated materials; • waste management and storage; • flood risk response actions; and • agreed traffic routes and access points. • providing training for site staff, particularly those working in public facing roles or in areas near residential communities, on how to appropriately respond to confrontational behaviour, verbal abuse, or hostility from members of the public. This should include guidance on deescalation techniques, reporting procedures, and support available to staff who experience such incidents.
GG06	A full photographic/aerial footage and descriptive record of condition (pre-condition survey) will be carried out of the working areas that may be affected by the construction activities prior to these works commencing. This record will be available for comparison following completion of reinstatement works to ensure that the standard of reinstatement at least meets that recorded in the pre-condition survey, or as agreed in the LEMP or if the DCO provides otherwise, then in accordance with the DCO.
GG07	Land used temporarily will be reinstated (bearing in mind restrictions on planting and land use) to its pre-construction condition and use, unless agreed otherwise, save where the DCO provides otherwise, in which case such reinstatement will be in accordance with the DCO. This is subject to the provisions of Article 27 of the draft DCO (**Application Document 3.1**). Hedgerows, fences and walls (including associated earthworks and boundary features) will be reinstated to a similar style/specification and quality to those that were removed where possible, with landowner consultation.
GG08	Where sensitive arboricultural features will be retained within or immediately adjacent to the Order Limits, an appropriate protective area will be established using appropriate fencing (in accordance with BS5837: 2012 Trees in Relation to Design, Demolition and Construction (British Standards Institute)) and signage and will be inspected, repaired and replaced as necessary. The protective areas will be shown on the Retention and Reinstatement Plans contained within the LEMP.
GG09	The name and contact details for the Proposed Project will be displayed at the entrance to all compounds. This will include an emergency number.
GG10	Any activity carried out or equipment located within a construction compound that may produce a noticeable nuisance, including but not limited to dust, noise, vibration and lighting, will be located away from sensitive receptors such as residential properties (where practical) or designated ecological sites. Where it is not practicable to avoid proximity to sensitive receptors, appropriate mitigation measures will be implemented to minimise any

REAC Ref	Commitment
	potential nuisance, and stakeholders will be given advanced notice of the proposed work, justification for the work and details of any proposed mitigation.
GG11	Appropriate site layout and housekeeping measures will be implemented by the contractor(s) at all construction sites. This will include but not be limited to: • preventing pests and vermin control and treating any infestation promptly, including arrangements for the proper storage and disposal of waste produced on site; • access gates will be located at least 10 m from receptors where possible; • inspecting and collecting any waste or litter found on site; • locating or designing site offices and welfare facilities to limit the overlooking of residential properties; • locating designated smoking/vaping areas to avoid nuisance to neighbours; • managing staff/vehicles entering or leaving site, especially at the beginning and end of the working day; and managing potential off-site contractor and visitor parking.
GG12	Plant and vehicles will conform to relevant applicable standards for the vehicle type as follows: • Euro 4 (NOx) for petrol cars, vans and minibuses; • Euro 6 (NOx and PM) for diesel cars, vans and minibuses; and • Euro VI (NOx and PM) for lorries, buses, coaches and Heavy Goods Vehicles (excluding specialist abnormal indivisible loads). Vehicles will be correctly maintained and operated in accordance with manufacturer's recommendations and in a responsible manner. All plant and vehicles will be required to switch off their engines when not in use and when it is safe to do so. In addition, plant and vehicles will conform to relevant applicable standards for the vehicle type.
GG13	Materials and equipment will not be moved or handled unnecessarily. When loading and unloading materials from vehicles, including cable drums and excavated materials, drop heights will be limited.
GG14	Fuels, oils and chemicals will be clearly marked as to their contents and stored responsibly, in a secure, bunded area with an impervious base, away from sensitive water receptors. They will be stored a minimum of 10m from watercourses, ponds and a minimum of 50m from springs, wells, boreholes and groundwater dependent terrestrial ecosystems and wetland habitats. Any spillages or leaks are to be dealt with promptly, and all waste disposed of in an appropriate manner. Before any tank is removed or perforated, all contents and residues will be emptied by a competent operator for safe disposal at a licensed facility. All refuelling, oiling and greasing of construction

REAC Ref	Commitment
	plant and equipment will take place in an appropriate bunded area that includes an impervious base and where possible interceptor drains. All pumps, generators and similarly fuelled equipment are to be placed on drip trays or in a bunded area and all valves, hoses and associated re-fuelling equipment will be regularly inspected and turned off and securely locked when not in use. Vehicles and plant will not be left unattended during refuelling. Appropriate spill kits will be made easily accessible for these activities. Potentially hazardous materials used during construction will be safely and securely stored including use of secondary containment where appropriate. Stored flammable liquids such as diesel will be protected either by double walled tanks or stored in a bunded area with a capacity of 110% of the maximum stored volume. Spill kits will be located nearby.
GG15	Runoff across the site will be controlled through a variety of methods including header drains, 10m buffer zones for all construction and associated activities such as refuelling and storage of materials around watercourses, on-site ditches, silt traps and bunding. Silt fences will be used to trap silt prior to any discharge to surface waters. There will be no intentional discharge of site runoff to ditches, watercourses, wetland habitats, drains or sewers without appropriate treatment and agreement of the appropriate authority (except in the case of an emergency). Where in over pumping takes place associated with in channel works, measures to prevent downstream siltation would be implemented. Examples include deployment of sedi-mats, straw bales/straw bale cages and rock filter dams. Specific measures for each work site would be selected in accordance with the size of the watercourse and the volume of flow.
GG16	Where required, wash down of vehicles and equipment will take place in designated areas within construction compounds. Wash water will be prevented from passing untreated into watercourses, wetland habitats and groundwater. Appropriate measures will include use of sediment traps. Ensure there is an adequate area of hard surfaced road between the wash facility and the site exit, wherever site size and layout permits.
GG17	Where required, wheel washing will be provided at each main construction works compound access point on to the highway. Wash water and rainfall runoff from concrete batching plant areas will be prevented from passing untreated into watercourses and groundwater . Flows from these designated impermeable areas will wither be discharged to foul sewer, or be collected and contained on site in accordance with EA Regulatory Position Statement 287, for example using leak proof skips, settling tanks (provided with 10% freeboard to prevent overtopping), prior to treatment to separate solids and neutralise pH e.g. using approved solutions or CO_2. Road sweepers will also be deployed on public roads where necessary to prevent excessive dust or mud deposits.
GG18	Use water-assisted dust sweeper(s) on the access and local roads, to remove, as necessary, any material tracked out of the site. Avoid dry sweeping of large areas.

REAC Ref	Commitment
GG19	Earthworks and stockpiled soil will be protected by covering, seeding or using water suppression where appropriate.
GG20	Bonfires and the burning of waste material will be prohibited.
GG21	Construction lighting will be of the lowest levels necessary to safely perform each task. It will be designed, positioned and directed to reduce the intrusion into adjacent properties, protected species and habitats (e.g. watercourses) and designated conservation sites.
GG22	A Material and Waste Management Plan will be submitted to and approved by the local planning authority prior to construction as secured by Requirement 6 in the **draft DCO** (**Application Document 3.1**). The contractor(s) will maintain and monitor this plan throughout the construction phase and oversee that any sub-contractor(s) adhere to it. The Material and Waste Management Plan will set out, in an auditable manner, how waste will be reduced, reused, managed and disposed of in accordance with the waste hierarchy. Dedicated areas will be identified on the construction plans to allow materials and wastes to be segregated at source, reducing the risk of damage or contamination.
GG23	A construction phase Safety Health and Environment (SHE) Plan will be prepared by the contractor prior to construction works commencing and will ensure that adequate arrangements and welfare facilities are in place to cover the safety of construction staff, visitors to site, the public and compliance with appropriate legislation and guidance.
GG24	An Incident Response Plan will be developed by the contractor for the construction phase. This will be prepared prior to construction works commencing and thereafter complied with. It will outline procedures that will be implemented in case of unplanned events, including but not limited to site flooding and pollution incidents and flood defence damage contingencies. Local authorities and the Environment Agency will be informed of any large scale incidents under the Incident Response Plan. Smaller scale issues will be recorded in a register that will be made available to local authorities and the Environment Agency for review on request.
GG25	Stone pads or equivalent will be installed in areas where heavy equipment, such as cranes and piling rigs, will be used. The stone pads will provide stable working areas and will reduce disturbance to the ground. The stone pad area will be stripped of the topsoil, which will be stored and reinstated in accordance with the soil management measures contained in the CEMP. Archaeological mitigation will be undertaken, as appropriate, in areas where the pads have the potential to impact on archaeological remains. The mitigation will be agreed with the relevant stakeholder and will be in line with the relevant Onshore Overarching Written Scheme of Investigation.
GG26	Where working areas are fenced, the type of fencing installed will depend on the area to be fenced and will take into consideration the level of security required in relation to the surrounding land and public access, rural or urban environment and arable or stock farming. Consultation on the type of fencing will be undertaken with the relevant landowner and tenant where required and

REAC Ref	Commitment
	where there are existing surface water flow paths, the fencing type will not cut off/block these routes. For some locations the fence used may also serve to provide acoustic and visual screening of the work sites and reduce the potential for disturbance of users in the surrounding areas. Fencing will be regularly inspected and maintained and removed as part of the demobilisation unless otherwise specified.
GG27	Members of the community and local businesses will be kept informed regularly of the works through active community liaison. This will include notification of noisy activities, heavy traffic periods and start and end dates of key phasing. A contact number will be provided which members of the public can use to raise any concerns or complaints about the Proposed Project. All construction-related complaints will be logged by the contractor(s) in a complaints register, together with a record of the responses given and actions taken. This will be made available to local authorities for review on request.
GG28	Ensure equipment is readily available on site to clean any dry spillages, and clean up spillages as soon as reasonably practicable after the event using wet cleaning methods.
GG32	To reduce the potential for significant overall cumulative effects, PRoW closures / diversions will be coordinated with East Anglia ONE North Offshore Windfarm and East Anglia TWO Offshore Windfarm.
GG39	The Applicant will implement the mitigation measures in accordance with the recommendations set out within the detailed UXO risk assessment reports appended to the Onshore oCEMP. Where the Applicant has influence over the controlled explosion of terrestrial UXO they will inform Natural England and RSPB in advance to take measures to protect Sites of Specific Scientific Interest where practicable.
GG40	Once detailed design is complete and detailed construction and programme information is available, the undertaker commits to undertaking a review of the intra-project cumulative effects assessment submitted with the application (as amended during the Examination) to consider: 1. if the significant intra-project cumulative effects are still considered likely to occur; and 2. if they are still considered likely to occur, what additional appropriate mitigation measures may be applied to reduce their significance in line with the mitigation hierarchy

~~5.~~6. Landscape and Visual

~~5.1~~6.1 Introduction

~~5.1.1~~6.1.1 **Application Document 6.2.2.1 Part 2 Suffolk Chapter 1 Landscape and Visual** and **Application Document 6.2.3.1 Part 3 Kent Chapter 1 Landscape and Visual** consider the potential effects on landscape designations, landscape character areas and visual effects on local communities.

~~5.1.2~~6.1.2 The main effects on landscape and visual receptors during construction comprise the removal of vegetation during construction along with the presence of construction activities within the landscape and views from communities. This chapter should be read alongside the **Application Document 7.5.7.1 Outline Landscape and Ecological Management Plan – Suffolk** and the **Application Document 7.5.7.2 Outline Landscape and Ecological Management Plan – Kent**, which contain additional information relating to planting and reinstatement.

~~5.2~~6.2 Implementation of Mitigation Measures

~~5.2.1~~6.2.1 Construction phase measures that relate to Landscape and Visual are primarily set out and secured in the Outline Landscape and Environmental Management Plans (LEMP) (**Application Document 7.5.7.1 Landscape and Ecological Management Plan – Suffolk** and **Application Document 7.5.7.2 Landscape and Ecological Management Plan – Kent**). These include construction phase measures in relation to vegetation retention, loss and reinstatement.

~~5.2.2~~6.2.2 ~~The Outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**) also contains general good practice measures and topic-specific control and management~~Table 6.1 presents the environmental commitments and mitigation measures relevant to the landscape and visual assessment as set out in **Application Document 6.2.2.1 Part 2 Suffolk Chapter 1 Landscape and Visual** and **Application Document 6.2.3.1 Part 3 Kent Chapter 1 Landscape and Visual**.

Table 6.1 Environmental commitments and mitigation measures relevant to landscape and visual

REAC Ref	Commitment
LV01	The contractor(s) will retain vegetation where practicable. Where vegetation is lost and trees cannot be replaced in situ due to the restrictions associated with land rights required for operational safety, native shrub planting approved by National Grid will be used as a replacement, in accordance with the outline vegetation reinstatement plans included within the Outline Landscape Environment Management Plan.
LV02	The contractor(s) will apply the relevant protective principles set out in British Standard (BS) 5837:2012: Trees in relation to design, demolition and construction. This will be applied to trees within and immediately adjacent to

REAC Ref	Commitment
	the Order Limits as identified within **Application Document 6.10 Arboricultural Impact Assessment Part 1 of 2** and **Arboricultural Impact Assessment Part 2 of 2**. All works to high grade trees, including trees under Tree Preservation Orders, and veteran and ancient trees, will be undertaken or supervised by a suitably qualified arboriculturist.
LV03	As set out within the Outline LEMP for Suffolk, a five-year aftercare period will be established for all reinstatement and mitigation planting along the HVDC and HVAC cable corridors. For the Suffolk Onshore Scheme, all planting associated with the Fromus Bridge, permanent access track, Friston substation and Saxmundham converter station will be managed and maintained for the lifetime of the asset.
LV04	A five-year aftercare period will be established for all reinstatement and mitigation planting along the HVDC cable corridor. All planting associated with the Minster Converter Station and Substation will be managed and maintained for the lifetime of the asset.
LV05	Subsoil and topsoil will be separated, documented and stored and replaced as close as possible to the location of origin to ensure no degradation in quality, with reinstatement undertaken as soon as possible after completion of construction of each section/area of works.
LV06	Temporary and separate placement of topsoil and subsoil will be stored adjacent to the trench where possible, with the additional height of the subsoil storage used on whichever side requires greater screening benefit, where practicable. In some locations stockpiles will be remote from the trench, such as at pinch points where the corridor has been narrowed, and the additional height of the storage will be sensitively placed as far as possible.

~~6.~~7. Ecology and Biodiversity

~~6.1~~7.1 Introduction

~~6.1.1~~7.1.1 **Application Document 6.2.2.2 Part 2 Suffolk Chapter 2 Ecology and Biodiversity** and **Application Document 6.2.3.2 Part 3 Kent Chapter 2 Ecology and Biodiversity** ~~considers~~consider the potential effects of the Proposed Project on ecology and biodiversity. The receptors considered were statutory designated sites, non-statutory designated sites, terrestrial and aquatic habitats (including ancient woodland and priority habitats), ornithology and other faunal species.

~~6.1.2~~7.1.2 The main effects on ecology and biodiversity receptors during construction include, but are not limited to, the temporary or permanent loss or fragmentation of habitats, direct loss of designated sites, disturbance of birds and other fauna, air quality impacts on designated sites and introduction of non-native species of habitats.

~~6.2~~7.2 Implementation of Mitigation Measures

~~6.2.1~~7.2.1 Construction phase measures that relate to ~~Ecology~~ecology and ~~Biodiversity~~biodiversity are included and secured in the Outline LEMPs (**Application Document 7.5.7.1 Landscape and Ecological Management Plan – Suffolk** and **Application Document 7.5.7.2 Landscape and Ecological Management Plan – Kent**). These include construction phase measures in relation to vegetation retention, loss and reinstatement.

~~6.2.2~~7.2.2 ~~The Outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**) also contains general good practice measures and topic-specific control and management~~Table 7.1 presents the environmental commitments and mitigation measures relevant to the ecology and biodiversity assessment as set out in **Application Document 6.2.2.2 Part 2 Suffolk Chapter 2 Ecology and Biodiversity** and **Application Document 6.2.3.2 Part 3 Kent Chapter 2 Ecology and Biodiversity**. This includes those measures relevant to the control of dust generation and water quality controls in addition to those specifically for the protection of biodiversity.

~~**Application Document 7.5.3.2 CEMP Appendix B Register of Environmental Actions and Commitments also contains embedded and additional mitigation measures which will be implemented during the construction phase as set out in Application Document 6.2.2.2 Part 2 Suffolk Chapter 2 Ecology and Biodiversity and Application Document 6.2.3.2 Part 3 Kent Chapter 2 Ecology and Biodiversity.**~~**Table 7.1 Environmental commitments and mitigation measures relevant to ecology and biodiversity**

REAC Ref	Commitment
B01	The contractor(s) will comply with relevant protected species legislation. Appropriate licences will be obtained where necessary from Natural England for all works affecting protected species as identified by the ES and through

REAC Ref	Commitment
	pre-construction surveys. Should protected species be identified during construction that require a licenced works in that location will be stopped, when safe to do so, until an appropriate licence is in place. All applicable works will be undertaken in accordance with the relevant requirements and conditions set out in those licences.
B02	The assumption will be that vegetation with the potential to support breeding birds will not be removed during the breeding bird season (March to August inclusive). If any works become necessary during the breeding bird season, works will be supervised by an ECoW. Appropriate protection measures will be put in place should active nests be found. These will include exclusion zones around active nests until chicks fledge or nests become inactive as determined by monitoring by the ECoW.
B03	As far as possible, trenches and excavations should not be left open overnight. Where there will be a risk of animal entrapment, a means of escape (such as a plank that can be used as a ladder) will be installed into all excavations that are left open overnight.
B04	To control the spread of invasive weeds in accordance with the Wildlife and Countryside Act 1981, any plant, machinery, or footwear used in areas containing invasive species (terrestrial and aquatic), such as Japanese knotweed, Azolla fern, and Himalayan balsam, will be thoroughly cleaned following the Check, Clean, Dry protocol outlined by the GB Non-Native Species Secretariat. Cleaning will take place at contained wash stations designed to remove all soil and debris from equipment and individuals before leaving site. Water used for cleaning vehicles and footwear will be treated as contaminated waste and managed appropriately to prevent the spread of invasive species via seeds, rhizomes, or plant fragments. Pre-commencement checks/surveys for presence of Invasive Non-Native Species (INNS) in works areas would be undertaken by the ECoW and a Biosecurity Management Plan (BMP) will be produced for the project following the latest guidance on from the Great Britain (GB) non-native species secretariat.
B05	All habitats suitable for common reptiles will be subject to two-stage habitat manipulation that will take place between mid-March and mid-October. Firstly, vegetation will be cut to approximately 150 mm (with the arisings removed) under the supervision of an ECoW and the site left for a minimum of two days to allow reptiles to naturally disperse from the area. Secondly, vegetation will be cleared down to ground level under the supervision of an ECoW. Vegetation will be cleared using appropriate equipment based on the type of vegetation to be removed, the area affected, and the risk of mortality or injuring reptiles. Construction works could commence immediately after completion of the second stage. Reptile hibernacula will be retained and protected during construction where practicable. If unavoidable, the removal of vegetation and groundworks at hibernacula will be timed to avoid the hibernation season (late October to early March). Replacement hibernacula and refugia will be provided.
B06	Where necessary, alternative roost structures (bat boxes) will be provided (with landowner consent) on retained trees within the Order Limits or areas outside of the Order Limits agreed with relevant landowners. Three boxes will

REAC Ref	Commitment
	be provided for each tree with moderate bat roost potential to be felled. Five boxes will be provided for each tree with high bat roost potential to be felled.
B07	Where the works require the crossing or removal of hedgerows, the gap will be reduced to a width required for safe working. Where hedge removals are necessary, 'dead hedging' should be used, where practicable, in the interim periods to retain connectivity during construction. Dead hedging can comprise vegetation arisings or artificial provision, such as willow screening panels or Heras fencing covered in camouflage netting. New hedgerow planting will contain native, woody species of local provenance.
B08	During culvert installation there would be a watching brief and fish rescue where required. Where over pumping is required, pumps would be fitted with 2mm screens to prevent injury to fish or eels.
B09	Measures to manage risk of frac out: • ensuring sufficient surveys have been undertaken to understand the ground conditions to inform the final design; • design a profile sufficiently deep for the methodology and conditions, with hydrofracture modelling used to check that there is sufficient factor of safety; • use of a drilling fluids engineer to design and monitor the fluid properties; • ensure that the trenchless bore is sufficiently clean of cuttings during drilling; • monitoring fluid pressures in the bore, and returns to the entry pit during drilling; • the use of "spotters", personnel stationed above the onshore drill line to look for any frac out or break out; and if drilling fluid losses occur, lost circulation material (LCM) may be added to seal the ground. As a last resort, cementitious grout may be used to seal fractures.
B10	The foundations of bridges across the River Fromus and the River Stour will be constructed using soft-start non-percussive piling techniques to limit disturbance, which would assist in allowing sounds to increase gradually allowing fish in the immediate vicinity to swim away.
B14	A precautionary method would be followed when undertaking vegetation clearance potentially suitable for dormice which would be undertaken in two stages under supervision of a suitably qualified ecologist.
B24	Where the proposed works are to take place within arable fields or acid grassland, one of two approaches would be applied to the Suffolk Onshore Scheme to ensure no likely significant effects. First would be to clear crops from the fields between October to January inclusive before works commence and then ensure that vegetation is kept clear from those areas until construction starts in that area as any regrowth of vegetation could attract

REAC Ref	Commitment
	ground-nesting birds such as skylark and woodlark. The second approach is to agree with the landowner and/or tenant to leave the previous crop in the ground so that there is already a tall, dense crop in spring, which would deter ground-nesting birds from utilising that field. Where works are to take place in areas of acid grassland, the first of the two approaches would be utilised.
B25	A watching brief would be introduced during vegetation clearance in the ditch west of the River Fromus. Displacement of water voles if any are encountered would occur under a Class Licence. This would restrict clearance of any locations where water voles are present to either 15 February to 15 April or 15 September to 31 October.
B26	During the construction phase no lighting will be placed within 40m of an active badger sett. There will be a 40 m setback between the identified badger sett (if active) and the construction compounds S04 and S08.
B27	A seasonal restriction on compound set-up and demobilisation for the trenchless bore such that it occurs outside the nesting season (February to August). The most potentially disturbing elements of trenchless installation (set up of trenchless compound S10) will take place between September and January, to minimise disturbance of breeding nightjar and woodlark in the adjacent Sandlings SPA.
B33	To minimise disturbance risk to nesting hobby, any old crow or other similarly large nests within the Order Limits will be removed, if possible, every winter in areas where works are planned for the following nesting season. To ensure no reduction in nesting opportunities for hobby, three wicker baskets will be placed in trees within the Order Limits (or outside the Order limits if agreed with landowners) before the breeding season commences. These baskets would be at least 200 m from planned construction activity in that nesting season. These will be moved, if necessary, each winter to ensure they continue to be in undisturbed locations. They can also be moved to alternative locations during a given nesting season if there is no evidence of nesting at the time.
B34	The barn owl nest box near the River Fromus bridge will be moved further south and two additional nest boxes added. Regarding the barn owl box north of compound S08, additional barn owl boxes will be erected to ensure no net reduction in nesting opportunities and the compound established when barn owls are not nesting. These barn owl boxes will be located on trees within the Order limits or outside the Order Limits if agreed with landowners.
B35	To avoid disturbance of nesting woodlark outside the SPA, works close to known nesting areas will be commenced during the winter so there is already activity before the nesting season; the birds will then choose alternative nesting locations. In addition, there will be appropriate monitoring for woodlark throughout the nesting season (February-August) by experienced ecologists. If singing males are present the site manager will be notified and steps taken to introduce construction works in the area prior to a nest being established. If a nesting pair is found to be present in the vicinity of construction, then the ecologist will

REAC Ref	Commitment
	consider the likely location of the nest alongside proposed works planned in the area. Appropriate stand off buffers will be implemented if works are to significantly vary from those already occurring and will remain in place until either the works are completed or an active nest and/or fledged chicks are no longer present. If necessary, advice will be sought from Natural England.
B36	Larger gaps in hedgerows or woodland belts would be reduced to 10 m maximum where practicable during the night by hurdles or similar.
B37	The gap for access traversing the hedgerow that runs north from Broomfield's Covert will be kept to 10 m maximum.
B38	Around construction compounds and the converter station and substation works areas, direct illumination of boundary features would be avoided. Lighting would be designed to comply with published guidelines, specifically, 'Bats and Artificial Lighting in the UK' Guidance Note (GN 08 / 23). The lighting design would be approved by a suitably qualified lighting professional.
B43	Measures will be adopted to avoid the trenchless drilling equipment getting stuck. There will generally be no excavation to retrieve a stuck drill head.
B44	Noise fencing or similar effective noise reduction methods will be implemented around works areas where required to avoid significant disturbance on noise sensitive receptors, particularly the SSSI and birds. Noise monitoring would be included adjacent to the SSSI to confirm the mitigation measures met the required noise thresholds.
B45	Installation of overhead line pylons either side of Sandwich Bay to Hacklinge Marshes SSSI will not cover the entire breeding season (March to September included) but will either take place outside the bird breeding season or will only occupy approximately two months of the breeding season unless otherwise agreed with Natural England. Any works causing noise levels above 60dB Lamax at the boundary of the SSSI, will take place outside the bird breeding season (March to August included).
B46	It is assumed that water voles could be present on any ditch section to be traversed and a watching brief will therefore be introduced during any vegetation clearance in these ditches. Displacement of water voles if any are encountered would be undertaken under the supervision of a licensed ecologist under Class Licence CL31. This would restrict clearance of any locations where water voles are present to either 15 February to 15 April or 15 September to 31 October.
B47	In order to avoid the nesting bird season and the water vole active season, vegetation clearance of sections of ditch will need to take place during 15th September to 31st October (this being one of the two legally permissible windows for excluding water voles by displacement). However, if pre-construction surveys undertaken immediately prior to the clearance works taking place confirm the absence of nesting birds, vegetation removal may also occur between 15 February to 15 April (this being the other legally permissible window for excluding water voles by displacement), provided that pre-construction surveys have been undertaken by a suitably qualified ecologist to ensure there is no suitable habitat for hibernating reptiles. If pre-

REAC Ref	Commitment
	construction surveys identify no water vole burrows or nesting birds are present within the area to be cleared, then vegetation clearance could also take place outside these windows. The actual culverts will then be installed at the appropriate time as the haul road progresses across the site.
B48	A 20 m buffer will be implemented during construction around any Cetti's warbler nests that do establish within the construction area in each nesting season. A specific decision will then be undertaken in discussion with the ecological clerk of works over the construction activities that can take place in that area while the nest is active. In addition, there will be continued monitoring for Cetti warbler throughout out the nesting season (March to August) by experienced ecologists. If singing males are present the site manager will be notified and steps taken to introduce construction works in the area prior to a nest being established.
B49	There will be no lighting within 40m of any active badger setts or any significant sources of noise that would affect active badger setts during construction.
B50	Any activities relating to construction of the Minster Converter Station and Substation, that are calculated, following detailed design, to be above 60dB LAmax at the boundary of the SSSI, are to be undertaken outside of the breeding bird season (March to June).
B51	The overhead line pylon base installation will be programmed to avoid the core wintering bird period of November to February.
B53	Larger gaps in hedgerows or woodland belts would be reduced to a maximum of 10 m during the night by hurdles or similar. Where practicable, the gap will be reduced to less than 10 m. Around construction compounds, direct illumination of boundary features will be avoided. Lighting will be designed to comply with published guidelines, specifically, 'Bats and Artificial Lighting in the UK' Guidance Note (GN 08 / 23). The lighting design would be approved by a suitably qualified lighting professional.
B56	Macroinvertebrate and macrophyte communities will be translocated from the ditch to be lost to the Minster Converter Station, into nearby watercourses (where this would not impede flow in the channel) or the balancing/attenuation ponds, in advance of infill.
B57	There will be no lighting directed towards any of the four trees with bat roost potential identified in the surveys for the Kent Onshore Scheme.
B59	In relation to trenchless landfall works at both Suffolk and Kent, the contractor(s) will: • Notify NE of changes to landfall HDD depth or any changes to the location of landfall exit pit • The Undertaker shall prepare a HDD landfall Method Statement and Drilling Fluid Management Plan in consultation with Natural England (NE), Kent Wildlife Trust (KWT) and Royal Society for the Protection of Birds (RSPB), National Trust, and Thanet District Council, and submit the same for approval by the Marine

REAC Ref	Commitment
	Management Organisation (MMO) in accordance with the Cable Specification and Installation Plan prior to the commencement of any HDD activities.
	Undertake HDD landfall hydrofracture modelling which is to be shared for information only with NE, KWT and RSPB when completed
B60	National Grid will notify and consult ESC, Natural England (NE) and / or RSPB, as appropriate, of methods, locations, and routes for spotters and, in the unlikely event of a frac out, vehicles, personnel and equipment for remediation; and will take into consideration any comments received in relation to them. Spotters will be on foot except where using existing vehicle access tracks. There will be no vehicle access to shingle habitats.
B61	If pumps are used to flush saltmarsh vegetation in the event of frac-out they will be hand held only and operated at low pressure
B62	Prior to HDD works commencing, the Undertaker will carry out Phase 2 botanical surveys within the area of the Proposed HDD route to support monitoring and mitigation of any impact of the Horizontal Directional Drilling (HDD).
B63	National Grid will inform Natural England and East Suffolk Council of any proposals to undertake additional groundwater investigation urveys on or adjacent to shingle habitats.
B64	Where there are existing ponds (as shown on Ordnance Survey mapping) within the Order Limits, it is confirmed that these will not be removed as part of the works. This measure does not apply to any new ponds created since submission of the application.
B66	To ensure ecological interest features of the former hoverport are not affected during construction, the following approach will be taken: a) pre-construction botanical survey will be undertaken to map vegetation stands of particular significance to protect, such as orchids or dense stands of dock or wild carrot (the larval floodplants of the two rarest invertebrates on site). b) An access route will subsequently be marked out which avoids these stands, along with dense stands of other vegetation. c) A suitable qualified ecologist will be on site to supervise and guide the marking out of the access route.
B67	To ensure there will be no vehicular or pedestrian access across the saltmarsh, access and egress of vehicles to the mudflats will be via the former hoverport with a buffer between the defined access route and the seaward (distal) limit of the saltmarsh. The locations and widths of access routes across the mudflats will be defined post consent in consultation with Natural England and Kent Wildlife Trust as appropriate, and will be informed by a pre-construction saltmarsh habitat survey. All vehicles accessing the intertidal mudflats will be low pressure bearing.
B68	The Undertaker will prepare a Pegwell Bay Landfall Construction Method Statement prior to commencement of the landfall works in Kent, in consultation with Natural England and Kent Wildlife Trust as appropriate, covering marine cable pull in and cable burial (including excavations)

REAC Ref	Commitment
	between Mean Low Water Springs (MLWS) and the Trenchless crossing exit pits .
B69	Trenchless crossing exit pits in Pegwell Bay will be at least 105 m seaward from the edge of the saltmarsh. The temporary working area will be located at a minimum distance of 50 m from the edge of the saltmarsh.
B71	During winter, construction work within 4 m of any watercourse are only to be undertaken during 7am to 7pm, except during emergencies, to avoid disturbing otter during the core of the night.

~~7.~~8. Cultural Heritage

~~7.1~~8.1 Introduction

~~7.1.1~~8.1.1 **Application Document 6.2.2.3 Part 2 Suffolk Chapter 3 Cultural Heritage** and **Application Document 6.2.3.3 Part 3 Kent Chapter 3 Cultural Heritage** considers the potential of the Proposed Project on archaeological remains, built heritage and historic landscape assets. The project could affect the historic environment during construction by disturbing known and unknown archaeology during excavation and through the removal of historic landscape features.

~~7.2~~8.2 Implementation of Mitigation Measures

~~7.2.1~~ ~~Construction phase control and management measures that relate to cultural heritage are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**), with the REAC (**Application Document 7.5.3.2 CEMP Appendix B Register of Environmental Actions and Commitments**) listing out additional mitigation to also be followed during construction.~~

8.2.1 Table 8.1 presents the environmental commitments and mitigation measures to be followed during construction, relating to cultural heritage.

~~7.2.2~~8.2.2 Potential direct impacts on buried archaeological remains would be managed through a programme of additional mitigation which includes preservation in situ, archaeological investigation and recording, and a protocol for dealing with unexpected archaeological discoveries during construction. The guiding principles and methodology for the planning and implementation of the archaeological mitigation are set out in the **Application Document 7.5.4.1 Outline Onshore Overarching Written Scheme of Investigation – Suffolk** and **Application Document 7.5.4.2 Outline Onshore Overarching Written Scheme of Investigation - Kent**, which are to be agreed with the Archaeology Advisors at Suffolk County Council and Kent County Council respectively as part of the DCO process.

~~7.2.3~~8.2.3 This includes a requirement for site-specific Written Scheme of Investigation (WSI) to be produced by National Grid's Archaeological Contractor to achieve the mitigation measures. The site-specific WSI would be agreed with the Archaeology Advisors for Suffolk County Council and Kent County Council, and any other relevant heritage stakeholders prior to the commencement of the archaeological works.

Table 8.1 Environmental commitments and mitigations measures relevant to cultural heritage

REAC Ref	Commitment
H01	Construction of the Proposed Project would employ the use of track matting for construction plant, where practicable, as opposed to topsoil stripping for the creation of haul roads. This measure would avoid permanent impacts to buried archaeological remains that may be present.

REAC Ref	Commitment
H02	To minimise change to the setting of heritage assets, land used temporarily will be reinstated to its pre-construction condition and use where practicable, unless agreed otherwise. Hedgerows, fences and walls (including associated earthworks and boundary features) will be reinstated to a similar style and quality to those that were removed where possible, with landowner consultation, through Outline Onshore CEMP measure GG07. This is subject to the DCO provisions on reinstatement.
H03	To minimise light intrusion into the setting of heritage assets, construction lighting will be of the lowest levels necessary to safely perform each task. It will be designed, positioned and directed to reduce light spill and intrusion, through Outline Onshore CEMP measure GG21.
H17	Timescales for the delivery, content and submission of OASIS records will be confirmed in consultation with Historic England and the Archaeological Curator(s) as part of the finalisation of the WSI.

~~8.~~9. Water Environment

~~8.1~~9.1 Introduction

~~8.1.1~~9.1.1 **Application Document 6.2.2.4 Part 2 Suffolk Chapter 4 Water Environment** and **Application Document 6.2.3.4 Part 3 Kent Chapter 4 Water Environment** considers the potential effects of the Proposed Project on the water environment. In addition, a Flood Risk Assessment (**Application Document 6.8 Flood Risk Assessment**) and Water Framework Directive Assessment (**Application Document 6.9 Water Framework Directive Assessment**) has been produced as part of the application for development consent.

~~8.2~~9.2 Implementation of Mitigation Measures

~~8.2.1~~9.2.1 ~~Construction phase control and management measures that relate to the water environment are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management~~Table 9.1 presents environmental commitments and mitigation measures relevant to the water environment assessment as set out in **Application Document 6.2.2.4 Part 2 Suffolk Chapter 4 Water Environment** and **Application Document 6.2.3.4 Part 3 Kent Chapter 4 Water Environment**.

~~8.2.2~~9.2.2 All works within main rivers, ordinary watercourses and board drains will be in accordance with a method approved under environmental permits issued under the Environmental Permitting Regulations by the Environment Agency and /or the relevant secondary consents or permits from the Lead Local Flood Authorities and Internal Drainage Boards. The contractor(s) will also comply with all relevant consent conditions or DCO provisions regarding de-watering and other discharge activities. This will particularly be with regard to volumes and discharge rates and will include discharges to land, water bodies or third-party drains/sewers.

~~**The REAC (Application Document 7.5.3.2 CEMP Appendix B Register of Environmental Actions and Commitments) also includes embedded mitigation to be followed during construction. This includes commitment W14 which states that the contractor shall develop a Drainage Management Plan. The plan shall demonstrate how the contractor would manage surface water runoff across the construction worksite, including details of how offsite impacts would be managed and mitigated. There is also a commitment W15 for the contractor to prepare a construction phase Flood Management Plan that would consider all construction phase activities and temporary works necessary to deliver the Proposed Project.~~Table 9.1

Environmental commitments and mitigation measures relevant to the water environment

REAC Ref	Commitment
W01	All works within main rivers and qualifying activities within floodplains such as installation of access tracks, within ordinary watercourses and board drains, will be in accordance with a method approved under environmental permits issued under the Environmental Permitting Regulations by the Environment Agency and /or the relevant secondary consents or permits from the Lead Local Flood Authorities and Internal Drainage Boards.
W02	For open cut watercourse crossings and installation of vehicle crossing points, good practice measures will include but not be limited to: • where practicable, reducing the working width for open cut crossings of an ordinary watercourse whilst still providing safe working; • no open cut crossing of main rivers; • installation of a pollution boom downstream of open cut works; • the use and maintenance of temporary lagoons, tanks, bunds, silt fences or silt screens as required; • have spill kits and straw bales readily available at all crossing points for downstream emergency use in the event of a pollution incident; • the use of all static plant such as pumps in appropriately sized spill trays; • prevent refuelling of any plant or vehicle within 10 m of a watercourse and within 50 m of any spring/borehole/well; • prevent storing of soil stockpiles within 15 m of a main river (16m where river is tidal) and Flood Zone 3b where practicable; • inspect all plant prior to work adjacent to watercourses for leaks of fuel or hydraulic fluids; and reinstating the riparian vegetation and natural bed of the watercourse, using the material removed when appropriate, on completion of the works and compacting as necessary. If additional material is required, appropriately sized material of similar composition will be used.
W03	Riverbank and in-channel vegetation will be retained where not directly affected by installation works. Where ditches retaining seasonal flows are crossed, culverts in waterbodies will either preserve the natural bed or be box culverts with inverts sunk a minimum of 300 mm below the hard bed of the watercourse and natural / existing bed material placed across the inside of the culvert, to maintain existing channel gradients and habitat for aquatic invertebrates, as well as to ensure continued passage for in channel species.
W04	Where watercourses are to be crossed by construction traffic, measures will include the use of culverts or temporary spanned bridges. Once the culvert is

REAC Ref	Commitment
	installed, the area above the culvert will be backfilled and construction mats placed over the backfilled area to permit the passage of plant, equipment, materials and people. Culverts will be sized to reflect the span width and the estimated flow characteristics of the watercourse under peak flow conditions and kept free from debris. The installation works would be timed to avoid flood flow conditions where practicable or if periods of work were necessary when higher flow conditions could be expected, suitable pumping provision would be put in place, with standby pumps also made available. Where used, temporary bridges will be designed specifically to consider the span length and the weight and size of plant and equipment that will cross the bridge. The bridge across the River Stour would have a soffit height sufficient to meet with navigational requirements and in excess of the 0.5% flood level plus 600 m freeboard.
W05	The contractor(s) will comply with all relevant consent conditions or DCO provisions regarding de-watering and other discharge activities. This will particularly be with regard to volumes and discharge rates and will include discharges to land, water bodies or third-party drains/sewers.
W06	Where new or additional impermeable surfacing is required on any access tracks, bellmouths and in compound areas e.g. for parking provision, site offices, Sustainable Drainage Systems (SuDS) will be incorporated appropriate to the existing ground conditions, with infiltration to ground preferred where conditions are suitable. These would be put in place as early activities in the construction schedule so as to avoid or reduce working on land that is prone to waterlogging and flooding. The Proposed Project will incorporate appropriate surface water drainage measures into its final design for the haul roads and access tracks so that they do not lead to a significant increase in flood risk. Temporary haul routes and all other temporary works within Flood Zone 3 and areas of high and medium risk of flooding from surface water will be removed at the end of the construction phase and the ground surface will be reinstated to pre-project levels, except in instances where the ground level has been adjusted as part of the Proposed Project subject to the provisions of the **draft DCO** in Article 27 (see **Application Document 3.1**). No construction materials should be stored within Flood Zone 3 and areas of high and medium risk of flooding from surface water, where this cannot be avoided, for example in the River Stour floodplain adequate mitigation measures will be applied. For example, model outputs would inform the placement of soil during construction and soil stockpiles would be aligned in the direction of flow to avoid impeding flood flow routes.
W07	The contractor(s) will subscribe to the Environment Agency's Floodline service, which provides advance warning of potential local flooding events, and subscribe to the Met Office's Weather Warnings email alerts system and any other relevant flood warning information. The contractor(s) will implement a suitable flood risk action plan, which will include appropriate evacuation procedures should a flood occur or be forecast.
W08	Active private water supplies will be identified with landowners through the landowner discussions. Appropriate measures will be considered during

REAC Ref	Commitment
	construction. In the event of a landowner or tenant reporting that installation activities have affected their private water supplies, an initial response will be provided within 24 hours. Where the installation works have affected a private water supply, an alternative water supply will be provided, as appropriate, and any groundwater contamination will be remediated.
W09	In the event of a significant spill during construction or maintenance, the incident will be reported to the Environment Agency incident hotline and all landowners/tenants with a private water supply within 250 m of the spill will be contacted within 24 hours. An assessment of the likelihood of groundwater contamination reaching identified private water supplies will be undertaken, and where a private water supply is judged likely to be affected, an alternative water supply will be provided, as appropriate and in agreement with the affected landowner/tenant, and any proven groundwater contamination will be remediated.
W10	Severance of existing land drainage routes, including agricultural field drainage systems would be managed during construction through provision of temporary alternative drainage routes, and these drainage systems would be permanently reinstated or rerouted ensuring their existing function is maintained.
W11	Surface water drainage from permanent above ground infrastructure would be managed and treated using SuDS in accordance with policy and guidance requirements of the relevant Lead Local Flood Authorities to include allowances for climate change in accordance with current (May 2022) Environment Agency guidelines. These SuDS would be maintained over the lifetime of the Proposed Project and the drainage infrastructure would provide the storage necessary to achieve discharges at greenfield rates and would not significantly alter groundwater recharge patterns by transferring recharge quantities from one catchment to another.
W12	At the Suffolk and Kent landfalls the offshore cables will be brought onshore using a trenchless technique, avoiding physical disturbance of several watercourses and areas of coastal floodplain. Monitoring of existing flood defences would be undertaken during the cable installation in agreement with Environment Agency protocols to ensure no detriment to the integrity of the defences.
W13	Bankside vegetation would be reinstated at culvert entries and exits following the completion of construction works as soon as conditions are suitable for planting and where identified as necessary, provision for mammal passage would also be included.
W14	The Contractor shall develop a Drainage Management Plan in accordance with the National Standards for Sustainable Drainage Systems and this must be submitted to the Local Planning Authority for approval prior to construction works for the Proposed Project commencing and thereafter the approved plan shall be complied with, subject to any amendments that are subsequently approved pursuant to Requirement 6 of Schedule 3 of the **draft DCO** (see **Application Document 3.1**). The plan shall demonstrate how the Contractor

REAC Ref	Commitment
	would manage surface water runoff across the worksite, including details of how offsite impacts would be managed and mitigated.
W15	The Contractor shall prepare a construction phase Flood Management Plan that shall consider all construction phase activities and temporary works necessary to deliver the Proposed Project and this must be submitted to the Local Planning Authority for approval prior to construction works for the Proposed Project commencing and thereafter the approved plan shall be complied with, subject to any amendments that are subsequently approved pursuant to Requirement 6 of Schedule 3 of the **draft DCO** (see **Application Document 3.1**).
W16	Water use efficiency and leakage reduction measures would be adopted during the construction phase, such as use of water-efficient fittings (taps, toilets) in site offices and welfare facilities, use of misting/atomising systems for dust suppression, drive-on recirculating systems for wheel washing, and sub-metering to help in detecting leaks where reasonably practicable.
W20	Construction compounds, haul roads and bellmouths served by SuDS systems would be constructed at the same time as the formation platform of these infrastructure (to reduce the risk of flooding during the construction stage) and would include pollution controls to address the possibility of runoff contamination with oils and silts. Installation of filter drains/swales/header drains along the perimeter of construction compounds/parallel to haul roads to intercept 'clean' runoff from the adjacent land.
W24	Construction compounds, haul roads and bellmouths served by SuDS systems would be constructed at the same time as the formation platform of these infrastructure (to reduce the risk of flooding during the construction stage) and would include pollution controls to address the possibility of runoff contamination with oils and silts. Installation of filter drains/swales/header drains along the perimeter of construction compounds/parallel to haul roads to intercept 'clean' runoff from the adjacent land.
W26	Where construction works are undertaken in proximity to the Hundred River and the River Fromus, which are of high sensitivity to water quality changes, regular visual monitoring for signs of water pollution would be undertaken by the Environmental Clerk of Works. Quarterly monitoring will be undertaken in the year prior to construction commencing, so an up-to-date water quality baseline is established. Monitoring will then be undertaken fortnightly during construction and after heavy rainfall events. Locations to be monitored are immediately upstream and downstream of any proposed surface water outfalls or water crossings. The primary method will be via in-situ handheld devices operated by the ECoW, with samples sent off to laboratories of potential pollution is detected. If pollution is confirmed, appropriate mitigation measures should be implemented to prevent further deterioration.
W29	Where vegetation removal is required at culvert construction sites, any herbicides would be used in accordance with the Agreement to Use of Herbicide in or Near Water guidance note and following agreement from the Environment Agency, as applicable.

REAC Ref	Commitment
W31	Drainage ponds serving temporary works during construction of the Proposed Project would be removed following construction, and the land reinstated.
W32	The Applicant will seek to use precast concrete instead of insitu concrete where practicable, particularly where works are in the vicinity of watercourses such as for culverts and headwalls. Areas where concrete works are proposed will be identified and each will be specified as either requiring concrete to be cast in-situ, or alternatively precast and delivered. Where in-situ concrete pours are required, there will be detailed provision for timing, weather conditions, and runoff control. These construction works will be minimised during heavy precipitation events, and carried out during dry months where practicable. Details of containment measures for concrete washout (such as lined washout (such as lined washout pits, bunded areas) will also be specified.
W33	Appropriate mitigation will be in place to avoid the possibility of debris or construction materials falling into the River Stour and causing potential blockages on the watercourse. This could include debris netting under the temporary bridge, though still allowing the 4m clearance for navigation, details of this will be included in the CEMP. The final CEMP will include a method statement for construction of the scaffolding either side of the River Stour.
W37	The Applicant will prepare a hoverport condition monitoring plan post consent to monitor the condition of the hoverport during construction. This will include measures for identifying and managing any potential contamination risk and will be prepared in consultation with the EA, NE, KWT and TDC for approval by TDC

~~9.~~10. Geology and Hydrogeology

~~9.1~~10.1 Introduction

~~9.1.1~~10.1.1 **Application Document 6.2.2.5 Part 2 Suffolk Chapter 5 Geology and Hydrogeology** and **Application Document 6.2.3.5 Part 3 Kent Chapter 5 Geology and Hydrogeology** ~~considers~~consider the potential effects of the Proposed Project on geology and hydrogeology. These chapters assess the potential significance of a number of effects to geology and hydrogeology, including but not limited to, damaging/ causing destruction to sites of geological importance, sterilisation of safeguarded minerals and increasing exposure to existing potential contamination through ground disturbance.

~~9.2~~10.2 Implementation of Mitigation Measures

10.2.1 Table 10.1 presents the construction phase environmental commitments and mitigation measures relevant to the geology and hydrogeology assessment as set out in **Application Document 6.2.2.5 Part 2 Suffolk Chapter 5 Geology and Hydrogeology** and **Application Document 6.2.3.5 Part 3 Kent Chapter 5 Geology and Hydrogeology**.

~~9.2.1~~10.2.2 Any temporary dewatering activities during construction will be undertaken in accordance with Environment Agency guidance, and if required, an Abstraction Licence and Environmental Permit (for the discharge) and will be limited to the depth and time required to facilitate construction activities (see GH07 in ~~the outline CoCP).~~Table 10.1).

~~9.2.2~~10.2.3 A drilling fluid breakout plan will be developed by the contractor prior to construction, where horizontal directional drilling is proposed for the Proposed Project, to provide a contingency plan in the event breakout occurs (see GH10 in ~~the outline CoCP). This will form part of the Onshore CEMP.~~Table 10.1).

~~9.2.3 A full list of the construction phase control and management measures that relate to geology and hydrogeology are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management measures relevant to the geology and hydrogeology assessment as set out in **Application Document 6.2.2.5 Part 2 Suffolk Chapter 5 Geology and Hydrogeology** and **Application Document 6.2.3.5 Part 3 Kent Chapter 5 Geology and Hydrogeology**.~~

Table 10.1 Environmental commitments and mitigation measures relevant to geology and hydrogeology

REAC Ref	Commitment
GH01	Intrusive ground investigations and assessment will be undertaken prior to construction which will inform appropriate geotechnical design in relation to the site/structure specific ground conditions including ground instability/adverse ground conditions

REAC Ref	Commitment
GH02	A Foundation Works Risk Assessment (FWRA) will be undertaken by the contractor where the use of piled foundations are anticipated and at trenchless crossings. The contractor will utilise construction methods such as appropriate piling techniques to minimise and avoid the risk of introducing new contamination (if required), creating new contamination pathways, and mixing of aquifer bodies. The FWRA would be undertaken once the proposed foundation solutions are known in consultation with the Environment Agency and in accordance with Environment Agency guidance 'Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination'. The FWRA would also seek to minimise impacts on buried archaeological remains as a result of contamination.
GH03	Use of appropriate occupational health and safety measures e.g. Personal Protective Equipment (PPE), and statutory health and safety compliance (e.g. compliance with the Confined Spaces Regulations, 1997 in relation to ground gas from working in confined spaces/trenches) to minimise the risks associated with anticipated/unexpected contamination. Based on risk assessment informed by site specific information.
GH04	Appropriate training of construction and maintenance workers in the handling and use of potentially hazardous substances and the associated risks.
GH05	All materials that could be hazardous to water quality will be stored in suitable areas, more than 10 m away from a watercourse and wetland habitats, away from site traffic and in containers which are fit for purpose, meeting the requirements of the Control of Pollution (Oil Storage) Regulations. The use and storage of chemicals and fuels will also be controlled and monitored under the Onshore CEMP which will include, for example, protection from vandalism, procedures for good general construction site practices, environmental and waste management procedures, regular vehicle checks, use of spill kits, correct waste storage and disposal, use of oil-water separators as necessary (for example, for drainage from refuelling areas). Any washing of vehicles or equipment will only take place in controlled areas, and wash waters will not be discharged into the water environment. The wash water will be treated and discharged to an approved location and in accordance with any relevant permitting requirements.
GH06	The control of earthworks or materials movement (including any re-use of materials) under appropriate Environmental Permits, exemptions or Contaminated Land: Applications in the Real Environment (CL:AIRE) 'The definition of Waste: The development industry Code of Practice (2011).
GH07	Any temporary dewatering activities during construction will be undertaken in accordance with EA guidance, and if required, an Abstraction Licence and Environmental Permit (for the discharge) and will be limited to the depth and time required to facilitate construction activities. If discharge at the site is required, a water discharge activity permit will be sought.
GH08	A protocol for dealing with any unexpected contamination will be developed by the Main Works Contractor(s) and will include: 1. Details of a watching brief and toolbox talks to be implemented throughout the construction phase;

REAC Ref	Commitment
	2. In the event that contamination (of land or groundwater) is found at any time when carrying out the authorised development, which was not identified in the environmental statement, then no further development shall be carried out within the identifiable perimeters of the area in which the suspected contamination is located. It must be reported as soon as reasonably practicable to the Local Planning Authority, and where necessary, the Environment Agency, and the Main Works Contractor must complete a risk assessment of the contamination in consultation with the Local Planning Authority, and where necessary, the Environment Agency. 3. The qualifications and competencies of the person appointed to complete the risk assessment. 4. Where the assessment determines that remediation is necessary, a written scheme and programme for the remedial measures to be undertaken to render the land fit for its intended purpose must be submitted to and approved in writing by the Local Planning Authority, following consultation with the Environment Agency. 5. The qualifications and competencies of the person appointed to oversee the works. 6. Remediation must be carried out in accordance with the approved scheme under sub paragraph (4). 7. Following the implementation of the remediation strategy approved under sub-paragraph (4), a verification report, based on the data collected as part of the remediation strategy and demonstrating the completion of the remediation measures must be completed and submitted to the relevant Local Planning Authority and the Environment Agency. This will also include consideration of potential impacts (both direct and indirect) from contamination on nearby buried archaeological remains.
GH09	Where indicated in the ES, a Hydrogeological Risk Assessment will be undertaken during detailed design to assess the specific risks to groundwater and groundwater receptors at those locations and identify any additional mitigation or remediation that may be required. The Hydrogeological Risk Assessment should include considerations of dewatering (where this is required) on archaeological remains. The nature and scope of any mitigation or remediation will be agreed with the Environment Agency or other stakeholders prior to construction, as appropriate.
GH10	The provision of a drilling fluid management plan, that includes drilling fluid breakout mitigation measures, where horizontal directional drilling is proposed. This plan will include consideration of potential impacts on nearby archaeological remains (both direct and indirect) as a result of drilling fluid breakout. The plan will be developed by the contractor and included within the Offshore and Onshore CEMPs. All relevant permits will be obtained or exemption/exclusions registered by the Main Works Contractor(s) for the use of drilling fluids / additives, as applicable.
GH11	The proposed construction compound within the Source Protection Zone 1 within Kent will be designed and operated in accordance with the following: 1. The conceptual ground model will be confirmed through intrusive ground investigation, 2. There will be no below ground storage of

REAC Ref	Commitment
	liquids/fuels/chemicals, 3. There will be no water abstractions or discharges within this compound, and 4. Best available techniques will be followed for both construction and operation of this compound. This will include commitments such as using double skinned and/or bunded tanks, drip trays, spill kits etc.

~~10.~~11. Agriculture and Soils

~~10.1~~11.1 Introduction

~~10.1.1~~11.1.1 **Application Document 6.2.2.6 Part 2 Suffolk Chapter 6 Agricultural and Soils** and **Application Document 6.2.3.6 Part 3 Kent Chapter 6 Agricultural and Soils** ~~considers~~consider the potential effects of the Proposed Project on agriculture and soils. These chapters assess the potential significance of a number of effects to agriculture and soils, including but not limited to temporary removal and loss of BMV land from agricultural production, permanent removal of BMV land from agricultural production and changes to one or more soil function.

~~10.2~~11.2 Implementation of Mitigation Measures

~~10.2.1~~11.2.1 ~~Construction phase control and management measures that relate to agriculture and soils are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management~~Table 11.1 presents environmental commitments and mitigation measures relevant to the agriculture and soils assessment as set out in **Application Document 6.2.2.6 Part 2 Suffolk Chapter 6 Agricultural and Soils** and **Application Document 6.2.3.6 Part 3 Kent Chapter 6 Agricultural and Soils**.

~~10.2.2~~11.2.2 **Application Document 7.5.10.1 Outline Soil Management Plan – Suffolk** and **Application Document 7.5.10.2 Outline Soil Management Plan – Kent** ~~sets~~set out specific measures to mitigate damage through the disturbance of in-situ soil materials. It contains specific guidance in relation to soil handling, including, soil stripping, soil stockpiling and soil reinstatement. The Soil Management Plans will be updated prior to construction commencing to include information from soil and agricultural land classification (ALC) surveys and to reflect the final design and construction approach/programme, which is secured by Requirement 6 within Schedule 3 of the **draft DCO** (**Application Document 3.1**).

Table 11.1 Environmental commitments and mitigation measures relevant to agriculture and soils

REAC Ref	Commitment
AS01	The Outline Soil Management Plans (see **Application Document 7.5.10.1 Outline Soil Management Plan – Suffolk** and **Application Document 7.5.10.2 Outline Soil Management Plan – Kent**) set out specific guidance in relation to soil handling, including, soil stripping, soil stockpiling and soil reinstatement. These will be updated to Soil Management Plans prior to construction, to include information from soil and agricultural land classification (ALC) surveys. Measures will include but not be limited to the following:

REAC Ref	Commitment
	• pre-construction surveys in accordance with published guidance to confirm ALC grade and soil type; • how topsoil and subsoil will be stripped and stockpiled; • suitable conditions for when handling soil will be undertaken, for example avoiding handling of waterlogged soil; • indicative soil storage locations; • how soil stockpiles will be designed taking into consideration site conditions and the nature/composition of the soil; • specific measures for managing sensitive soils; • suitable protective surfacing where soil stripping can be avoided, and weed suppression encouraged, based on sensitivity of the environment and proposed works; • approach to reinstating soil that has been compacted, where required; and details of measures required for soil restoration, Including target specification for the proposed end uses.
AS02	Where land is being returned to agricultural use, the appropriate soil conditions (for example through the replacement of stripped layers and the removal of any compaction) will be recreated. This will be achieved to a depth of 1.2 m (or the maximum natural soil depth if this is shallower) except over buried cables where the reinstated soil depth will be a minimum of 0.9 m. This will aim to restore land to the pre-construction ALC grade (unless otherwise agreed with the landowner).
AS03	Access to and from residential, commercial, community and agricultural land uses will be maintained throughout the construction period or as agreed through the landowner discussions. This may require signed diversions or temporary restrictions to access. The means of access to affected properties, facilities and land parcels will be communicated to affected parties at the start of the project, with any changes communicated in advance of the change being implemented. Where field-to-field access points require alteration as a result of construction, alternative suitable field access will be provided in consultation with the landowner/occupier.
AS04	Existing water supplies for livestock and irrigation will be identified pre-construction. Where supplies will be lost or access compromised by construction works, temporary alternative supplies will be provided. Water supplies will be reinstated following construction.
AS05	Consultation with affected landowners will be carried out to investigate the current extent of land drainage which will be taken into account in the development of the Drainage Management Plan (see W14) prior to construction, with the intent of maintaining the efficiency of the existing land drainage system.

REAC Ref	Commitment
AS06	Should animal bones be discovered during construction, which may indicate a potential burial site, works will cease, and advice will be sought from the Animal Health Regional Office on how to proceed, relevant to the origin and age of the materials found.
AS07	All movement of plant and vehicles between fields will cease in the event of a notification by the Department for Environment, Food and Rural Affairs (Defra) of a disease outbreak in the vicinity of the site that requires the cessation of activities. Advice will be sought from Defra in order to develop suitable working methods required to reduce the biosecurity risk associated with the continuation of works.
AS08	Clay bungs or other vertical barriers will be constructed within trench excavations where deemed necessary by a suitably experienced person, to prevent the creation of preferential drainage pathways.
AS12	Where arable field margin and acid grassland reinstatement will occur, the top 10 cm of topsoil will be stored separately from the remaining topsoil to ensure it is replaced last.

~~11.~~12. Traffic and Transport

~~11.1~~12.1 Introduction

~~11.1.1~~12.1.1 **Application Document 6.2.2.7 Part 2 Suffolk Chapter 7 Traffic and Transport** and **Application Document 6.2.3.7 Part 3 Kent Chapter 7 Traffic and Transport** ~~considers~~consider the potential effects of the Proposed Project on traffic and transport.

~~11.2~~12.2 Implementation of Mitigation Measures

~~11.2.1~~12.2.1 ~~Construction phase control and management measures that relate to traffic and transport are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management~~Table 12.1 presents environmental commitments and mitigation measures relevant to the traffic and transport assessment as set out in **Application Document 6.2.2.7 Part 2 Suffolk Chapter 7 Traffic and Transport** and **Application Document 6.2.3.7 Part 3 Kent Chapter 7 Traffic and Transport**.

~~11.2.2~~12.2.2 Construction phase measures that relate to traffic and transport are also described in the **Application Document 7.5.1.1 Outline Construction Traffic Management Plan and Travel Plan – Suffolk** and **Application Document 7.5.1.2 Outline Construction Traffic Management Plan and Travel Plan – Kent** which includes details of their proposed implementation. These identify measures to reduce route and journey mileage to and from and around site, and prevent nuisance to the residents, businesses and the wider community caused by parking, vehicle movements and access restrictions. They also provide suitable control for the means of access and egress to the public highway and set out measures for the maintenance and upkeep of the public highway. The plans also identify access for emergency vehicles and set out measures to reduce safety risks through construction vehicle and driver quality standards and measures to manage abnormal loads.

~~11.2.3~~12.2.3 **Application Document 7.5.9.1 Outline Public Rights of Way Management Plan – Suffolk** and **Application Document 7.5.9.2 Outline Public Rights of Way Management Plan – Kent** outline the measures that will be implemented in support of the Proposed Project, to avoid any adverse impacts on the surrounding PRoW network during all phases of the Proposed Project. Trenchless methods of installation are proposed at the landfalls to minimise potential impacts on the highway and walking/cycling routes.

Table 12.1 Environmental commitments and mitigation measures relevant to traffic and transport

REAC Ref	Commitment
TT01	The Outline CTMTPs identify measures to reduce route and journey mileage to and from and around site, and prevent nuisance to the residents,

REAC Ref	Commitment
	businesses and the wider community caused by parking, vehicle movements and access restrictions. They also provide suitable control for the means of access and egress to the public highway and set out measures for the maintenance and upkeep of the public highway. The plans also identify access for emergency vehicles. They also set out measures to reduce safety risks through construction vehicle and driver quality standards and measures to manage abnormal loads.
TT02	The contractor(s) will implement a monitoring and reporting system to check compliance with the measures set out within the Outline CTMTPs. This will include the need for a Global Positioning System (GPS) tracking system to be fitted to Heavy Goods Vehicles to check for compliance with authorised construction routes. The contractor(s) will also be expected to monitor the number of construction vehicles between the site and the strategic road network. Deviations from the authorised routes or changes to traffic levels that are higher than the CTMTP assumptions will require discussion with the relevant highways authorities to determine whether additional mitigation measures are needed.
TT03	All designated Public Rights of Way (PRoWs) will be identified, and any potential temporary and/or permanent diversions applied for/detailed in the DCO. PRoWs will be kept open as far as possible and, where crossed by construction access, priority will be given to PRoW users over construction traffic. All designated PRoWs crossing the working area will be managed with access only closed for the shortest period necessary to allow construction activities to occur. Any required diversions will be clearly marked at both ends with signage explaining the diversion, the duration of the diversion (for temporary diversions) and a contact number for any concerns. This is outlined in the Outline Public Rights of Way Management Plans.
TT04	The Proposed Project is not anticipated to have any traffic and transport impacts on Sundays/Bank Holidays with the restrictions identified in the Outline CTMTPs, which includes limiting HGV activity to a maximum of 30 HGVs per day on Sundays and public holidays.
TT10	No public vehicles will be able to access/exit Ebbsfleet Lane North from the new A256 junction (K-BM02), during construction or operation, with fencing and gates used to prevent unauthorised access.

~~12.~~13. Air Quality

~~12.1~~13.1 Introduction

~~12.1.1~~13.1.1 **Application Document 6.2.2.8 Part 2 Suffolk Chapter 8 Air Quality** and **Application Document 6.2.3.8 Part 3 Kent Chapter 8 Air Quality** considers the potential effects of the Proposed Project on air quality. These chapters assess the potential significance of a number of air quality effects including but not limited to the impact of dust emissions on human health, soils and ecological receptors and the increase in nitrogen dioxide and particulate matter concentrations at human and ecological receptor locations as a result of emissions from construction vehicles and non-road mobile machinery.

~~12.2~~13.2 Implementation of Mitigation Measures

~~12.2.1~~13.2.1 Construction phase control and management measures that relate to air quality are included in the Construction Dust Assessment and Methodology (**Application Document 6.3.2.8.A ES Appendix 2.8.A Construction Dust Assessment and Methodology**~~) and outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management~~). Table 13.1 presents environmental commitments and mitigation measures relevant to the air quality assessment as set out in **Application Document 6.2.2.8 Part 2 Suffolk Chapter 8 Air Quality** and **Application Document 6.2.3.8 Part 3 Kent Chapter 8 Air Quality**.

~~12.2.2~~13.2.2 It includes commitments to develop and implement an Air Quality Management Plan (AQMP) to be approved by the relevant local planning authorities. **Application Document 7.5.6.1 Outline Air Quality Management Plan – Suffolk** and **Application Document 7.5.6.2 Outline Air Quality Management Plan – Kent** are submitted with the application for development consent, setting out the specific mitigation measures required for the construction phase of the Proposed Project. They also include proposed approximate air quality monitoring locations which will be in place for the construction phase of the Proposed Project, which will be used to ensure mitigation measures are working effectively.

~~12.2.3~~13.2.3 Measures relating to construction traffic have been included in **Application Document 7.5.1.1 Outline Construction Traffic Management and Travel Plan - Suffolk** and **Application Document 7.5.1.2 Construction Traffic Management Plan and Travel Plan – Kent**.

Table 13.1 Environmental commitments and mitigation measures relevant to air quality.

REAC Ref	Commitment
AQ01	Develop and implement an Air Quality Management Plan (AQMP), approved by the Local Authority.

REAC Ref	Commitment
AQ02	Monitoring • Undertake daily on-site and off-site inspection, where receptors (including roads) are nearby, to monitor dust, record inspection results, and make the log available to the Local Authority when asked. This should include regular dust soiling checks of surfaces such as street furniture, cars and windowsills within 100 m of site boundary, with cleaning to be provided if necessary. • Carry out regular site inspections to monitor compliance with the AQMP, record inspection results, and make an inspection log available to the local authority when asked. • Increase the frequency of site inspections by the person accountable for air quality and dust issues on site when activities with a high potential to produce dust are being carried out and during prolonged dry or windy conditions. • Agree dust deposition, dust flux, or real-time PM_{10} continuous monitoring locations with the Local Authority prior to installation. Where possible, commence baseline monitoring at least three months before work commences on site or, if it a large site, before work on a phase commences. Provide Local Authority access to real-time monitoring data.
AQ03	Preparing and maintaining the site Erect solid screens or barriers around dusty activities or the site boundary so that they are at least as high as any stockpiles on site. Fully enclose site or specific operations where there is a high potential for dust production and the site is active for an extensive period. Keep site fencing, barriers and scaffolding clean using wet methods. Remove materials that have a potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site, cover as described below.
AQ04	Operating vehicle/machinery and sustainable travel Avoid the use of diesel or petrol powered generators and use mains electricity or battery powered equipment where practicable. Impose and signpost a maximum speed limit on unsurfaced haul roads and work areas. Hold regular liaison meetings with other high risk construction sites within 500 m of the site boundary, to ensure plans are co-ordinated to minimise dust and particulate matter emissions and to understand the interactions of the off-site

REAC Ref	Commitment
	transport/deliveries which might be using the same strategic road network routes.
AQ05	Operations Only use cutting, grinding or sawing equipment fitted or in conjunction with suitable dust suppression techniques such as water sprays or local extraction, e.g. suitable local exhaust ventilation systems. Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate. Use enclosed chutes and conveyors and covered skips. Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.
AQ06	Earthworks Use Hessian, mulches or trackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable. Only remove the cover in small areas during work and not all at once.
AQ07	Construction Avoid scabbling (roughening of concrete surfaces) if possible. Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place. Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery. For smaller supplies of fine powder materials ensure bags are sealed after use and stored appropriately to prevent dust.
AQ08	Trackout Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport. Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable. Record all inspections of haul routes and any subsequent action in a site log book.

REAC Ref	Commitment
	Install hard surfaced haul routes, which are regularly damped down with fixed or mobile sprinkler systems, or mobile water bowsers and regularly cleaned where possible.
AQ09	Ensure all equipment complies with the appropriate Non-Road Mobile Machinery (NRMM) standards. Use stage 4 NRMM as a minimum and stage 5 where possible. The use of Stage 4 equipment will be notified to the LPA in advance. Additionally, where possible, use alternative / renewable energy to power NRMM.
AQ12	Weather forecasts will be checked on a daily basis. Should periods of particularly dry or windy weather be forecast, dust mitigation measures would be reviewed and where possible high-risk activities will be rescheduled to minimise air quality impacts on sensitive receptors.
AQ13	Site logs will include a list of NRMM being used, recording whether each item is Stage 5 or Stage 4 and the reason for any approved Stage 4 use. This log will be made available to the LPA upon request.
AQ14	The Air Quality Management Plan will be reviewed and updated throughout the construction phase of the project as necessary, based on monitoring results

~~13.~~14. Noise and Vibration

~~13.1~~14.1 Introduction

~~13.1.1~~14.1.1 **Application Document 6.2.2.9 Part 2 Suffolk Chapter 9 Noise and Vibration** and **Application Document 6.2.3.9 Part 3 Kent Chapter 9 Noise and Vibration** ~~considers~~consider the potential effects of the Proposed Project on noise and vibration. Construction noise and vibration attenuates with distance from source. The highest construction noise and vibration impacts will therefore be confined to works that take place in close proximity to receptor locations.

~~13.2~~14.2 Implementation of Mitigation Measures

~~13.2.1~~14.2.1 ~~Construction phase control and management measures that relate to noise and vibration are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and topic-specific control and management~~Table 14.1 presents environmental commitments and mitigation measures relevant to the noise and vibration assessment as set out in **Application Document 6.2.2.9 Part 2 Suffolk Chapter 9 Noise and Vibration** and **Application Document 6.2.3.9 Part 3 Kent Chapter 9 Noise and Vibration**.

~~13.2.2~~14.2.2 **Application Document 7.5.8.1 Outline Construction Noise and Vibration Management Plan – Suffolk** and **Application Document 7.5.8.2 Outline Construction Noise and Vibration Management Plan – Kent** (the OCNVMPs) provide the overarching general principles, controls and arrangements that would be applied to the Proposed Project with regards to noise and vibration during construction. Construction phase measures to control and manage noise and vibration during construction are secured via these OCNVMPs. The OCNVMPs cover the requirement for applications for prior consent under Section 61 of the Control of Pollution Act 1974.

~~13.2.3~~14.2.3 As per commitment NV03 in ~~the outline CoCP,~~Table 14.1, the contractor would conduct detailed construction noise and vibration assessments to determine whether additional measures, including site-specific best practicable means, may be required. The OCNVMPs would be updated into NVMPs, incorporating the findings of their detailed assessment and include associated site-specific noise and vibration mitigation as may be required.

Table 14.1 Environmental commitments and mitigation measures relevant to noise and vibration

REAC Ref	Commitment
NV01	Construction working will be undertaken within the agreed working hours set out within the DCO. Best practicable means (e.g. screening) to reduce construction noise will be set out within the CEMP and Construction Noise and Vibration Management Plan (CNVMP), which will be substantially in

REAC Ref	Commitment
	accordance with the Outline Construction Noise and Vibration Management Plan (OCNVMP) (see **Application Document 7.5.8.1 Outline Construction Noise and Vibration Management Plan – Suffolk** and **Application Document 7.5.8.2 Outline Construction Noise and Vibration Management Plan – Kent**).
NV02	Construction traffic routes, access tracks, and construction haul routes will be surveyed for damage and irregularities (e.g. potholes) that may lead to vibration from construction traffic. Access tracks and construction haul routes will be well maintained.
NV03	The contractor will conduct detailed construction noise and vibration assessments to determine whether there are likely to be any new or different significant adverse effects at noise and vibration sensitive receptors and therefore whether additional measures, including site-specific Best Practicable Means (BPM), may be required. The contractor will update the OCNVMP into the CNVMP and include site specific noise and vibration mitigation, as may be required.
NV04	For routine and more substantial maintenance activities, the contractor will conduct a proportionate assessment of potential noise and vibration impacts, as may be required. Where applicable, mitigation measures will be incorporated into the works to reduce the effects from noise and vibration.
NV05	For decommissioning activities, the contractor will conduct a proportionate assessment of potential noise and vibration impacts, as may be required. Where applicable, mitigation measured will be incorporated into the works to reduce the effects and noise and vibration.

~~14.~~15. Socio-economics, Recreation and Tourism

~~14.1~~15.1 Introduction

~~14.1.1~~15.1.1 **Application Document 6.2.2.10 Part 2 Suffolk Chapter 10 Socio-economics, Recreation and Tourism** and **Application Document 6.2.3.10 Part 3 Kent Chapter 10 Socio-economics, Recreation and Tourism** considers the potential effects of the project on socio-economics, recreation and tourism. These chapters assess the potential significance of a number of socio-economics, recreation and tourism effects including but not limited to direct and indirect employment opportunities and temporary closure/diversion of Public Rights of Way (PRoW).

~~14.2~~15.2 Implementation of Mitigation Measures

~~14.2.1~~15.2.1 ~~Construction phase control and management measures that relate to socio-economics, recreation and tourism are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains general good practice measures and traffic and transport specific control and management~~Table 15.1 presents environmental commitments and mitigation measures relevant to the socio-economics, recreation and tourism assessment as set out in **Application Document 6.2.2.10 Part 2 Suffolk Chapter 10 Socio-economics, Recreation and Tourism** and **Application Document 6.2.3.10 Part 3 Kent Chapter 10 Socio-economics, Recreation and Tourism**.

~~14.2.2~~15.2.2 **Application Document 7.5.9.1 Outline Public Rights of Way Management Plan – Suffolk** and **Application Document 7.5.9.2 Outline Public Rights of Way Management Plan – Kent** outline the mitigation measures which will be required to maintain the operation of impacted PRoW. It also details how these mitigation measures will be managed, including who will be responsible for their management. Trenchless methods of installation are proposed at the landfalls to minimise potential impacts on the walking/cycling routes.

~~14.2.3~~15.2.3 The REAC (**Application Document ~~7.5.3.2 CEMP Appendix B~~9.84 Register of Environmental Actions and Commitments~~)~~ (REAC)**) also includes commitment SE03, which is an embedded measure to programme utility trenching works associated with the Kent Onshore Scheme during the school holidays or as agreed with Great Oaks Small School to avoid impacts on users of this receptor.

Table 15.1 Environmental commitments and mitigation measures relevant to socio-economics, recreation and tourism

REAC Ref	Commitment
SE04	Liaison will be undertaken with tourism related businesses, through proactive collaboration with the Local Destination Management Organisation (“DMO”)

REAC Ref	Commitment
	and the Local Visitor Economy Partnership (“LVEP”) prior to and during construction , not only to provide businesses with construction updates but to seek their views on how tourism impacts can be minimised such, as through the phasing of works to avoid impacts on tourism receptors at peak times.
SE05	For works in Suffolk, the Applicant will establish a process to monitor where workers are staying by type of accommodation and location on a quarterly basis. Should these results indicate that during a monitoring period on average greater than 18 workers are utilising accommodation that would otherwise be utilised by tourists in the Suffolk Coastal area, then the Applicant will consider whether there are steps that can be taken to encourage more workers to stay in accommodation less commonly used by tourists to the coast. This could include discussions with other developers in the Suffolk area about shared use of specialist accommodation or encouraging use of accommodation in a larger settlement such as Ipswich or surrounding areas with financial incentives and/ or transport from Ipswich to work locations. The applicant recognises seasonal variations and that in the cooler months outside holiday periods it may beneficial to the economy for accommodation to be occupied by workers because this accommodation would not be occupied by tourists. This will be taken into account when determining whether steps should be taken to encourage workers to stay outside the area. Accommodation that would otherwise be utilised by tourists in the context of this requirement relates to hotel and b&b accommodation that would otherwise be used by tourists within 15 km of Aldeburgh.

~~15.~~16. Health and Wellbeing

~~15.1~~16.1 Introduction

~~15.1.1~~16.1.1 **Application Document 6.2.2.11 Part 2 Suffolk Chapter 11 Health and Wellbeing** and **Application Document 6.2.3.11 Part 3 Kent Chapter 11 Health and Wellbeing** considers the potential effects of the project on the following health determinants:

- access to healthcare services and other social infrastructure;
- access to open space, leisure and play;
- air quality;
- noise and vibration;
- transport modes, access, connections and physical activity;
- employment and income; and
- social cohesion and community identity.

~~15.2~~16.2 Implementation of Mitigation Measures

~~15.2.1~~16.2.1 ~~Construction~~There are no specific construction phase control and management measures that relate to health and wellbeing ~~are included in the outline CoCP (**Application Document 7.5.3.1 CEMP Appendix A Outline Code of Construction Practice**). This contains~~beyond general good practice measures and topic specific measures related to air quality, noise and vibration, socio-economics, recreation and tourism and traffic and transport ~~specific~~ control and management measures relevant to the health and wellbeing assessment as set out in **Application Document 6.2.2.11 Part 2 Suffolk Chapter 11 Health and Wellbeing** and **Application Document 6.2.3.11 Part 3 Kent Chapter 11 Health and Wellbeing**.

17. Arboriculture

17.1 Introduction

17.1.1 **Application Document 6.10 Arboricultural Impact Assessment Part 1 of 2** and **Part 2 of 2** considers the potential effects of the Proposed Project on arboriculture. The arboricultural impact assessment identifies and evaluates the likely impacts on trees, tree groups, woodlands and hedgerows located within or immediately adjacent to the Order Limits, including statutory and non-statutory designations, root protection area (RPA) constraints, and the presence of veteran and ancient trees.

17.1.2 The main effects on arboricultural receptors during construction include the loss of trees, incursion into the RPAs of retained trees, potential changes in exposure to retained trees, pruning requirements to facilitate access, and potential impacts arising from tree diseases already present within the Order Limits.

17.2 Implementation of Mitigation Measures

17.2.1 Table 17.1 presents the environmental commitments and mitigation measures relevant to the arboricultural assessment as set out in **Application Document 6.10 Arboricultural Impact Assessment Part 1 of 2** and **Part 2 of 2**.

17.2.2 An Arboricultural Method Statement will be prepared, as required by Requirement 8(1) within Schedule 3 of the **draft DCO** (**Application Document 3.1**) which states *'No stage of authorised development may commence until, for that stage, an Arboricultural Method Statement identifying the trees, groups of trees and hedgerows to be retained during that stage has been submitted to and approved by the relevant planning authority'.*

Table 17.1 Environmental commitments and mitigation measures relevant to arboriculture

REAC Ref	Commitment
A01	All tree work will follow the principles of BS3998:2010 Treework – Recommendations (BS3998:2010) (British Standards Institute) and will be carried out by suitably qualified and insured contractors.
A02	A pre-construction check will be undertaken of trees within the Order Limits and remedial works actioned where appropriate (e.g. where they pose an unacceptable risk to people or property). Trees will be monitored during the construction period, and during operation where they pose a risk to infrastructure constructed as part of the Proposed Project. All staff operating on the Site are to be made aware of the need to look out for obvious signs of tree defects and to report them to the Site Manager who will seek further advice as necessary. Where remedial works are required in respect of those trees which are subject of commitment A05, then details of such works will be agreed in advance with the relevant local planning authority, save where

REAC Ref	Commitment
	already addressed in the Arboricultural Method Statement as required by Requirement 8, Schedule 3 and save in the case of emergency.
A03	A banksman will be used where the movement of plant or long reach machinery occurs within 5m of any part of a retained tree to ensure no damage is sustained. Works within 5m of any part of a retained tree should only occur if they cannot be avoided.
A04	All storage or mixing of materials will take place in agreed allocated areas at least 5 m from the edge of the RPA of retained trees and at least 5 m from the edge of an ancient woodland buffer zone.
A18	Access required for monitoring and) maintenance within the RPAs of T612K (ancient tree) and T614K (veteran tree) in wet conditions, will be achieved by pedestrian only access or, where all-terrain vehicle access is required, fit for purpose ground protection specified to the highest expected load in accordance with Application Document 6.10 Arboricultural Impact Assessment will be utilised to avoid negatively impacting the soil structure.
A19	The final alignment of the cable and haul road will be positioned to avoid all moderate and high quality tree features within the Order Limits, including the identified veteran tree (T1227). These will be fully retained and protected in accordance with the tree protection fencing shown on Sheet 5 of **Application Document 9.76.5.9 Change Request Appendix I Tree Protection Plans Suffolk Onshore Scheme**.

~~16.~~18. Monitoring and Review

~~16.1.1~~18.1.1 The Environment Manager will hold the responsibility for maintaining a register of all environmental monitoring, which will be made available for auditing and inspection.

~~16.1.2~~18.1.2 Reporting procedures will be defined by the Environment Manager who will hold overall responsibility for providing feedback to the contractors and National Grid on the environmental performance of the construction works.

Audits and Inspections

~~16.1.3~~18.1.3 Regular monitoring shall occur to ensure compliance with the Onshore CEMP, check compliance with the legal and contractual requirements and to minimise the risk of damage to the environment. All environmental incidents shall be reported to the Environmental Manager.

~~16.1.4~~18.1.4 The Environmental Manager shall assess the works' environmental performance measured against environmental standards, relevant legislation and the Onshore CEMP objectives.

~~16.1.5~~18.1.5 Document control shall be in accordance with a Quality Management System and copies of all environmental audit reports, consents and licences shall be maintained by the contractor's Environmental Manager.

~~16.1.6~~18.1.6 Contractors shall be responsible for investigating and addressing any non-conformances raised by the inspection within an agreed time frame and ensuring that corrective and preventative actions have been fully closed out.

~~16.1.7~~18.1.7 Contractors and National Grid representative shall be responsible for updating and reviewing the Onshore CEMP on a regular basis to ensure continual improvements.

Inspections

~~16.1.8~~18.1.8 The contractor will undertake daily inspections, which will include monitoring. Daily assessment forms will be completed during the daily checks. Checks on equipment will be undertaken to reduce the risk of incidents occurring (for example oil leaks, or biosecurity breaches). As a minimum the following equipment will be inspected:

- fencing;
- waste storage facilities;
- oil separators;
- chemical storage facilities;
- foul water storage facilities;
- silt traps;
- drainage ditches and watercourses;
- storage vessels (including pumps, gauges, pipework and hoses);
- secondary containment (for example, secondary skins for oil tanks);

- spill response materials; and
- equipment with potential to leak oils and other liquids, for example, compressors and transformers.

~~16.1.9~~18.1.9 Weekly inspections will be undertaken by National Grid and the contractors to ensure the daily checks are being undertaken correctly. The daily and weekly inspections will also include:

- reviewing the daily risk assessment forms;
- ensuring that faults and defects are identified and rectified; and
- providing data for performance monitoring.

~~16.1.10~~18.1.10 Environmental performance data will be collected and collated into the SHE Plan by the contractor.

~~16.1.11~~18.1.11 Immediate action including, if necessary, 'stopping the activity in question, where safe to do so', will be taken should any incidents or non-conformance with the Onshore CEMP, be found during inspection. See the earlier Section 3.5 Incident Procedure and Response for further details.

~~16.1.12~~18.1.12 National Grid and the contractors' monitoring reports will be made available to statutory and non-statutory bodies on request.

Change Process

Introduction

~~16.1.13~~18.1.13 The Onshore CEMP is one of the plans listed in Requirement 6(1) of the **draft DCO** (**Application Document 3.1**) which states: '*No stage of the authorised development may commence until, for that stage, the following plans as relevant to that stage have been submitted to and approved by the relevant planning authority or other discharging authority as may be appropriate to the relevant plan, scheme or strategy concerned, unless otherwise agreed with the relevant planning authority or other discharging authority as may be appropriate.*'

~~16.1.14~~18.1.14 Requirement 1(4) of the **draft DCO** (**Application Document 3.1**) states: 'Where an approval or agreement is required under the terms of any Requirement or a document referred to in a Requirement, or any Requirement specifies "unless otherwise approved" or "unless otherwise agreed" by the relevant highway authority or the relevant planning authority, such approval or agreement may only be given in relation to minor or immaterial changes and where it has been demonstrated to the satisfaction of the relevant highway authority or the relevant planning authority that the subject matter of the approval or agreement sought will not give rise to any materially new or materially different environmental effects from those assessed in the Environmental Statement.'

~~16.1.15~~18.1.15 Where there is a need to update the Onshore CEMP beyond derogations addressed pursuant to the above, the below text addresses the process for changing the Onshore CEMP itself. This does not cover changes to the DCO (material or non-material) which would be managed through the process set out in Schedule 6 of the Planning Act 2008. Therefore, the below process is limited to changes to the Onshore CEMP.

Onshore CEMP Changes

~~16.1.16~~18.1.16 It may be necessary to amend the details contained in the Onshore CEMP as a result of the iterative discussion and engagement that will continue after the Onshore CEMP has been approved. The resulting changes would not alter any of the underlying commitments, mitigations and methodologies set out in the Onshore CEMP. An example may be where a preconstruction survey identifies that a measure already committed to is no longer required in the Onshore CEMP. In every case, consideration will be given to any changes to the outcome of the assessment of environmental effects.

~~16.1.17~~18.1.17 Where there is a proposed change to the Onshore CEMP, National Grid will provide details to the relevant planning authority together with evidence of relevant stakeholder engagement, where upon, the relevant planning authority will, acting reasonably, endeavour to respond within 28 days to either confirm its consent to the change to the Onshore CEMP or provide its reasons why the change is not accepted. National Grid will also publish any amended version of the Onshore CEMP on the project website and will make clear in doing so that any previous version(s) are superseded.

Appendix A Detailed Unexploded Ordnance Risk Assessment

SAFELANE
GLOBAL





Detailed Unexploded Ordnance Risk Assessment

In Respect Of:
Friston 1

For:
Mott MacDonald Ltd

Report Reference:
9758-1 RA



safelaneglobal.com

2020
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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry.

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Executive Summary

The Site	
Address:	The site spans a large area, roughly centred on Fitches Lane, Aldringham, East Suffolk, IP16 4QQ
OS National Grid Reference:	TM 44479 60460
Site Description:	• The site is irregular in shape, mostly comprising open agricultural ground. • The northern extent is located to the south of Sizewell, encompassing a large portion of Sizewell Gap. • The site then extends south to Aldringham, containing part of the B1353, several buildings and the Old Vicarage, and part of Aldeburgh Road. A small section of Hundred River also crosses the site within this central section. • The western arm of the site extends north-west towards Friston, mostly comprising fields and some small sections of roadways. • The south-eastern arm of the site extends towards the north of Aldeburgh, again mostly comprising fields and small sections of roadways. • The south of the site encompasses a small section of the A1094 and a pond. • The extension area comprises part of a nature reserve, encompassing open ground, marsh and ponds, before leading out to the beach.
Proposed Works	
• Ground investigation at all areas will comprise boreholes to a depth of between 15 and 35m bgl and trial pits to max. 4m depth. • Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. There is the possibility of piles for heavy equipment at the substation/ convertor station location and where a new bridge is required to cross the River Frome.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating **Risk Map: Annex F**	**High Risk Zone 1:** • High risk from Land Service Ammunition • Medium Risk from German HE bombs, Anti-Aircraft Shells and Small Arms Ammunition • Low Risk from German 1kg Incendiary Bombs.

	High Risk Zone 2: • High risk from Land Service Ammunition and Landmines. • Medium Risk from German HE bombs, Anti-Aircraft Shells and Small Arms Ammunition • Low Risk from German 1kg Incendiary Bombs.
	Medium Risk Zone 1: • Medium Risk from German HE bombs and Anti-Aircraft Shells • Low Risk from German 1kg Incendiary Bombs, Small Arms Ammunition and Land Service Ammunition
	Medium Risk Zone 2: • Medium Risk from German HE bombs, Anti-Aircraft Shells, Small Arms Ammunition and Land Service Ammunition • Low Risk from German 1kg Incendiary Bombs
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	
Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **9-11m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Recommended Risk Mitigation		
Risk Level	**Planned Site Activity**	**Recommendations**
Medium / High	**Shallow Intrusive Works eg excavations**	UXO Safety & Awareness Briefing (Toolbox Brief, TBB) Site Specific Safety Instructions (SSSIs) Training Course Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) Target Investigation (Required as a follow-on from NI magnetometer survey) Search & Clear Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey)
	Deep intrusive works (eg piling)	UXO Safety & Awareness Briefing (Toolbox Brief, TBB) Site Specific Safety Instructions (SSSIs) Training Course Intrusive Magnetometer Survey of pile/borehole positions

	Offshore works	Appropriate risk mitigation measures can be provided for any works taking place in marine (coastal or offshore) parts of the project site if necessary. These can usually include the following: • UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Client threat briefing • Authorities engagement where required • Non-Intrusive (NI) High-Resolution Marine Survey – Area specific to each project module • Assessment and production of a Master Target List • Target Investigation (Required as a follow-on from NI Marine Survey) • ROV/Diver Investigation / Survey • Disposal if requested
In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.		

Table of Contents

Distribution i
Executive Summary ii
Table of Contents v
List of Annexes vii
Glossary of Terms viii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations *4*
4.5.2 Bombing Records *5*
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Site History 6
7.1 General Overview 6
7.2 Dunwich Heath 7
7.3 Pre and Post-WWII OS Mapping 7
8 The Threat from Allied Military Ordnance 10
8.1 Live Fire Range, Weapons Testing / Training 10
8.2 Ordnance / Ammunition Storage, Use and Disposal 11
8.2.1 WWII Storage and Disposal *11*
8.2.2 Post-WWII Storage and Disposal *11*
8.3 WWII Ground Defence 12
8.3.1 Coastal Defence and Defensive Fortifications *12*
8.3.2 Home Guard Activity *12*
8.3.3 Soldier Accommodation *13*
8.3.4 Battle Training *14*
8.4 Anti-Aircraft Defences 14
8.5 Mustard Gas 15
8.6 Generic Types of WWII British / Allied Unexploded Ordnance 15
8.6.1 Land Service Ammunition (LSA) *15*
8.6.2 Small Arms Ammunition (SAA) *17*
8.6.3 Anti-Aircraft Shells *17*
8.6.4 Miscellaneous *18*

8.7 Site-Specific Threat from Allied Military Ordnance 18
9 The Threat from German Aerial Bombing 21
9.1 General Bombing History of Suffolk and the Project Site 21
9.1.1 First World War 21
9.1.2 Second World War 21
9.2 Generic Types of WWII German Air-delivered Ordnance 22
9.3 Second World War Bombing Statistics 23
9.3.1 Original ARP Bombing Incident Records 24
9.3.2 Home Office Intelligence Reports 25
9.3.3 Secondary Source / Anecdotal Evidence 27
9.3.4 WWII-era RAF Aerial Photography 28
9.3.5 Abandoned Bombs 29
9.4 UXB Ground Penetration 29
9.4.1 General Considerations 29
9.4.2 The "j" Curve Effect 30
9.4.3 Second World War Bomb Penetration Studies 30
9.4.4 CIRIA Bomb Penetration Depth Specifications 31
9.4.5 Site Specific Bomb Penetration Considerations 31
9.5 Likelihood of Post-raid UXO Detection 32
9.5.1 Density of Bombing 32
9.5.2 Bomb Damage 32
9.5.3 Frequency of Access 32
9.5.4 Ground Cover 33
9.5.5 German Air-Delivered Ordnance Failure Rate 33
9.5.6 Site Specific Analysis 34
10 The Overall Unexploded Ordnance Risk Assessment Methodology 38
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance 39
10.1.1 General 39
10.1.2 Likelihood of Contamination from British / Allied UXO 40
10.1.3 Likelihood of Contamination from German UXO 41
10.2 The Likelihood that Unexploded Ordnance Remains on Site 42
10.2.1 General 42
10.2.2 EOD Bomb Disposal and Clearance Tasks 42
10.2.3 Post War Redevelopment 45
10.2.4 Site-Specific Analysis 45
10.3 The Likelihood that Ordnance may be Encountered during the Works 46
10.4 The Risk that Ordnance may be Initiated 47
10.4.1 Initiation of Unexploded Bombs 47
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance 47
10.5 The Consequences of Encountering or Initiating Ordnance 48
11 SafeLane Global's Risk Assessment 51
11.1 Conclusions 51
12 Proposed Risk Mitigation Strategy 54
12.1 Summary 54
12.2 Additional Notes 55
Bibliography 59

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C Pre and Post-WWII OS Maps

Annex D Potential Risk Contributors

Annex E WWII-era RAF Aerial Photography

Annex F Risk Map

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Friston 1 Revision

1 Introduction

Groundsure Ltd, on behalf of Mott MacDonald Ltd has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Friston 1 Revision project site.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Historic England.
- The GeoInformation Group.
- National Collection of Aerial Photography.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed

level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	The site spans a large area, roughly centred on Fitches Lane, Aldringham, East Suffolk, IP16 4QQ
OS National Grid Reference	TM 44479 60460
Site Description	• The site is irregular in shape, mostly comprising open agricultural ground. • The northern extent is located to the south of Sizewell, encompassing a large portion of Sizewell Gap. • The site then extends south to Aldringham, containing part of the B1353, several buildings and the Old Vicarage, and part of Aldeburgh Road. A small section of Hundred River also crosses the site within this central section. • The western arm of the site extends north-west towards Friston, mostly comprising fields and some small sections of roadways. • The south-eastern arm of the site extends towards the north of Aldeburgh, again mostly comprising fields and small sections of roadways. • The south of the site encompasses a small section of the A1094 and a pond. • The extension area comprises part of a nature reserve, encompassing open ground, marsh and ponds, before leading out to the beach.
Proposed Works	• Ground investigation at all areas will comprise boreholes to a depth of between 15 and 35m bgl and trial pits to max. 4m depth. • Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction

	compounds and construction of the permanent substation/ convertor station platform. There is the possibility of piles for heavy equipment at the substation/ convertor station location and where a new bridge is required to cross the River Frome.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Mapping	**Superficial Deposits**	Parts of the site have recorded no superficial deposits. The remainder of the site contains areas of the following superficial deposits: - Lowestoft Formation (Sand & Gravel) - Lowestoft Formation (Diamicton) - Lowestoft Formation (Clay & Silt)
	Bedrock	From north to south: - Crag Group (Sand) - Chillesford Church Sand Member (Sand) - Coralline Crag Formation (Calcarenite)

7 Site History

7.1 General Overview

The site was located local to several military features, comprising training areas, airfields and anti-invasion defences. Suffolk's coastline was heavily utilised during WWII for these purposes, due to the strategic location.

During WWII, the Suffolk coastline underwent drastic change as the threat of invasion increased. Large complexes of anti-invasion defences were installed across the shoreline and the countryside, particularly following the Emergency Coastal Defence Battery programme in 1940. Pillboxes, trenches, minefields, barbed wire entanglements, beach scaffolding, artillery, anti-tank features and more were constructed within the general project area.

Anti-tank obstacles and anti-landing ditches were dug on areas of open flat lane (such as that within the site), examples of which could be found at Aldringham Common and Sutton Common.

Large areas of heathland were also used for WWII training grounds, usually located further inland. Large training areas were installed on Dunwich Heath (immediately north of the site), Sutton Common and at Aldeburgh. A large area was also given over for training to the north of Orford.

Vulnerable ports and beaches were most heavily defended, including Sizewell, Thorpeness and Aldeburgh.

7.2 Dunwich Heath

During WWII, Dunwich Heath (immediately north of the site) was one of the most heavily defended parts of the Suffolk coastline with a radar station, coastal artillery battery and anti-invasion defences.

In May 1941, a coastal artillery battery was built on the cliffs at Dunwich comprising 2 x 6" guns and was operational for around 2 years. In order to protect this site, along with the radar station, Dunwich Heath was covered with infantry positions and defences. One spigot mortar emplacement still survives today, which was constructed along with other defences.

By 1944, the final defences to be constructed at Dunwich were "Diver" anti-aircraft batteries, which were tasked with defending from the threat of V1s.

In the early stages of the war, an important training ground was established, within which the north of the project site was located. The training area was used throughout the conflict, whereby hundreds of troops and tanks used the heath for live firing practice. It was particularly important in the lead up to D-Day. In 1943, it was used for the exercise 'Kruschen' which was one of the first exercises to trial the specialised equipment that would be needed to break the concrete defences for the German Atlantic Wall.

7.3 Pre and Post-WWII OS Mapping

Section	Pre-WWII		Post-WWII		Reference
	Date	Observations	Date	Observations	
1	1938	The site comprises open fields, adjacent to coastal embankments. *Sizewell Farm* is located immediately south, with small ancillary buildings and access path leading into the site. The surrounding area is predominantly rural, with the coastline immediately east and *Sizewell Common* to the south.	1946-47	Two small ancillary buildings within the site appear to have been removed. A field to the north of the site appears to be wooded. A small area which resembles a military compound of rectangular huts has been constructed to the south of the site. No other significant changes are visible on site or in the surrounding area.	Annex C-1 and C-2
2	1938	Most of the site comprises agricultural / rural fields and rough pasture. A rail line crosses the site from north to south. *Halfway Cottages* are located on site, adjacent to a roadway,	1946-47	To the south of *Halfway Cottages,* a number of small structures have been installed within the site. Several more have been constructed in the field to the north of the cottages.	Annex C-3 and C-4

		access paths and another building. The surrounding area is a mixture of rural and urban, with the town of *Leiston* located immediately north-west.		Additional structures have been constructed to the south of the site. No other significant changes are visible on site or in the area.	
3	1938	The northern portion of the site as shown within this map is predominantly rural, comprising fields, footpaths and *Aldringham Green*. A *School* is present within this section, as well as a *School Plantation* and two roads. A section of the *Hundred River* flows through this section of the site. The southern portion of the site shown within this map consists of a field.	1947	No significant changes are visible on site or in the surrounding area. However, a previously wooded area adjacent to the site now appears to have been cleared.	Annex C-5 and C-6
4	1938	The majority of this section of the site encompasses rural fields. *Owl's Hole,* a small woodland area, is located within the western arm. *Ten Acre's Covert* and *Five Acres Pickle*, two woodland areas are located in the central portion. Several *footpaths* are identified across the site, in addition to a number of roads. Part of the southern portion is not covered by this map.	1945-47	No significant changes are identified on site. This map shows the missing section on the previous map, indicating that the southern extent is occupied by *Lily Pond* and roadways.	Annex C-7 and C-8
5	1938	The southern extent of the site is occupied by a road, surrounding fields and a pond.	1945-47	No significant changes visible.	Annex C-9 and C-10
6	1938	This part of the site is occupied by rural open fields.	1946	No significant changes visible.	Annex C-11 and C-12

7	1938	This part of the site is occupied by rural open fields.	1946-47	No significant changes visible.	Annex C-13 and C-14
8	1938	This part of the site is occupied by rural open fields.	1945-46	No significant changes visible.	Annex C-15 and C-16
9	1938	The majority of this section of the site was occupied by rural open fields. Towards the south, the site was occupied by rough pasture and furze, within a *Golf Course*. *Warren House* is present in the south-eastern extent, as well as roadways and a *Crag Pit*. The eastern site is bounded by the railway line. The extension area encompasses open ground, drainage channels and a section of the shoreline.	1947	A compound containing several rectangular buildings has been constructed immediately south of the site, with access and another structure within the site boundary. Some clearance is visible to the south of the site, along with some redevelopment and clearance immediately north. No significant changes are visible within the site itself.	Annex C-17 and C-18
Source					**Groundsure Ltd**

8 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✓
Military Training Areas / Weapons Ranges	✓
Ordnance / Explosives Factories and Storage Depots	✓
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✓
Locations of Army Explosive Ordnance Clearance Tasks	✓
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✓

The frequency and intensity of combat operations during WWII, coupled with a generally more relaxed attitude towards matters of health and safety, meant that during this conflict UXO contamination was more likely. This is evidenced by the regularity of UXO finds (of WWII vintage) on former military sites by the public and the construction industry. Note, peacetime military activity at such sites is far less likely to have resulted in significant contamination of larger, more hazardous British / Allied UXO.

In the immediate aftermath of WWII, the vast quantities of surplus equipment resulted in an "out of sight out of mind" attitude on many military bases, which led to a culture of onsite burial.

While health and safety regulations became more rigorous following WWII, health and safety policy at military facilities up until relatively recently (~1990s) was still not as stringent as it is today. Consequently, the risk from post-WWII UXO, particularly LSA/SAA, cannot be discounted.

8.1 Live Fire Range, Weapons Testing / Training

Dunwich Training Area was in use throughout WWII, along with several other military facilities, batteries and defensive positions.

Potential contamination associated with these facilities includes live rounds (bullets of various calibre) and heavy metals such as Lead, Antimony and Barium. The hazard associated with small arms ammunition (SAA) is relatively low, however, due to the fact that such ammunition is solid shot and does not contain any explosive fill.

However, historically, ranges were not always used for one type of weapons training. Particularly during times of war, when training facilities were in much greater demand, it is conceivable that peripheral sections of the ranges and the surrounding area were also used for training with other weapons / items of Land Service Ammunition (grenades, mortars, rockets etc). Furthermore, such variety in activity would not have necessarily been recorded in official documentation. Potential contamination at such localities could include unspent smoke, phosphorus, fragmentation or blast grenades, as well a partially expended or faulty grenades.

It is known that historical health and safety policy at military facilities has not been as stringent as it is today. Munitions expended on land, whether they functioned as designed or not, are likely to have been abandoned rather than recovered, therefore increasing the likelihood that items of UXO still remain in-situ today.

In the past, SafeLane Global has encountered a wide variety of pre-WWI projectiles at comparable locations within the Shoeburyness Range (Essex), another 20th – 21st Century firing practice area.

8.2 Ordnance / Ammunition Storage, Use and Disposal

8.2.1 WWII Storage and Disposal

During WWII, a wide range of ordnance and ammunition was stored, handled and disposed of at military training sites. Broadly speaking this would have included:

a) Land Service Ammunition: Grenades, Mortars

b) Small Arms Ammunition: machine gun / canon, rifle, pistol

c) Anti-Aircraft Artillery shells

d) Bombs and Rockets: High Explosive, Incendiary, Shot, Smoke, Flares, Photoflash

e) Air-Delivered Maritime Weapons: Depth Charges, Torpedoes, Mines

f) Practice Bombs

Anecdotal accounts suggest that faulty or surplus ordnance / ammunition on WWII military sites would often be burnt, buried or otherwise disposed of locally. In many cases designated burning pits were sited at peripheral open ground within the site perimeter.

At the former locations of bomb stores and / or ammunition stores there is a higher likelihood of UXO contamination as such items would have frequently transited to and from / been handled within these areas.

8.2.2 Post-WWII Storage and Disposal

In the immediate aftermath of WWII, the armed forces were left with a vast quantity of surplus ordnance and ammunition. Within wartime airfields, for example, several RAF Maintenance Units (MUs) specialising in weapons servicing were tasked with their long-term storage and eventual disposal. Bombs and ammunition were stacked up on the runways and in any spare buildings at a number of military airfields in Britain.

Although the quantities were vast, these large-scale storage activities are unlikely to have resulted in UXO contamination, partly due to the secure nature of the dumps (being guarded by armed troops) and also due to the size of the stored items; relatively large individual bombs and crates of ammunition / sub-munitions.

8.3 WWII Ground Defence

If a military site was constructed either prior to WWII or during 1940 / 1941 (the period of anticipated German invasion), provision was made for ground defence.

8.3.1 Coastal Defence and Defensive Fortifications

Following the evacuation of Allied troops from Dunkirk in June 1940, Britain was under threat of German invasion from occupied France. Indeed, Germany began planning an intended amphibious invasion, codenamed Operation Sealion.

The Emergency Coastal Defence Battery programme, from 1940, saw a surge in the construction of fortifications and defences along the coast. This included, but was not limited to, concrete structures such as pillboxes, trenches, minefields, barbed wire, beach scaffolding, artillery and associated structures, anti-tank ditches and anti-tank blocks.

Pivotal locations all across Britain were designated as Nodal Points, and defensive stop lines were installed across the country in preparation for an invasion. Leiston and Saxmundham were main nodal points close to the study area.

Open flat land was also subject to defensive fortification, with the installation of anti-tank obstacles and anti-landing ditches, usually close to potential invasion beaches.

During the period when the threat of enemy invasion was high, such positions would have been manned by armed troops and therefore the likelihood of UXO contamination is locally higher at these places.

8.3.2 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[1]

[1] Various News Sources

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

8.3.3 Soldier Accommodation

During WWII Army, Royal Marine and Home Guard detachments were temporarily accommodated at sites requisitioned by the military for training and / or defence purposes. Soldiers could face serious disciplinary action if found to have misplaced ammunition, therefore it was not uncommon historically for troops to hoard extra items of ammunition to make up for any lost during exercises. Once these surplus items became redundant, they were often buried or hidden.

This is substantiated by anecdotal evidence, for example, a grenade was found in an accommodation block drainpipe within the Rowcroft Barracks (Ashford, Kent). Also, whilst SafeLane Global carried out EOD clearance works at Church Crookham Barracks near Fleet, a search and clear dog team sent into a disused barracks building discovered a grenade. In 2003 SafeLane Global encountered a grenade hidden in the roofing of another disused barrack block at Colchester Garrison. Thus, such a scenario cannot be discounted.

8.3.4 Battle Training

Anti-invasion exercises were frequent at WWII military sites operational during the period of anticipated German invasion. It was not uncommon for Allied Army or Marine units to visit such sites to test the base's defences during mock attacks.

Such exercises were both beneficial to the Home Guard / Army troops manning the defences as well as the attacking forces who were often in training for upcoming combat tours overseas. During these attacks live ammunition was sometimes used, as were pyrotechnic training aids to create realistic battle conditions.

This is substantiated by an eyewitness account associated with a WWII-era RAF Bomber Command airfield. A young boy who moved to Methwold village in 1942 notes that whilst exploring the areas around RAF Methwold, he would 'sometimes come across live ammunition'.[2]

8.4 Anti-Aircraft Defences

At the start of WWII, two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA), firing large shells (3.7" plus calibre) and Light Anti-Aircraft Artillery (LAA) employing smaller calibre weapons, firing .303", 20mm and 40mm shells.

8.4.1.1 LAA Guns

Most important military sites were defended by light anti-aircraft batteries (as a minimum) which were usually dispersed around the site in isolated positions, giving them some protection during aerial attack.

These batteries were intended to engage the fast, low flying German fighter bombers that operated against strategic locations, such as airfields, depots etc. These batteries were mobile and could be moved to new positions with relative ease when required.

Most extensively used were 20mm Oerlikon guns in the anti-aircraft role, until the introduction of the Bofors 40mm gun from 1943, although many Army / RAF units retained a mix of both types until the end of WWII.

The 40mm Bofors gun could fire up to 120 x shells per minute to over 1,800m. The Oerlikon canon could fire up to 330 rounds per minute to over 4,000m.

8.4.1.2 HAA Guns

During the early war period there was a severe shortage of AAA available and older WWI 3" and modified naval 4.5" guns were deployed alongside those available 3.7" weapons. The maximum ceiling height of fire at that time was around 11,000m (for the 3.7" gun and less for other weapons).

As the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, larger 4.5 and 5.25" weapons began to be brought into service. These had significantly improved ceiling heights of fire, reaching over 18,000m.

[2] https://joemasonspage.wordpress.com/2013/07/16/memories-of-methwold/

Before the war all the clockwork fuses used by the Royal Artillery had come from Switzerland. When that source of supply was cut off, Britain had been forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse.

This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all; falling to the ground as UXBs. For instance, In January 1944 more people in London were killed by HAA shells than by German bombs.

WWII military sites were not defended by static HAA batteries as standard, however the 3.7" was a mobile weapon and it is known that these guns were temporarily stationed at some of the more important and vulnerable bases during the German bombing campaign.

Note, any site located close to a city or large town would have also been vulnerable to HAA fire from the static gun batteries constructed around these neighbouring urban areas during 1939.

Each weapon could fire between 10 and 20 rounds per minute and so multiple gun HAA batteries could expend numerous shells in even short engagements. Any unexploded HAA projectiles could then land several kilometres away.

8.5 Mustard Gas

Britain stockpiled large quantities of Mustard Gas during WWII. In 1940-41, plans were put in place to use chemical weapons to help repel any German invasion of the Britain. More stocks were amassed in 1942-43, in case they were needed to bomb Germany and then again in 1944, in the lead up to the D-Day landings, as a deterrent and for retaliation. More stocks were produced after the war, in response to the Soviet threat, however the build-up ceased from the mid-1950s, when nuclear weapons became readily available to Britain.

Historically there were four Mustard Gas production facilities in the UK, four forward filling facilities and >60 storage sites, mainly former RAF and USAAF bases, where operational records show Mustard Gas was stored and then disposed of. However, some of these latter sites, declared as clear / safe by the MOD have since yielded up to 120 Mustard Gas artillery shells.

Note, due to the secrecy and sensitivity relating to chemical warfare during WWII, information relating to such matters was not always put on public record, hampering present day research.

Attempts to clean up the 60-plus sites over the last 40 years were often botched, leaving significant amounts of the highly corrosive, persistent chemical agent in the soil. Furthermore, detailed records of the chemicals stored at the sites appear to have been misplaced.

8.6 Generic Types of WWII British / Allied Unexploded Ordnance

8.6.1 Land Service Ammunition (LSA)

8.6.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK and therefore the possibility cannot be discounted that they were stored on site. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

8.6.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

8.6.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

8.6.1.4 Pyrotechnics

This group of LSA are mainly used for battle simulation training within Army training areas. Although they do not contain significant quantities of HE they do have small burster charges and incendiary charges which have the potential to cause serious injury.

- **The Signal Kit 16 mm (Mini Flare)** consists of a green rectangular pack containing eight flare cartridges. Each cartridge can be fired from a straight tubular pistol complete with striker, spring and thumb stud.

- **Simulator Battle Sound L35A1 (SBS)** area explosives used during exercises and demonstrations to simulate the noise of mortar fire, shell fire or Claymores. They are powerful explosives and can cause injuries to soldiers and damage to equipment.

  It consists of a cardboard tube 160mm long and 23mm in diameter which weighs 65g. One end is sealed by a removable top which serves to protect the igniter and charge. This also has the friction striker attached to the outside. The other end is the handle and is open. The handle is filled with sand to provide weight to assist in the throwing process. The SBS is waterproof and can be used in wet conditions. The SBS is coloured blue. A label with user instructions is wrapped around the tube. The charge and igniter are coloured red as is the friction striker. The removable top is sealed by a white label.

- **Schermuly Parachute Rocket**. This flare is used as an illuminating device. It comprises a small rocket which releases a flare suspended on a parachute. The flare produces a white light of about 60,000 candle power and burns for 30 – 35 seconds. It can reach a maximum height of about 350m and the rocket casing has green and white markings. There are various types with different illuminating colours.

- **Flare Tripwire Kit L10A1**. The flare may be initiated by trip wire or electrical means. It comprises three pickets, one spring-arm with spring and clamp, 20m spool of wire, an anti-glare shield and a flare pot. Eye damage can occur from the high intensity light emitted by an ignited flare tripwire. On no account should anyone continue to look directly at an ignited Flare Tripwire with unprotected eyes.

8.6.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

8.6.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

8.6.4 Miscellaneous

When working on land used currently or historically by the military, all manner of explosive ordnance related items dating back over 100 years could be encountered. These may include practice (dummy) items, experimental weapons and other miscellanea such as detonators, pyrotechnics and fuzes. Although small, detonators and some fuzes contain enough primary explosive to cause serious injury.

All RAF aircraft were issued with distress flares stored in an inflatable dinghy. Flares are a type of pyrotechnic that produces a brilliant light or intense heat without an explosion. WWII RAF flares did not contain explosives material however produce their light through the high temperature combustion of a pyrotechnic composition. Therefore, such an item could potentially cause injury.

8.7 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO. The approximate locations of all relevant features are presented at Annex D.

Potential Source	Details
Live firing ranges / weapons testing on site	The north of the project site extends into Dunwich Battle Training Area. It is known that training with live ammunition was undertaken within this area during WWII. A training range was located at Dunwich, with the firing arc facing east into the sea. As such, it is not likely that these ranges will have fired towards the site.
Ordnance / Ammunition storage on site	Several areas have been identified within the project site which indicate the presence of buildings / huts relating to military sites. It is possible that ammunition could have been stored at these locations, however no direct evidence has been found.
Ordnance / Ammunition disposal on site	No official disposal areas have been recorded or identified within the project site. However, disposal was often undertaken on peripheral parts of military facilities. Some parts of the site were located in such areas where burial or discarding of UXO could have occurred. This is substantiated by post-WWII UXO finds within previously military-owned land.
Nearest Home Guard Battalion to the site	8th Suffolk (Saxmundham) Battalion

Home Guard activity on site	It is likely that the local training areas were utilised for Home Guard training exercises. The significant concentration of anti-invasion defences along the coastline and within the general project site area means Home Guard presence and activity is likely to have been significant.
Troop accommodation on site	It is likely that troop accommodation will have been provided for personnel stationed at or training at the military facilities within the site and surrounding area. No recorded accommodation blocks have been found directly within the site boundary, however it cannot be discounted in the area.
Defensive features within the vicinity	The following features have been identified / recorded on site: - WWII Strong Point & Potential Radar Station - WWII Anti-Tank Ditch - WWII Strong Points & Training Areas - WWII Diver Battery - WWII Anti-Glider Ditches The following features have been identified / recorded in the surrounding area: - At least 50 pillboxes - At least 41 defence-related positions (inc. anti-tank and anti-landing trenches, ditches, cubes, blocks etc) - At least 15 gun posts, Leiston - WWII Anti-Tank Ditch - WWII Anti-Aircraft Batteries - WWII Strong Point & Possible Depot - WWII Practice Trenches - Beach Defences - Beach Minefields The extension area contains additional defence related positions, comprising a minefield and other anti-landing / anti-invasion fortifications. Reportedly, the defences were heaviest in between Aldeburgh and Sizewell (including part of the site), as it was low-level and would have been easily accessible for landing craft, infantry and tanks.[3]
Anti-invasion exercises on site	Dunwich Battle Training Area encroaches into the north of the site, and several anti-invasion features have been identified within the project site and the surrounding area. As such, it is likely that anti-invasion exercises will have been undertaken on site and in the vicinity.

[3] http://news.bbc.co.uk/local/suffolk/hi/people_and_places/history/newsid_8868000/8868937.stm

Mines on site	Beach minefields are recorded to have been in use throughout WWII on the beachfront. The extension area encompasses a section of the beach, which was reportedly defended by minefields in addition to other types of fortification. Since anti-landing trenches and other anti-invasion installations were recorded directly on site, mines would have been used to bolster these anti-landing features.[4] RAF aerial photography confirms the presence of beach defences on the coastline within this area. One photograph shows the area in which B Type C mines are believed to have exploded: 
Threat to the site from unexploded AA shells	At least 10 possible batteries have been identified within the site and the surrounding area, including Heavy AA and Diver AA Batteries. However, it is also possible that additional or temporary AA batteries will have also been brought to the area during periods of most significant threat. The majority of the site was occupied by rural / agricultural open ground, vegetation, woodland and beach. Had an unexploded AA shell landed within such ground types, it could have been left unnoticed, easily obscured within dense vegetation or unconsolidated material.
Practice bombing on site	None recorded.
Live Training on site	The site encroached onto a training area during WWII, and contained a number of other military sites. As such, it is likely that training exercises involving live ammunition will have taken place within these locations. The remaining areas of the site are occupied mostly by rural open ground. It is possible that training activity may also have taken place within these areas. However, it is likely that live munitions are most likely to have been used within designated live training areas.

[4] https://heritage.suffolk.gov.uk/Monument/MXS19737

Mustard gas production / storage on site	None recorded

9 The Threat from German Aerial Bombing

9.1 General Bombing History of Suffolk and the Project Site

9.1.1 First World War

London and Eastern England suffered aerial bombardment during WWI, beginning with indiscriminate night raids by Zeppelin airships. However as British defensive measures became more effective and aircraft development progressed, the German military switched to daylight raids by fixed-wing aircraft in June 1917.

Available bomb plot mapping indicate that at least one Zeppelin raid occurred directly over the general site area on 24th August 1916. Additionally, several aircraft crossed the Suffolk coast on their way to / from raids on London in October 1915. However, no recorded WWI bombs are confirmed to have fallen within the project site.

Furthermore, WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

9.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Historically the north of the site was located within the Urban District of Leiston-cum-Sizewell while the remainder of the site was situated within the Rural District of Blyth.

The Ministry of Home security reported that 13 air raids were recorded over Leiston-cum-Sizewell with approximately 15 metric tonnes of ordnance dropped on the region. Targets would have included Garrets Engineering Works (approximately 1km north-west of the site) which had switched from peacetime production of agricultural plant and machinery to war time production of munitions and other military equipment.

Later in the war a number of Air stations, both British and American, became operational in East Anglia, including RAF Leiston (approx. 2.6km north of the site) and RAF Framlingham.

Airfields and radar stations such as RAF Leiston and RAF High Street would have been potential targets for the Luftwaffe and defensive measures were installed, including Light Anti-Aircraft guns, pill boxes, road blocks and air raid shelters. A Luftwaffe target identification photograph (not annexed) identifies RAF Leiston, to the north of the site, then under construction.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying

Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

9.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

9.3 Second World War Bombing Statistics

The site was located partially within the Urban District of Leiston-cum-Sizewell, and partially within the Rural District of Blyth. The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on these locations between 1940 and 1945.

Record of German Ordnance Dropped		
Location	**Urban District of Leiston-cum-Sizewell**	**Rural District of Blyth**
Area Acreage	4,462	98,184
High Explosive Bombs (all types)	83	555
Parachute Mines	-	7
Oil Bombs	-	3
Phosphorus Bombs	-	12
Fire Pots	-	16
Pilotless Missile (V1)	-	14
Long Range Rocket (V2)	-	1
Total	83	608
Items Per 1,000 Acres	**18.6**	**6.2**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

9.3.1 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

Written ARP records were reviewed for	Sizewell, Leiston and surrounding area		
Source	Suffolk County Archives		
Records of bombing on / near the site were found			✓
Date	**Location**	**Weapon**	**Details**
06/10/1940	Wickham Market	Machine gun	Little damage caused
18/08/1940	Leiston and East Suffolk	Machine gun	Attacks to search light positions
	Leiston	15 x HE bombs	n/a
01/02/1941	Leiston	10 x UXB HE bombs	n/a
02/02/1941	Leiston	10 x HE bombs and machine gun	Attack on Garrett Engineering Works (approx. 1-1.2km north-west)
10/10/1941	Leiston	HE	24 houses and school damaged
01/06/1942	Leiston	9 x HE bombs and IBs	Believed to be an off shoot of raid over Ipswich.
01/02/06/1942	Sizewell	2 x 500kg HE bombs	One bomb fell 260ft south of Leiston-Sizewell Road and 400ft east of Halfway Cottages (on site). Severe damage to an Army hut and damage to Halfway Cottages, Leiston. The second bomb fell around 265ft to the south-east of the first. This incident occurred directly within the project site.
19/10/1942	Wickham Market	HE bomb	Damage to 114-118 High Street (>11km south-west). Resulted in the deaths of three civilians
03/10/1943	Leiston	SD2 'Butterfly' bombs	Crown Farm (immediately west of the site).
15/10/1943	Leiston	HE bomb	n/a

9.3.2 Home Office Intelligence Reports

The Home Office Intelligence reports document enemy action on British domestic soil and were prepared twice a day for the Home Security War Room. The summaries were prepared by intelligence staff, who compiled reports received from the twelve civil defence regions.

However, available records only document time and general location of attack and numbers of casualties. The intelligence officials generally only recorded locations on municipal level (town, village, or city), rarely providing specific addresses.

Date	Location	Details
18/08/1940	Leiston	No casualties
22/08/1940	Aldeburgh	No casualties
04/10/1940	Aldeburgh	6 injured
06/10/1940	Leiston	No casualties
03/11/1940	Aldeburgh	No casualties
06/11/1940	Aldeburgh	No casualties
25/11/1940	Friston	No casualties
15/12/1940	Sizewell	No casualties
21/01/1941	Aldeburgh	1 injured
02/02/1941	Leiston	No casualties
15/02/1941	Aldeburgh	No casualties, 2 raids
	Friston	No casualties
18/02/1941	Leiston	No casualties
20/02/1941	Leiston	No casualties
27/02/1941	Friston	No casualties
06/03/1941	Friston	No casualties
15/03/1941	Aldringham	No casualties
02/04/1941	Aldeburgh	No casualties
29/04/1941	Between Leiston and Aldeburgh	1 injured

09/05/1941	Aldeburgh	No casualties
12/05/1941	Aldeburgh	No casualties
13/05/1941	Leiston	No casualties
15/05/1941	Leiston	1 killed, 3 injured
02/06/1941	Sizewell	No casualties
22/07/1941	Aldeburgh	No casualties
24/07/1941	Leiston	No casualties
29/07/1941	Aldeburgh	No casualties
08/09/1941	Aldringham-cum-Thorpe	No casualties
07/10/1941	Aldeburgh	No casualties
11/10/1941	Leiston	2 killed, 2 injured
05/11/1941	Aldeburgh	No casualties
17/01/1942	Aldeburgh	No casualties
30/01/1942	Leiston	No casualties
02/06/1942	Leiston	Unexploded bomb – no casualties
27/07/1942	Aldeburgh	No casualties
02/08/1942	Aldeburgh	2 injured
19/10/1942	Aldeburgh	No casualties
15/12/1942	Aldeburgh	11 dead, 29 injured
25/04/1943	Sizewell	No casualties
14/05/1943	Leiston	No casualties
03/10/1943	Aldeburgh	No casualties
04/10/1943	Sizewell	No casualties
16/10/1943	Leiston	No casualties

19/04/1944	Leiston	No casualties
30/08/1944	Friston	No casualties
13/10/1944	Aldeburgh	No casualties
15/10/1944	Aldeburgh	No casualties
20/10/1944	Aldeburgh	No casualties
05/11/1944	Aldeburgh	No casualties
06/11/1944	Aldeburgh	4 injured
07/11/1944	Aldeburgh	No casualties
10/11/1944	Aldeburgh	No casualties
11/11/1944	Aldeburgh	No casualties
15/11/1944	Aldeburgh	No casualties
13/12/1944	Aldeburgh	No casualties
03/01/1945	Aldeburgh	No casualties

9.3.3 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
WWII	HE bombs	Several bomb craters were recorded approximately 1km north of the site, around Sizewell.[5]
08/09/1940	Incendiary bombs	Blyth Rural District[6]
20/09/1940	Parachute Mine	Blyth Rural District[7]
22/09/1940	Parachute Mine	Blyth Rural District[8]
06/10/1940	HE bomb	Plotted ~1.3km north-east of the site, within Leiston town.[9]

[5] https://heritage.suffolk.gov.uk/map
[6] Bowyer, 1986
[7] Bowyer, 1986
[8] Bowyer, 1986
[9] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474

05/11/1940	16 x HE bombs	Blyth Rural District[10]
11/11/1940	10 x HE bombs	Blyth Rural District[11]
24/11/1940	HE bomb	Plotted ~670m west of the site, within Friston town.[12]
14/12/1940	HE bomb	Plotted ~800m north of the site, within the current Sizewell nuclear power station facility.[13]
09/01/1941	4 x HE bombs	Blyth Rural District[14]
21/01/1941	HE bomb	Plotted ~1km south of the site, within Aldeburgh town.[15]

9.3.4 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	26th August 1942	
Source	NCAP	
Image Type	Aerial	
Image quality	Partial coverage, small scale, high resolution	
Observations	• Within the north of the site, the site comprised rural open ground. • A number of structures are visible in the northern section. • Within the south-east, the site encroaches onto a golf course. • The remainder of the site (visible on the photograph) appears to comprise agricultural or rural open ground. • Within the surrounding area, the anti-glider defences are visible adjacent to the site.	
Reference		**Annex E-1, E-2**

[10] Bowyer, 1986
[11] Bowyer, 1986
[12] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474
[13] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474
[14] Bowyer, 1986
[15] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474

Date	Circa 1945
Source	The GeoInformation Group
Image Type	Aerial
Image quality	Partial coverage, small scale, low resolution
Observations	• The north-eastern extent of the site is shown to be occupied by rural open ground. • One roadway extends west to east to the coast. • Several small features are visible to the south of the road, which may contain some structures. Similar features are visible in the surrounding area. • The anti-glider ditches are visible in the fields to the south of the site. • The southern part of the site predominantly comprises rural / agricultural open ground, with the south-east extending into a golf course. • Within the south-east, the site extends into an area containing a military facility, consisting of huts and access roads.
Reference	**Annex E-3, E-4**

9.3.5 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✘
Additional Comments	n/a

9.4 UXB Ground Penetration

9.4.1 General Considerations

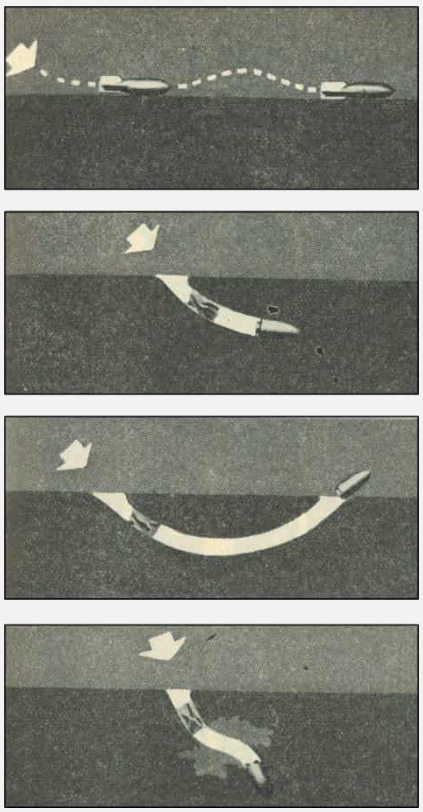
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on

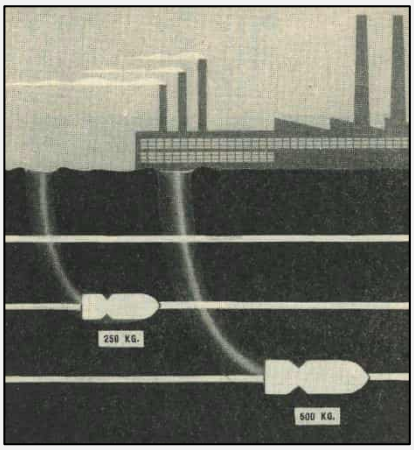
the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

9.4.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

9.4.3 Second World War Bomb Penetration Studies

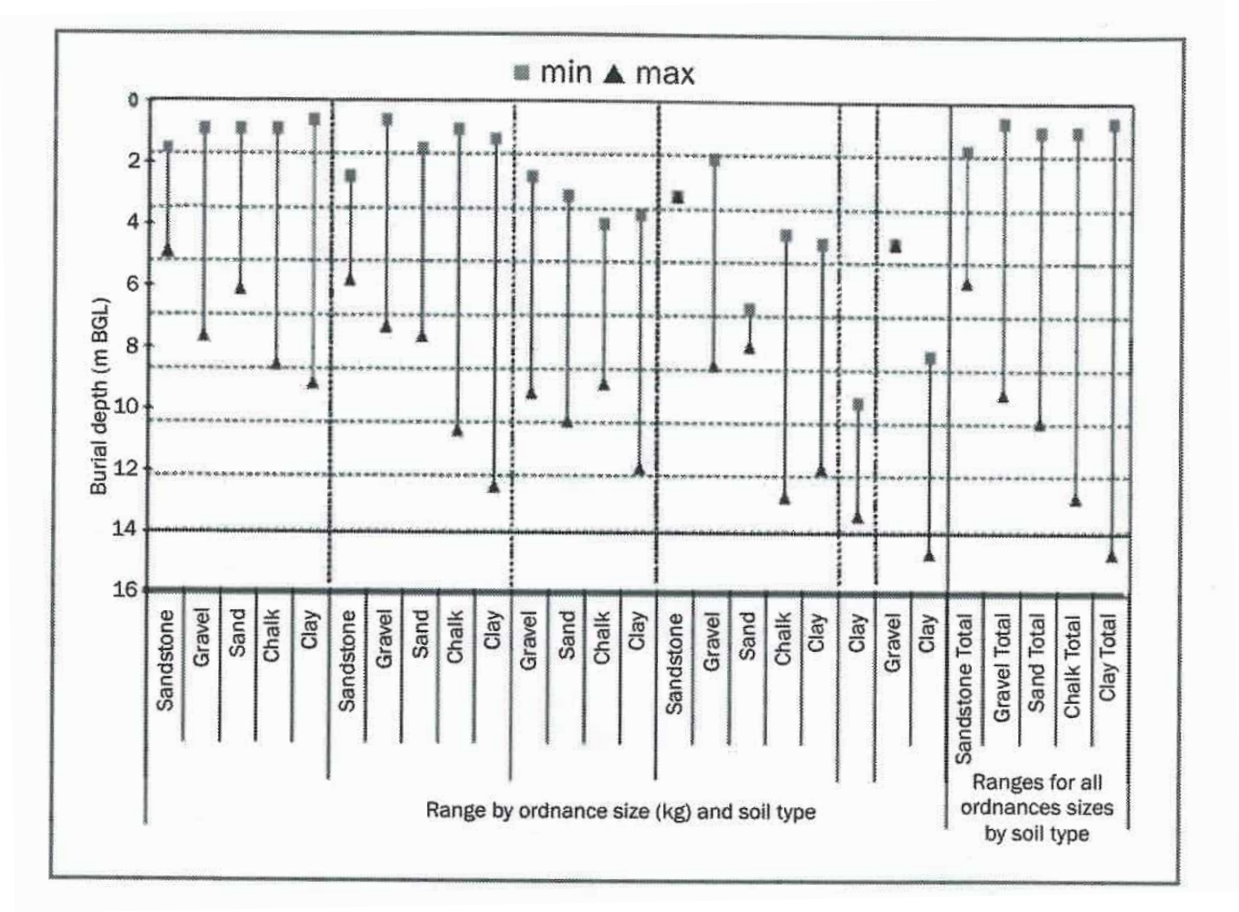
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

9.4.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



9.4.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – Bedrock varies across the site, but largely consists of Sand or Calcarenite. This underlies a range of Superficial Deposits, comprising Sand & Gravel, Diamicton and Clay & Silt, with some parts of the site recording no superficial deposits.
- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 9-11m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

9.5 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 9.3, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

9.5.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

9.5.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

9.5.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg

incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

9.5.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

9.5.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

9.5.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			Additional Comments
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Moderate	
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✓	Bombing records over the general site location are not comprehensive, with many local bombing records only containing general incident locations. As such, it cannot be accurately determined how many bombs fell on site and their exact locations. However, bombing has ben confirmed near Halfway Cottages and Crown Farm, both within or adjacent to the site's northern section.
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	At least 2	
	Were any nearby sticks of large bombs recorded in line with the site?	✓	
	Were any 1kg incendiary bomb showers recorded over the site?	✘	None recorded, although the possibility cannot be discounted.
Bomb Damage	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✓	Damage recorded to Halfway Cottages and an Army Hut (within north of the site).

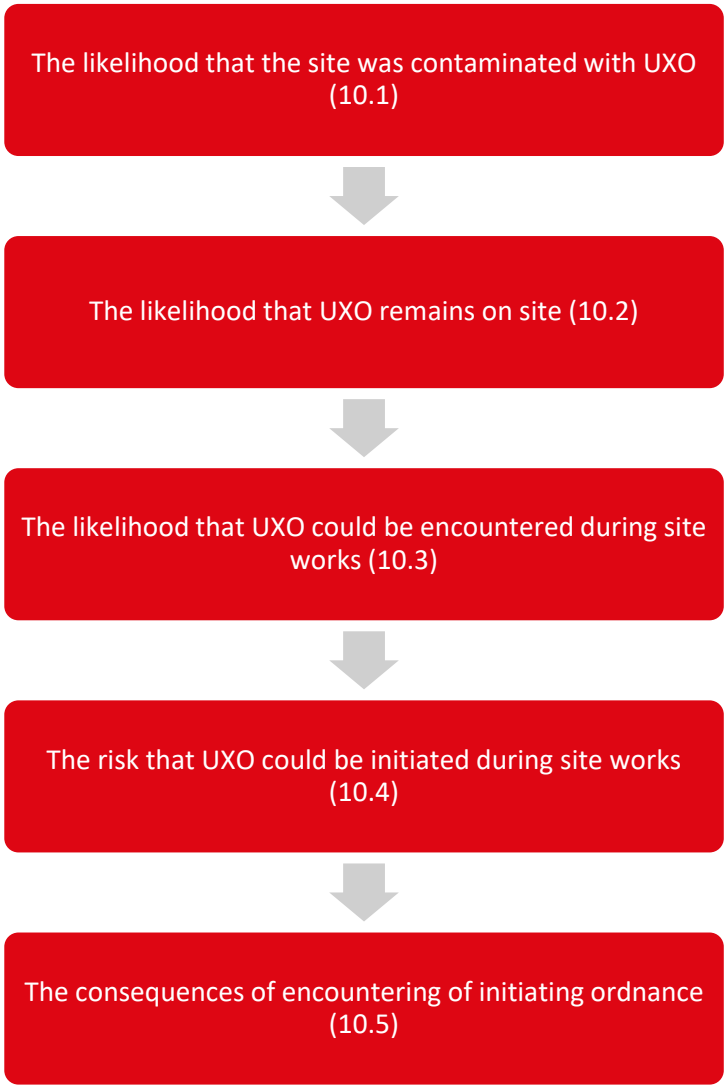
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✖	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✖	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	✖	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✖	
	The site was exclusively or partially developed during WWII.	✓	
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✓	
	The site was occupied by a school during WWII.	✓	
	Part of the site is likely to have been subject to post-raid searches for UXO.	Possibly	The school and occupied buildings on site may have been checked for evidence of UXO.
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	Possibly	Following bomb damage to the Halfway Cottages / Army Hut, these locations may have been abandoned.
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✖	

	The site was occupied by a graveyard which would have experienced limited access.	✗	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✗	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✗	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✗	
	The site was occupied by dense, inaccessible vegetation during WWII.	✓	
	The site may have been susceptible to waterlogged conditions during WWII.	✓	
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓	
	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✓	
	The site was occupied by stockpiled material during WWII.	✗	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✓	
	The site was occupied by well-maintained, manicured lawn during WWII.	✗	

	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	Much of the site and it's vicinity was occupied by rural, agricultural or otherwise vegetated open ground during WWII. Had a UXB landed within this material, it could have come to rest up to 15m away from its original entry point due to the J-Curve Effect. This could have resulted in UXBs coming to rest elsewhere beneath the site.
Bomb Failure Rate	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition	• The north of the site extends into the site of Dunwich Training Area, which was used for live training exercises during WWII. • As such, it is possible that this part of the site was contaminated by land service or small arms ammunition as a result of training, storage or disposal. • Furthermore, within several parts of the site, military structures, buildings and facilities were present. It is also possible that the storage, use or disposal of munitions may have taken place at these locations. • Within the general site location, a large number of defensive features are present, several of which are located directly within the site boundary. Due to these features, military presence within the area will have been drastically increased, and anti-invasion sites will have been manned. • As such, the high-level military presence will have increased the possibility for LSA and SAA items to have contaminated the site and the surrounding area.
Small Arms Ammunition	
Anti-Aircraft Projectiles	• At least 10 possible batteries have been identified within the site and the surrounding area, including Heavy AA and Diver AA Batteries. However, it is also possible that additional or temporary AA batteries will have also been brought to the area during periods of most significant threat. • The majority of the site was occupied by rural / agricultural open ground, vegetation and woodland. • Had an unexploded AA shell landed within such ground types, it could have been left unnoticed, easily obscured within dense or unconsolidated material.
Landmines	• The extension area encompassed a section of the beach known to have been defended by a minefield, in addition to a range of other coastal fortifications. Although these were reportedly cleared during / post-WWII, it is known that these weapons were often left in place or lost due to tidal activity. • As such, the possibility that the site was contaminated by landmines cannot be discounted.
Overall Likelihood of Contamination	**Medium & High**

10.1.3 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• Moderate bombing density over the general site area. • Bombing records over the general site location are not comprehensive, with many local bombing records containing only general incident locations. • As such, it cannot be accurately determined how many bombs fell on site and their exact locations. • The available records indicates over 55 separate air raids over the general area. It is possible that the site was affected during one or more of these raids. • Bombing was confirmed within the northern part of the site, damaging Halfway Cottages and an Army hut. • "Butterfly" Bombs recorded near to Crown Farm (immediately west of the site).
Bomb Damage	• The site was mostly occupied by open, rural, agricultural or vegetated ground. • Damage was reported to Halfway Cottages and an Army hut, located in the northern section of the site. • Available aerial photography only partially covered the site and was low resolution. As such, clear evidence of bomb craters in open ground or the extent of bomb damage to buildings was not visible. • Furthermore, it is possible that bombing incidents may have occurred after the 1942 photographs were taken.
Ground Conditions	• Rural, agricultural and vegetated ground within the majority of the site. • Parts of the site appear to be unmaintained.
Frequency of Access	• Seasonal access to agricultural land. • The location of the training area will have been accessed for military exercises, however, access to these peripheral sections may have been less common. • Less maintained or heavily vegetated areas may have been very infrequently accessed.
J-Curve Effect	• Had any UXB landed within the soft ground or vegetation on site / in the vicinity, it could have come to rest up to 15m from its original entry point due to the J-Curve Effect.
Overall Likelihood of Contamination	**Medium**

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	During the 1960s, a major heath fire at Dunwich caused large quantities of unexploded ordnance to detonate. As a result, a decision was taken to systematically clear the area of its WWII remains. During these operations, the wartime defence structures were also removed and the concrete used on other construction projects.[16] The image below shows an Army bomb disposal team clearing ordnance in the 1960s:  This area was located primarily to the north of the project site, however the site's northern extent encroaches into the area previously designated as Dunwich Training Area. Several WWII defences were positioned on or close to the site, and as such, it is possible that these clearance operations extended into the project site boundary. The table below details the available records from these operations. The requirement for these operations also illustrates how unexploded ordnance was still present after the end of WWII, and in significant amounts. At any location within the training area and local to the military sites / defences which was not subject to these clearance operations in the 1960s, the possibility that UXO remains cannot be discounted. SafeLane Global records also indicate that the WWII anti-invasion defensive minefields located at Sizewell (north of the site) were cleared on 5th January 1946 and 25th June 1946. Within the extension area, post-war clearance has been alluded. Available secondary sources also suggest that clearance operations along the shoreline were not always

[16] https://heritage.suffolk.gov.uk/dunwich-heath

	comprehensive. Several features were left in place, such as dragons teeth framework, and the success rate for removal of minefields and other fortifications was not entirely accurate or complete. *Further Bomb Disposal tasks have been undertaken within the wider area, and details are found in the tables below.*
Local ordnance finds	The following local finds have been reported: - April 2022, a WWII-era mortar was discovered on Dunwich beach, Suffolk.[17] - December 2013, WWII UXB and two mortars found on the beach over two days, near Dingle Marshes, Dunwich beach.[18] - November 2021, a WWII white phosphorous mortar was discovered near Beach Road, Dunwich.[19]

10.2.2.1 Clearance Operations at Dunwich

Date	Location	Site of Area (ha)	OS Grid Reference	No of Items Recovered	
				Live	Expended
11/03/1981	Dunwich Forest, Leiston	3.23	465640	0	0
15/08/1958	Dunwich Heath, Dunwich	41.29	465695	116	756
18/03/1971	Dunwich Heath, Dunwich	41.29	465695	7	56
09/02/1976	Scottshall, Nr Dunwich	188.66	460675	202	1,017
03/04/1979	Minsmere Nature Reserve, Dunwich	-	461676	5	19
12/02/1959	Dunwich Forest, Leiston	8.90	465645	9	0
04/03/1982	Dunwich Forest, Leiston	14	471645	6	5
01/05/1984	Thorpeness Meare, Thorpeness	1	472595	0	0
Total				**345**	**1853**

[17] https://www.eadt.co.uk/news/suffolk-bomb-disposal-unit-called-to-dunwich-beach-8909820
[18] https://www.eadt.co.uk/news/dunwich-second-unexploded-bomb-washes-up-on-beach-2118294
[19] https://www.bbc.co.uk/news/uk-england-suffolk-20180562

10.2.2.2 Bomb & Mine Disposal Incident Case File Sweeps

Date	Location	Comments
02/09/1963	The Old Abbey, Leiston	Area of Dyke cleared
25/06/1946	Sizewell	n/a

10.2.2.3 Demolition & Depth Charges Clearance

Date	Location	OS Grid Reference
04/09/1962	Crown Farm, Leiston	459628
	Halfway Cottage, Leiston	462623
	Sizewell, Leiston	472621
	Sizewell, Leiston	471625
	Sizewell, Leiston	470628
	Sizewell, Leiston	474627
	Sizewell, Leiston	472622
	Halfway Cottages	465623

10.2.2.4 Other Clearance Operations

Date	Location	Size of Area Searched (ha)	No of UXO Items	Comments
17/12/1958	Kenton & Goose Hills, Leiston	23	9	n/a
	Dunwich Forest	22	8	Drainage ditches and all areas permanently under water have not been searched, they should not necessarily be considered clear of UXO.

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✘
Further Details	Aside from agricultural ground works, no known significant redevelopment has occurred within the site.

10.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	The available evidence suggests that the site has been subject only to shallow ground works since the end of WWII. It is possible that clearance operations may have been undertaken within the northern section of the site, within the original bounds of Dunwich Training Area. However, the details and extents of these works are not known, and therefore the possibility that UXO could still remain in this area cannot be ruled out.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. At any location on site where no bulk excavations have been carried out, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth.

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works are expected to consist of site investigation works, comprising boreholes and trial pits. As such, it is considered possible that an item of UXO could be encountered during these works.

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.
Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

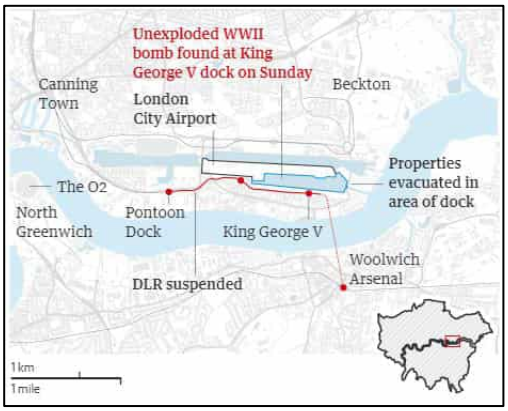
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've **Blown up by history** found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14.	A WWII bomb killed 3 and injured 8 in Berlin - 1944
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII bomb found in Birmingham, causing a construction site to be evacuated.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be heterogeneous and can therefore be divided into areas of Medium and High risk. The Medium Risk Zones are also divided into Medium Risk Zones 1 and 2. A UXO Risk Map detailing these areas is presented in Annex F.

High Risk Zone 1:

- Areas within WWII-era training areas and military facilities.
- Previously encountered UXO items.
- High possibility of anti-aircraft fire over the area.
- Moderate German bombing density.
- Vegetated / rural open ground.
- Buffer area to account for the J-Curve Effect.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	High	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	High	High	High	Not Significant	**Medium**
Land Service Ammunition	High	High	High	Severe	**High**

High Risk Zone 2:

- Areas within a fortified beach, including beach minefield.
- High possibility of anti-aircraft fire over the area.
- Moderate German bombing density.
- Buffer area to account for the J-Curve Effect.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	High	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	High	High	High	Not Significant	**Medium**
Land Service Ammunition	High	High	High	Severe	**High**
Landmines	High	High	High	Severe	**High**

Medium Risk Zone 1:

- Moderate German bombing density.
- Vegetated / rural open ground.
- Buffer area to account for the J-Curve Effect.
- High possibility of anti-aircraft fire over the area.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	High	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Low	Low	Low	Not Significant	**Low**
Land Service Ammunition	Low	Low	Low	Severe	**Low**

Medium Risk Zone 2:

- Moderate German bombing density.
- Vegetated / rural open ground.
- Buffer area to account for the J-Curve Effect.
- High possibility of anti-aircraft fire over the area.
- WWII-era military activity (non-training area).

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	High	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Medium	Medium	Medium	Not Significant	**Medium**
Land Service Ammunition	Medium	Medium	Medium	Severe	**Medium**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in Section 12.2.

Risk Level	Planned Site Activity	Recommendations
Medium / High	Shallow Intrusive Works eg. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey) • Search & Clear • Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey) • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation Works
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
	Offshore works	Appropriate risk mitigation measures can be provided for any works taking place in marine (coastal or offshore) parts of the project site if necessary. These can usually include the following: • UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Client threat briefing • Authorities' engagement where required • Non-Intrusive (NI) High-Resolution Marine Survey – Area specific to each project module • Assessment and production of a Master Target List • Target Investigation (Required as a follow-on from NI Marine Survey) • ROV/Diver Investigation / Survey • Disposal if requested

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of

	an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	Non-Intrusive Survey This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required.

	The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. Target Investigation If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Bowyer, M. J. F., *Air Raid!: Enemy Air Offensive Against East Anglia, 1939-45,* (Patrick Stephens Ltd, 1986).

iii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iv. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

v. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

vi. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

vii. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

viii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

ix. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

x. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

xi. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).

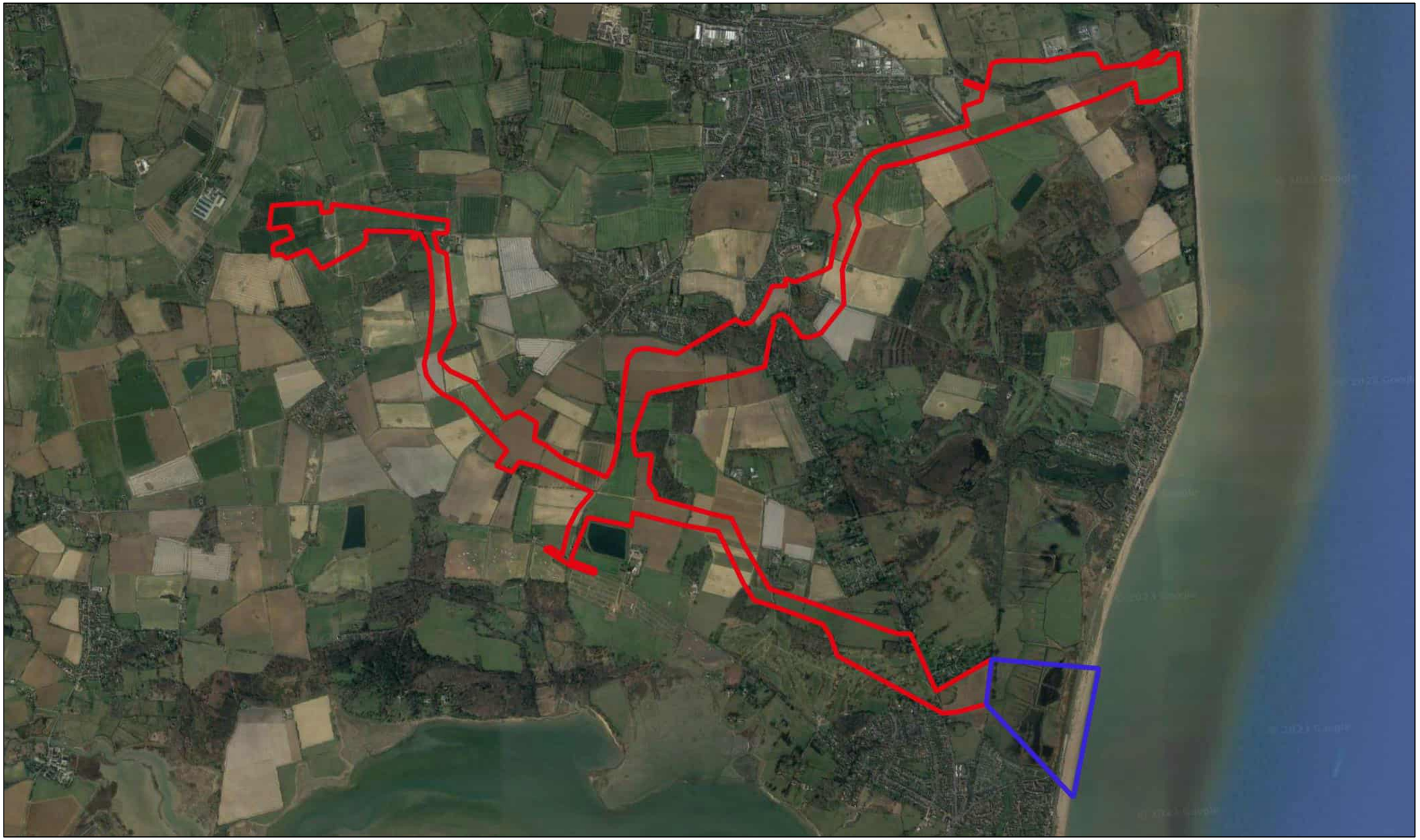




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Recent Aerial Photograph

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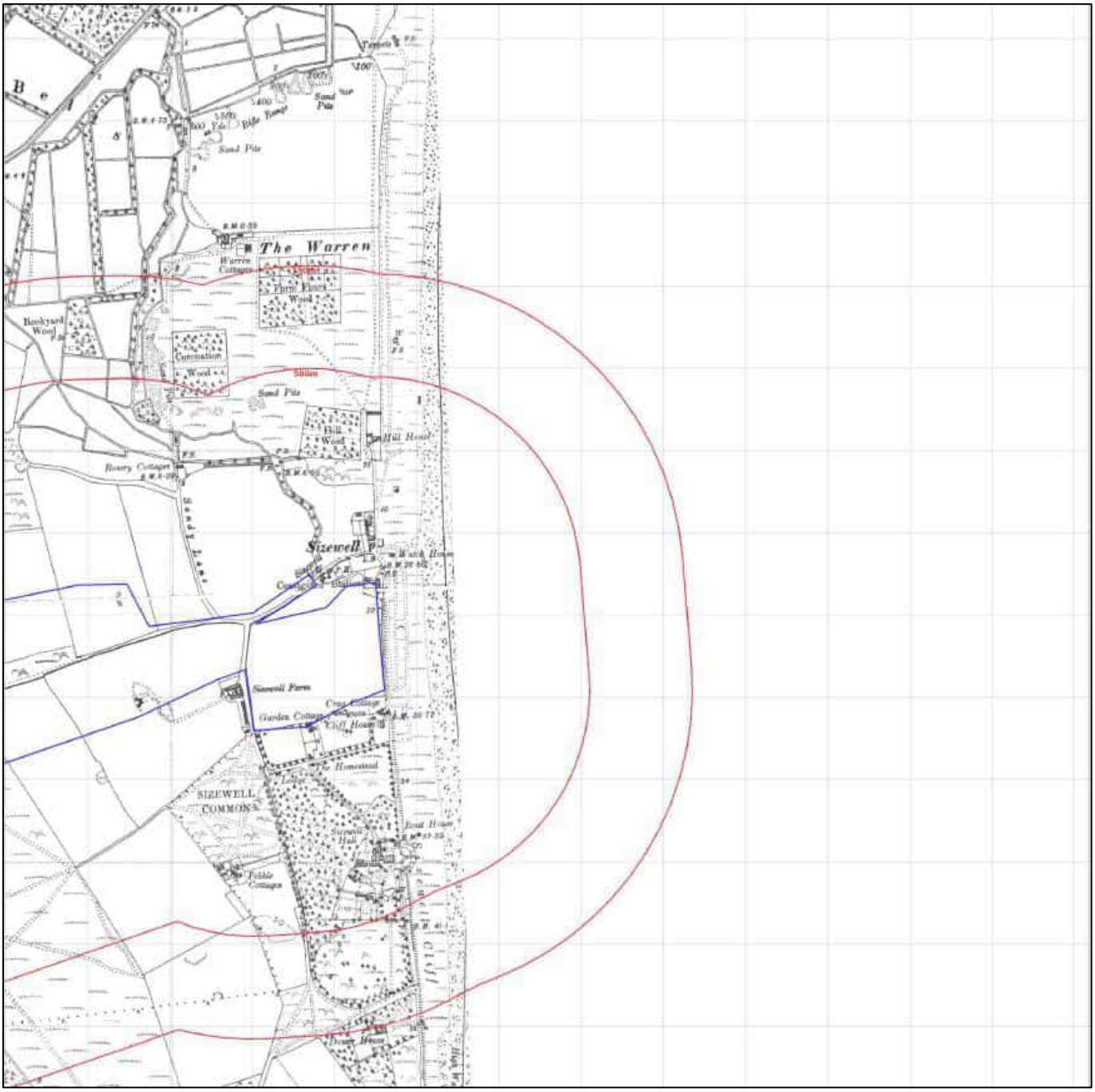


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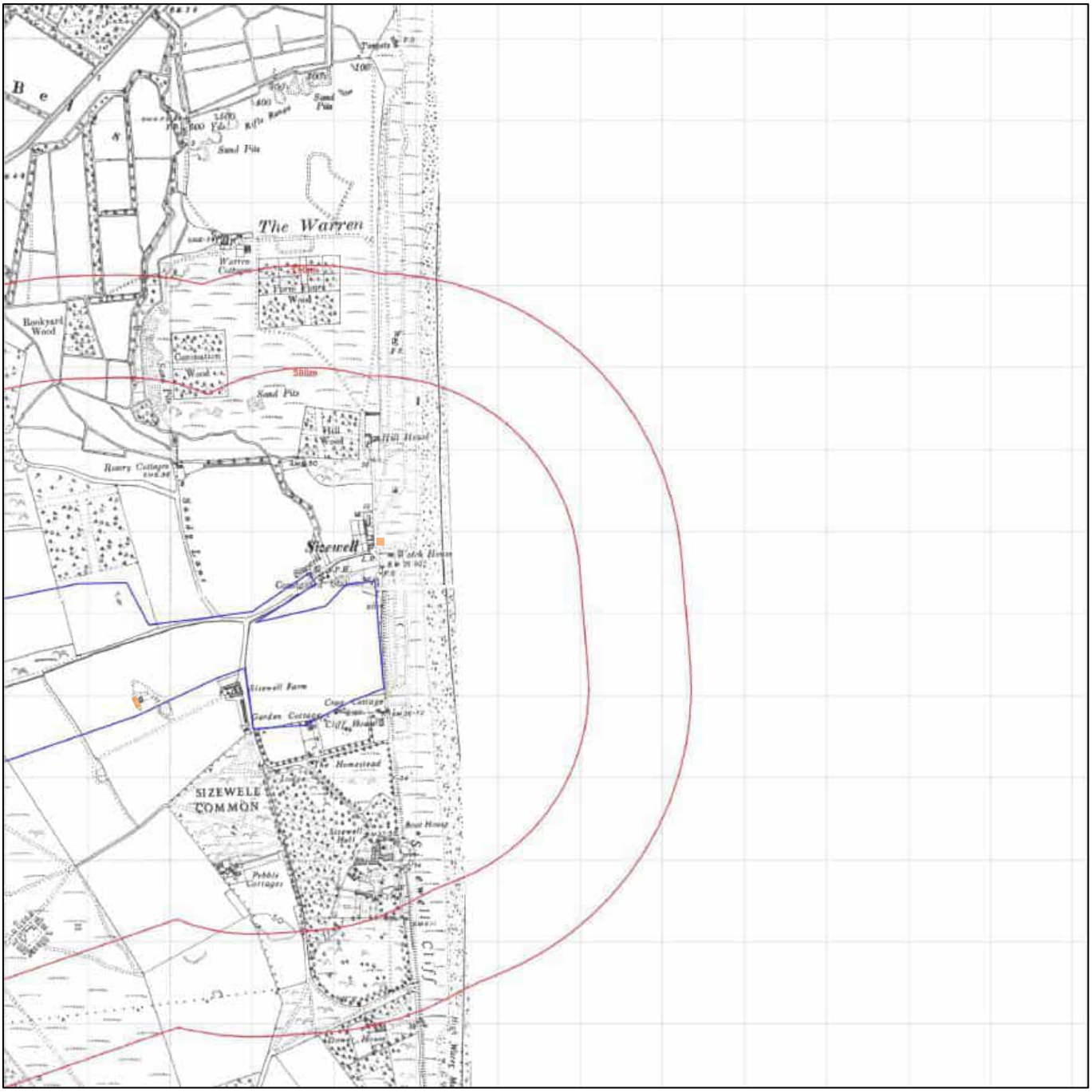
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Approximate site boundary Clearance

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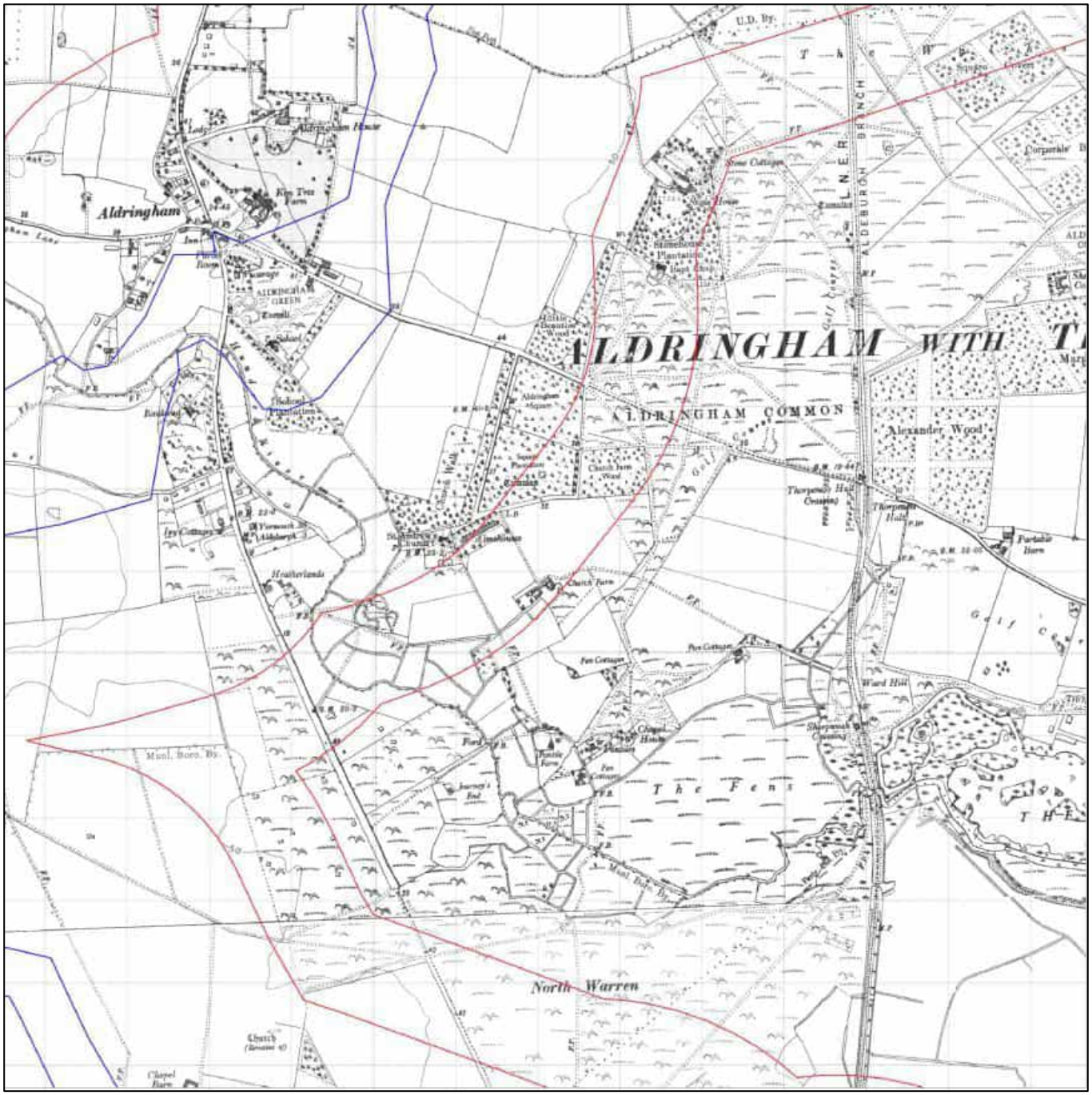
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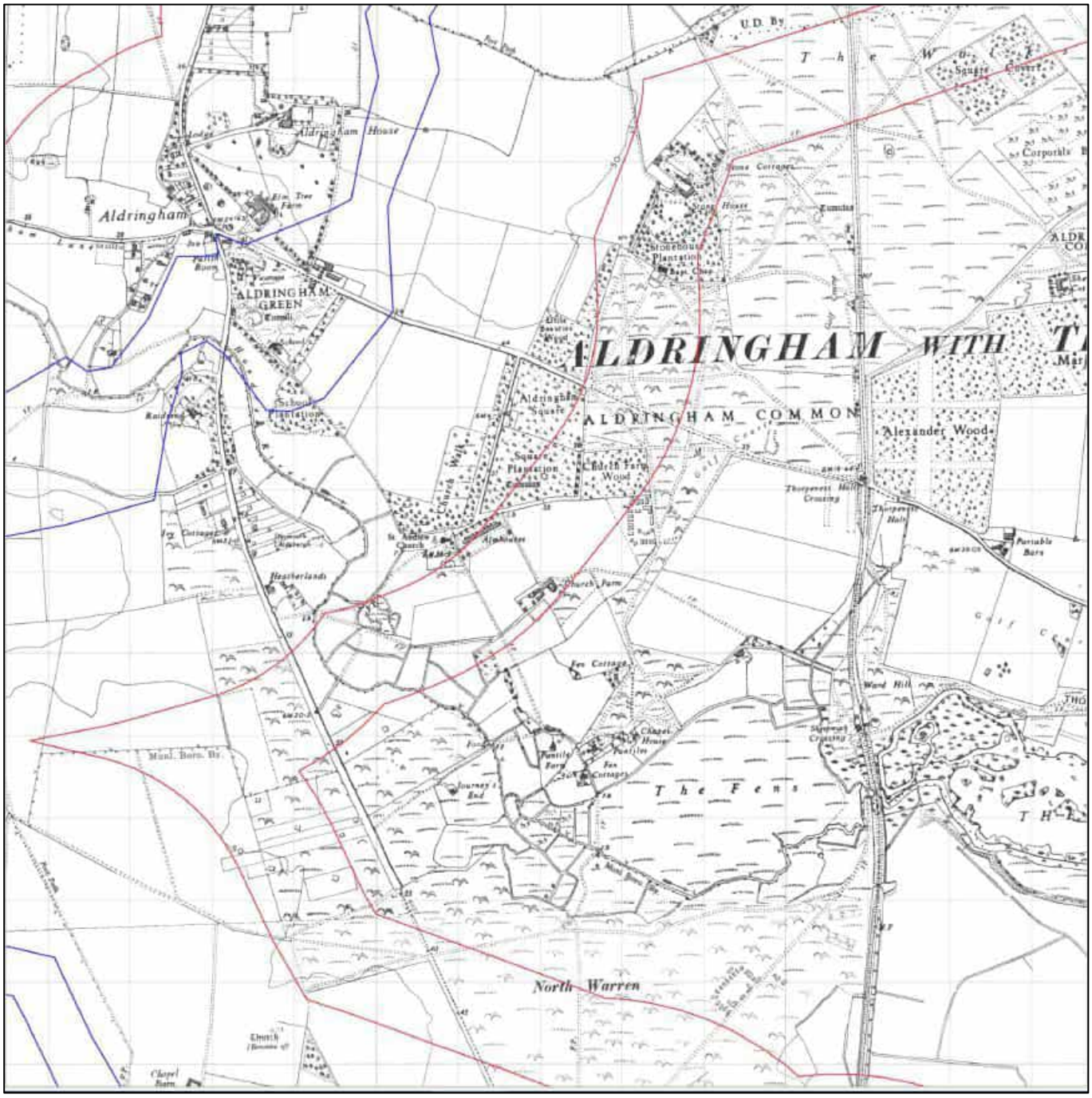
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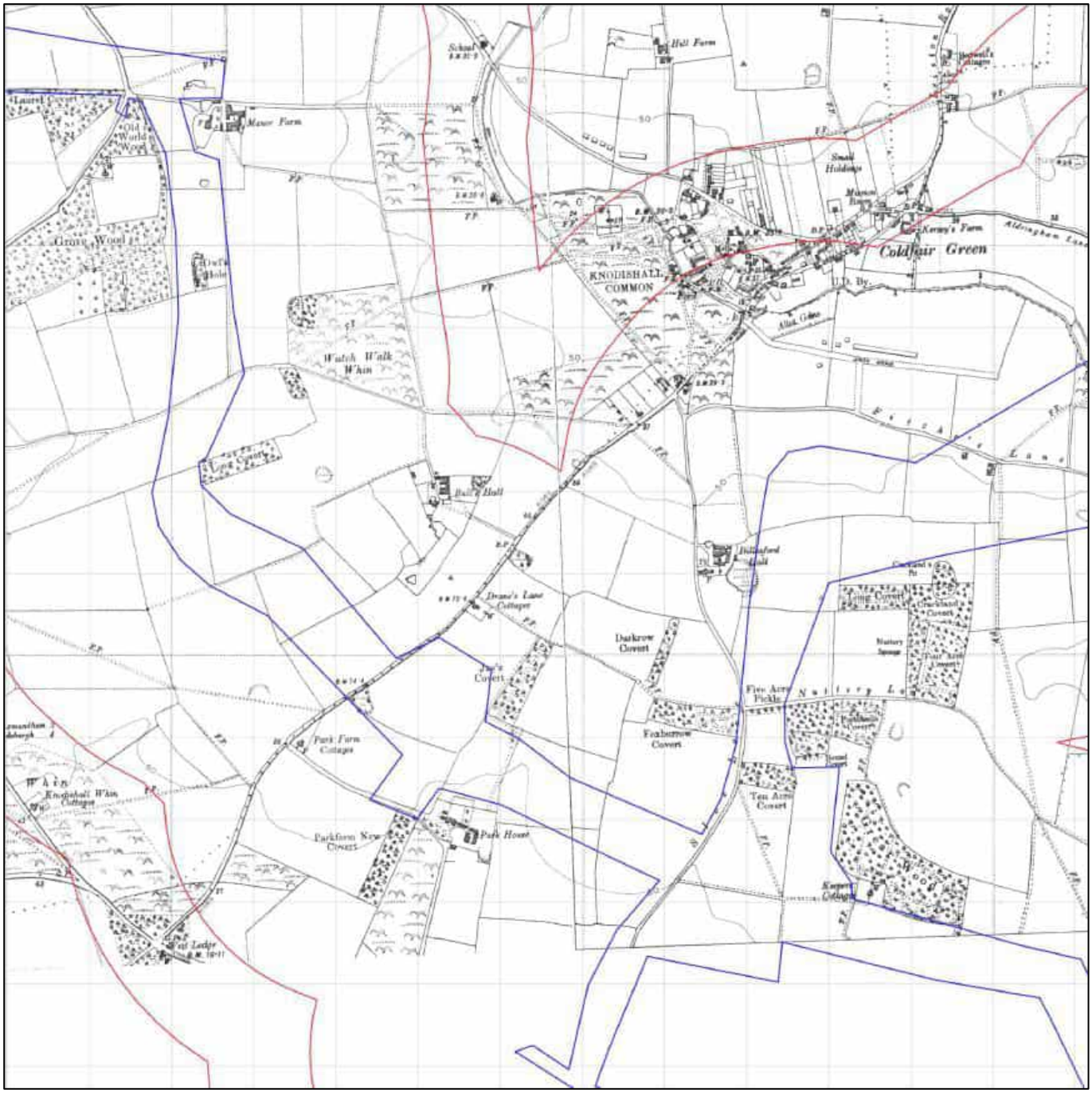
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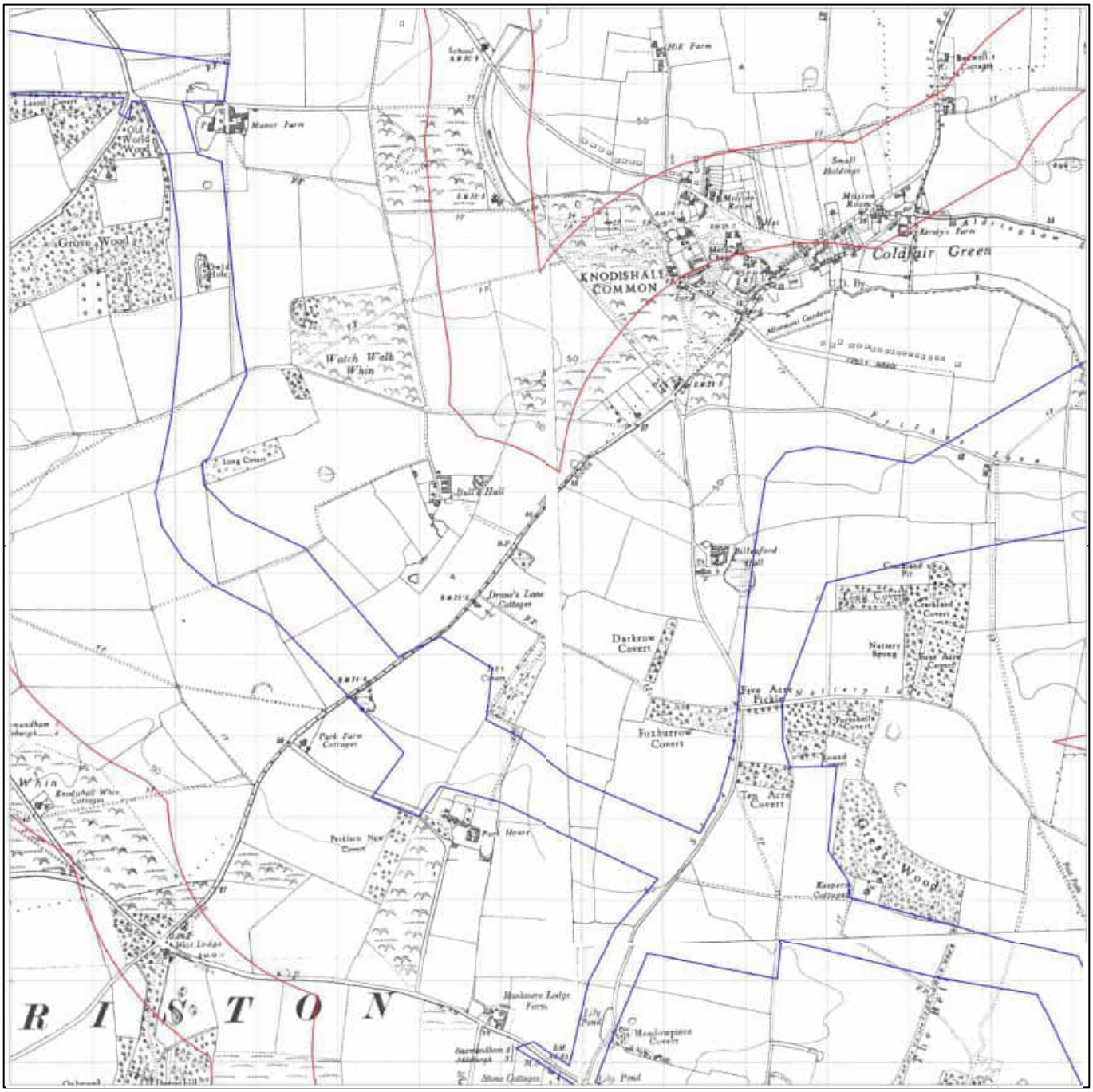
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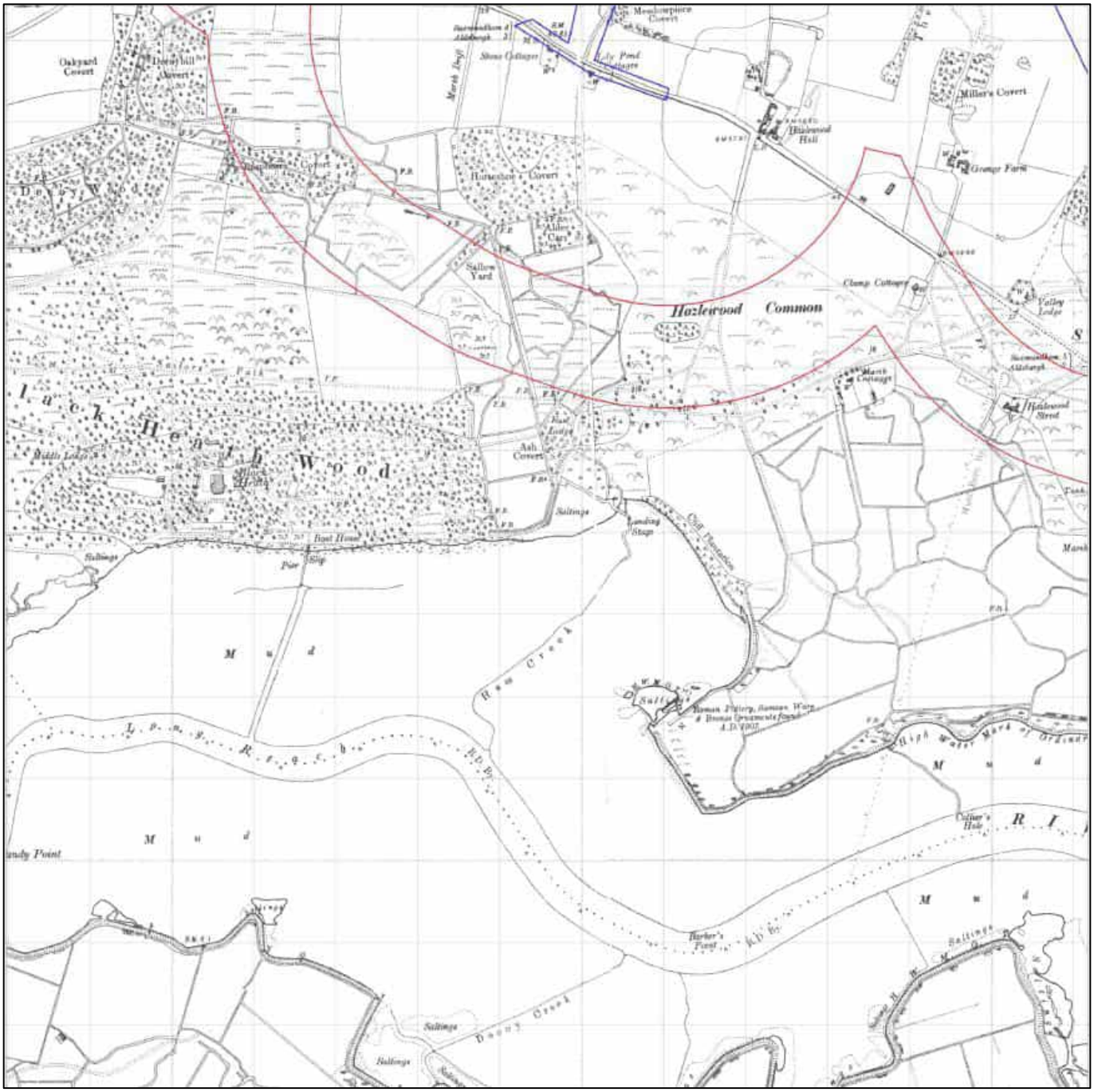
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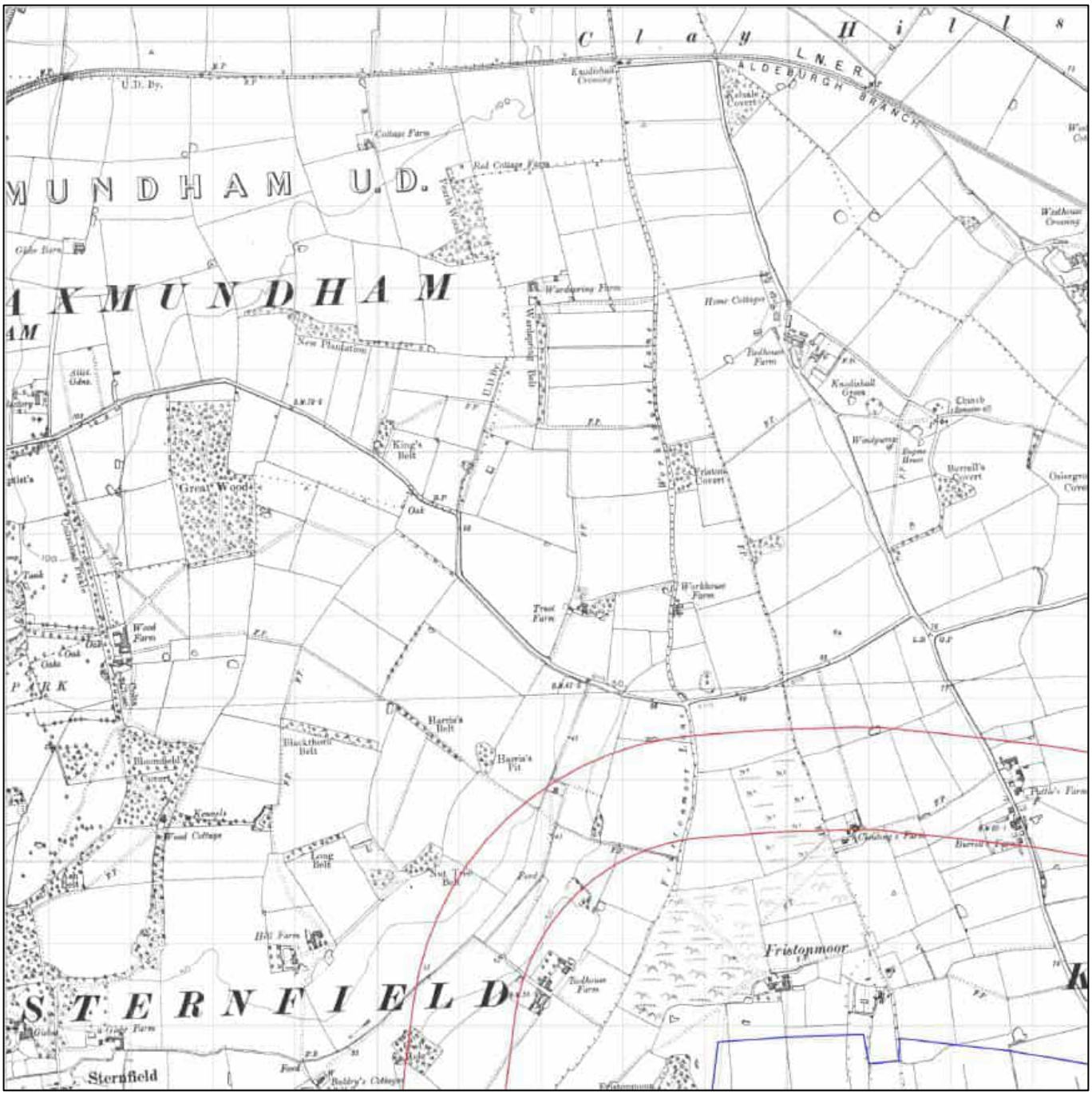
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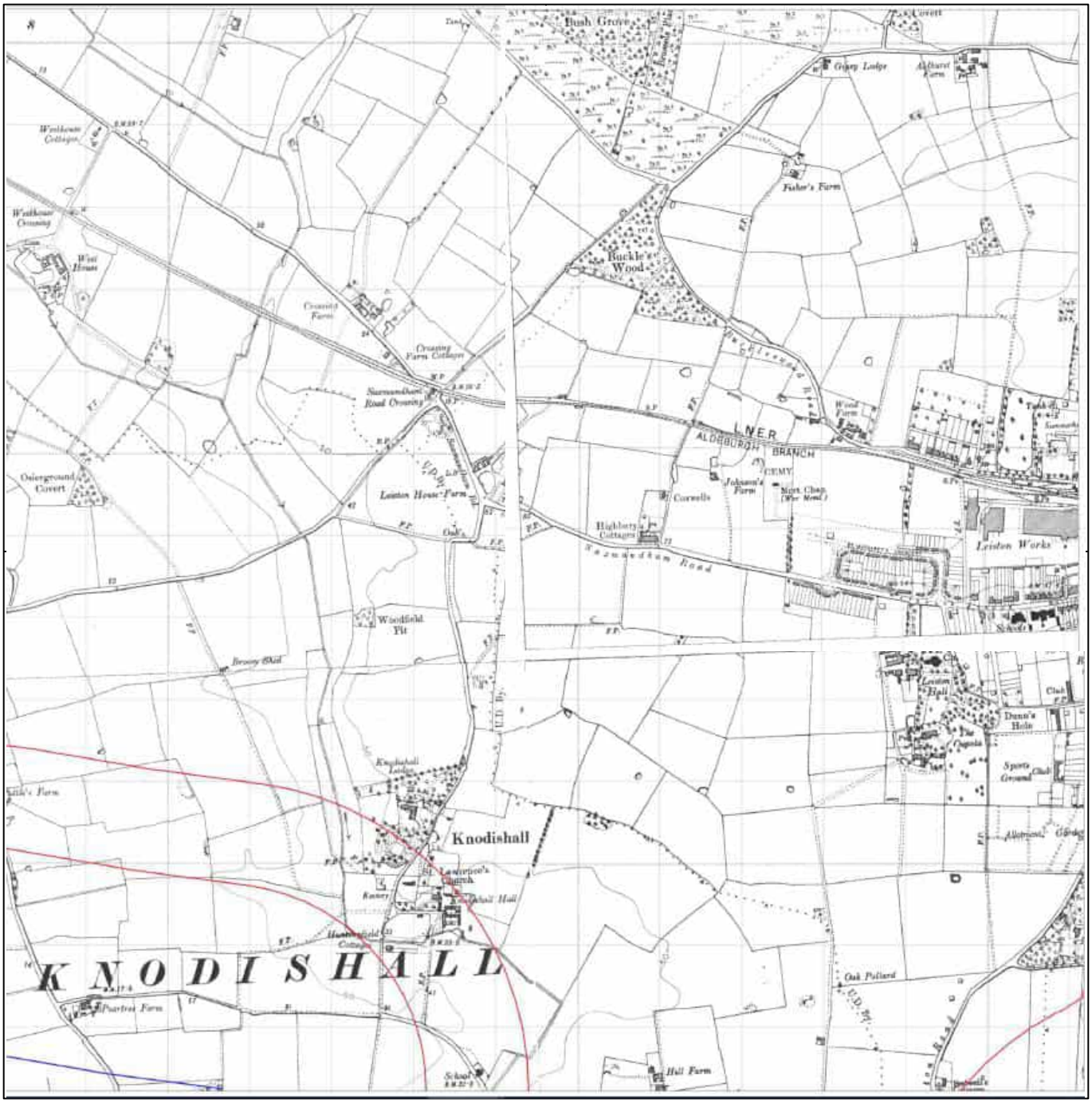
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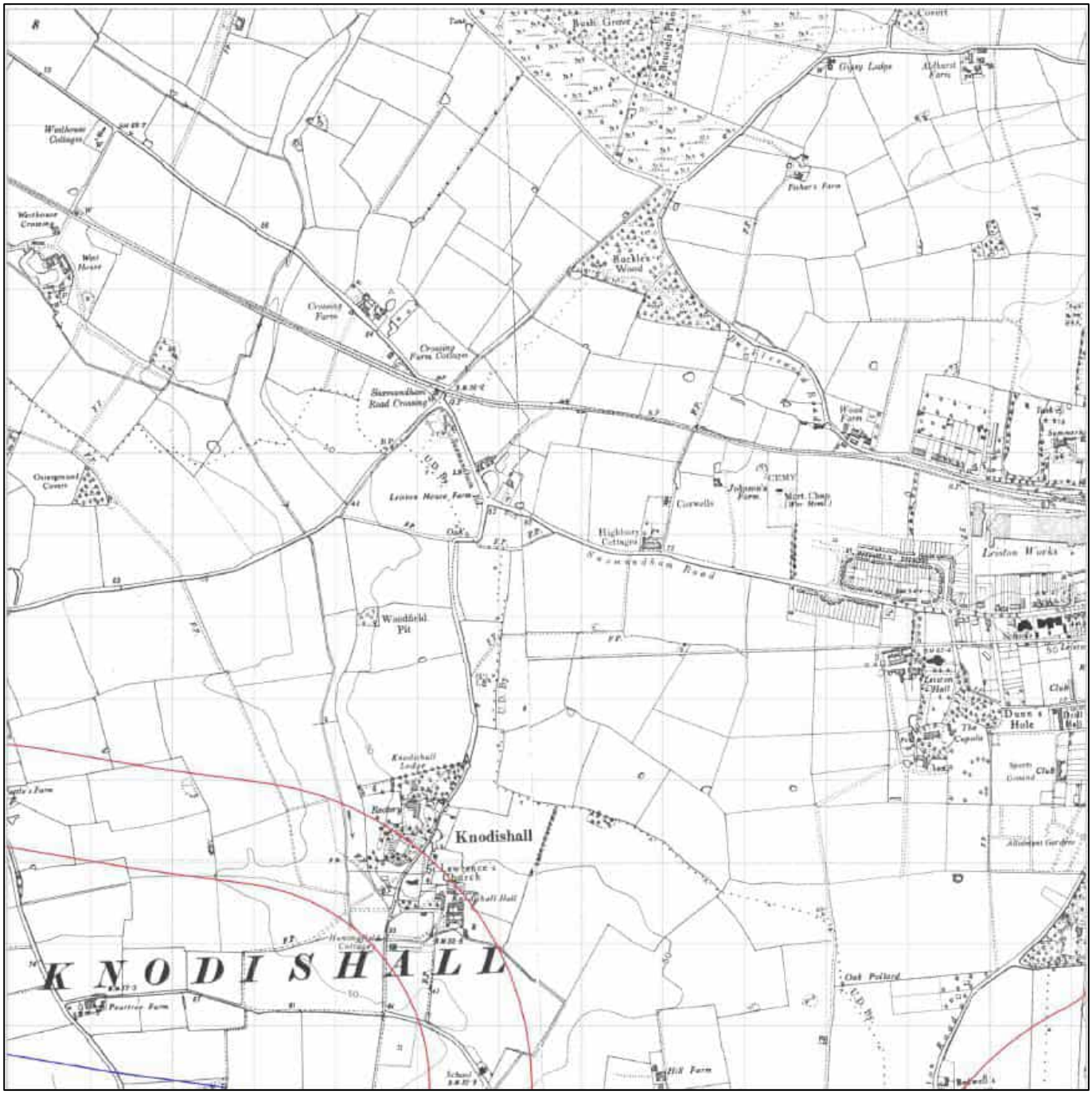
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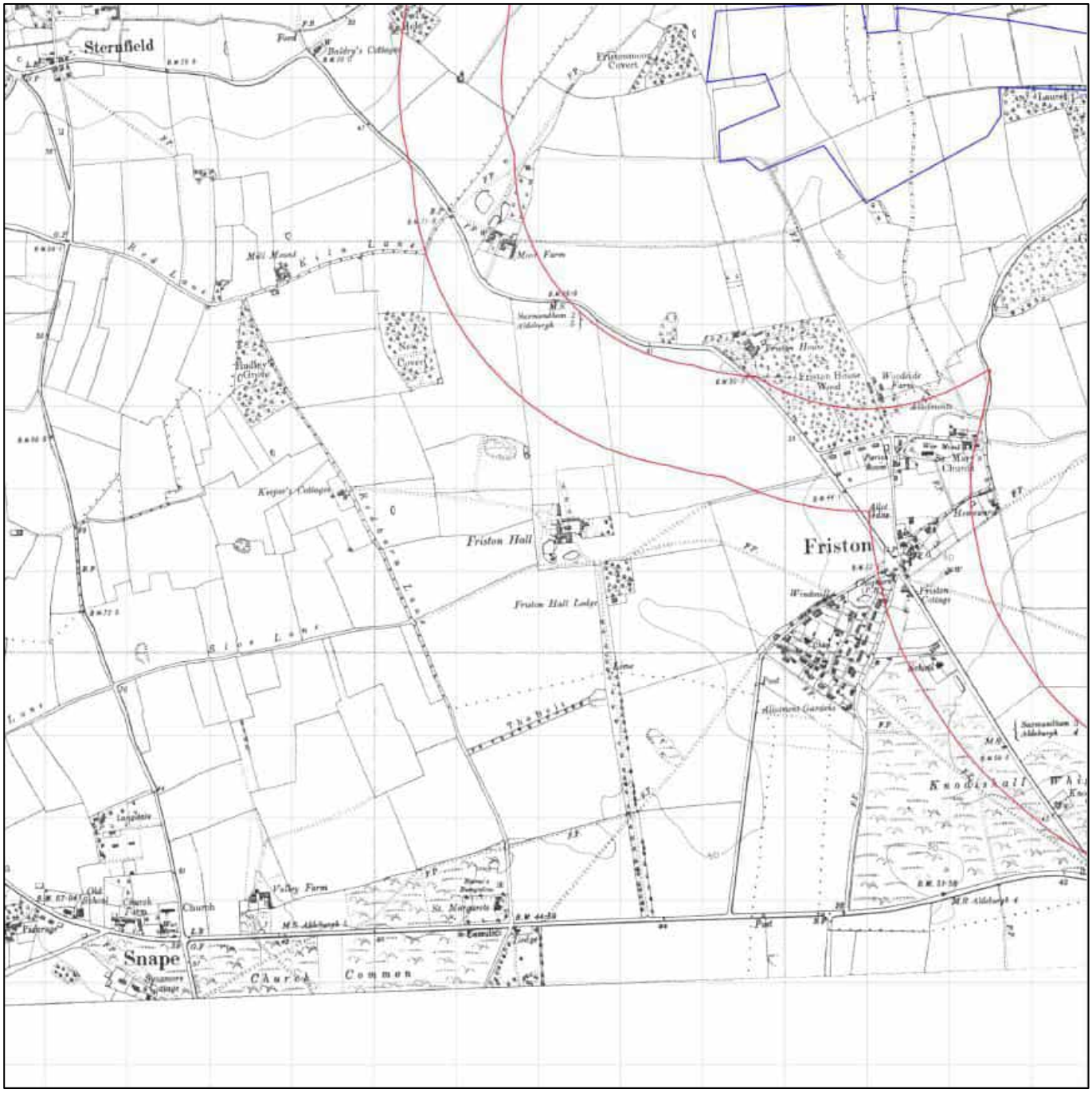
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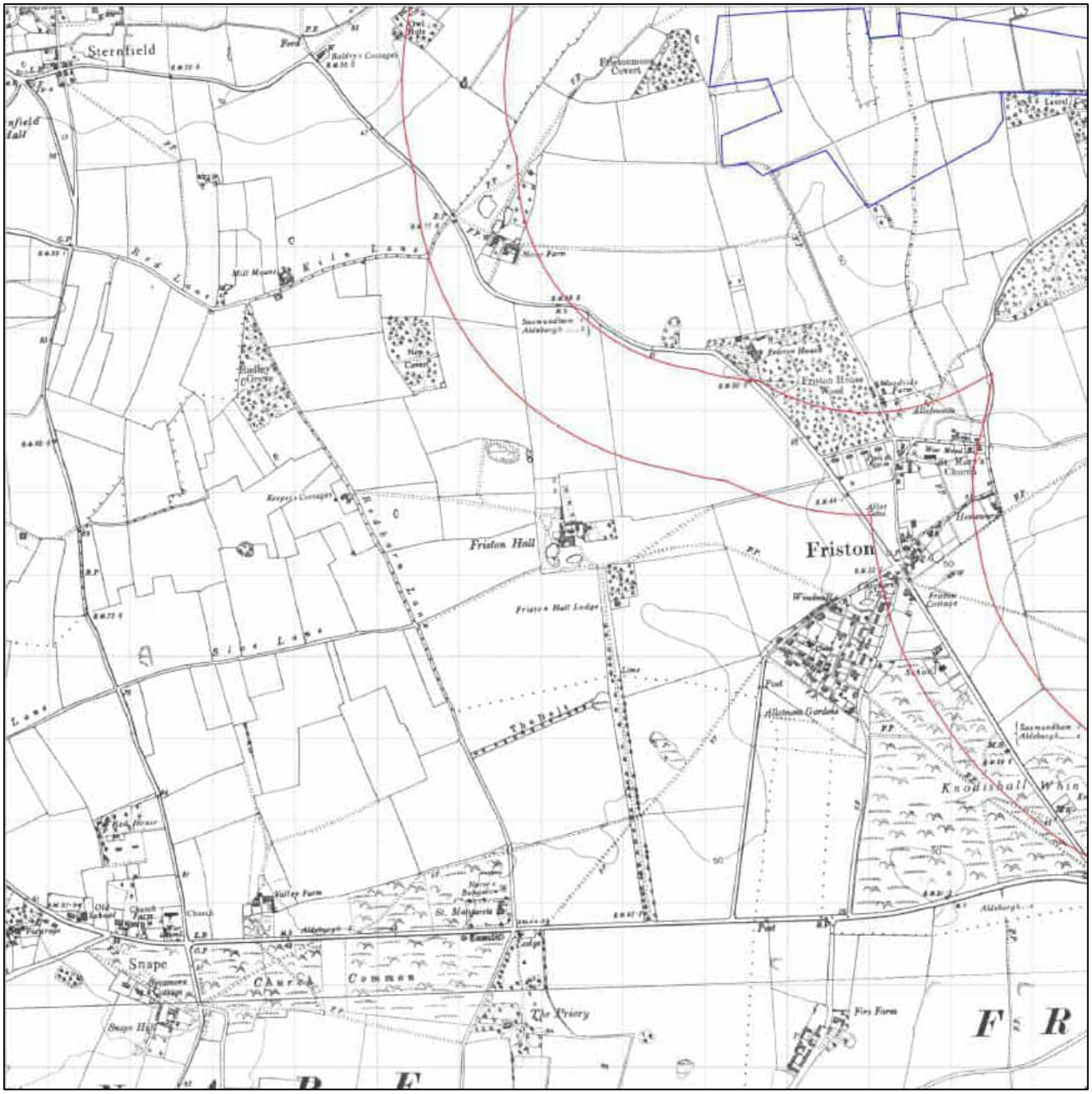
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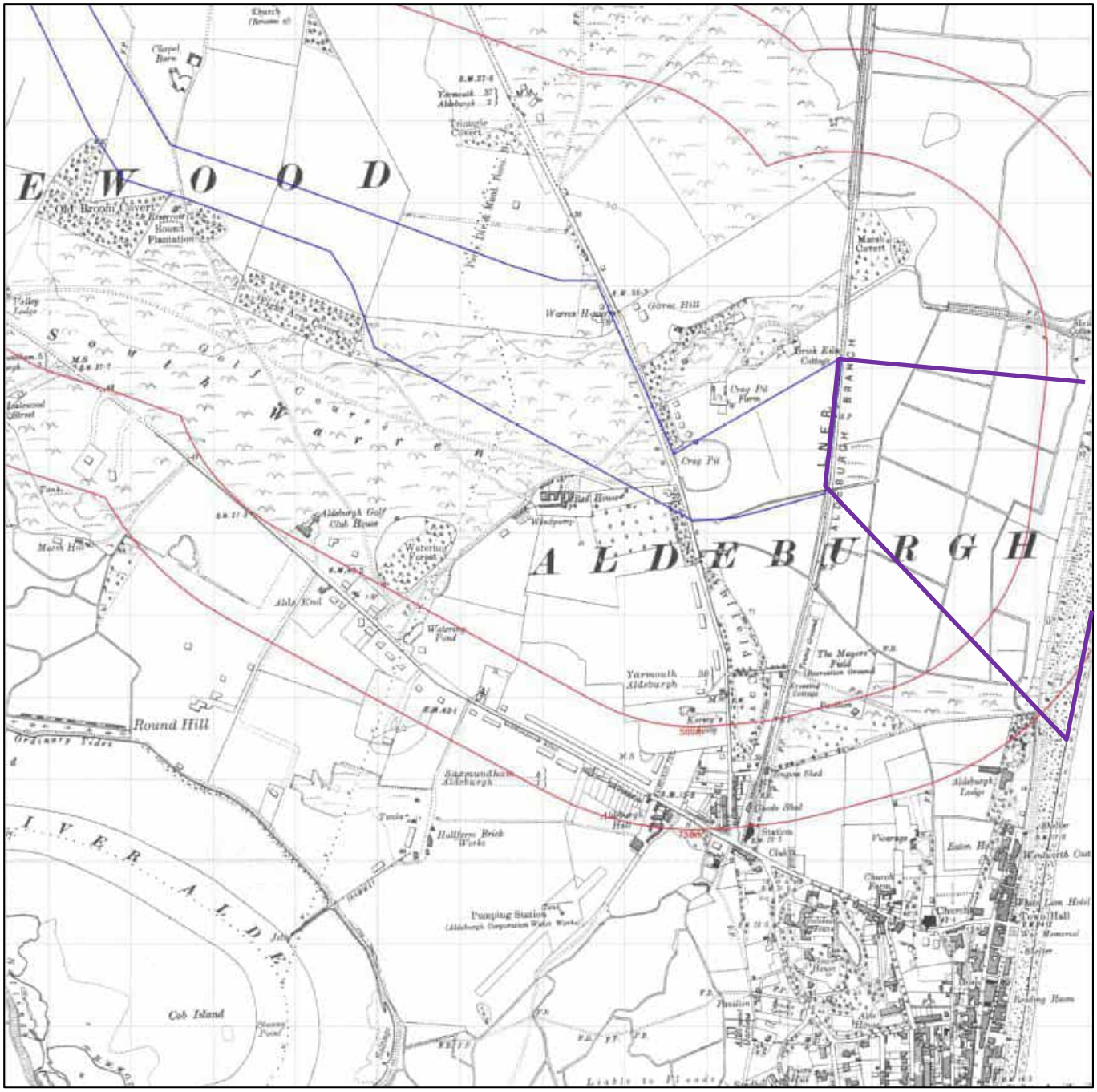
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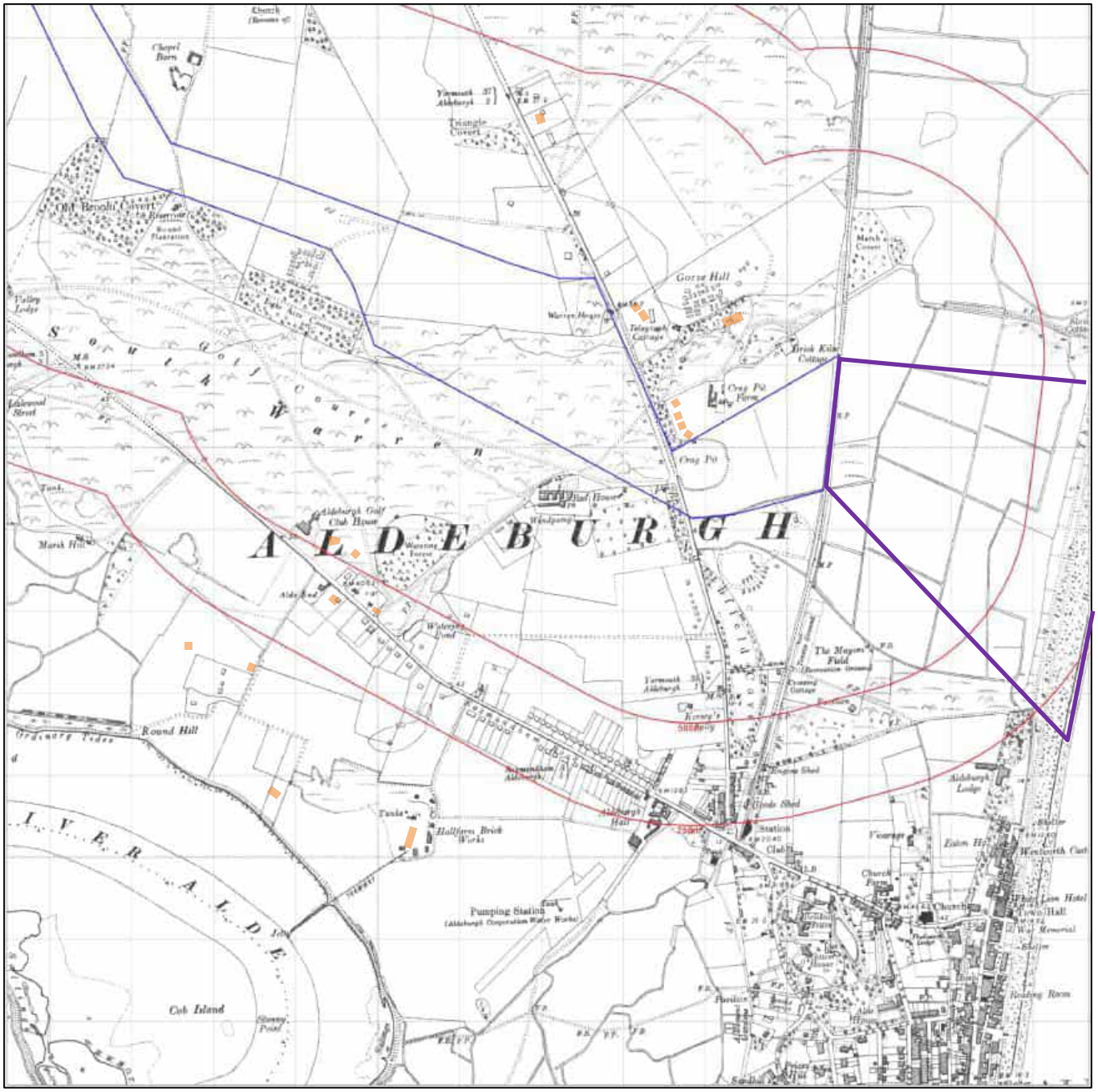
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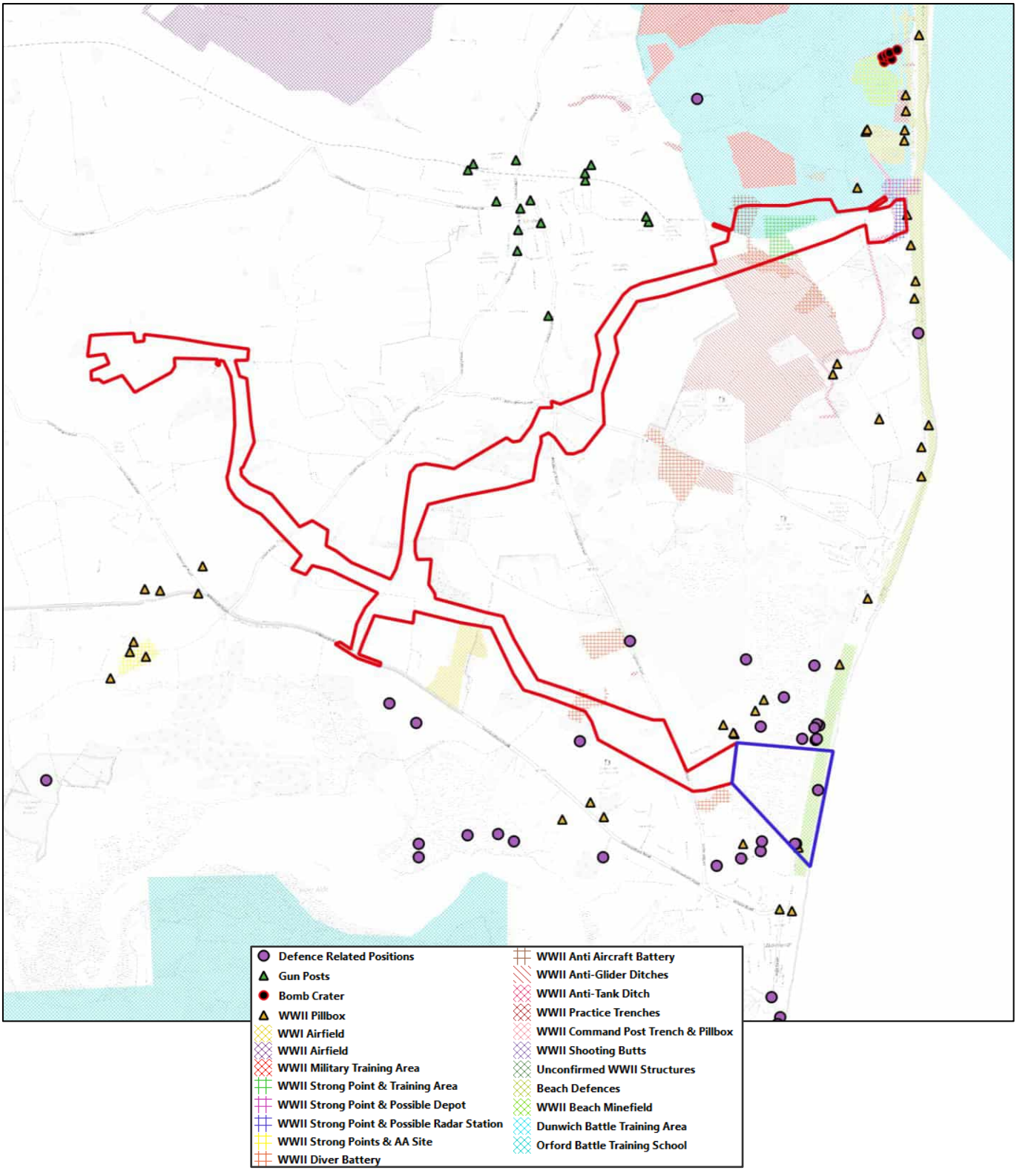
Clearance

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Potential Risk Contributors - Overview

Annex
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9758-1 RA

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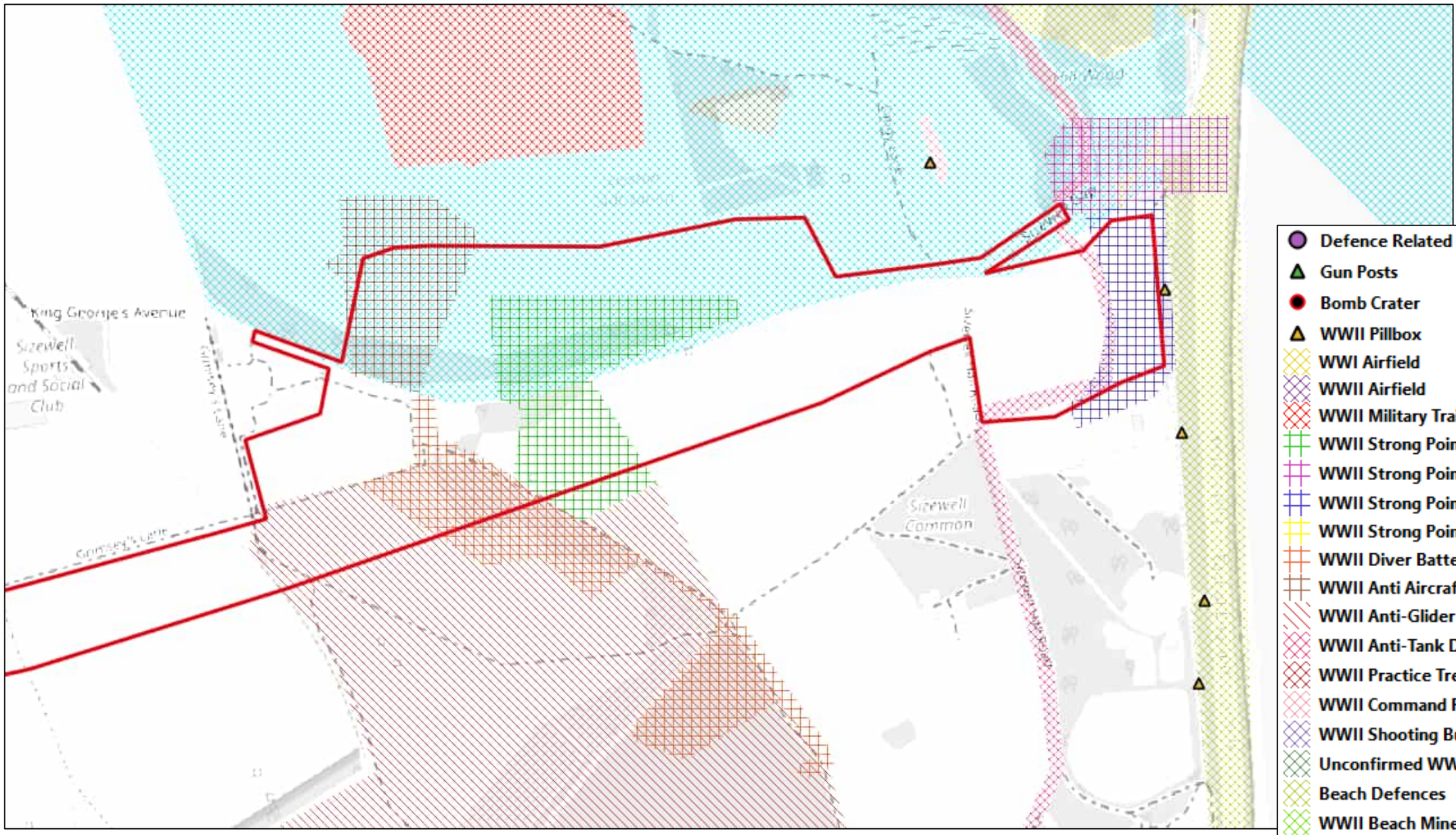
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SafeLane Global & Various Historical Sources

Potential Risk Contributors - Northern Section

N



- Defence Related Positions
- Gun Posts
- Bomb Crater
- WWII Pillbox
- WWI Airfield
- WWII Airfield
- WWII Military Training Area
- WWII Strong Point & Training Area
- WWII Strong Point & Possible Depot
- WWII Strong Point & Possible Radar Station
- WWII Strong Points & AA Site
- WWII Diver Battery
- WWII Anti Aircraft Battery
- WWII Anti-Glider Ditches
- WWII Anti-Tank Ditch
- WWII Practice Trenches
- WWII Command Post Trench & Pillbox
- WWII Shooting Butts
- Unconfirmed WWII Structures
- Beach Defences
- WWII Beach Minefield
- Dunwich Battle Training Area
- Orford Battle Training School

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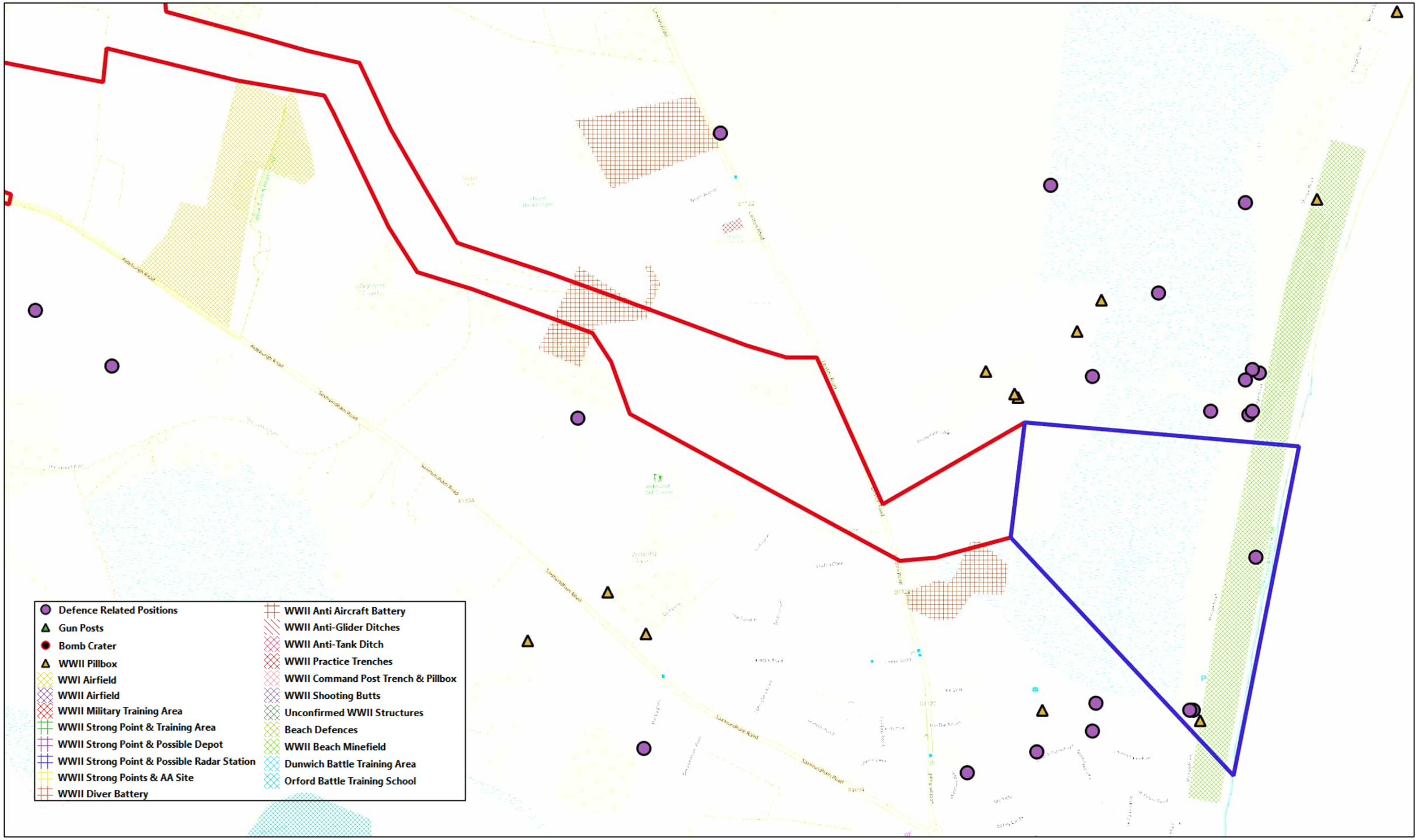
SafeLane Global & Various Historical Sources

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Potential Risk Contributors - Southern Section

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Approximate site boundary

Extension site boundary

SafeLane Global & Various Historical Sources

WWII-era RAF Aerial Photography – 26th August 1942



Approximate site boundary

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WWII-era RAF Aerial Photography – 26th August 1942

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WWII-era RAF Aerial Photography – Circa. 1945

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WWII-era RAF Aerial Photography – Circa. 1945

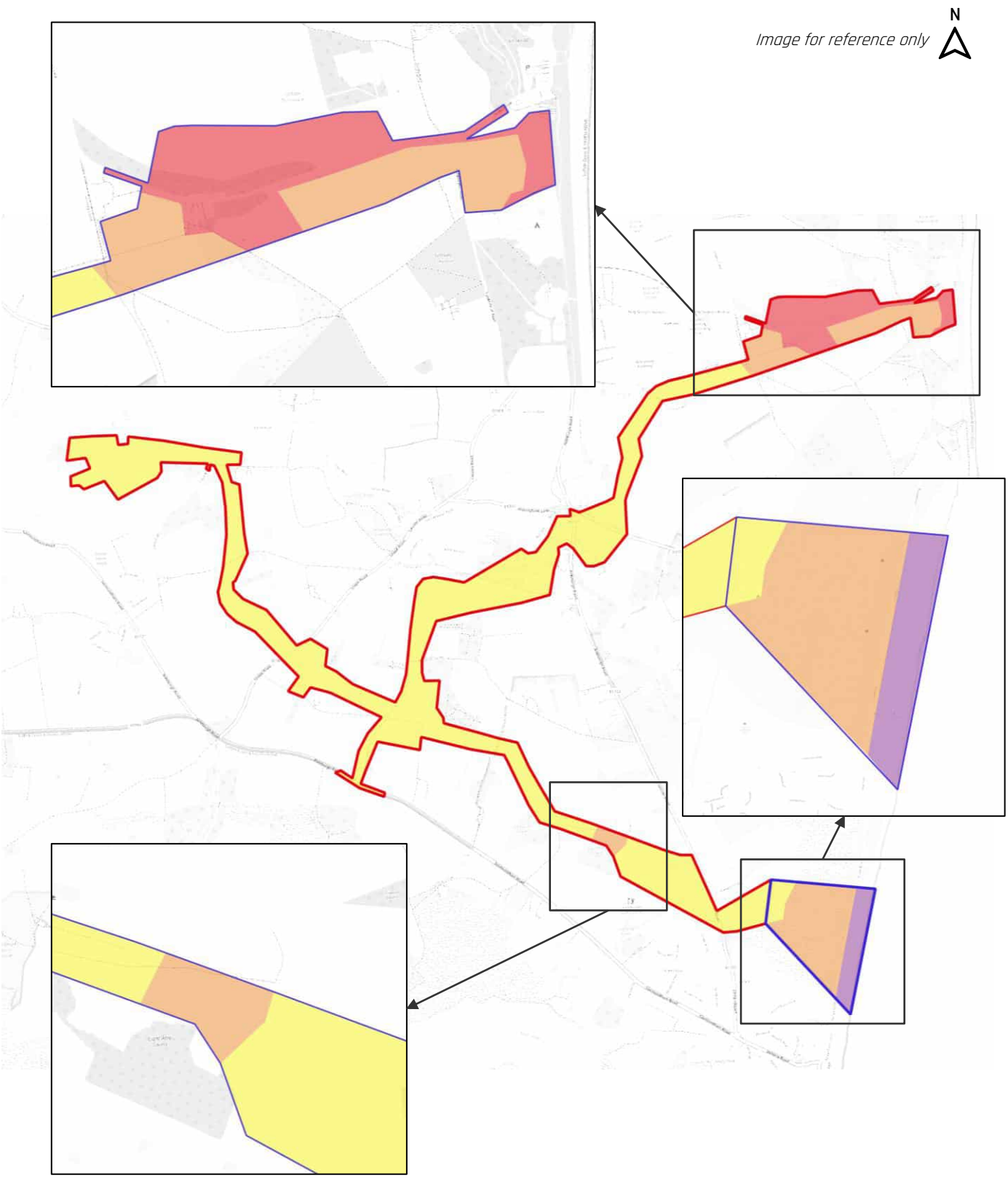
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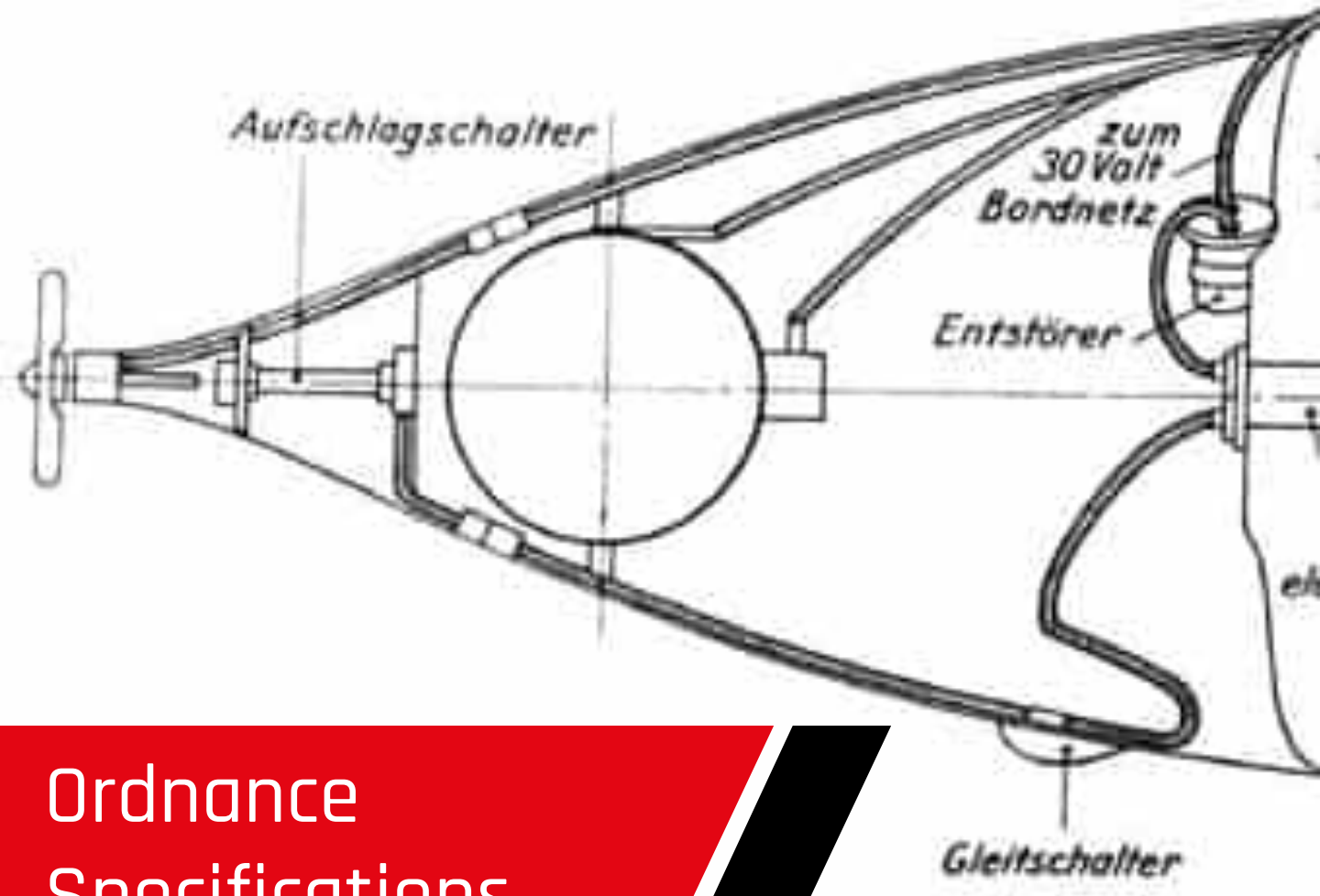
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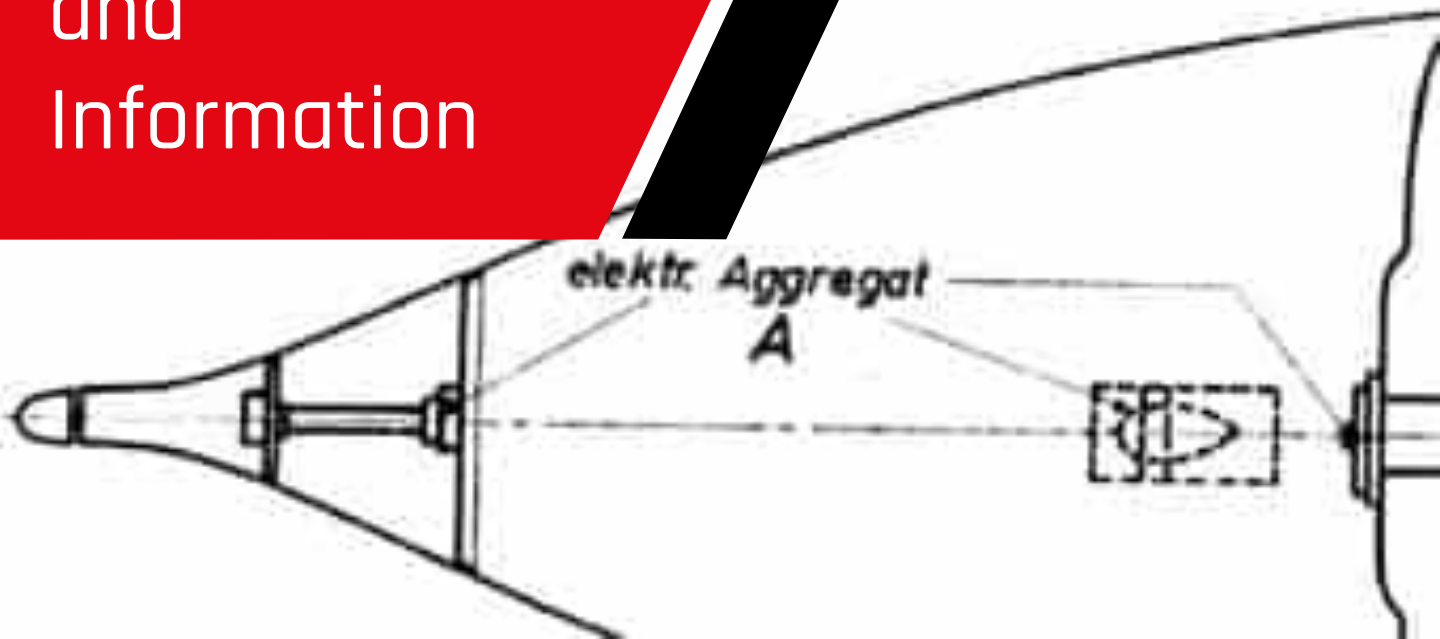
Please see Executive Summary or Section 12 for recommended scope-specific UXO risk mitigation measures.

Medium Risk Zone 1 | Medium Risk Zone 2 | High Risk Zone 1 | High Risk Zone 2

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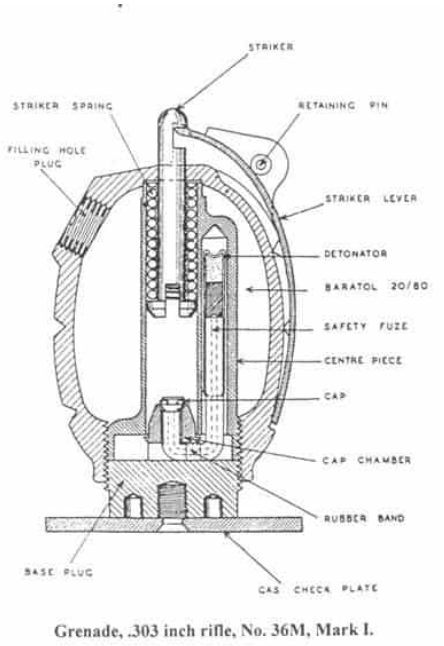
Ordnance Specifications and Information





British & Allied Ordnance



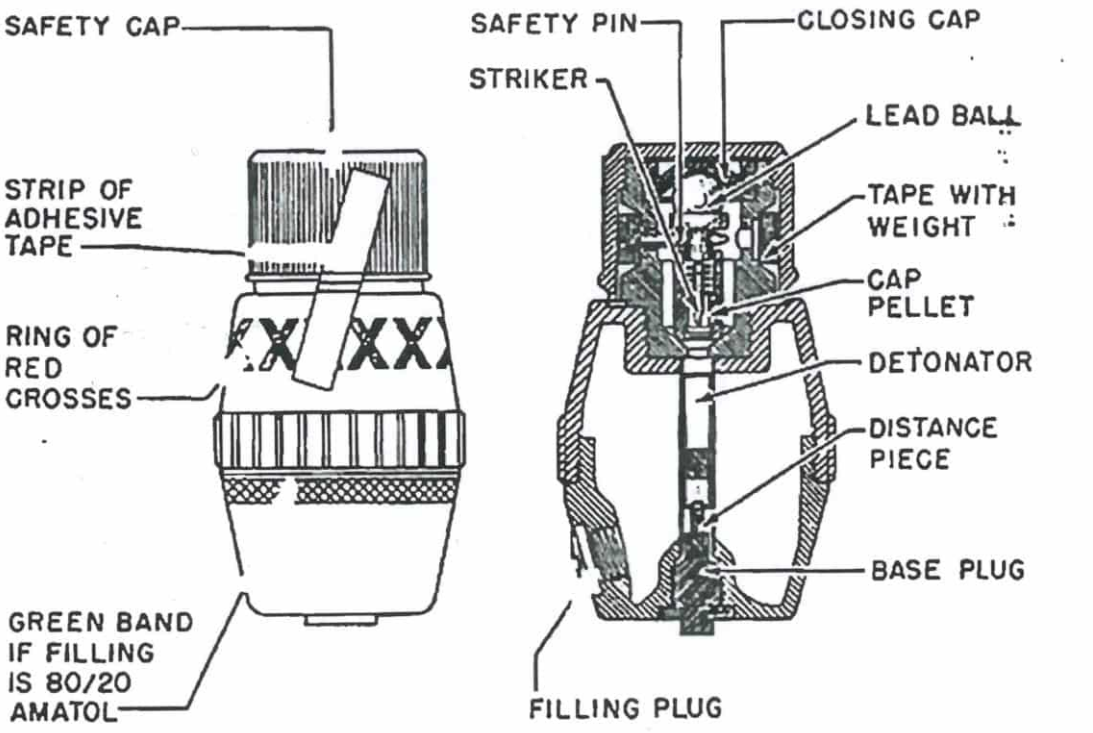


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



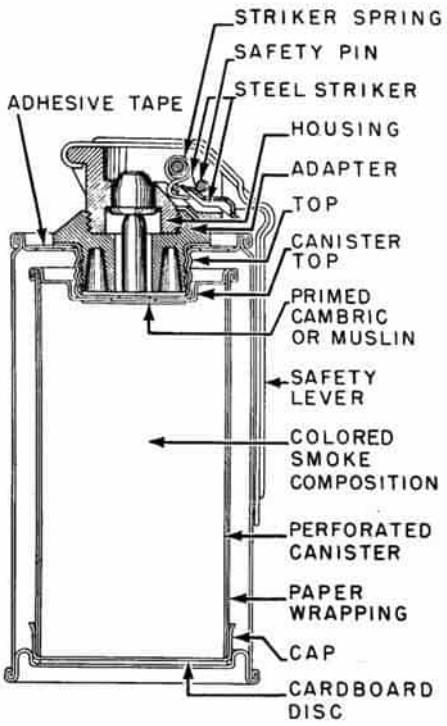


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





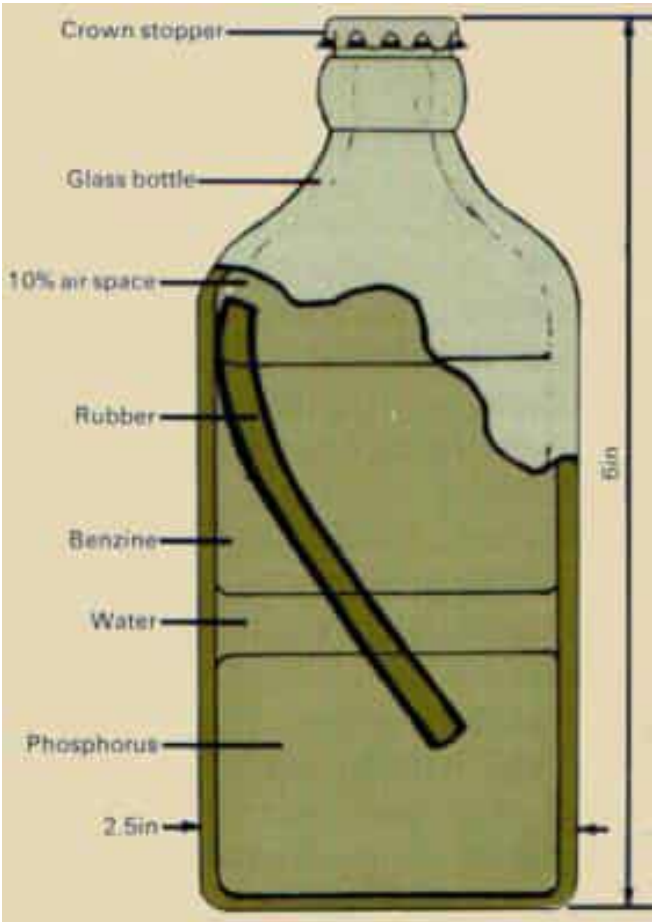


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

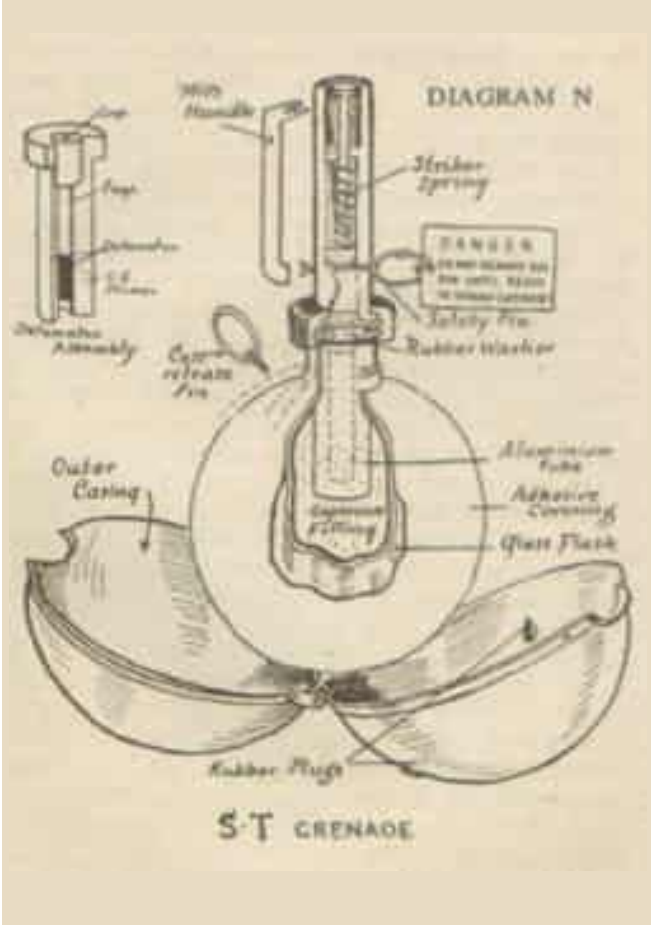






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

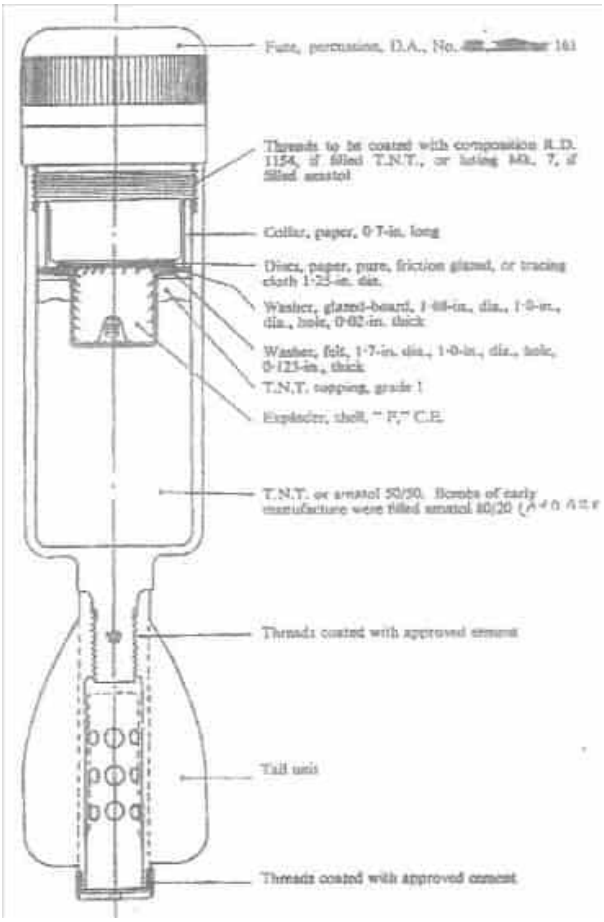






Typical 2" High Explosive Mortar

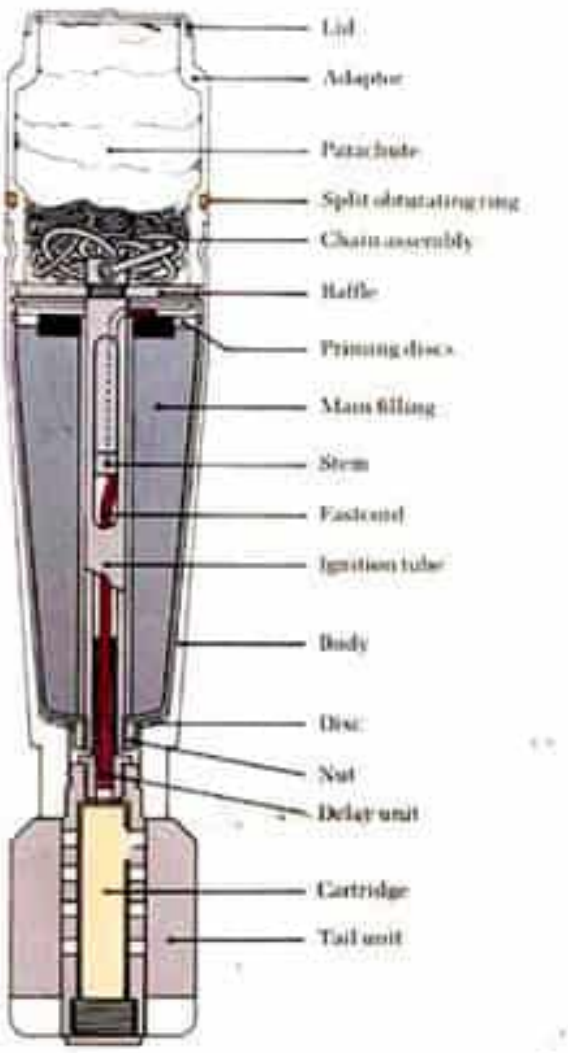
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







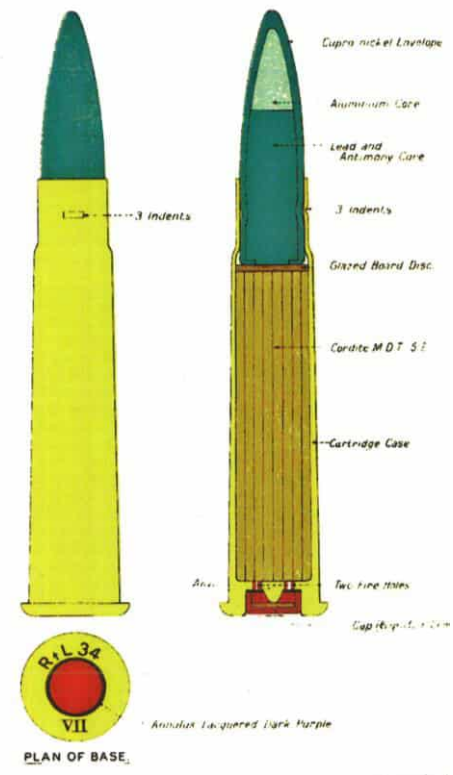


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



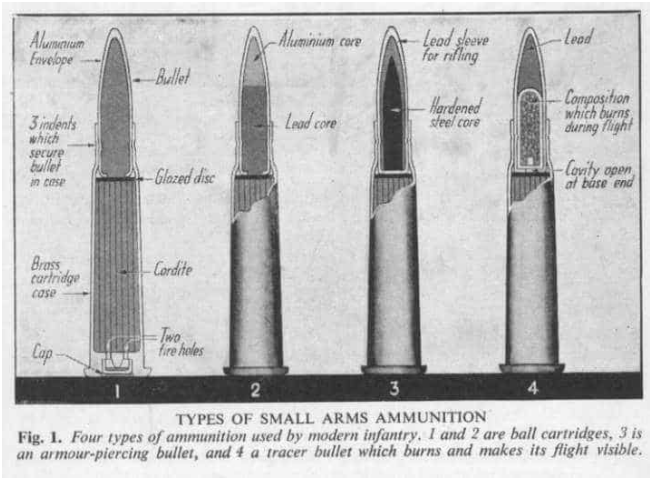




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



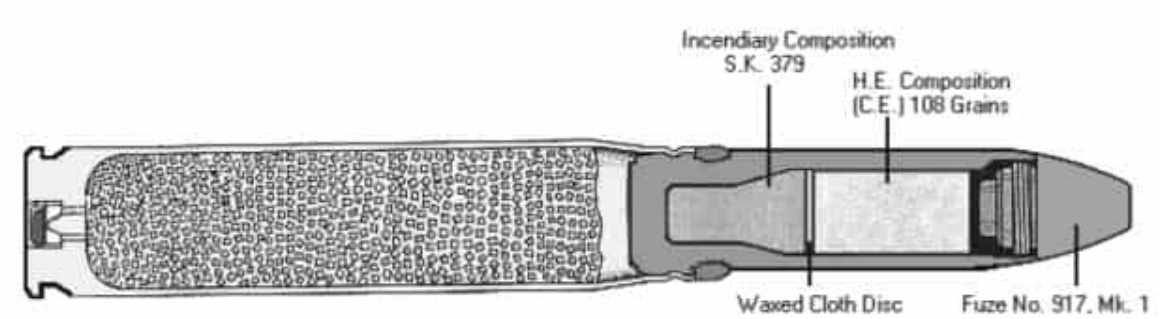


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

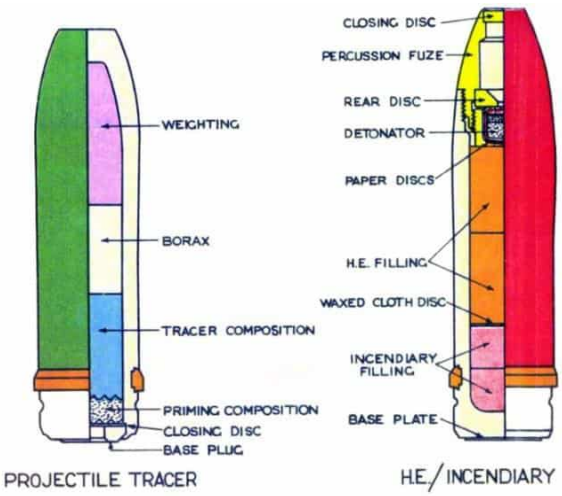




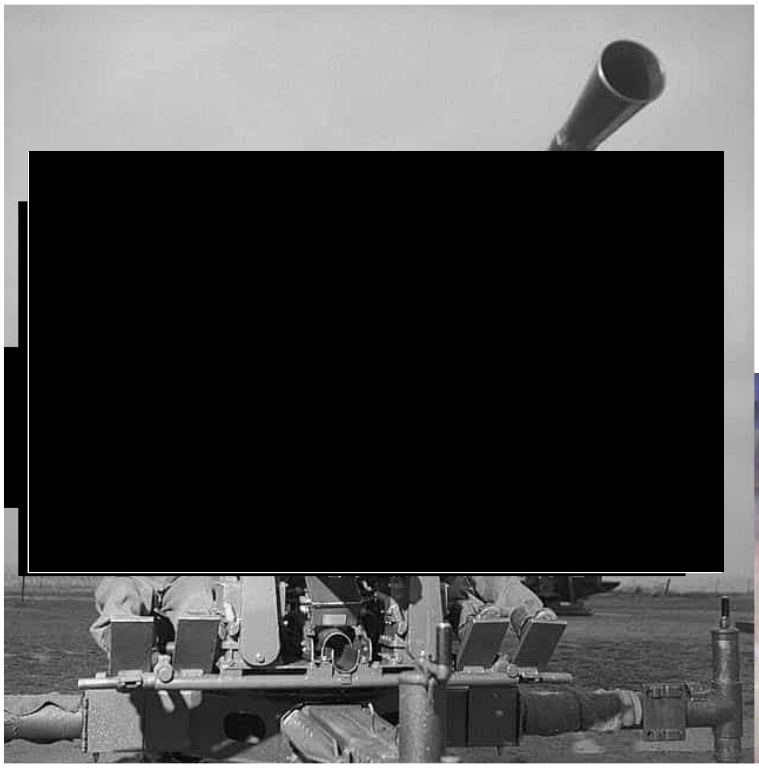


20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	

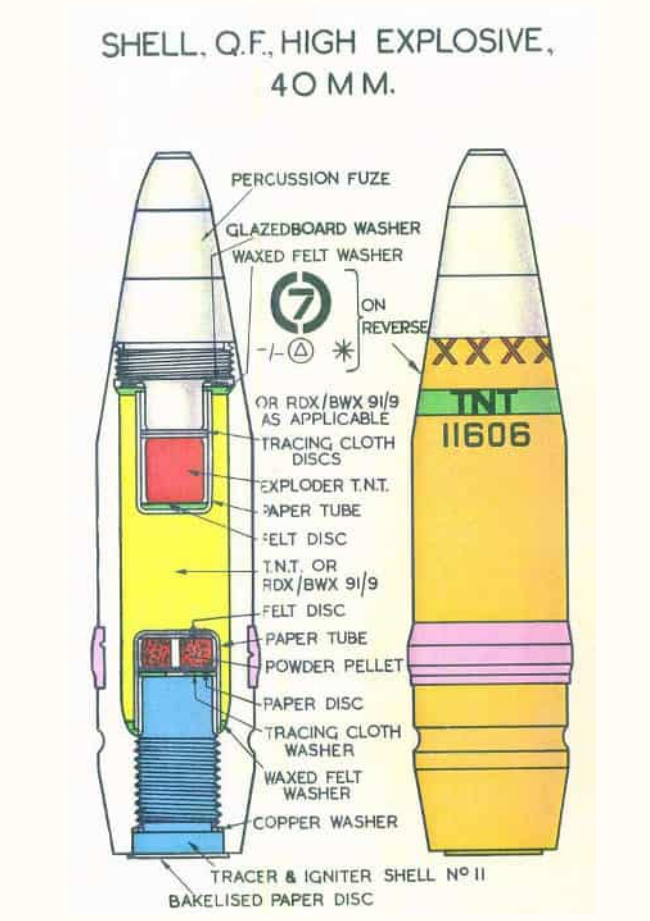






40mm Bofors Gun Projectile

Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

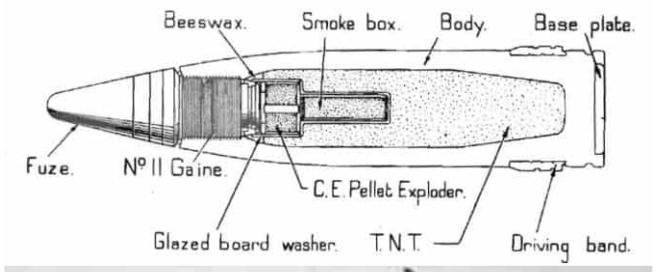




3.7" Anti-Aircraft Projectile

Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.







Miscellaneous Military Contamination: Detonators, Flares, Fuzes

When working on land currently or historically used by the military, all manner of explosive ordnance-related items dating back over 100 years could be encountered. These may include practice (dummy) items, experimental weapons and other miscellanea such as detonators, flares and fuzes. It should be noted that, although small, detonators contain enough primary explosive to cause serious injury.

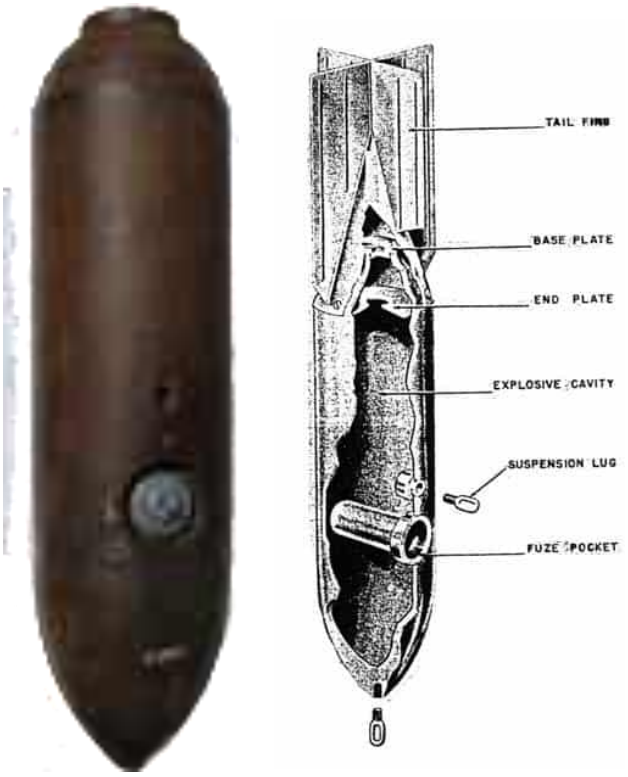








German Ordnance





Sprengbombe Cylindrisch 50

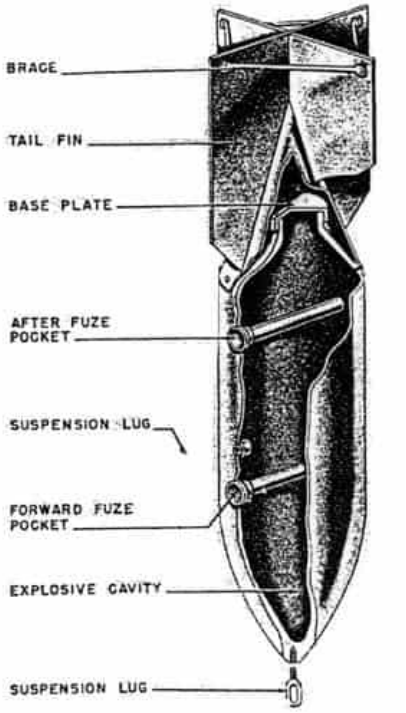
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

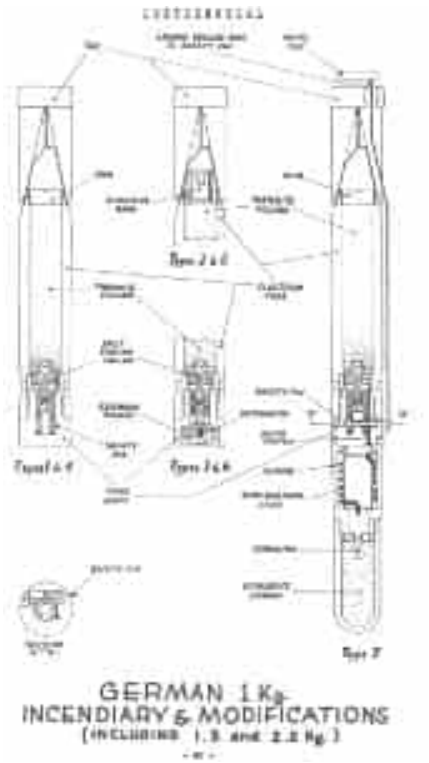
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









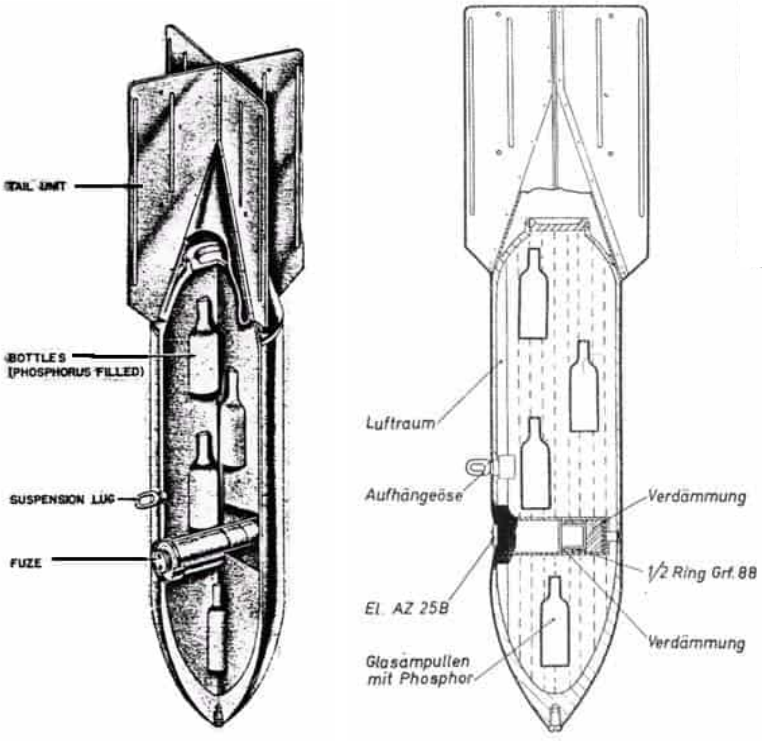
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

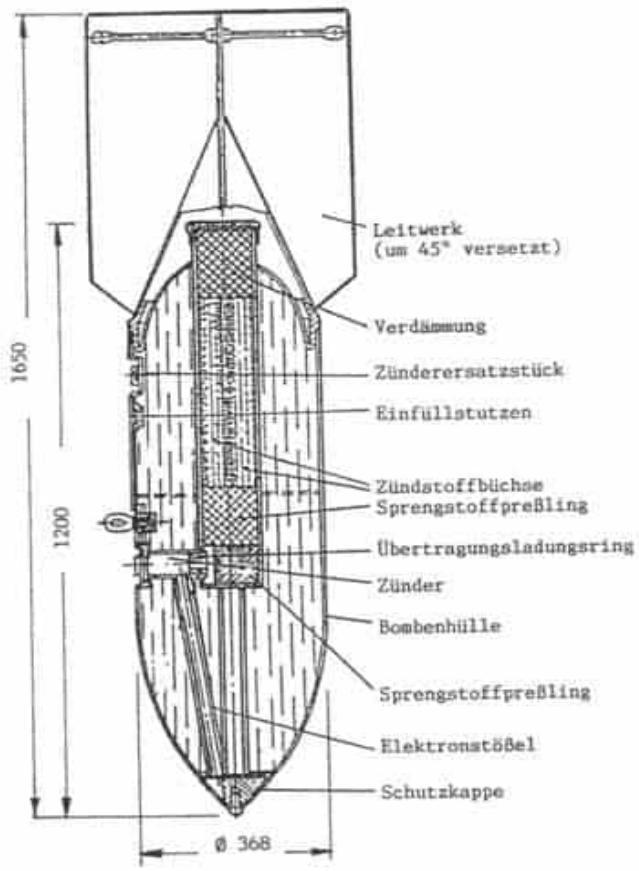






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

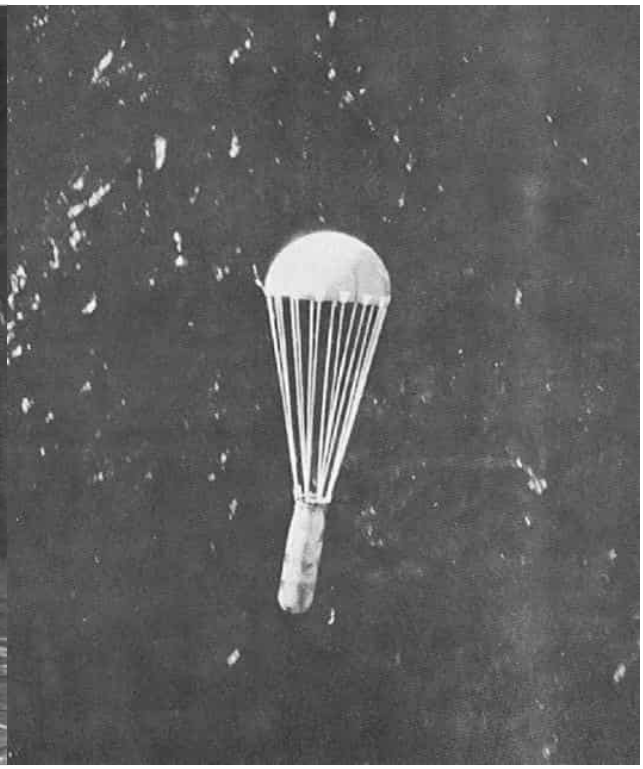




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration





Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg

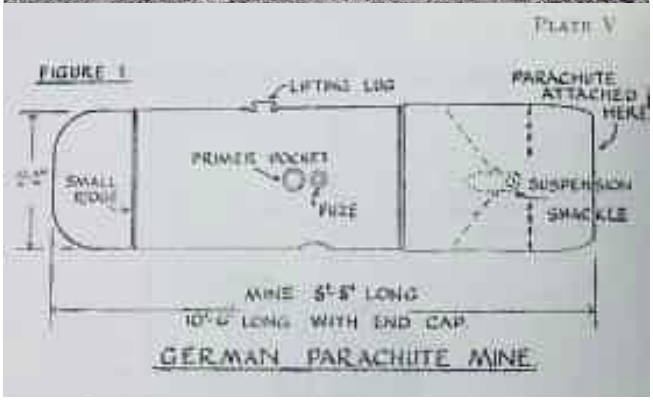
Fuze Type: Mechanical clockwork fuze

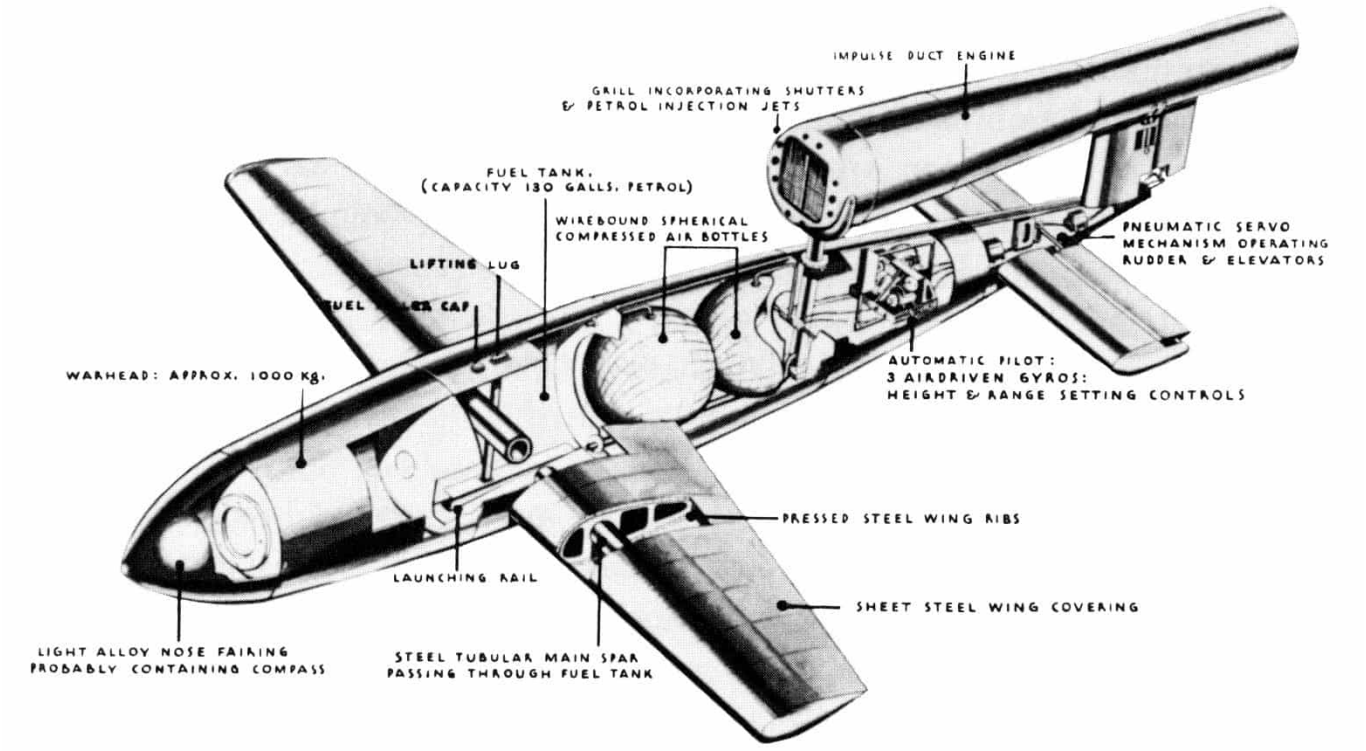
Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

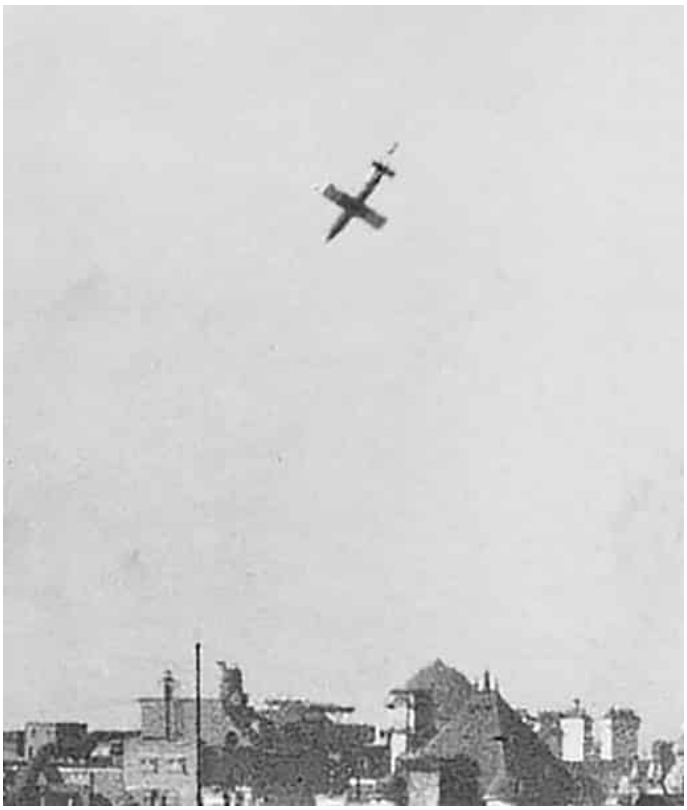




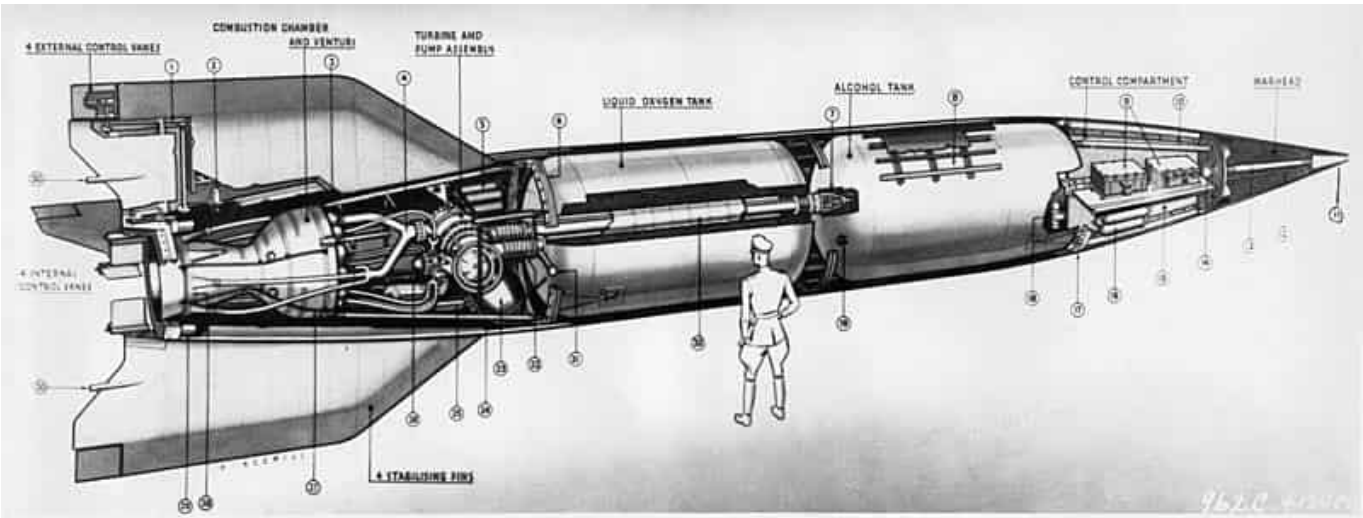


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.



SAFELANE
GLOBAL





Detailed Unexploded Ordnance Risk Assessment

In Respect Of:
Sea Link Outline, Suffolk - Revision

For:
Mott MacDonald Ltd

Report Reference:
9758-2 RA



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2020
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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry. This report has been compiled using all due diligence and expertise and having made all proper but reasonable enquiries within given time limitations. However, in accepting and implementing the recommendations contained in this report, the client does so strictly at his own risk.

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Executive Summary

The Site	
Address:	Leiston Road, Sternfield, Suffolk IP17 1TG
OS National Grid Reference:	TM 39343 62967
Site Description:	The site is irregular in shape, located between Friston and Saxmundham. The study area comprises agricultural, open fields. Access to the site is gained through Liston Road which runs adjacent to the site's northern boundary. An additional section of land (highlighted in blue) is present to the north of the site. This section largely comprises open ground, overlapping onto Priors Grange in the west.
Proposed Works	
Ground investigation will comprise boreholes to a depth of between 15 and 35m bgl and trial pits to max. 4m depth.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**MEDIUM from the following UXO types:** • German Air-Delivered HE bombs • Anti-Aircraft Projectiles
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	
Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **8-10m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Recommended Risk Mitigation

Risk Level	Planned Site Activity	Recommendations
Medium	**Shallow Intrusive Works eg excavations**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only)

		• Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.		

Table of Contents

Distribution i
Executive Summary ii
Table of Contents iv
List of Annexes vi
Appendices vi
Glossary of Terms vii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations *4*
4.5.2 Bombing Records *5*
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Pre and Post-WWII OS Mapping 7
7.1 Area Observations 7
7.2 Additional Notes 14
8 The Threat from Aerial Bombing 14
8.1 General Bombing History of Suffolk 14
8.1.1 First World War *14*
8.1.2 Second World War *14*
8.2 Generic Types of WWII German Air-delivered Ordnance 15
8.3 Second World War Bombing Statistics 16
8.4 Site Specific WWII Bombing Records 17
8.4.1 Original ARP Bombing Incident Records *17*
8.4.2 Home Office Intelligence Reports *17*
8.4.3 Secondary Source / Anecdotal Evidence *18*
8.4.4 WWII-era RAF Aerial Photography *19*
8.4.5 Bombing Decoy Sites *19*
8.4.6 Abandoned Bombs *20*
8.5 UXB Ground Penetration 20
8.5.1 General Considerations *20*
8.5.2 The "j" Curve Effect *20*
8.5.3 Second World War Bomb Penetration Studies *21*

8.5.4 CIRIA Bomb Penetration Depth Specifications ... *22*
8.5.5 Site Specific Bomb Penetration Considerations ... *22*
8.6 Likelihood of Post-raid UXO Detection ... 23
8.6.1 Density of Bombing ... *23*
8.6.2 Bomb Damage ... *23*
8.6.3 Frequency of Access ... *23*
8.6.4 Ground Cover ... *24*
8.6.5 German Air-Delivered Ordnance Failure Rate ... *24*
8.7 Site Specific Threat from German Air-Delivered Ordnance ... 25
9 The Threat from Allied Military Ordnance ... 29
9.1 Dunwich Heath Training Area ... 29
9.2 RAF Leiston ... 30
9.3 Home Guard Activity ... 30
9.4 Anti-Aircraft Gun Batteries ... 32
9.5 Generic Types of WWII British / Allied Unexploded Ordnance ... 32
9.5.1 Land Service Ammunition (LSA) ... *32*
9.5.2 Small Arms Ammunition (SAA) ... *33*
9.5.3 Anti-Aircraft Shells ... *34*
9.6 Site-Specific Threat from Allied Military Ordnance ... 35
10 The Overall Unexploded Ordnance Risk Assessment Methodology ... 37
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance ... 38
10.1.1 General ... *38*
10.1.2 Likelihood of Contamination from German UXO ... *39*
10.1.3 Likelihood of Contamination from British / Allied UXO ... *40*
10.2 The Likelihood that Unexploded Ordnance Remains on Site ... 41
10.2.1 General ... *41*
10.2.2 EOD Bomb Disposal and Clearance Tasks ... *41*
10.2.3 Post War Redevelopment ... *41*
10.2.4 Site-Specific Analysis ... *42*
10.3 The Likelihood that Ordnance may be Encountered during the Works ... 42
10.4 The Risk that Ordnance may be Initiated ... 43
10.4.1 Initiation of Unexploded Bombs ... *43*
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance ... *44*
10.5 The Consequences of Encountering or Initiating Ordnance ... 45
11 SafeLane Global's Risk Assessment ... 49
11.1 Conclusions ... 49
12 Proposed Risk Mitigation Strategy ... 50
12.1 Summary ... 50
12.2 Additional Notes ... 51
Bibliography ... 55

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C British Geological Survey - Superficial Deposits

Annex D OS Mapping – Area Reference Map

Annex E Pre and Post-WWII OS Maps

Annex F WWII-era RAF Aerial Photography

Appendices

Ordnance Specifications and Information

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Sea Link Outline, Suffolk - Revision

1 Introduction

Groundsure Ltd, on behalf of Mott MacDonald Ltd, has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Sea Link Outline revised project site, Suffolk.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- RAF Aerial Collection.
- Groundsure Limited.
- Landmark Maps.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Leiston Road, Sternfield, Suffolk IP17 1TG	
OS National Grid Reference	TM 39343 62967	
Site Description	The site is irregular in shape, located between Friston and Saxmundham. The study area comprises agricultural, open fields. Access to the site is gained through Liston Road which runs adjacent to the site's northern boundary. An additional section of land (highlighted in blue) is present to the north of the site. This section largely comprises open ground, overlapping onto Priors Grange in the west.	
Proposed Works	Ground investigation will comprise boreholes to a depth of between 15 and 35m bgl and trial pits to max. 4m depth.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	Borehole Reference	TM46SW3
	Location	Highhouse Farm, approximately 110m north of the site.
	Date	Unknown.
	Recorded Shallow Geology	• 0.30m SOIL. • 27.13m blue CLAY. • 12.19m brown SAND.
British Geological Survey Mapping	Superficial Deposits	Superficial deposit types vary across the site. A map detailing these areas is presented in **Annex C**. • Lowestoft Formation – Diamiction. • Lowestoft Formation – Sand and Gravel. • Lowestoft Formation – Clay and Silt. • Alluvium – Clay, Silt, Sand, and Gravel.
	Bedrock	Crag Group – Sand.

7 Pre and Post-WWII OS Mapping

7.1 Area Observations

An area reference map can be found in **Annex D**.

	Date	Area 1: Observations	Reference	Source
Pre-WWII	1927	• Area 1 is occupied predominantly by open ground. • Two structures, listed on mapping as a *Miniature Rifle Range* are present approximately 80m west to the revised site area. • In addition, a railway line runs adjacent to the western extent of the site. • *Glebe Barn* is located within the revised section of the site. • A pond is present within one of the fields on site.	Annex E-1	Landmark Maps
Post-WWII	1971	• The rifle range buildings to the west of the site have been cleared. • In addition, *Glebe Barn* has been cleared by this time.		Landmark Maps

	Date	Area 2: Observations	Reference	Source
Pre-WWII	1927	• Area 2 is occupied predominantly by open ground. • An area of woodland is demarcated in Area 2's eastern extent. • A pond is present within one of the fields.	Annex E-2	Groundsure Ltd
Post-WWII	1970	• The woodland appears to have been cleared in this period, along with most field boundaries and the pond. • *Glebe Barn* has been cleared by this time.		Groundsure Ltd

	Date	Area 3: Observations	Reference	Source
Pre-WWII	1927	• Area 3 is occupied predominantly by open ground. • *Great Wood* is labelled in the western extent of the site.	Annex E-3	Groundsure Ltd
Post-WWII	1970	• The site appears consistent with the conditions highlighted in historical pre-war mapping. • The *Great Wood* has been cleared; however, some areas of vegetation can be identified in the south-western extent.		Groundsure Ltd

	Date	Area 4: Observations	Reference	Source
Pre-WWII	1927	• Area 4 is largely comprised of agricultural fields. • *Wood Farm* can be identified within close proximity to the site. • Dense vegetation runs adjacent to the site's western boundary.	Annex E-4	Groundsure Ltd
Post-WWII	1970	• The site appears consistent with the conditions highlighted in historical pre-war mapping. • A small area of clearance can be identified in the southern extent of the site. • Redevelopment is evident to the *Wood Farm* buildings, as well as to ancillary buildings to *Hurls Hall*.		Groundsure Ltd

	Date	Area 5: Observations	Reference	Source
Pre-WWII	1927	• Area 5 of the site is largely comprised of a woodland area, demarcated *Harris' Belt*.	Annex E-5	Groundsure Ltd
Post-WWII	1970	No data.		Groundsure Ltd

	Date	Area 6: Observations	Reference	Source
Pre-WWII	1927	• Area 6 of the site is largely comprised of open ground. • A section towards the south of this area comprises various features, identified on the mapping as embankments or ditches, rough pasture and a possible drain.	Annex E-6	Groundsure Ltd
Post-WWII	1970	No data.		Groundsure Ltd

	Date	Area 7: Observations	Reference	Source
Pre-WWII	1927	• Area 7 of the site comprises open ground with some mature trees. • A river / stream runs across the site in a south to north orientation. A *Footbridge* is identified to the north of the site boundary. • A drain runs parallel to this, also crossing the site. • Towards the south, *Bigsby's Corner* is demarcated.	Annex E-7	Groundsure Ltd
Post-WWII	1970	• No changes can be identified within the site boundary, aside from the potential removal of the formerly identified trees. • Clearance of some structures can be identified in *Bigsby's Corner*.		Groundsure Ltd

	Date	Area 8: Observations	Reference	Source
Pre-WWII	1927	• Area 8 is occupied by open ground. • Dense vegetation occupies the northern extent of the site, likely associated with *Bloomsfield's Covert*. • A small feature is visible in the site boundary, comprising mature vegetation and rough pasture.	Annex E-8	Groundsure Ltd
Post-WWII	1970	• The majority of the site appears to remain consistent with the conditions present in historical pre-war OS mapping.		Groundsure Ltd

		• However, the aforementioned demarcated feature has seemingly been removed. • A small area of clearance can be identified within Bloomsfield's Covent, approximately 70m south of the site.		

	Date	Area 9: Observations	Reference	Source
Pre-WWII	1927	• Area 9 appears to be primarily occupied by agricultural ground. • The *Long Belt*, an area of woodland is demarcated within the centre of the site, running adjacent to the boundary. A second wooded area, the *Nut Tree Belt,* encroaches on the south-eastern part of this area. • A pond can be identified in the south-eastern extent of the site.	Annex E-9	Groundsure Ltd
Post-WWII	1970	• Majority of the site appears to remain consistent with the conditions present in historical pre-war OS mapping. • Within the surrounding area, redevelopment can be identified to the *Hill Farm*, located approximately 200m to the south of the site.		Groundsure Ltd

	Date	Area 10: Observations	Reference	Source
Pre-WWII	1927	• Area 10 is occupied by areas of open ground, mainly agricultural, with rough pasture demarcated to the south. • An area of woodland, demarcated *Harris' Pit* is located within the north-eastern extent. • The eastern extent is bisected by an embanked road running from north to south.	Annex E-10	Groundsure Ltd
Post-WWII	1970	• No data was available for the north of this area. • Some further changes are demarcated on site, including the installation of a drain and a *Track,* in addition to some possible augmentation to the surrounding ground.		Groundsure Ltd

	Date	Area 11: Observations	Reference	Source
Pre-WWII	1927	• Area 11 appears to be occupied by areas of open ground, similar to the conditions shown in Area 9, with rough pasture / heath and agricultural ground. • *Clouting's* Farm is demarcated to the north and the village of *Fristonmoor* is highlighted to the south.	Annex E-11	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping, although ground types are no longer demarcated here. • A small area of clearance is present on an ancillary building to the south of the site on *Moor Farm*. • A building on *Clouting's Farm* has seen some redevelopment.		Groundsure Ltd

	Date	Area 12: Observations	Reference	Source
Pre-WWII	1927	• Area 12 appears to be occupied by agricultural open ground. • A road bisects the centre of the study area. • A *drain* occupies the northern extent of the site. • *Burrell's Farm* is located to the north of the site.	Annex E-12	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping. • Multiple structures associated with *Burrell's Farm* have been cleared.		Groundsure Ltd

	Date	Area 13: Observations	Reference	Source
Pre-WWII	1927	• Area 13 appears to be occupied by agricultural open ground. • The study area is located approximately 200m west to the village of *Knodishall*.	Annex E-13	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping. • Two areas of clearance are present within the village, likely on ancillary buildings.		Groundsure Ltd

	Date	Area 14: Observations	Reference	Source
Pre-WWII	1927	• Area 14 comprises a small parcel of agricultural land. • A pond is present along the southern boundary. • *Fristonmoor Covert* is demarcated approximately 60m to the south of the site.	Annex E-14	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping.		Groundsure Ltd

	Date	Area 15: Observations	Reference	Source
Pre-WWII	1927	• Area 15 is occupied predominately by agricultural land. • A pond is labelled in the north-eastern extent of the site.	Annex E-15	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping. • Pylons have been erected approximately 80m east of the site.		Groundsure Ltd

	Date	Area 16: Observations	Reference	Source
Pre-WWII	1927	• Area 16 comprises a small parcel of land, comprising a road, likely hard-standing. • A farm is highlighted immediately adjacent to the east of the site.	Annex E-16	Groundsure Ltd
Post-WWII	1970	• The site appears to remain consistent with the conditions present in historical pre-war OS mapping. • Within the farm immediately adjacent, several small structures have been cleared. • Moreover, to the west, multiple buildings have been erected.		Groundsure Ltd

	Date	Area 17: Observations	Reference	Source
Pre-WWII	1927	• Area 17 is occupied predominately by agricultural land. • A demarcated *Footpath (FP)* crosses the south of the site, from west to east. • Two roads (or similar) cross the northern extent and centre of the site. • A farm is indicated to the west of the site.	Annex E-17	Groundsure Ltd
Post-WWII	1970	• The majority of the site appears to remain consistent with the conditions present in historical pre-war OS mapping. The road in the centre is now labelled as a *Track*. • The footpath is no longer demarcated on the mapping. • Evidence of clearance is present on *Manor Farm* to the west of the site.		Groundsure Ltd

	Date	Area 18: Observations	Reference	Source
Pre-WWII	1927	• Area 18 is occupied predominately by open ground. • The *Watch Walk Whin,* an area of rough pasture and woodland, is demarcated to the east of the site.	Annex E-18	Groundsure Ltd
Post-WWII	1970	• The site and surrounding area appear to remain consistent with the conditions present in historical pre-war OS mapping.		Groundsure Ltd

7.2 Additional Notes

The available post-WWII mapping was dated at least 25 years after the end of WWII. As such, changes to the project site may have occurred after WWII, unrelated to any wartime action.

Furthermore, a large proportion of the site was rural throughout WWII, and therefore damage from aerial bombing, as well as any defence-related features constructed during WWII, are unlikely to be visible on these available maps.

8 The Threat from Aerial Bombing

8.1 General Bombing History of Suffolk

8.1.1 First World War

London and Eastern England suffered aerial bombardment during WWI, beginning with indiscriminate night raids by Zeppelin airships. However as British defensive measures became more effective and aircraft development progressed, the German military switched to daylight raids by fixed-wing aircraft in June 1917.

Available bomb plot mapping indicates that at least one Zeppelin raid occurred directly over the general site area on 24th August 1916. Additionally, several aircraft crossed the Suffolk coast on their way to / from raids on London in October 1915. However, no recorded WWI bombs are confirmed to have fallen within the project site.

Furthermore, WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Later in the war a number of Air stations, both British and American, became operational in East Anglia, including RAF Leiston (approximately 2.0km north-east of the site) and RAF Framlingham.

Airfields and radar stations such as RAF Leiston and RAF High Street would have been potential targets for the Luftwaffe and defensive measures were installed, including Light Anti-Aircraft guns, pill boxes, road blocks and air raid shelters. A Luftwaffe target identification photograph (not annexed) identifies RAF Leiston, to the north of the site, then under construction.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe. Totals of 2,419 V1s and 517 V2s were recorded in the London Civil Defence region.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.

- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the following administration areas covering the site between 1940 and 1945.

Record of German Ordnance Dropped	Rural District of Blyth	Urban District of Saxmundham
Area Acreage	98,184	1107
High Explosive Bombs (all types)	555	8
Parachute Mines	7	-
Oil Bombs	3	-
Phosphorus Bombs	12	-
Fire Pots	16	-
Pilotless Missile (V1)	14	-
Long Range Rocket (V2)	1	-
Total	608	8
Items Per 1,000 Acres	**6.2**	**7.2**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records. ARP records covering the region the site is located in were sought out, none could be found in the timeframe of this report.

8.4.2 Home Office Intelligence Reports

The Home Office Intelligence reports document enemy action on British domestic soil and were prepared twice a day for the Home Security War Room. The summaries were prepared by intelligence staff, who compiled reports received from the twelve civil defence regions.

However, available records only document time and general location of attack and numbers of casualties. The intelligence officials generally only recorded locations on municipal level (town, village, or city), rarely providing specific addresses.

Date	Location	Details
8th/9th July 1940	Saxmundham	0 casualties.
19th/20th August 1940	Benhill, Saxmundham	0 casualties.
7th/8th September 1940	Saxmundham	0 casualties.
5th January 1941	Saxmundham	0 casualties.
13th/14th April 1941	Saxmundham	0 casualties
14th/15th May 1941	Saxmundham	0 casualties.
2nd August 1942	Saxmundham	0 casualties.
26th/27th August 1942	Saxmundham	0 casualties.
14th/15th March 1944	Saxmundham	0 casualties.

8.4.3 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
31/08/1940	Unspecified	Benhill, plotted approximately 750m south-west of the site.[1]
08/09/1940	Incendiary bombs	Blyth Rural District.[2] No exact location was specified.
20/09/1940	Parachute Mine	Blyth Rural District.[3] No exact location was specified.
22/09/1940	Parachute Mine	Blyth Rural District.[4] No exact location was specified.
05/11/1940	16 x HE bombs	Blyth Rural District.[5] No exact location was specified.
11/11/1940	10 x HE bombs	Blyth Rural District.[6] No exact location was specified.
24/11/1940	Unspecified	Friston, plotted approximately 1.1km south of the site.[7]
05/01/1941	Unspecified	Saxmundham, plotted approximately 800m west of the site.[8]
09/01/1941	4 x HE bombs	Blyth Rural District.[9]

[1] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474
[2] Bowyer, 1986
[3] Bowyer, 1986
[4] Bowyer, 1986
[5] Bowyer, 1986
[6] Bowyer, 1986
[7] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474
[8] https://www.cambridge-news.co.uk/news/local-news/second-world-war-bombing-cambridge-20248474
[9] Bowyer, 1986

8.4.4 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	28th July 1946
Source	RAF Aerial Collection
Image Type	Aerial
Image quality	Low resolution and large scale. Partial coverage (parts of Areas 12, 13, 16 and 17).
Observations	• The site appears to remain consistent with the conditions shown in historical OS mapping. • The photography highlights the eastern extent of the site, it is predominately occupied by agricultural fields. • There does not appear to be any sign of ground disturbance or features indicative of bomb damage.
Reference	**Annex F**

8.4.5 Bombing Decoy Sites

A national decoy authority headed by Colonel John Fisher Turner was set up in July 1940, and following earlier experiments in Glasgow and Sheffield, a system of urban lighting decoys was set up. These were known as "Civil" sites; Civil 'QL' for urban lighting simulation, and Civil 'QF' for dummy fires. "Q" – sites were equipped with assorted electrical and pyrotechnical apparatus to simulate the flare given from furnace doors, steel-making, railway marshalling yards, and light given off by inefficient blackout precautions.

Other sites simulated small fires started by incendiary bombs, with oil-storage area fire simulation being developed near large oil installations. A further variation on fire decoy sites was the "SF", or "Special Fires" sites. A larger, longer-burning type of fire was provided at these sites - known as "Starfish" sites - to draw incendiary bombs, and hopefully as a consequence the full enemy payload, from falling on the larger conurbations and defence installations during heavy air raids. Decoy sites had a good level of success – airfield decoy sites across Britain for example had received 359 attacks by the end of 1941. The real airfields were bombed 358 times.

A bombing decoy site was established in close proximity to the site	✘

8.4.6 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✗

8.5 UXB Ground Penetration

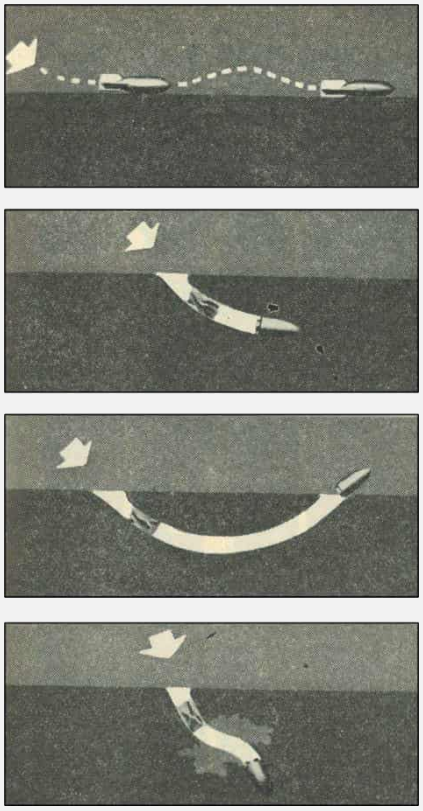
8.5.1 General Considerations

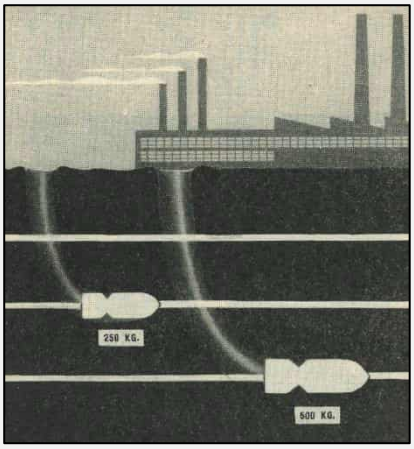
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

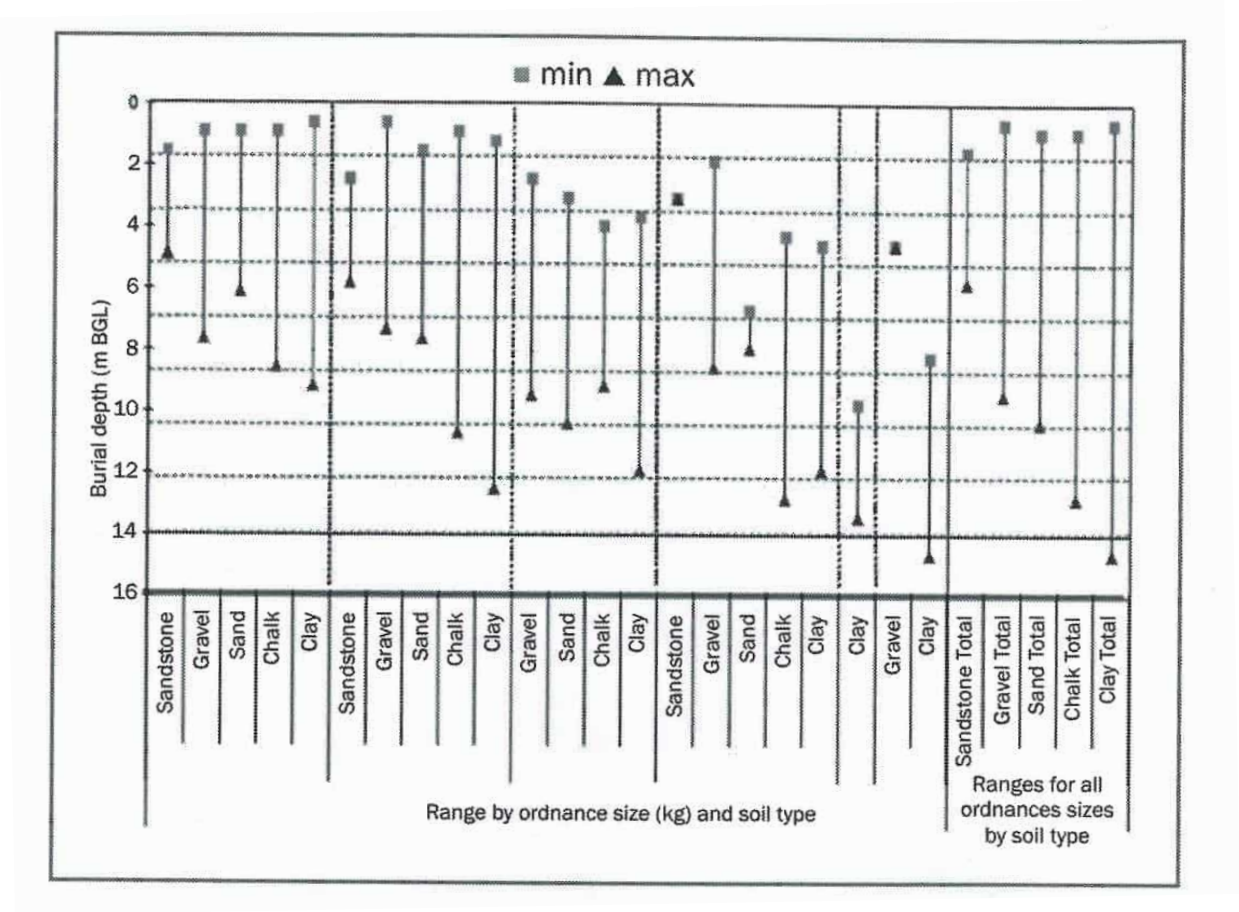
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 0.30m of SOIL, >27.13m of CLAY, > 12.19m SAND.
- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.7 Site Specific Threat from German Air-Delivered Ordnance

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Low	
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✘	Home Office statistics indicate that there were numerous raids over Saxmundham & the surrounding area. It is feasible that the site could have been affected during these raids.
	What is the distance between the site boundary and the closest recorded large bomb strike?	750m	
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	0	
	Were any nearby sticks of large bombs recorded in line with the site?	✘	
	Were any 1kg incendiary bomb showers recorded over the site?	✘	
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✘	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✘	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✘	

	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✘	
	The site was exclusively or partially developed during WWII.	✓	The site was almost entirely undeveloped, aside from occasional farmland dwellings / structures. However, these features occupied a very small proportion of the whole project site.
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✘	
	The site was occupied by a school during WWII.	✘	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✘	
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✘	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	Due to nature of the ground conditions present on site, it is feasible that a UXB could have remained undetected.
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✘	
	The site was occupied by a graveyard which would have experienced limited access.	✘	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	

	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✖	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✖	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖	
	The site was occupied by dense, inaccessible vegetation during WWII.	✓	Some areas were occupied by woodland and other dense vegetation.
	The site may have been susceptible to waterlogged conditions during WWII.	✓	.
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✖	Note, that drains and ponds were present within the site.
	The site was occupied by tidal mud or marshland during WWII.	✖	
	The site was occupied by railway tracks crossing soft ground during WWII.	✖	
	The site was occupied by stockpiled material during WWII.	✖	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓	These features occupied a very small proportion of the whole project site.
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✖	
	The site was occupied by well-maintained, manicured lawn during WWII.	✖	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	

Bomb Failure Rate Assessment	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✓
Military Training Areas / Weapons Ranges	✗
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✗
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 Dunwich Heath Training Area

During WWII, Dunwich Heath (approximately 3.5km north-east of the site) was one of the most heavily defended parts of the Suffolk coastline with a radar station, coastal artillery battery and anti-invasion defences.

In May 1941, a coastal artillery battery was built on the cliffs at Dunwich comprising 2 x 6" guns and was operational for around 2 years. In order to protect this site, along with the radar station, Dunwich Heath was covered with infantry positions and defences. One spigot mortar emplacement still survives today, which was constructed along with other defences.

By 1944, the final defences to be constructed at Dunwich were "Diver" anti-aircraft batteries, which were tasked with defending from the threat of V1s.

In the early stages of the war, an important training ground was established, within which the north of the project site was located. The training area was used throughout the conflict, whereby hundreds of troops and tanks used the heath for live firing practice. It was particularly important in the lead up to D-Day. In 1943, it was used for the exercise 'Kruschen' which was one of the first exercises to trial the specialised equipment that would be needed to break the concrete defences for the German Atlantic Wall.

9.2 RAF Leiston

RAF Leiston (approximately 2km north-east of the site) was built as a fighter station for RAF Fighter Command, its location approximately 5km from the North Sea coast meant it was ideal as a base for fighters.[10] In 1942, the airfield was designated to the Eighth Air Force of the USAAF, where it was operational until October 1945. During Leiston's occupation history, it was occupied by the 357th Fighter Group, 50th Service Group, 358th Fighter Group, 362nd Fighter Squadron, 363rd Fighter Squadron, 364th Fighter Squadron, and the 469th Service Squadron.[11]

9.3 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[12]

[10] https://www.americanairmuseum.com/place/212
[11] https://www.americanairmuseum.com/place/212
[12] Various News Sources

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.4 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.5 Generic Types of WWII British / Allied Unexploded Ordnance

9.5.1 Land Service Ammunition (LSA)

9.5.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

9.5.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.5.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.6 Site-Specific Threat from Allied Military Ordnance

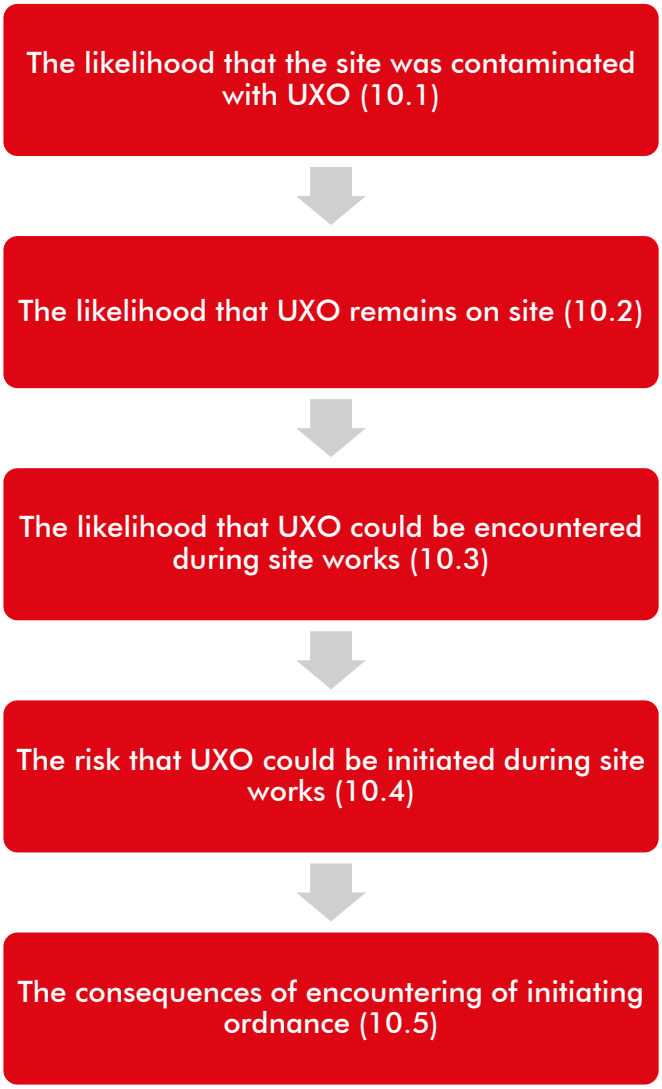
The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Military Activity on site	RAF Leiston: • Past experience has shown that contamination commonly occurred at WWII airfields, notably around munitions stores or areas such as dispersal pans where ordnance was loaded on and off aircraft. It also resulted from the deliberate disposal of damaged or unwanted ordnance which typically was burnt or buried in more remote areas. • Due to the distance from the site to the airfield, it is unlikely the site will have been contaminated from such activity. Dunwich Training Area: • A training range was located at Dunwich, with the firing arc facing east into the sea. As such, it is not likely that these particular ranges will have fired towards the site.
Home Guard Activity on site	• The closest Home Guard battalion to the site was the 8th Suffolk Battalion – Saxmundham. • An Auxiliary Operational Base was located approximately 2.7km north-west of the site, it is possible this was used as a headquarters for the Home Guard during WWII. • It is likely that the local training areas were utilised for Home Guard training exercises. • Typically, HG soldiers would take part in training exercises in areas occupied by open countryside, the conditions within the site would prove to be an opportunistic place for such activity. • An UX shell was discovered in Saxmundham 420m west of the site, this indicates that the Home Guard were active within the area. Home Guard are known to have purposefully buried ammunition in tactical locations. • An example of the Saxmundham Home Guard carrying out an exercise can be seen below, note, the exercise appears to have taken place in dense vegetation as well as with live ammunition. • The significant concentration of anti-invasion defences along the coastline and within the general project site area means Home Guard presence and activity is likely to have been significant.

	 *Source: https://ww2db.com/image.php?image_id=23262*
Defensive features within the vicinity	• 2 defensive features are located within close proximity to the site, a nodal point approximately 560m from the site, and a pillbox approximately 1.1km from the revised section of the site. The presence of a nodal point also implies the existence of various defensive features. • A cluster of pillboxes were located to the south of Friston, approximately 1.7km to the south of the site. • It is possible that additional defensive features could be found around the RAF base and the surrounding countryside, however this cannot be corroborated.
Threat to the site from unexploded AA shells	• At least 10 possible batteries have been identified towards the east of the site around Sizewell, including Heavy AA and Diver AA Batteries. One permanent battery is recorded 4.9km to the east. • However, it is likely that additional, temporary AA batteries will have been active in the area. For example, RAF airfields were often protected by anti-aircraft batteries, RAF Leiston was located 2km to the north-east and RAF Framlingham was located 4.7km west. • During WWII there was a lot of German air traffic over East Anglia, as such, the batteries would have been firing consistently throughout the war. • Had a UX AA landed on the open ground or dense / soft vegetation on site, it is possible that it would have remained undetected.

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• Low bombing density. • The closest recorded strike was 750m west of the site. • However, Home Office Statistics indicate that there were multiple raids over Saxmundham and other villages in the local area during WWII. • Comprehensive bombing records and clear locations of bomb strikes are less likely to have been recorded in rural / agricultural areas. It is unlikely that the site was subject to stringent and detailed bombing records at the time.
Bomb Damage	• No direct evidence of bomb damage can be found on the site. • Cleared structures within the revised site area unlikely to be attributed to bomb damage. • However, the available historical sources and aerial photography only covered a small proportion of the site. • Damage is not likely to have been recorded within rural or agricultural areas to the same degree as an urban or developed area.
Ground Conditions	• Agricultural land occupied majority of the site. • There are areas of denser, wooded vegetation. • Small ponds and drains are also featured throughout the site. • The ground conditions within the majority of the site mean a UXB landing on site is unlikely to have been identified.
Frequency of Access	• Seasonal access to agricultural land. • Areas of woodland and more dense vegetation unlikely to be frequently accessed. • Taking into consideration the level of access to the site, had a UXB landed within much of the site, it is likely to have remained undetected.
J-Curve Effect	• Had any UXB landed within the soft ground on site, it could have come to rest up to 15m away from its original entry point, potentially even beneath adjacent undamaged buildings.
Other considerations	n/a
Overall Likelihood of Contamination	**Medium**

10.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• RAF Leiston and the Dunwich Training Area indicate an increased military presence within the general site location. • A concentration of defensive features is located within close proximity to the site, including a nodal point approximately 560m from the site, and a pillbox approximately 1.1km from the revised section of the site. • An UX shell was discovered approximately 420m west of the site. • Despite the increased Home Guard and military activity in the area, no evidence has been found to suggest that the site formerly had any British / Allied military occupation or usage that could have led to contamination with items of UXO. • Although the possibility is considered to be unlikely, it can never be entirely discounted.
Anti-Aircraft Projectiles	• At least 10 possible batteries have been identified towards the east of the site around Sizewell, including Heavy AA and Diver AA Batteries. One permanent battery is recorded 4.9km to the east. • However, it is likely that additional, temporary AA batteries will have been active in the area, especially due to the proximity of two RAF airfields. • Had a UX AA landed on the open ground or dense / soft vegetation on site, it is possible that it would have remained undetected. • There was likely to have been a lot of German air traffic over the site, as such, the batteries would have been firing consistently throughout the war.
Overall Likelihood of Contamination	**Medium**

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	7th August 1992 - EOC Task at Wayside Breakers Yard recovered 1,187 items of expended ordnance, approximately 3.5km west. 15th March 2002- EOC Task at Carlton Hall recovered several items of UXO, including reports of AA rounds uncovered by digger and multiple .303 rounds. Located approximately 890m north-west of the site's revised section.
Local ordnance finds	15th February 2011 – An unexploded shell was discovered on Church Street, approximately 500m west of the site.
Local tasks undertaken by SafeLane Global	None

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✓
Further Details	Some farm structures within the site have likely been redeveloped, but, since majority of the site was undeveloped agricultural land, it is likely these sections will not have been redeveloped. The remainder of the site is likely to have been subject only to shallow ground works & agricultural works.

10.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	Aside from shallow agricultural or maintenance works on site, as well as likely redevelopment to existing farm buildings, the site is not known to have undergone any significant redevelopment.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially small arms or land service ammunition) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. At any location on site where no bulk excavations have been carried out, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth.

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	Proposed works are expected to include piling and excavation works. As such, it is possible that any remaining UXO could be encountered during these works.

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.
Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

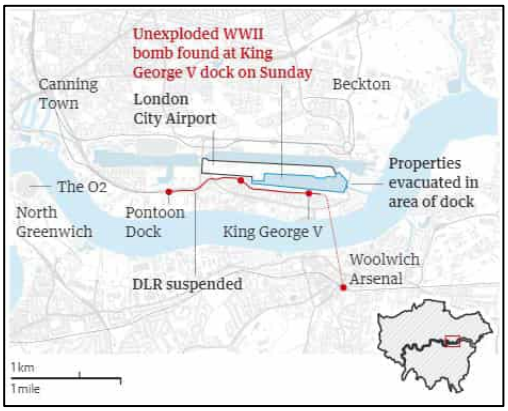
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be Medium.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Low	Low	Low	Not Significant	**Low**
Land Service Ammunition	Low	Low	Low	Moderate	**Low**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
Medium	Shallow Intrusive Works eg. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of

	an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required.

	The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iii. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

iv. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

v. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

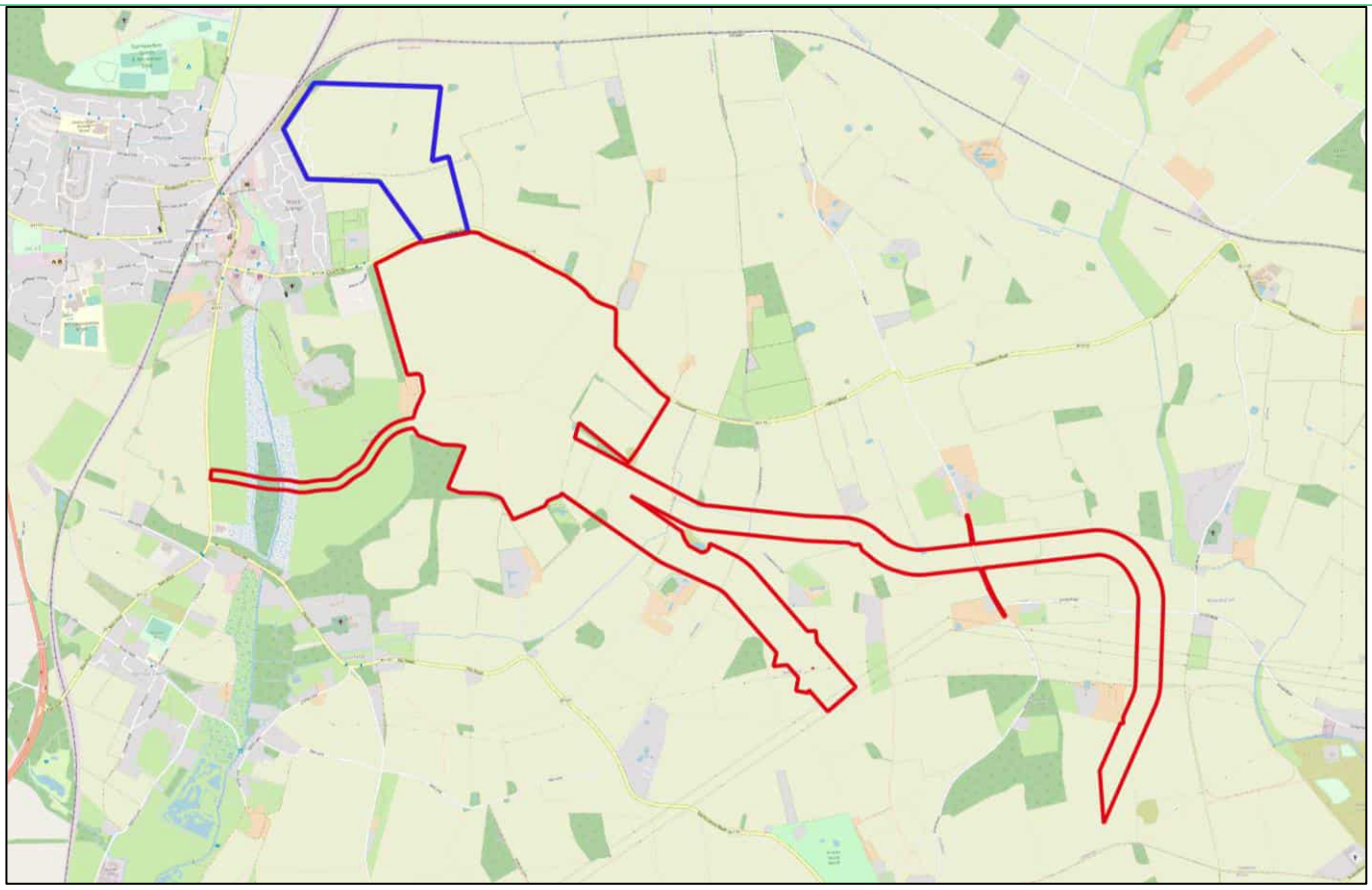
vi. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

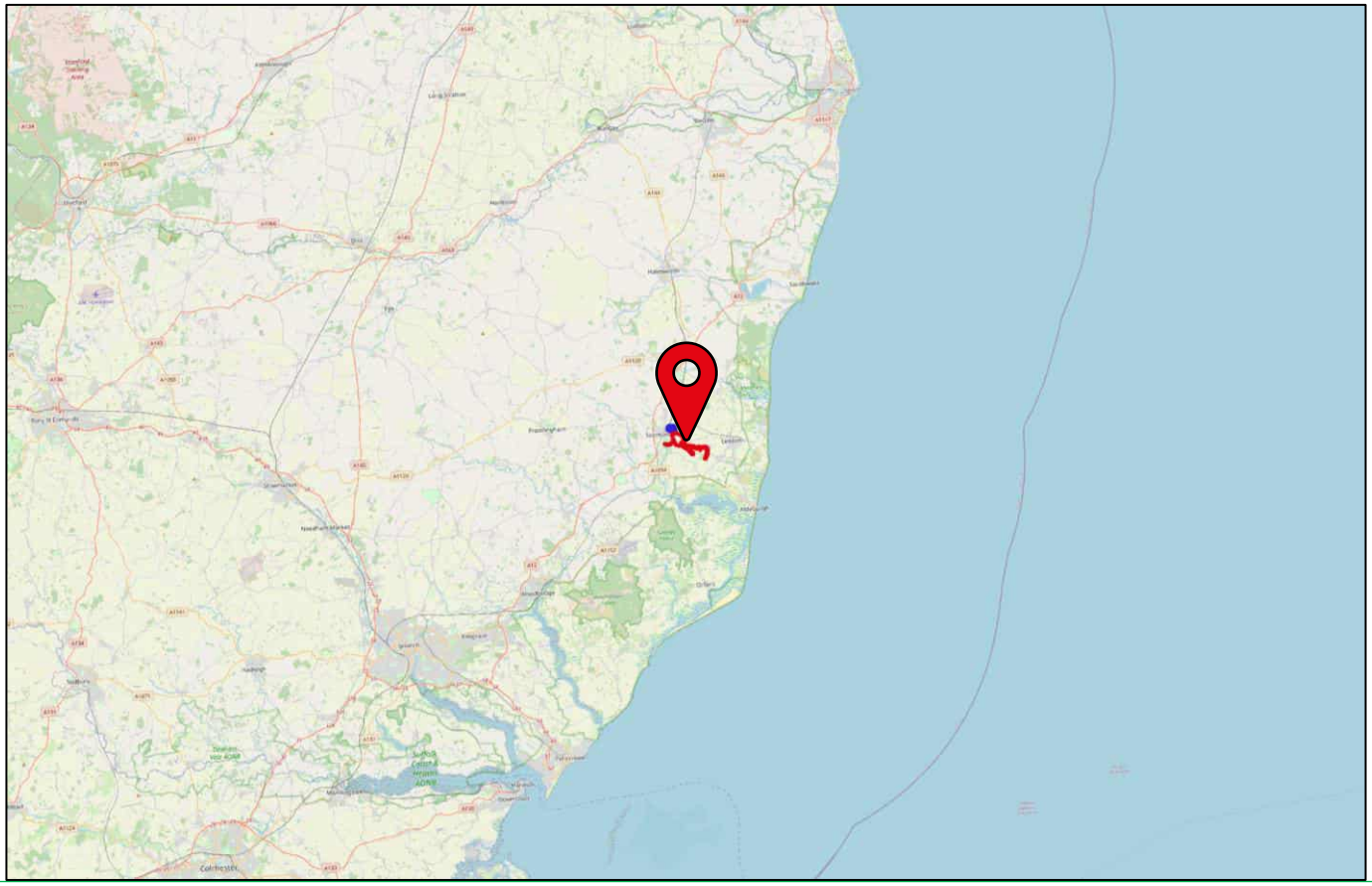
vii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

viii. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

ix. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

x. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).

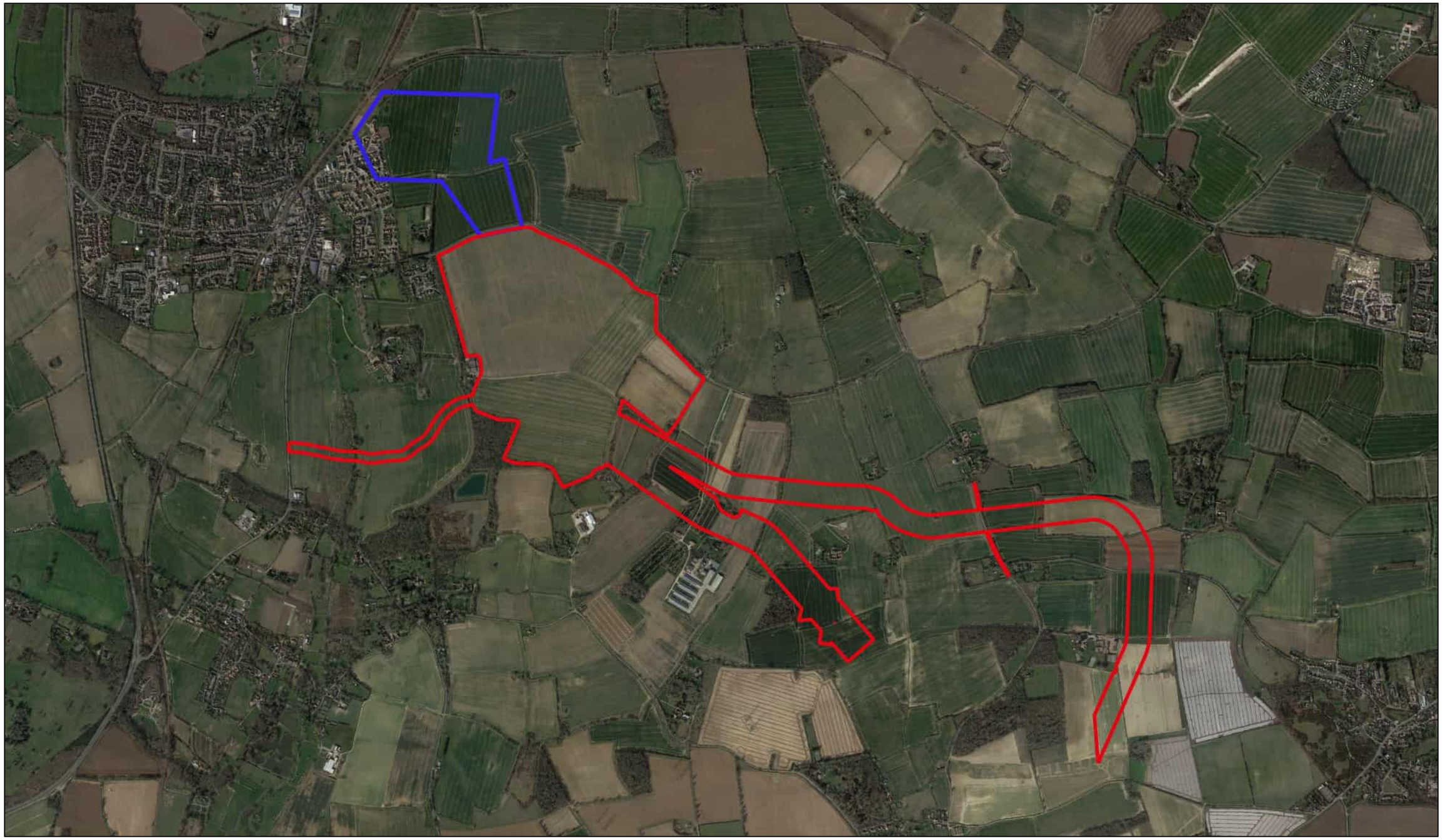




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Recent Aerial Photograph / Site Plan

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Approximate site boundary

Google Earth™ Mapping Services



Approximate site boundary

Lowestoft Formation - Diamiction

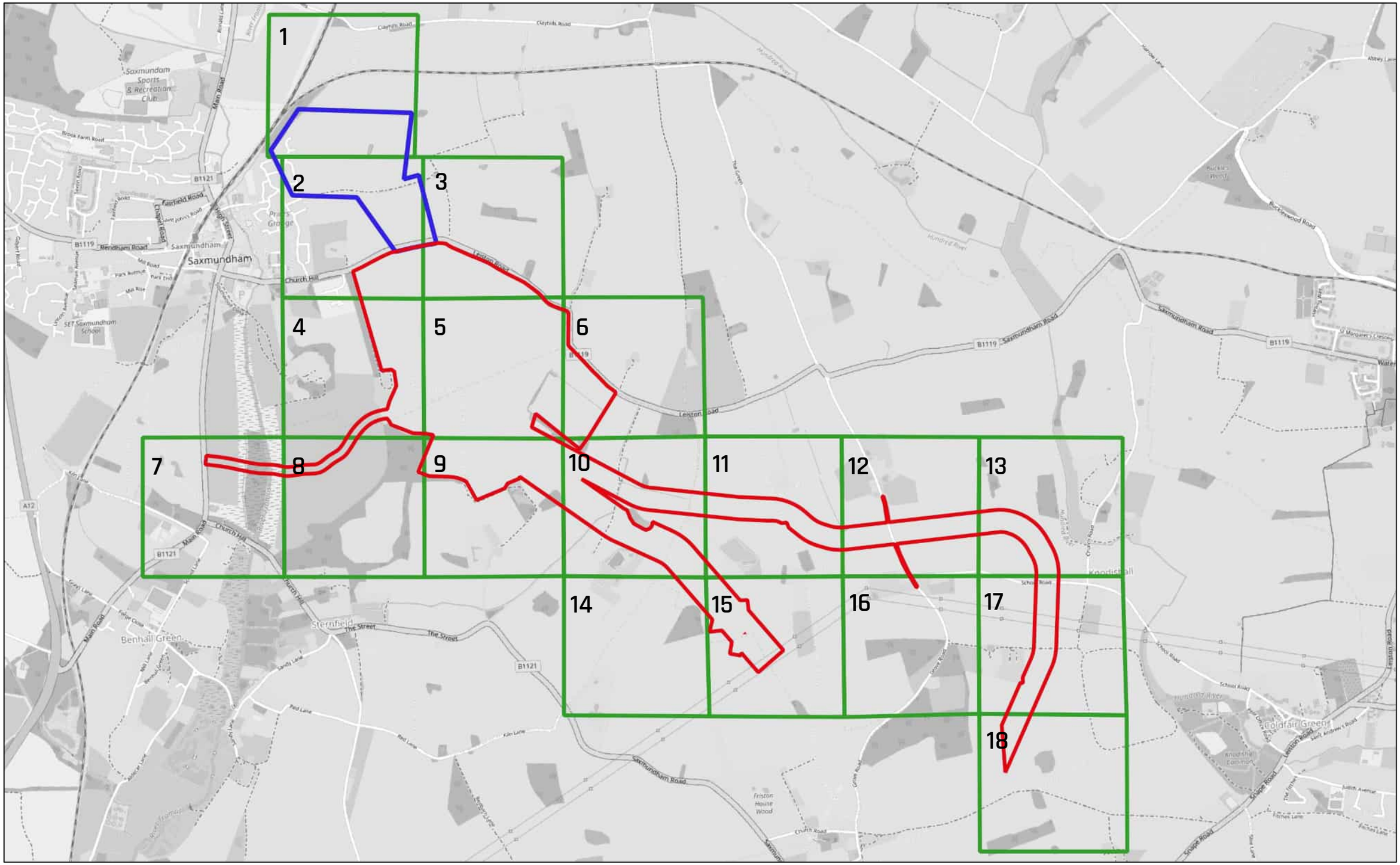
Lowestoft Formation – Clay and Silt

Lowestoft Formation – Sand and Gravel

Alluvium – Clay, Silt, Sand, and Gravel

OS Mapping - Area Reference Map

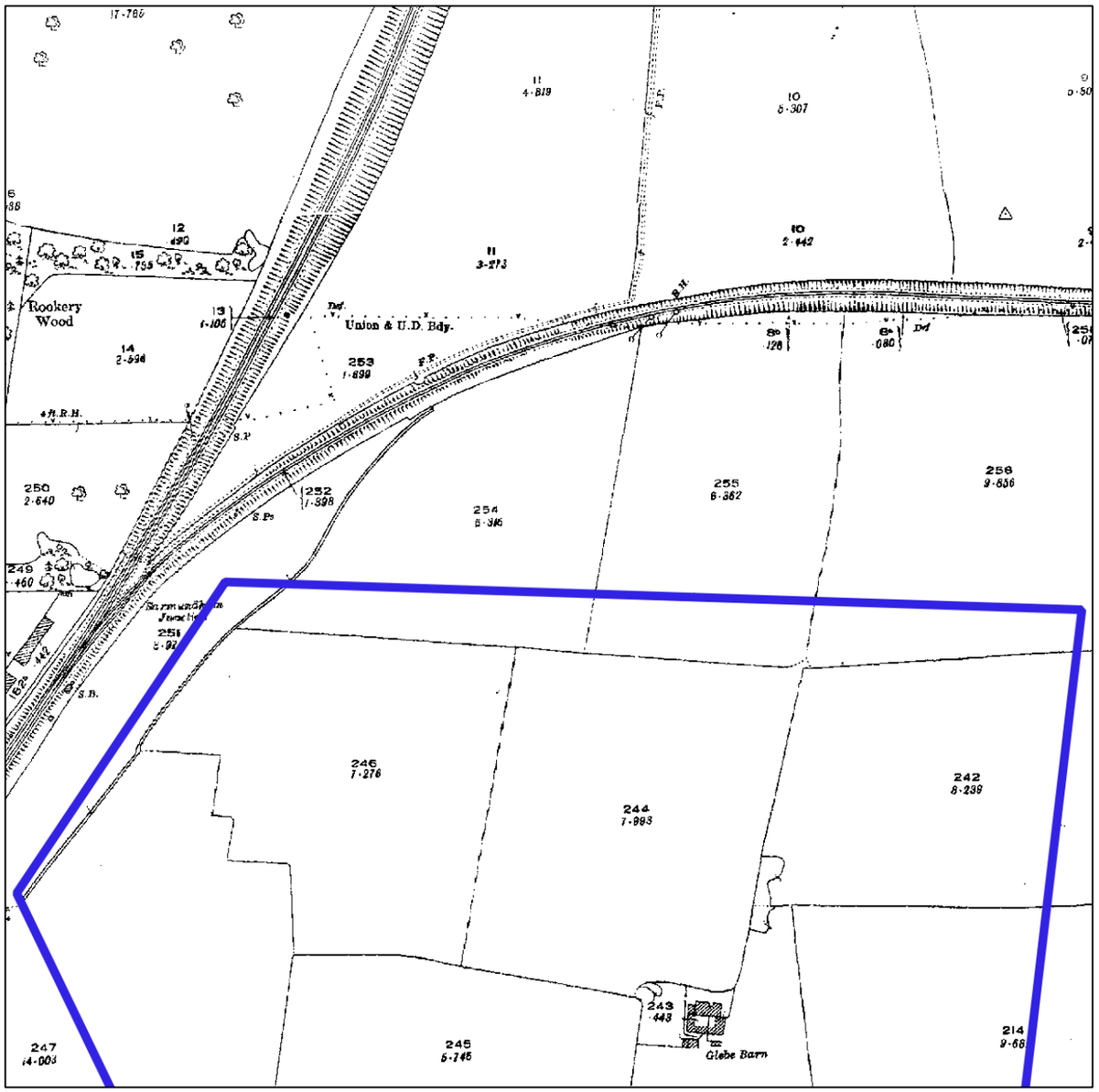
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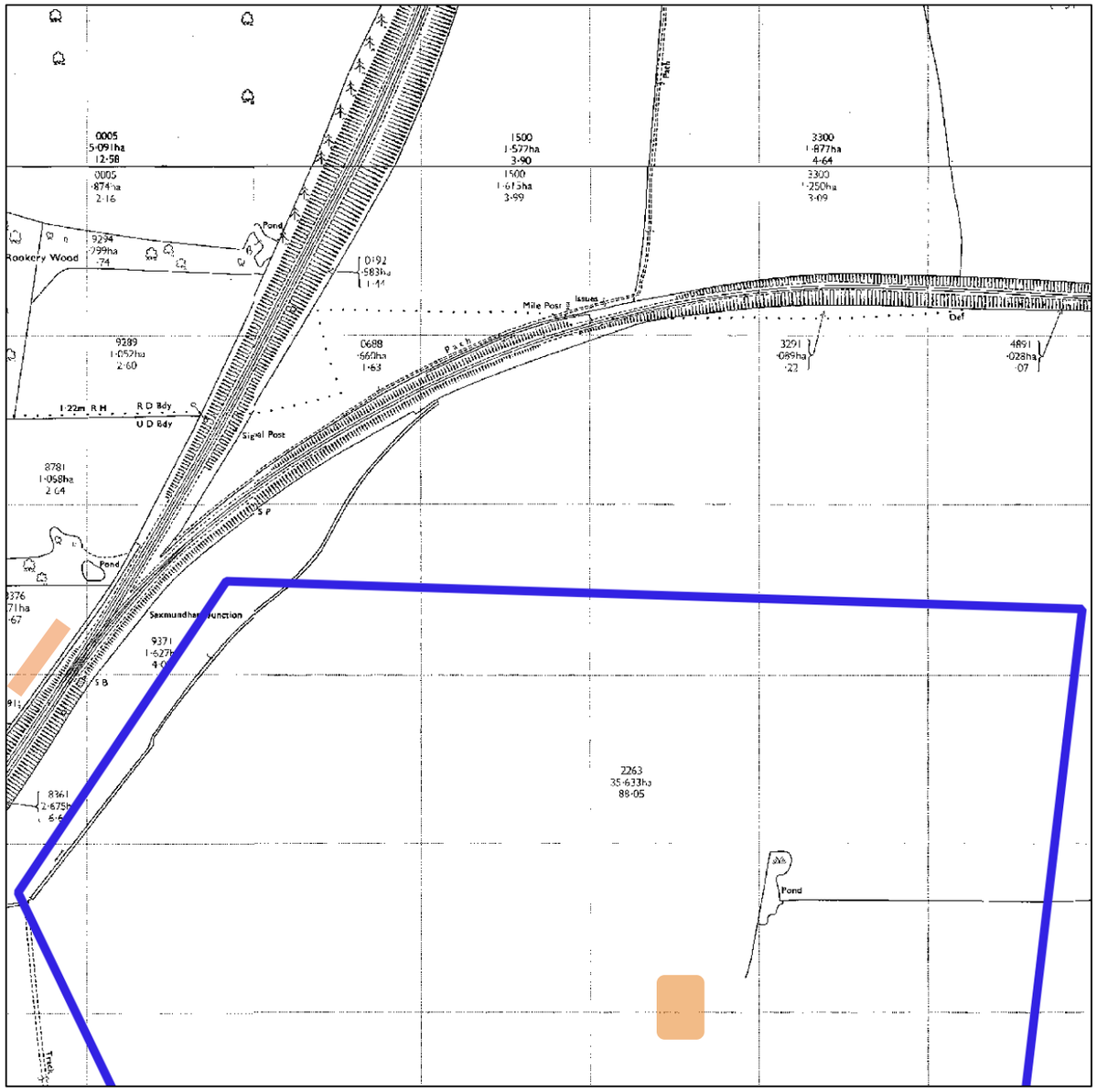
Approximate site boundary

N

1927



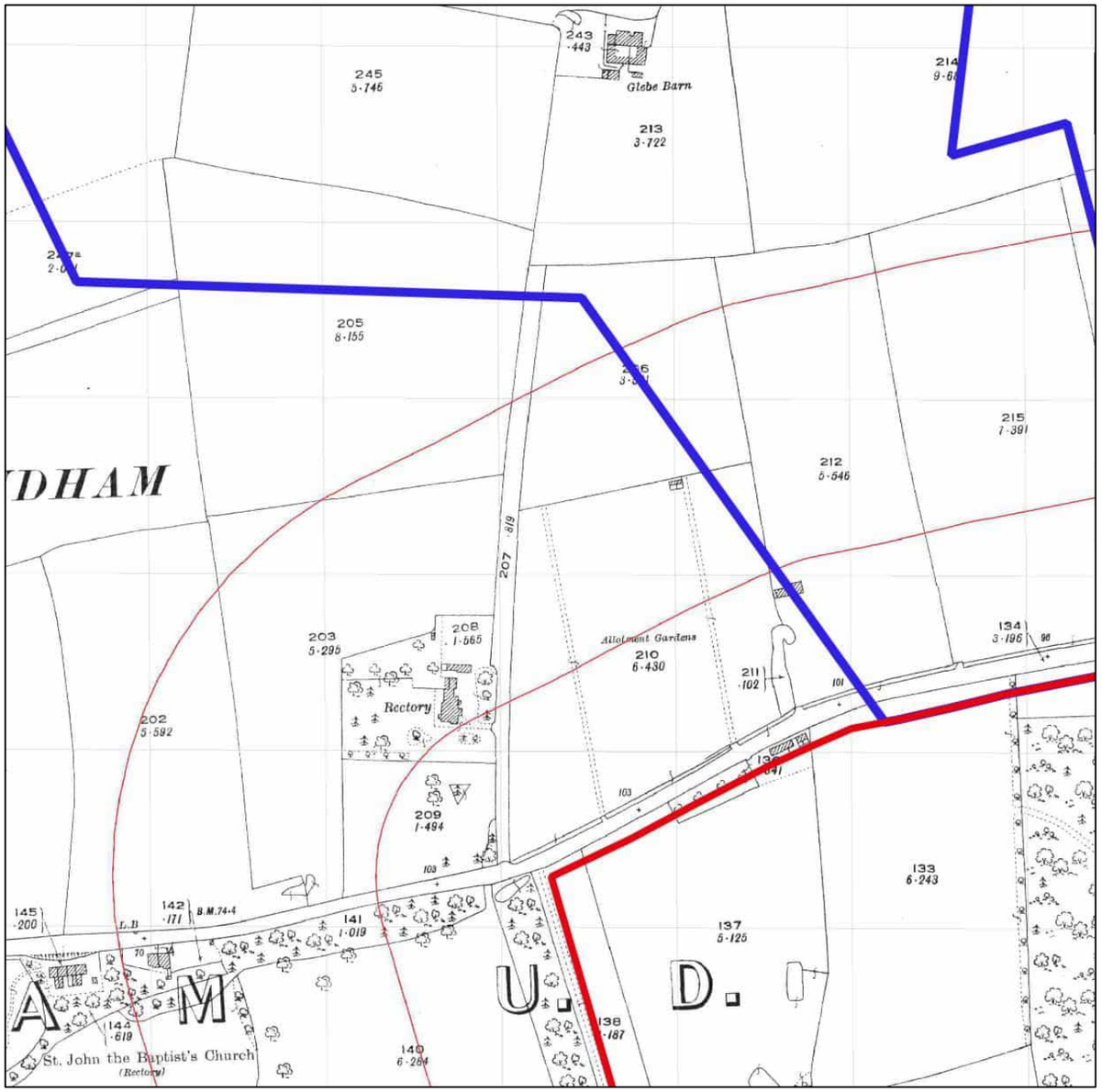
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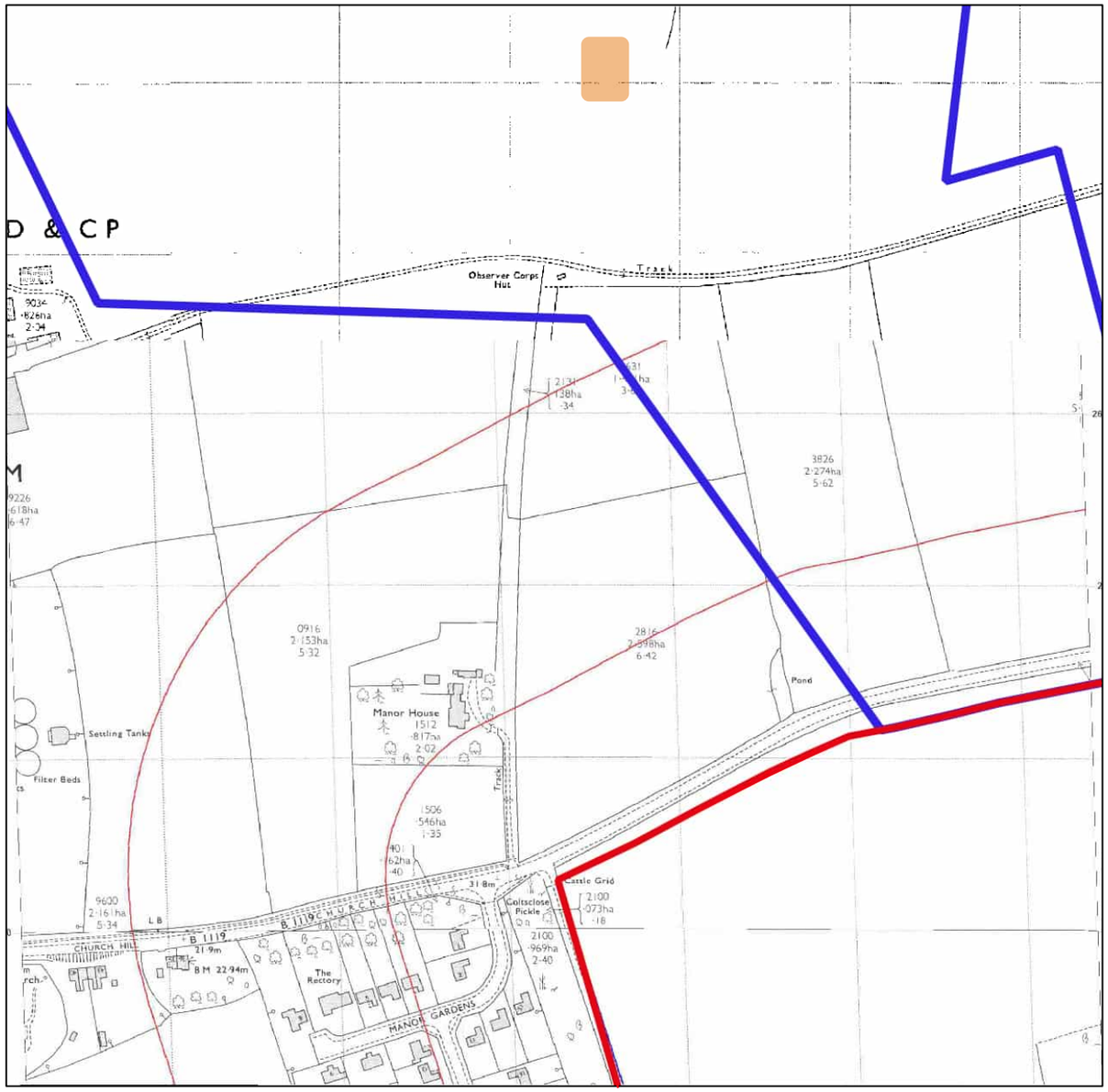
Approximate site boundary (Revised section)

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1927



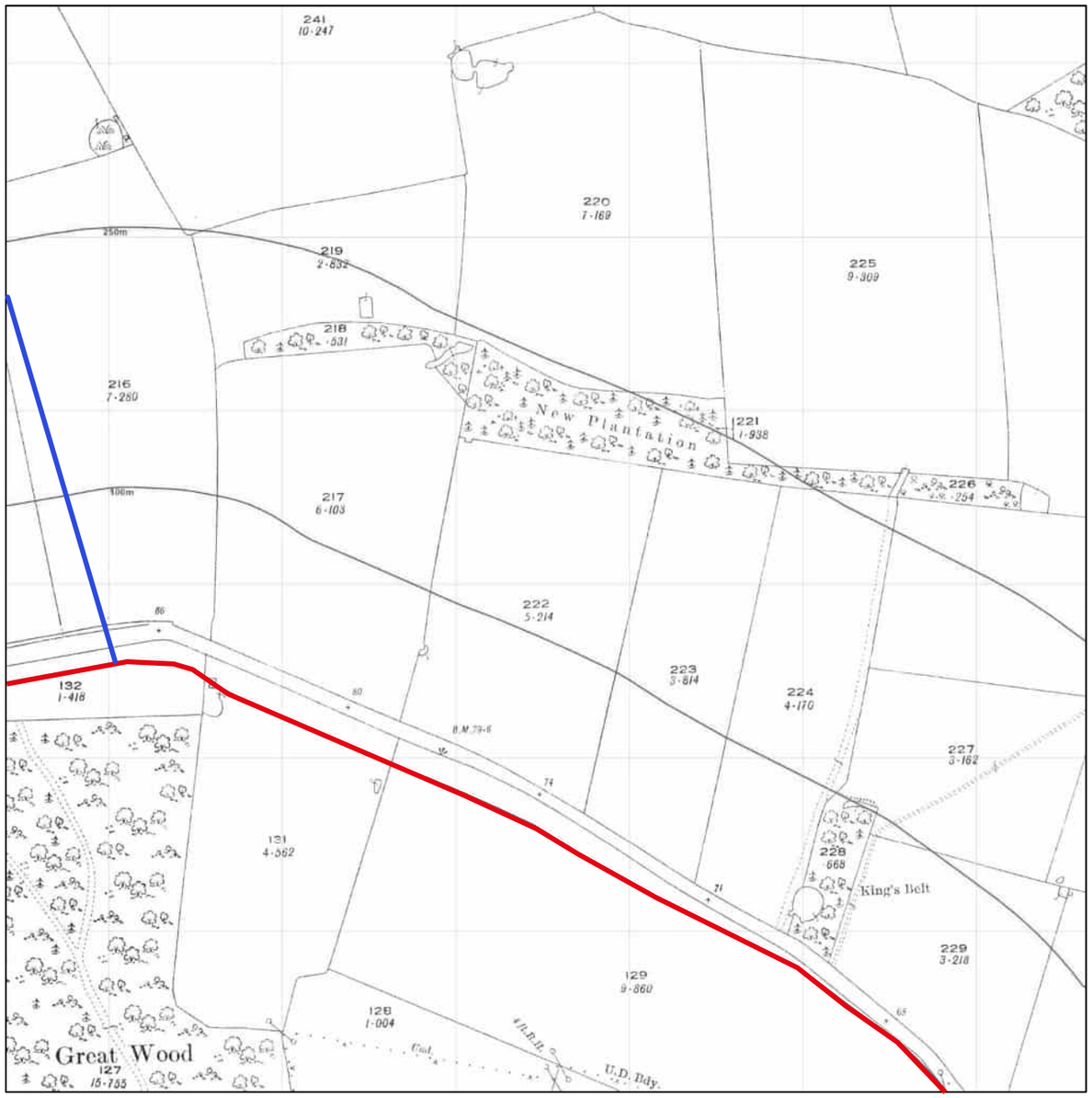
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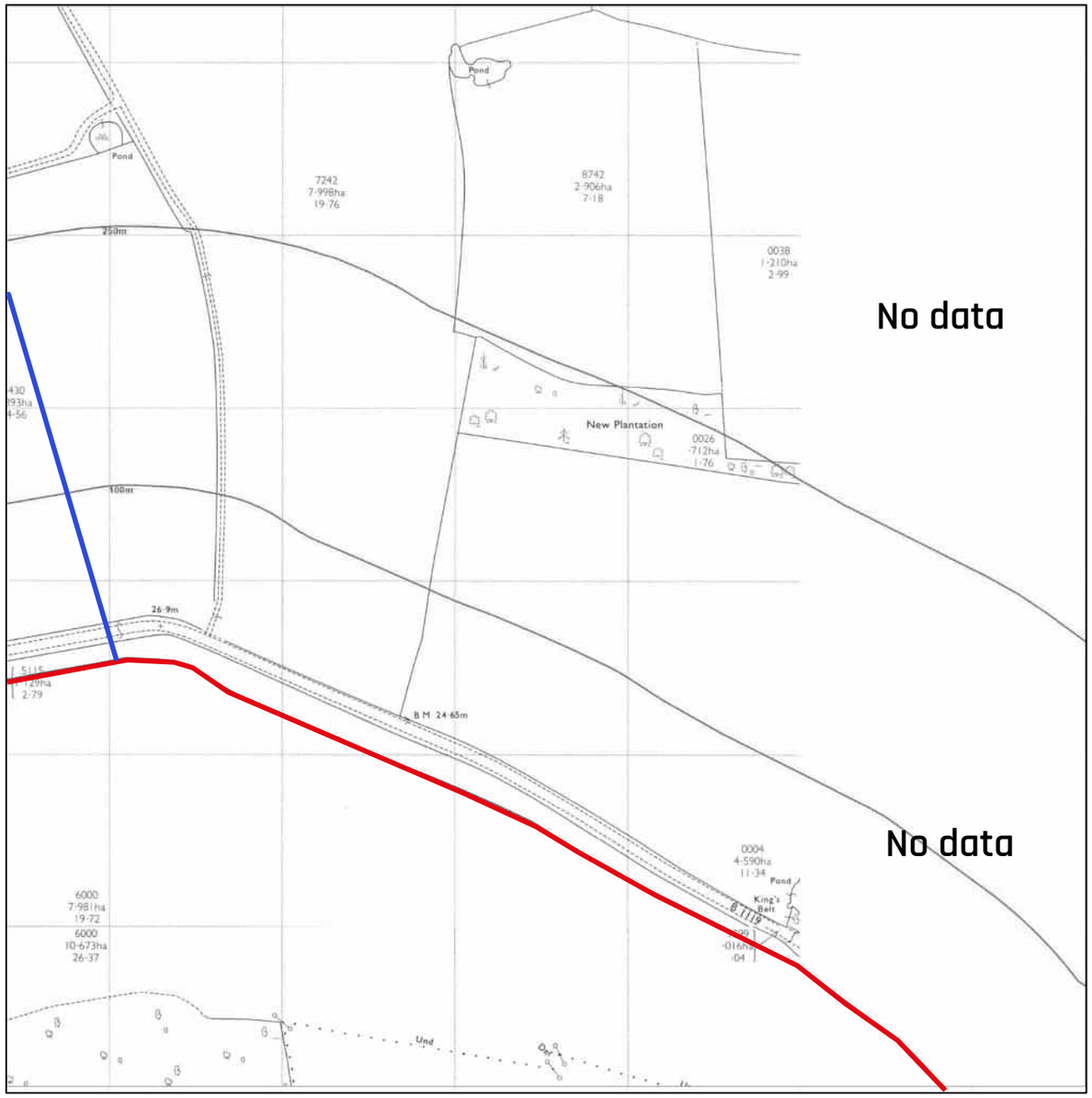
Approximate site boundary Approximate site boundary (Revised section) Clearance

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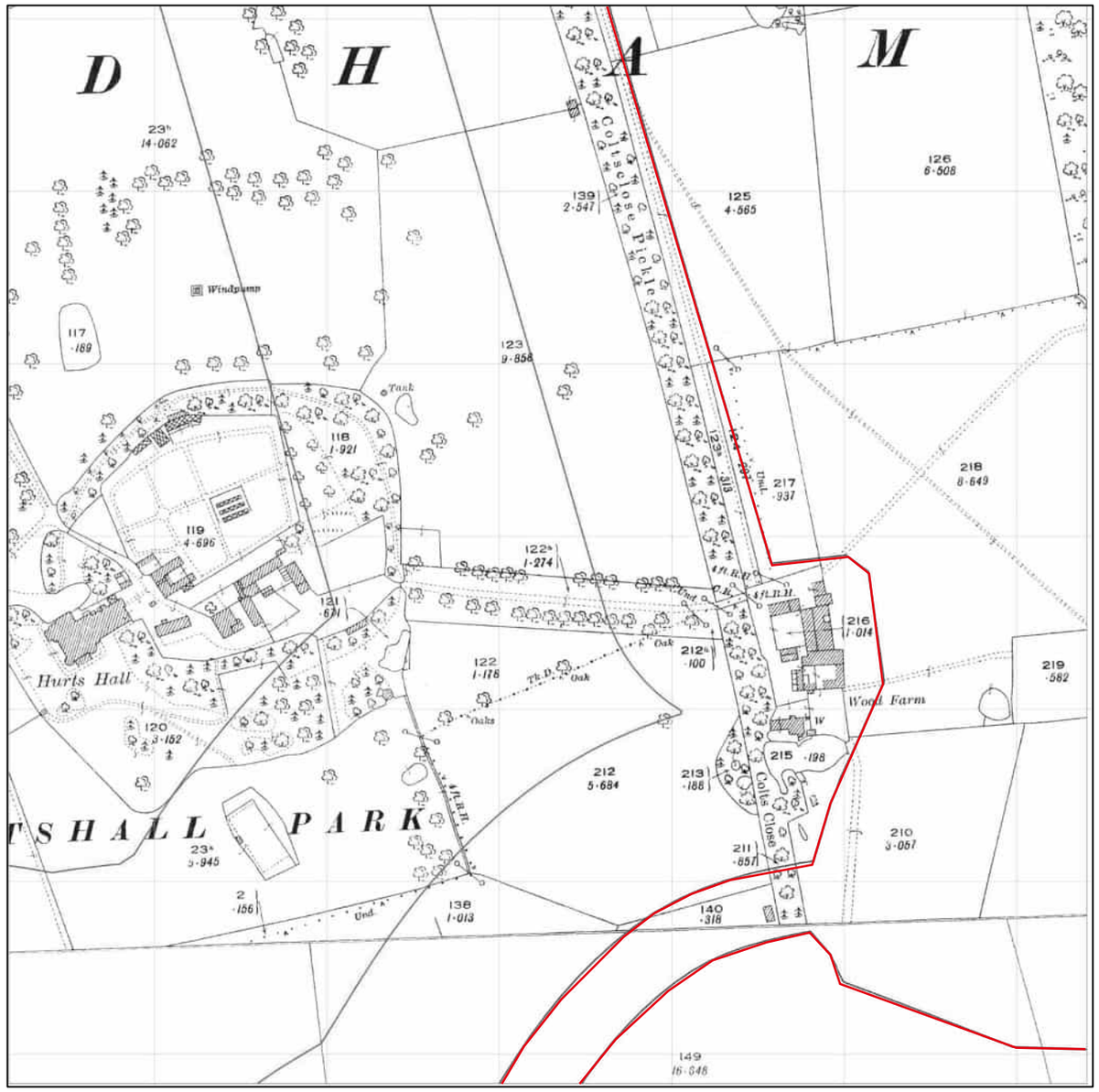
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Approximate site boundary Approximate site boundary (Revised section)

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1927

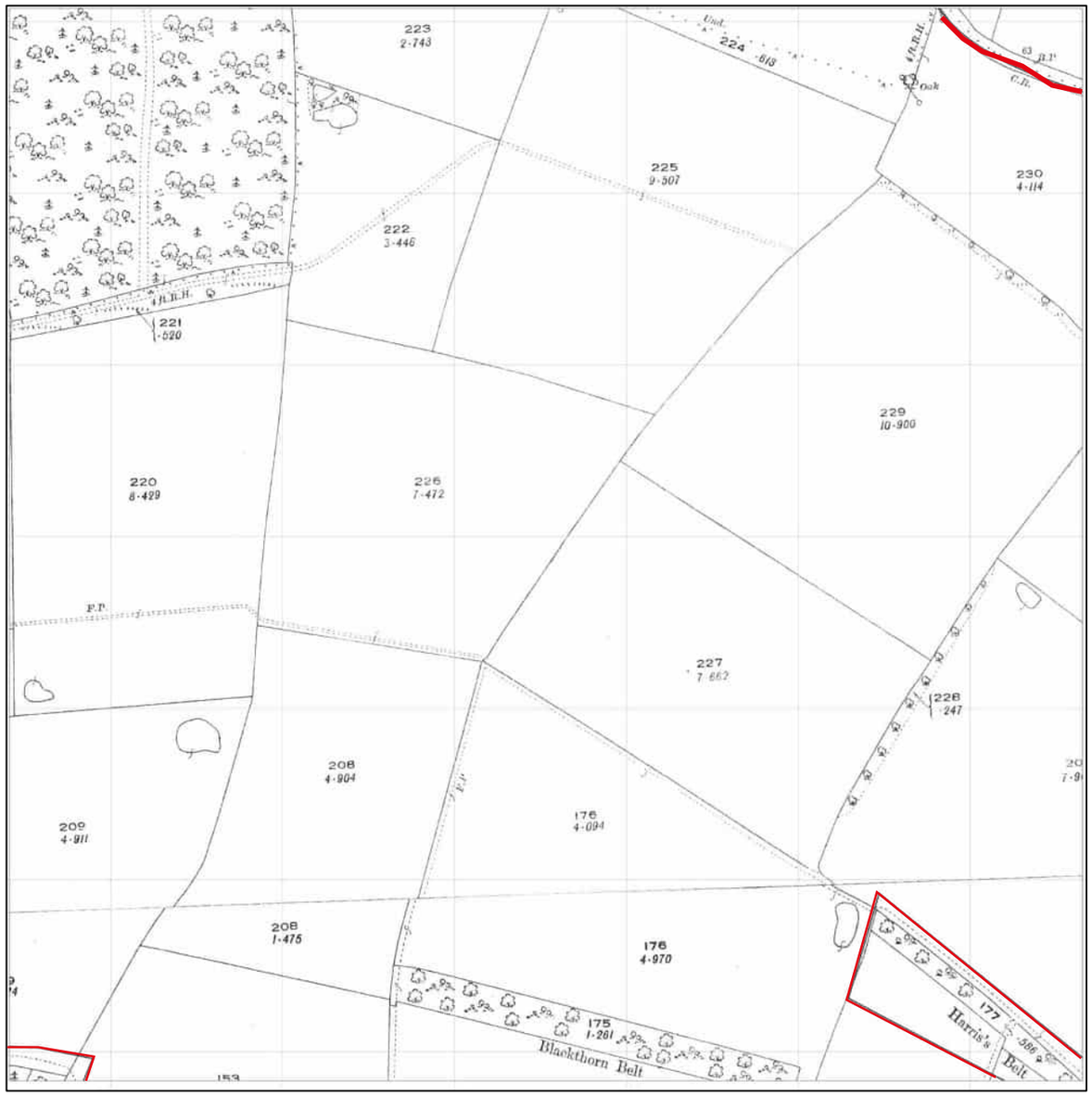


1970

Approximate site boundary Clearance Redevelopment

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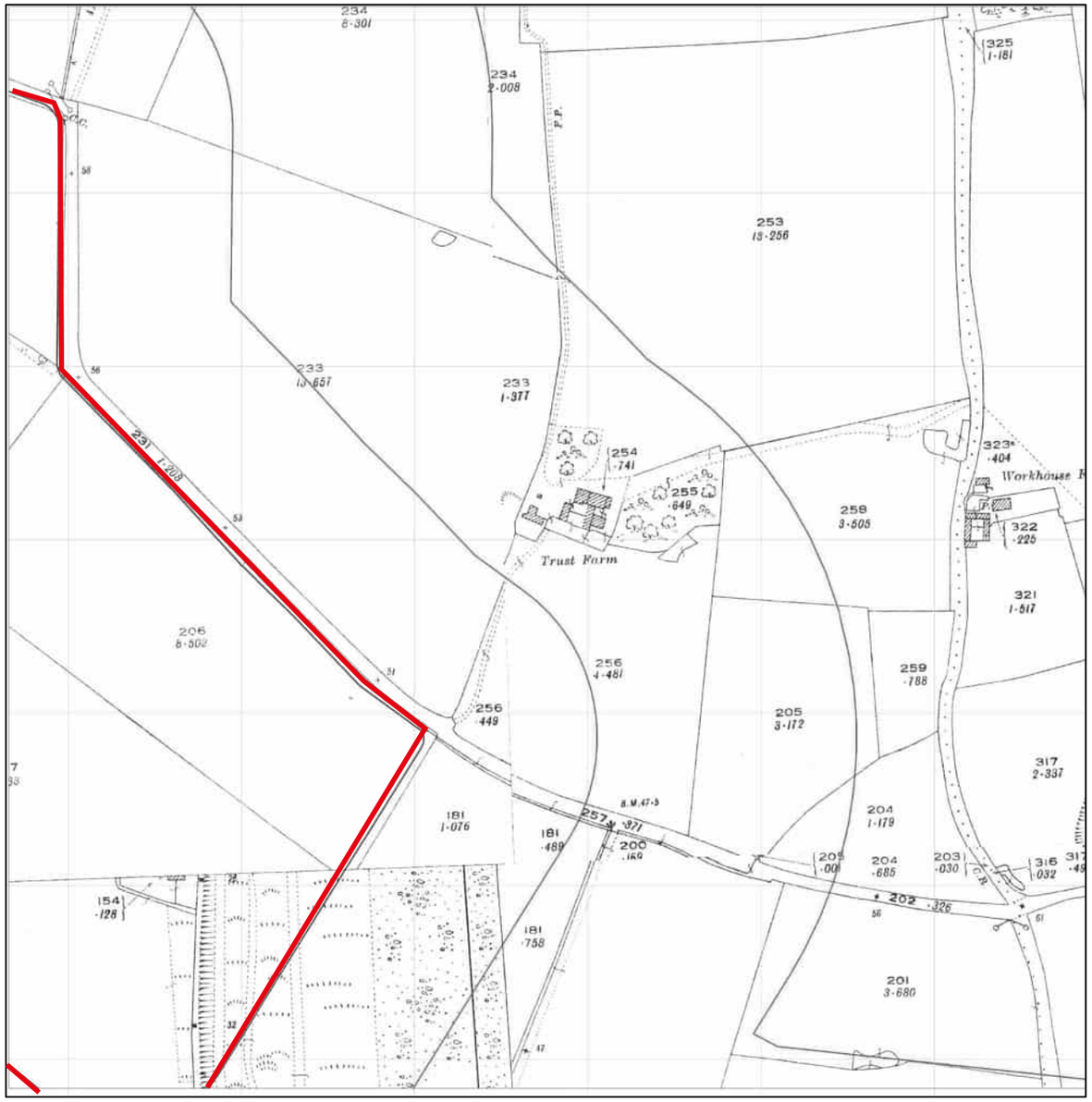
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Approximate site boundary

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1927



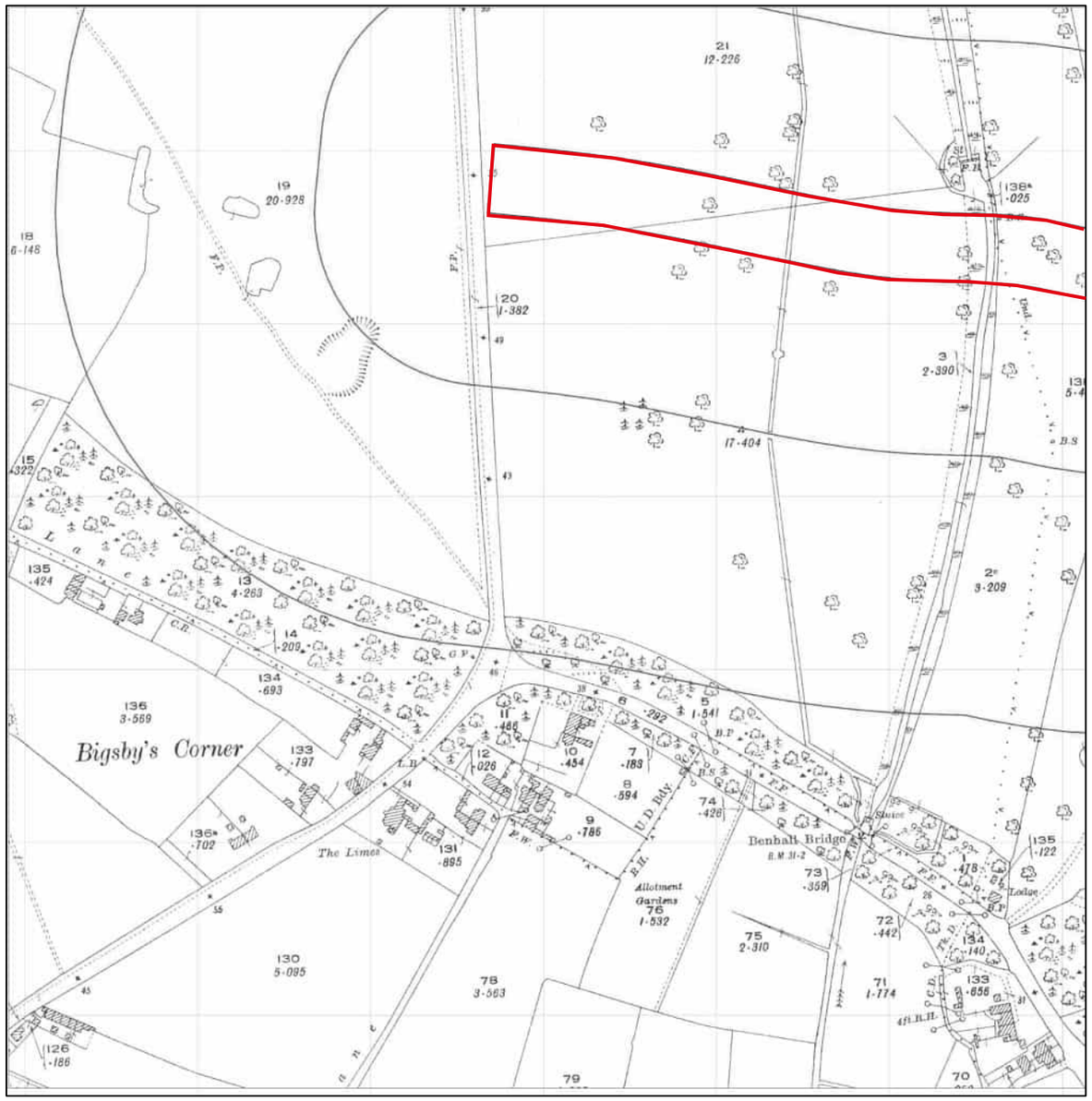
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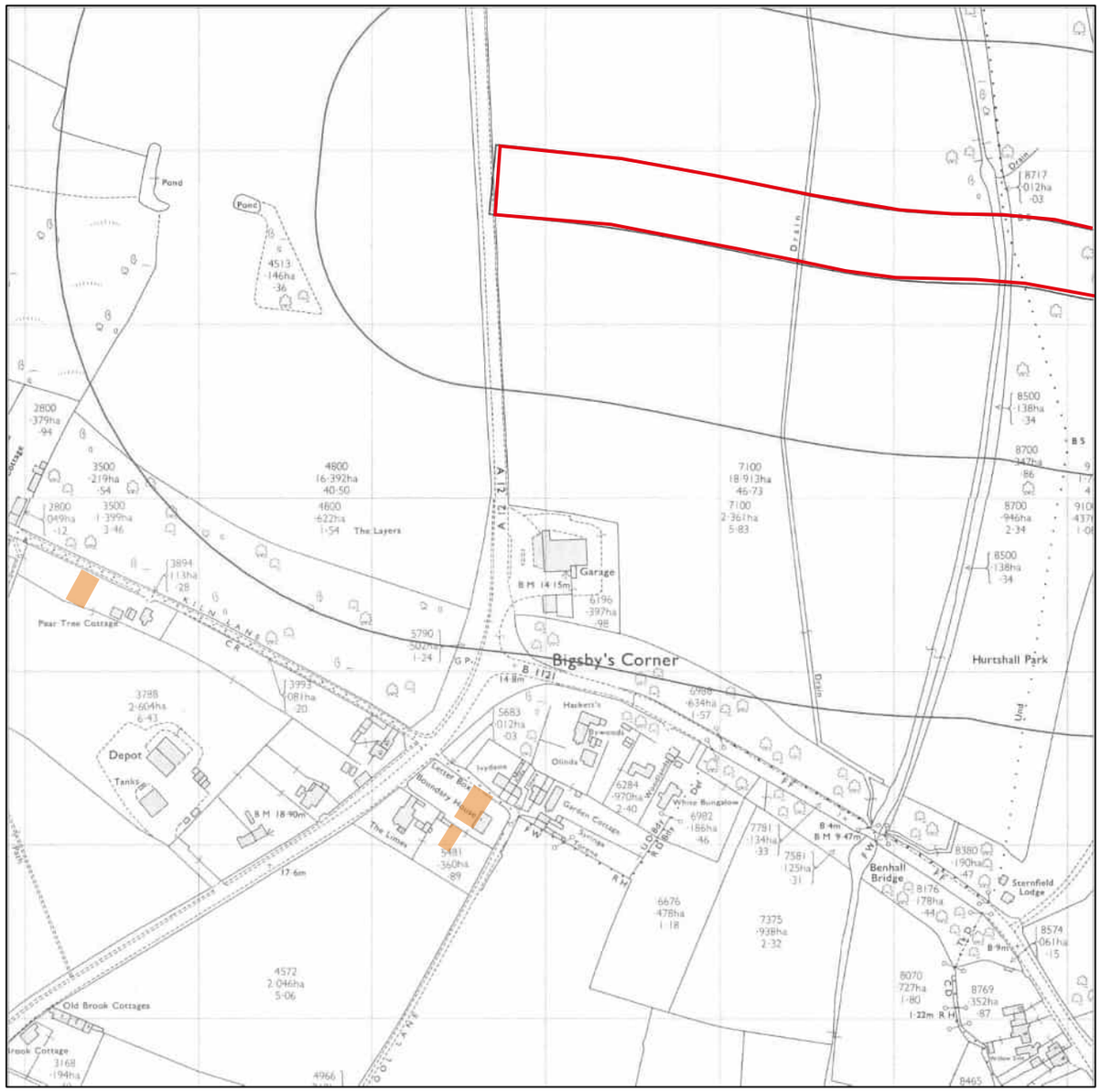
Approximate site boundary

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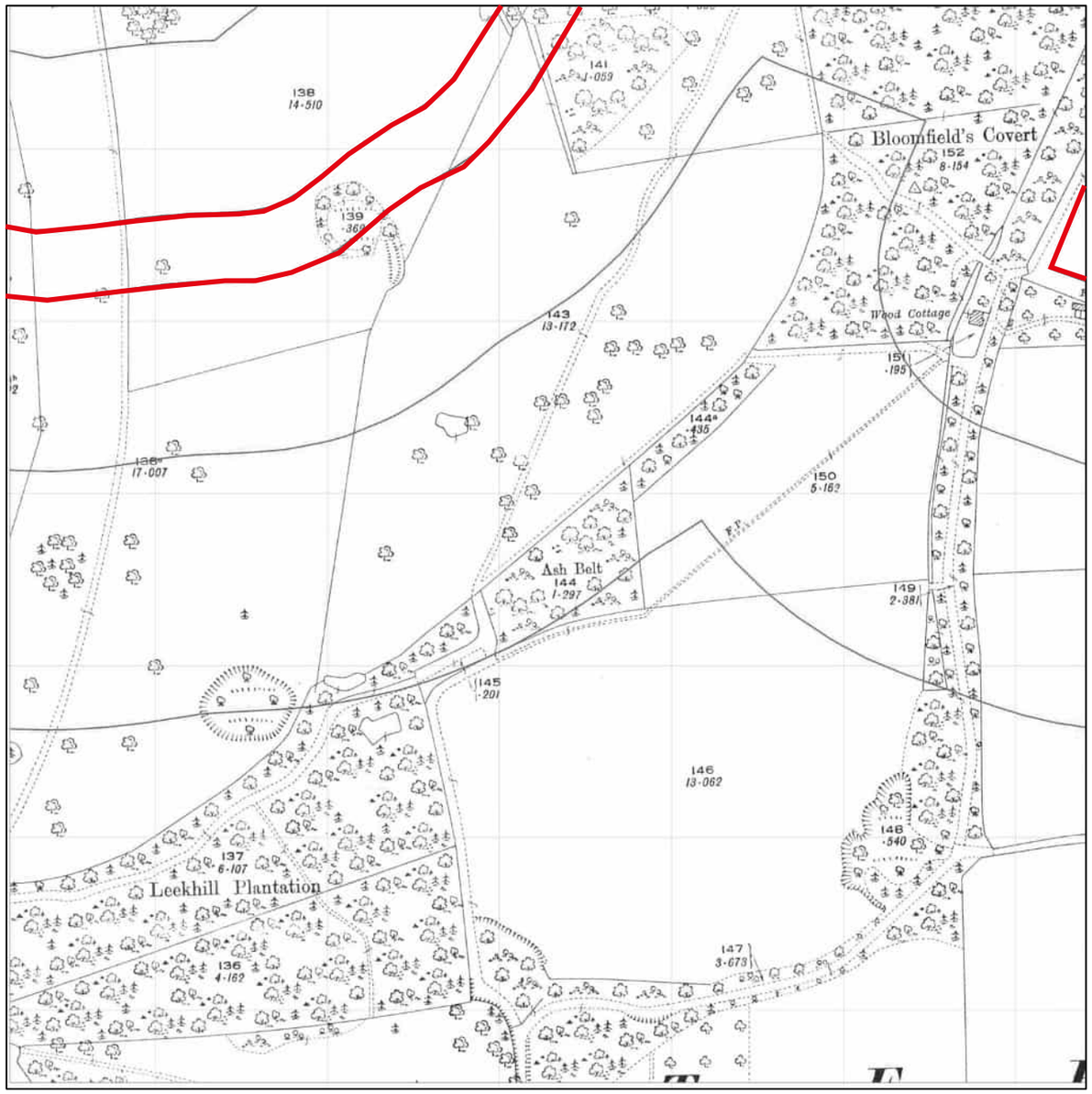
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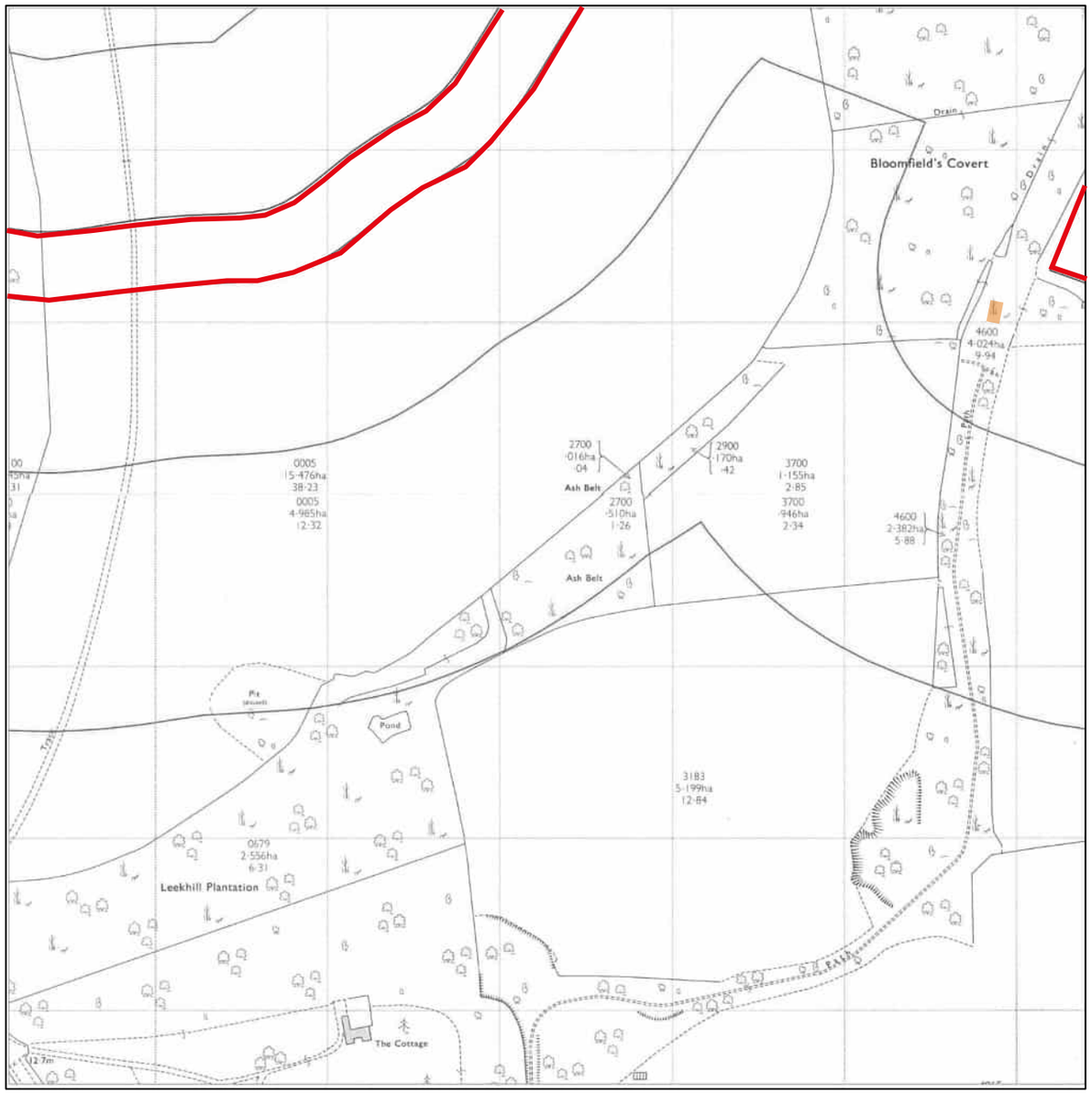
Approximate site boundary Clearance

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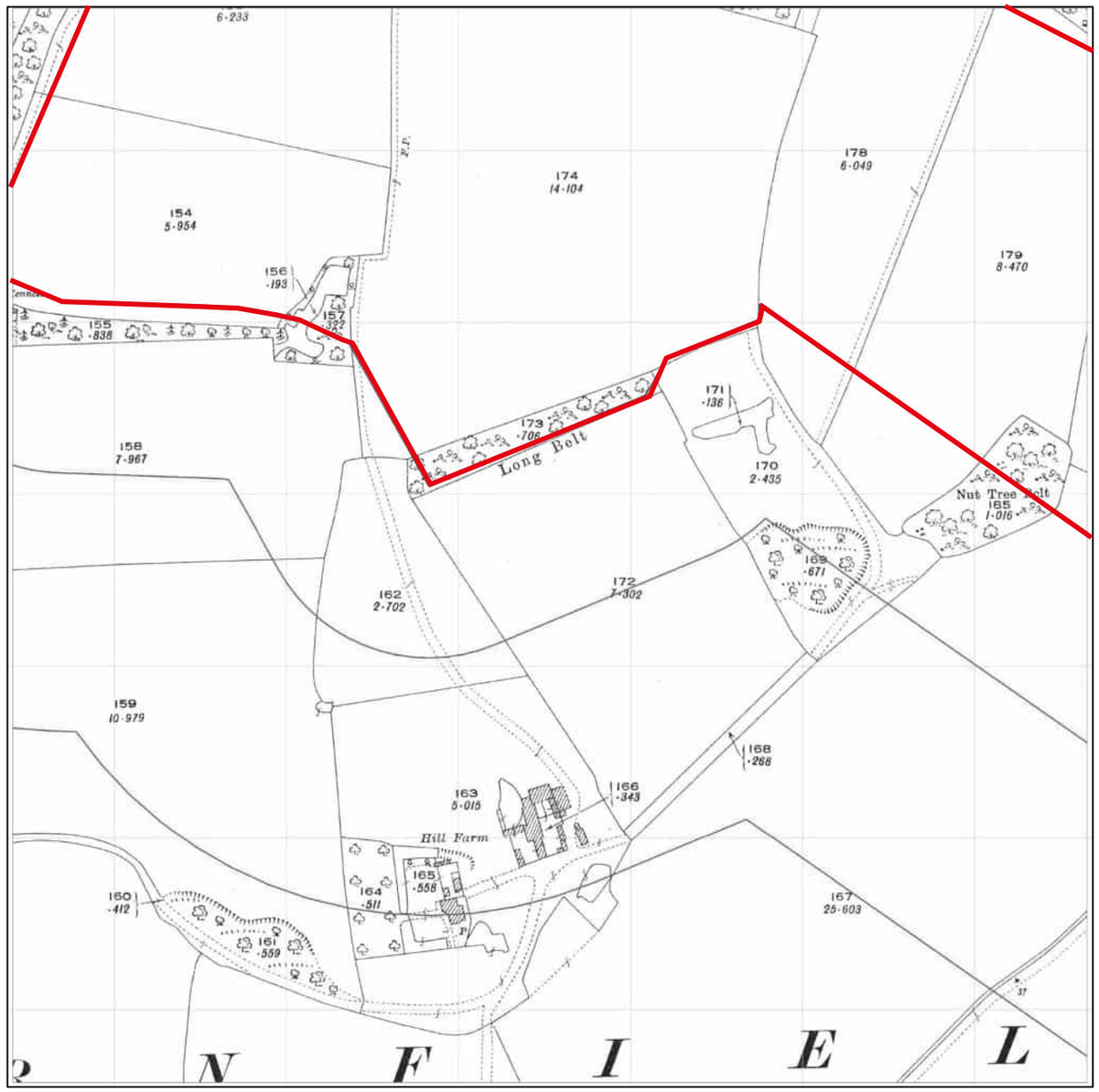
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Approximate site boundary

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1927



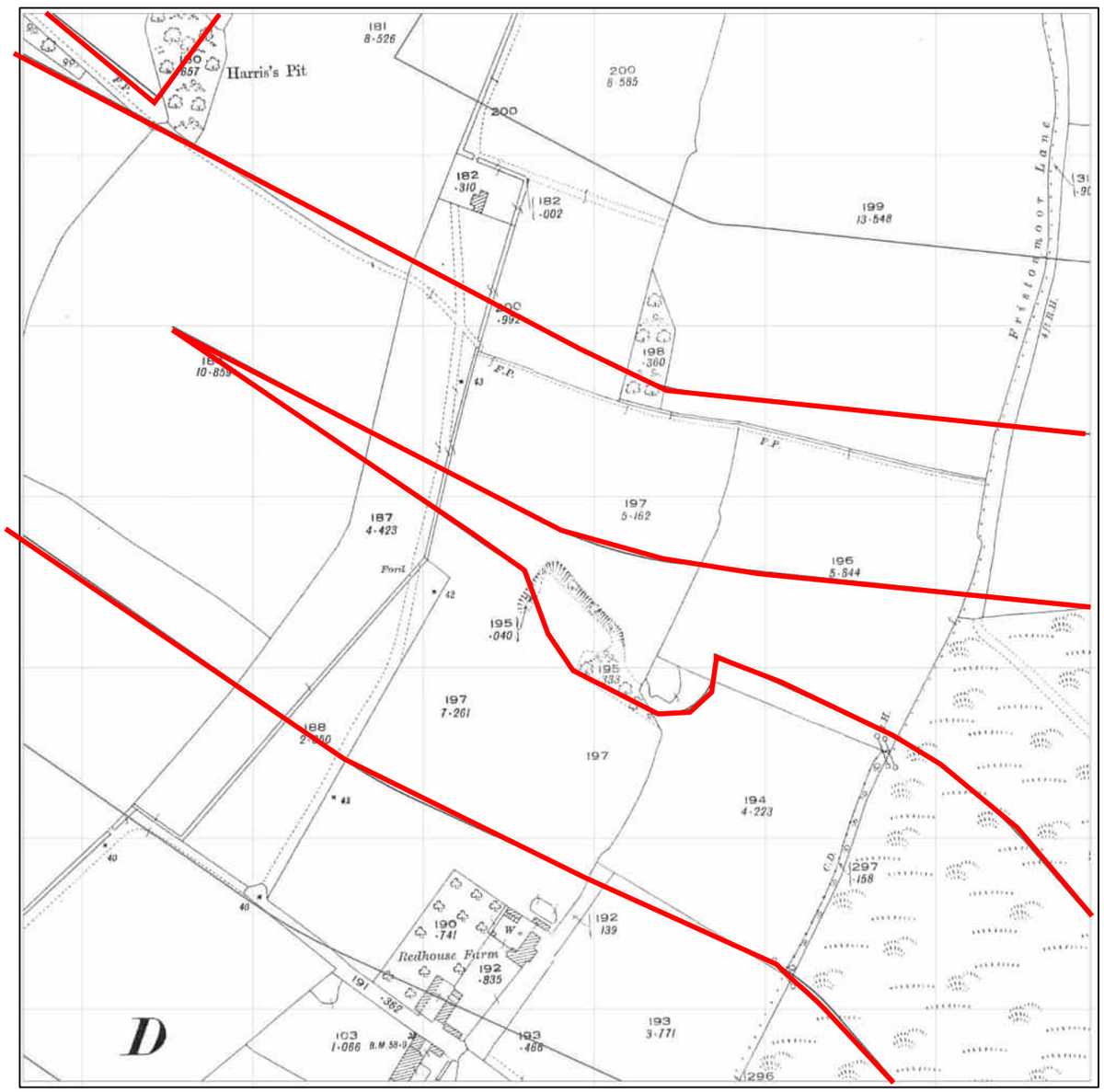
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Approximate site boundary Redevelopment

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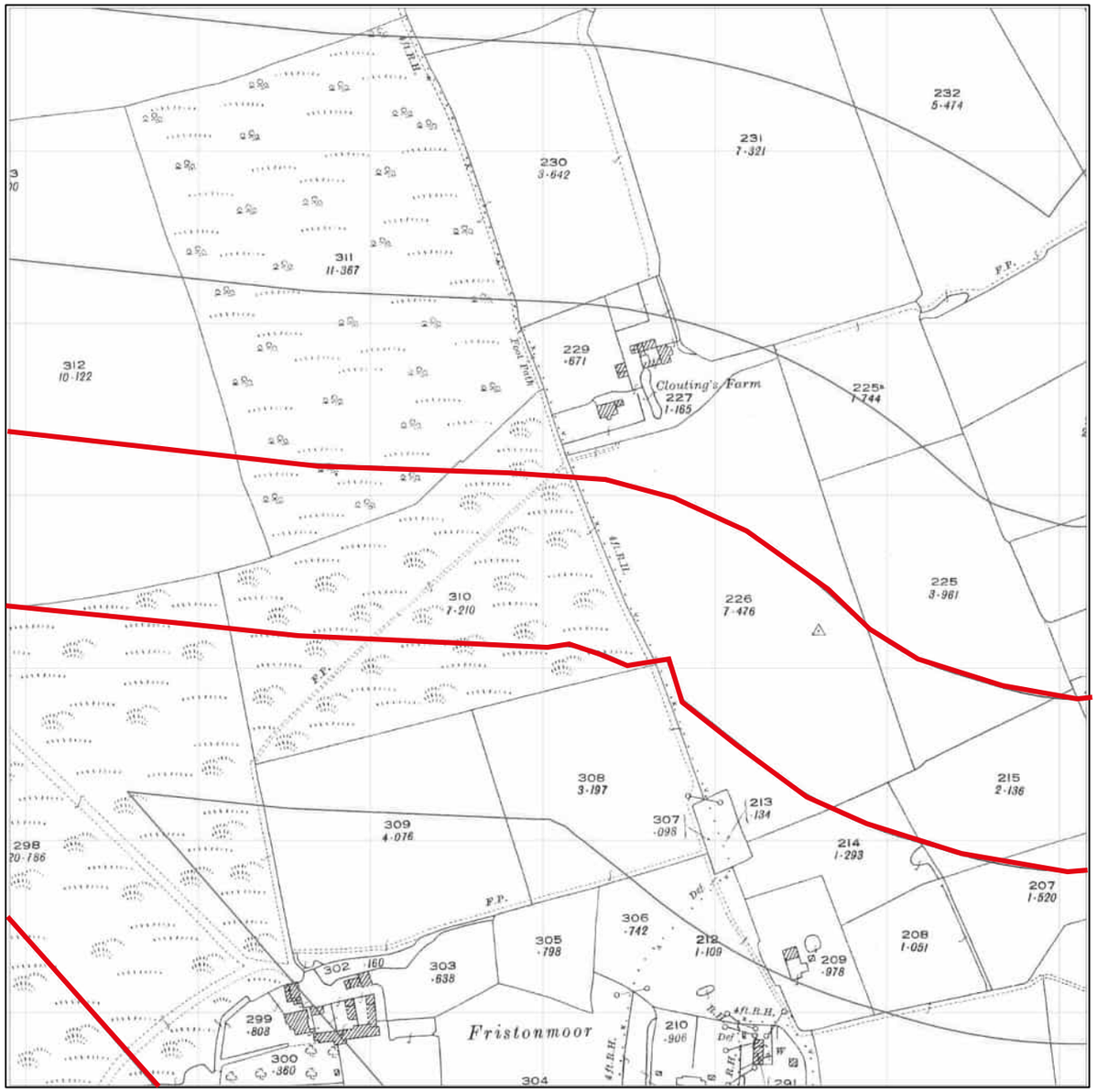
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Approximate site boundary

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1970



Approximate site boundary Clearance Redevelopment

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1970



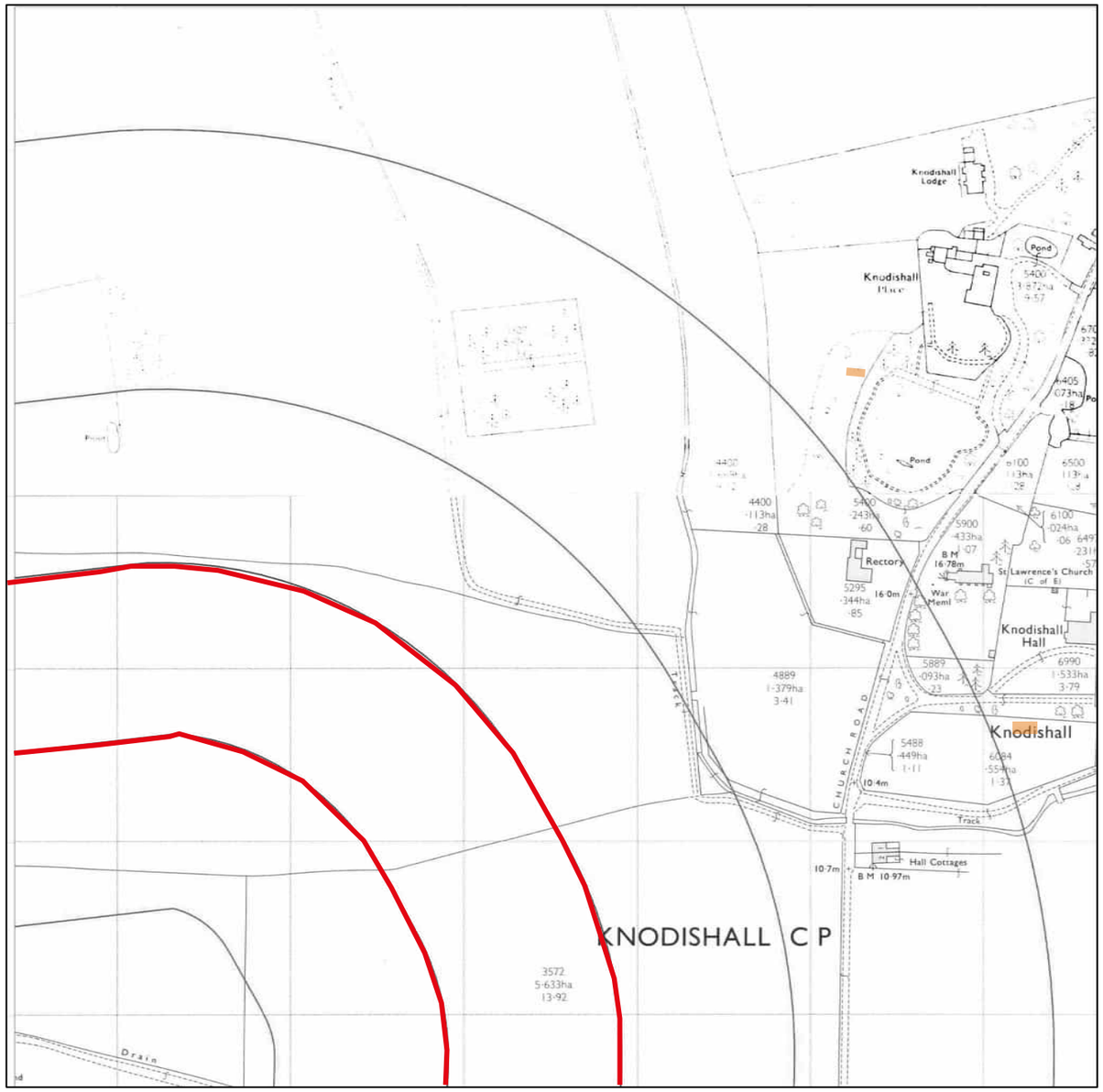
Approximate site boundary Clearance

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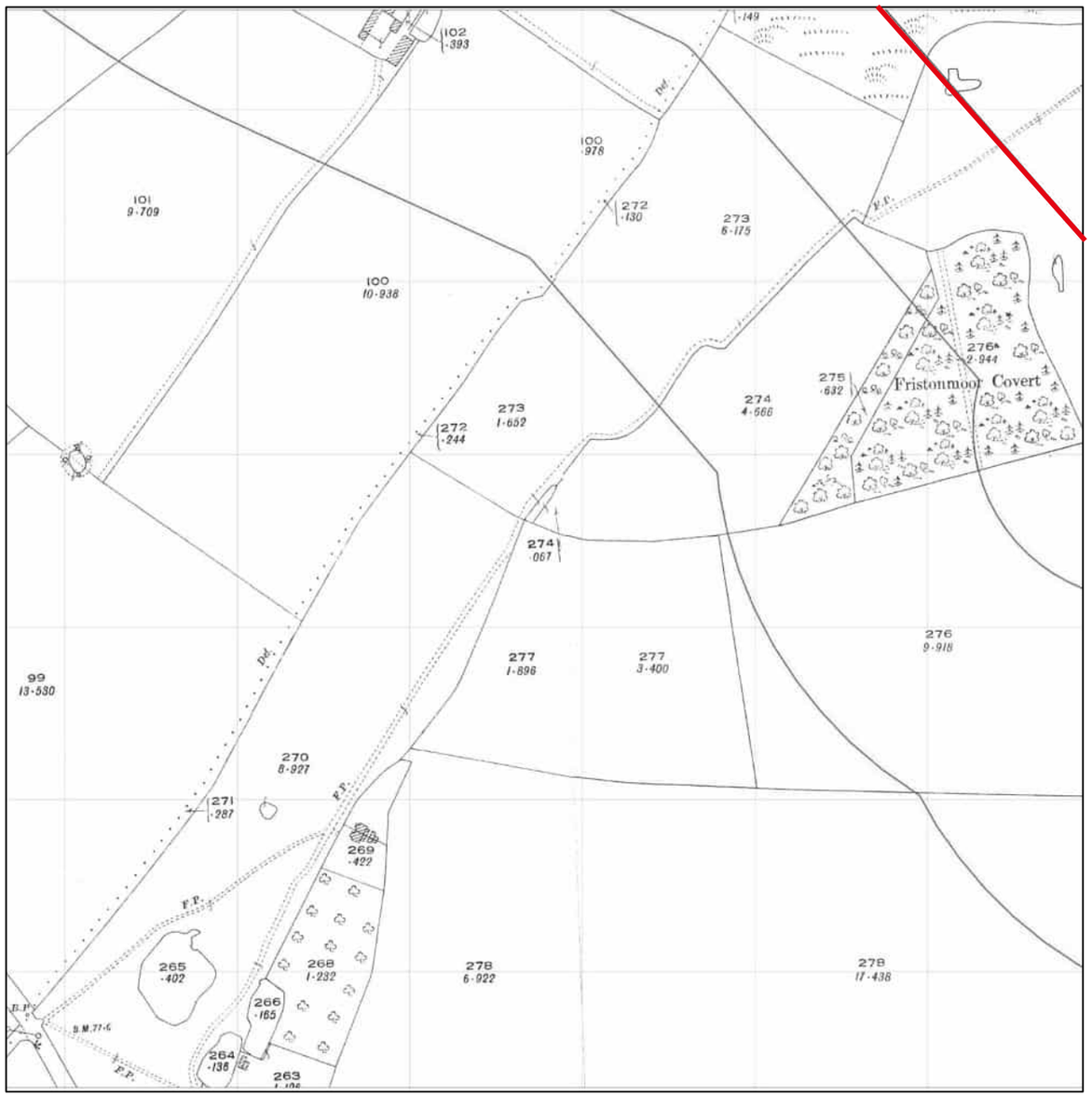
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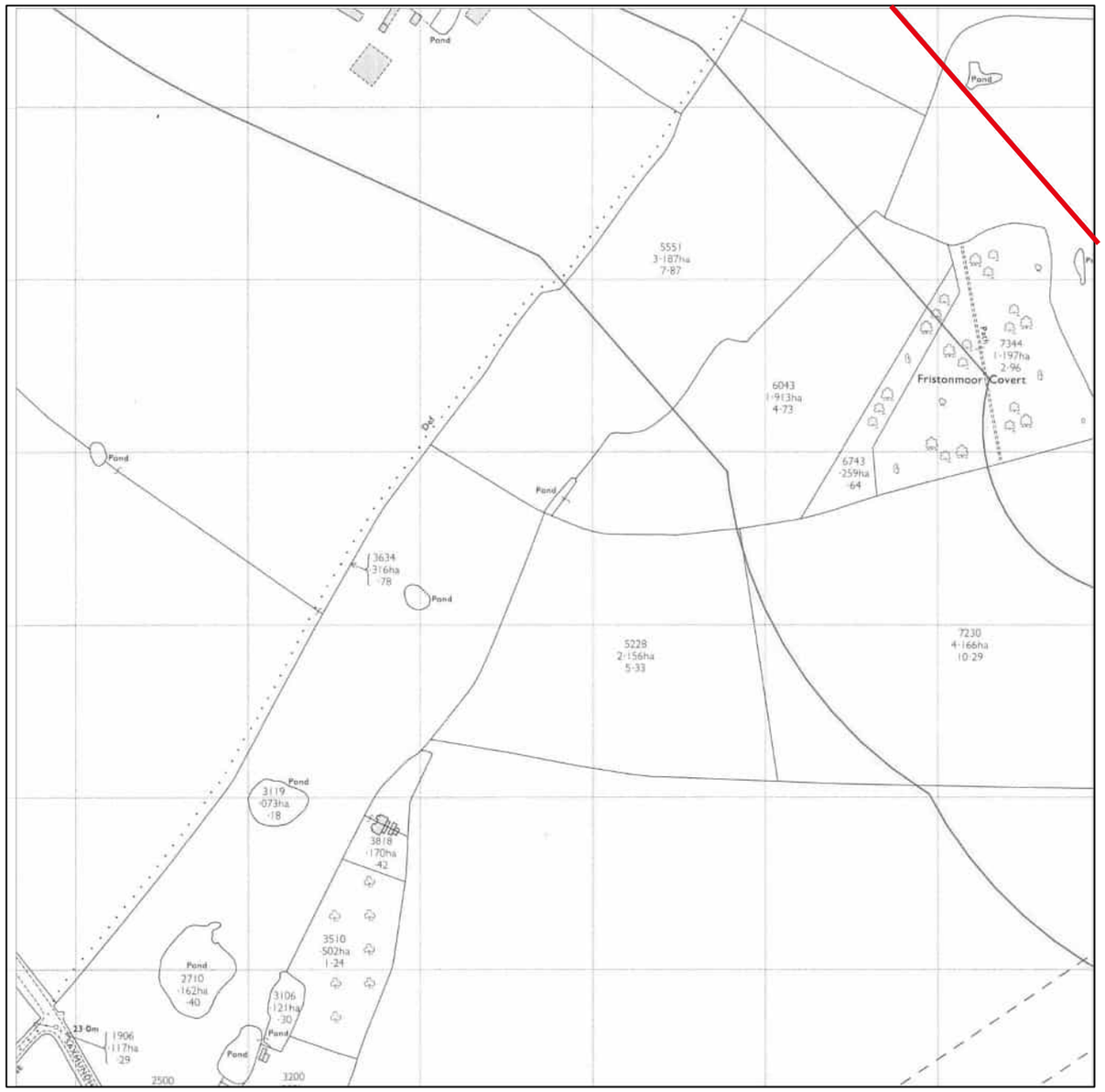
Approximate site boundary Clearance

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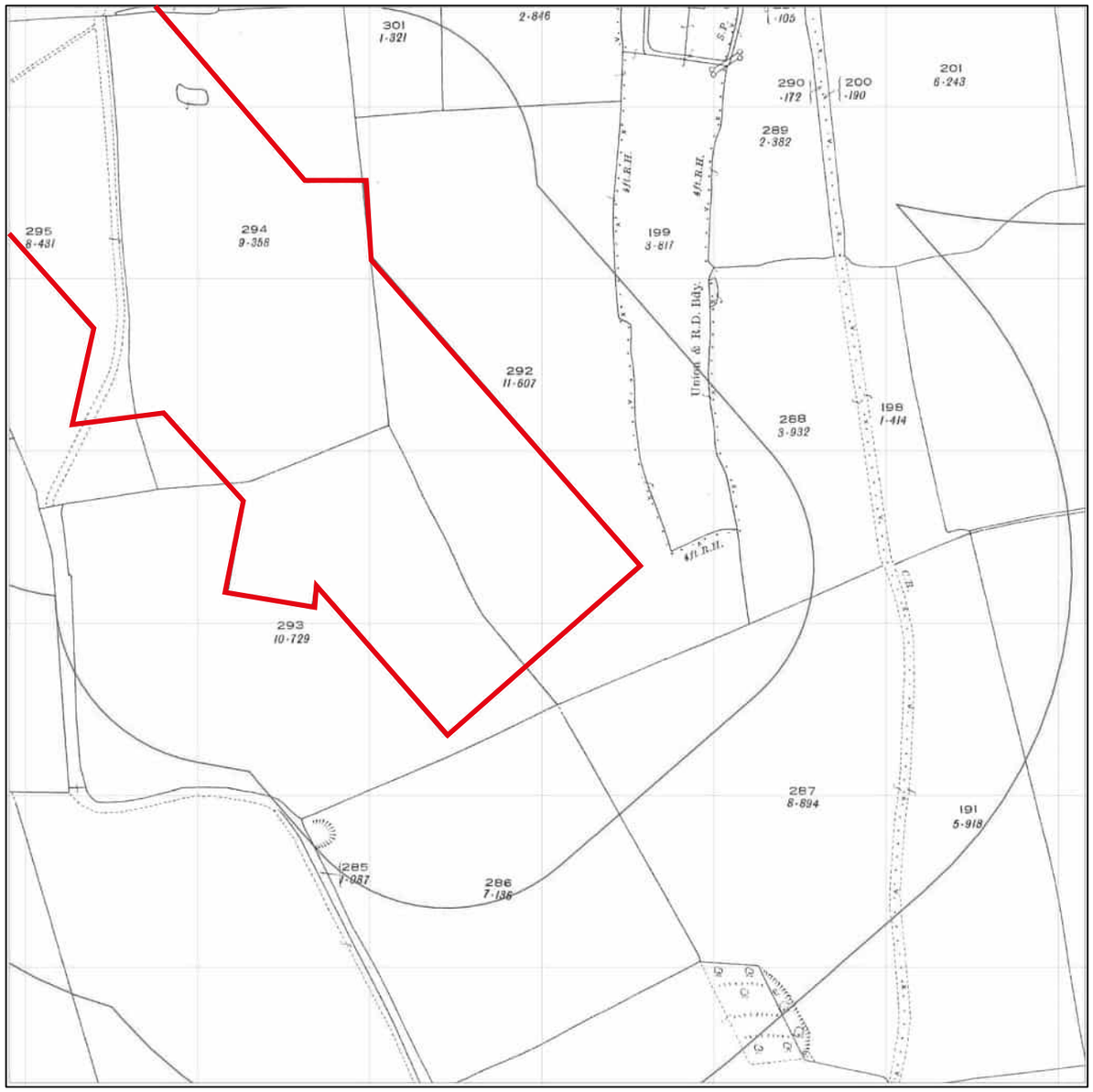


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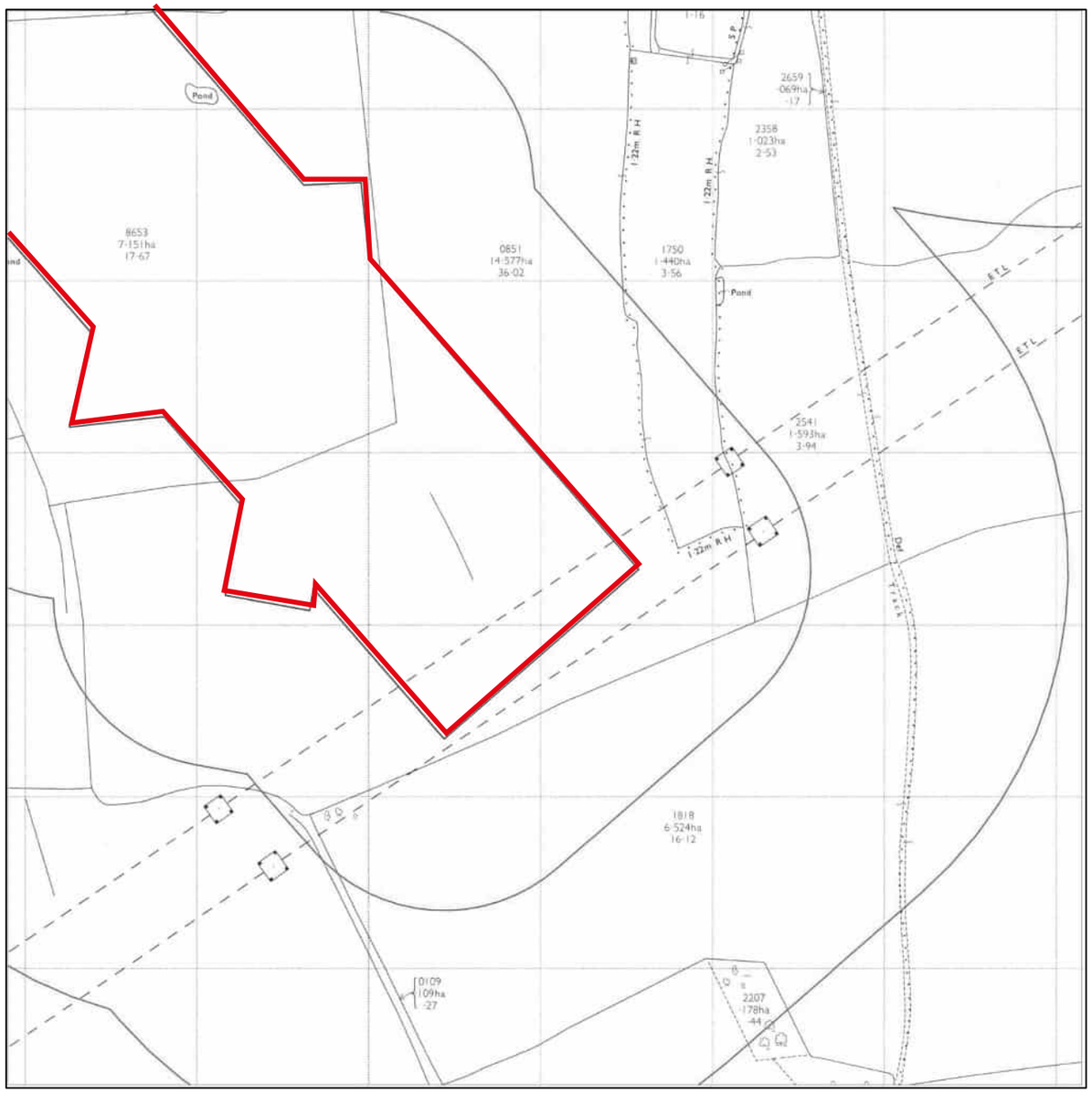

Fristonmoor Covert
Pond
Pond
Pond

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1927



1970



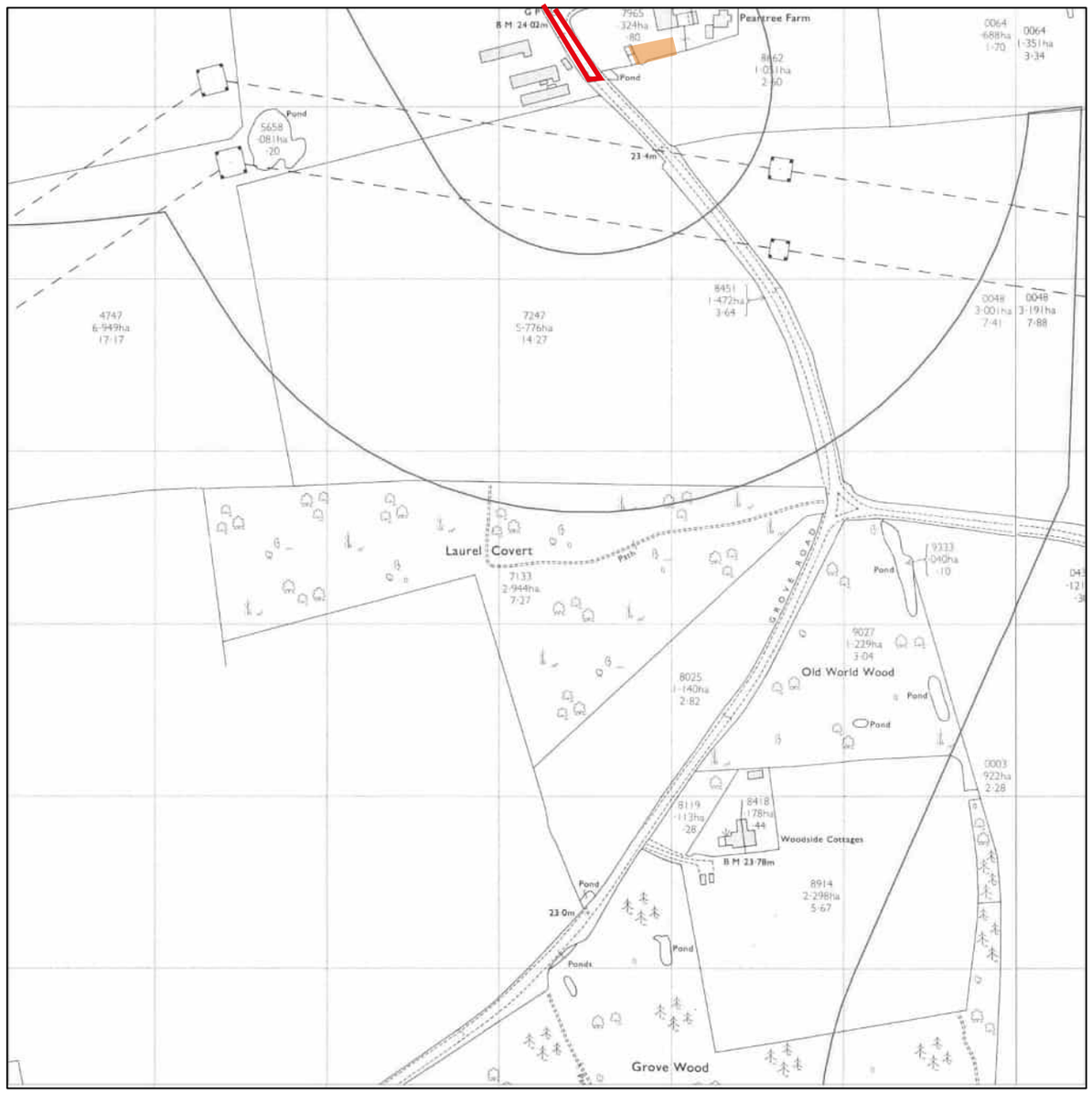
Approximate site boundary

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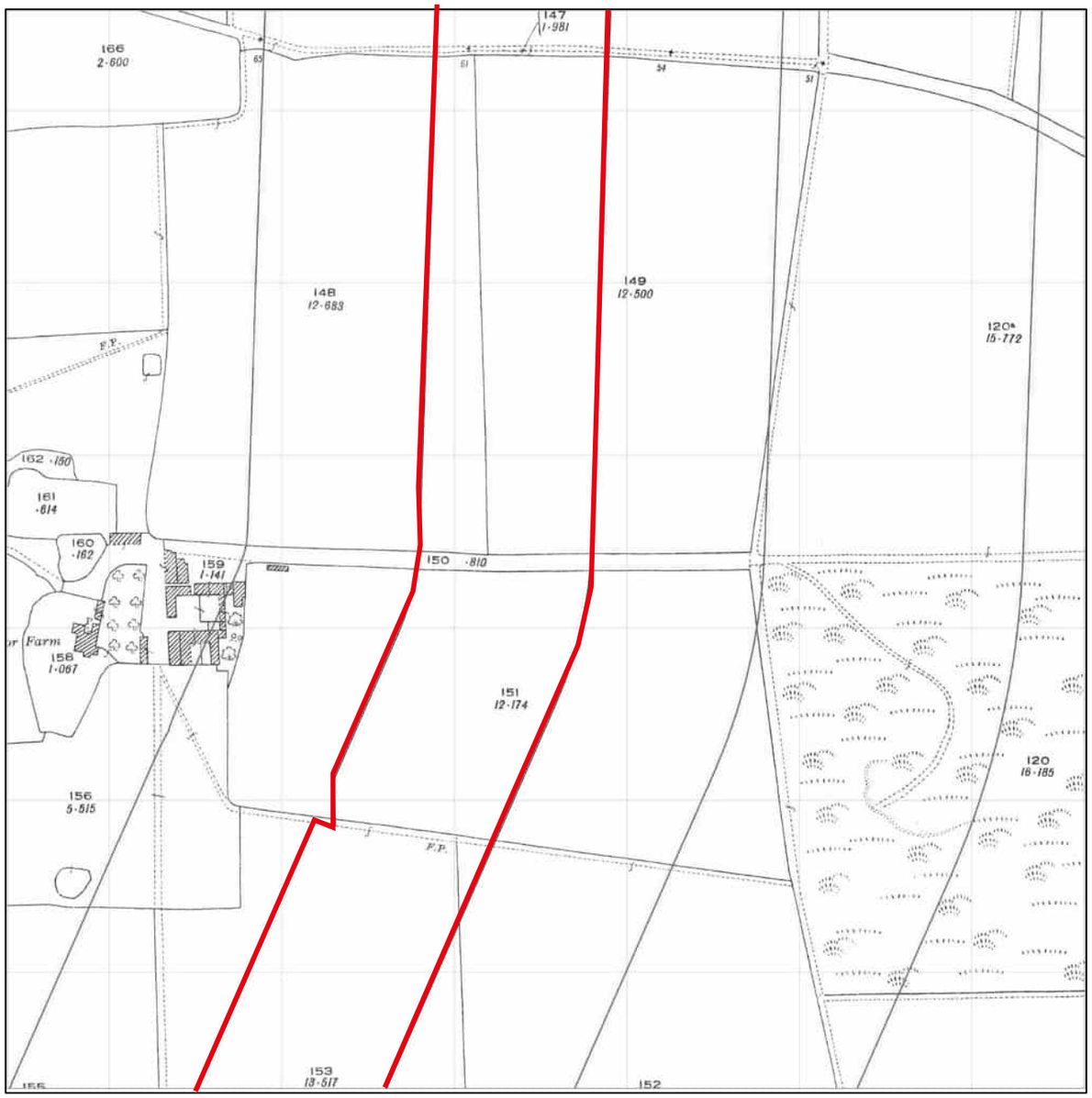
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Approximate site boundary

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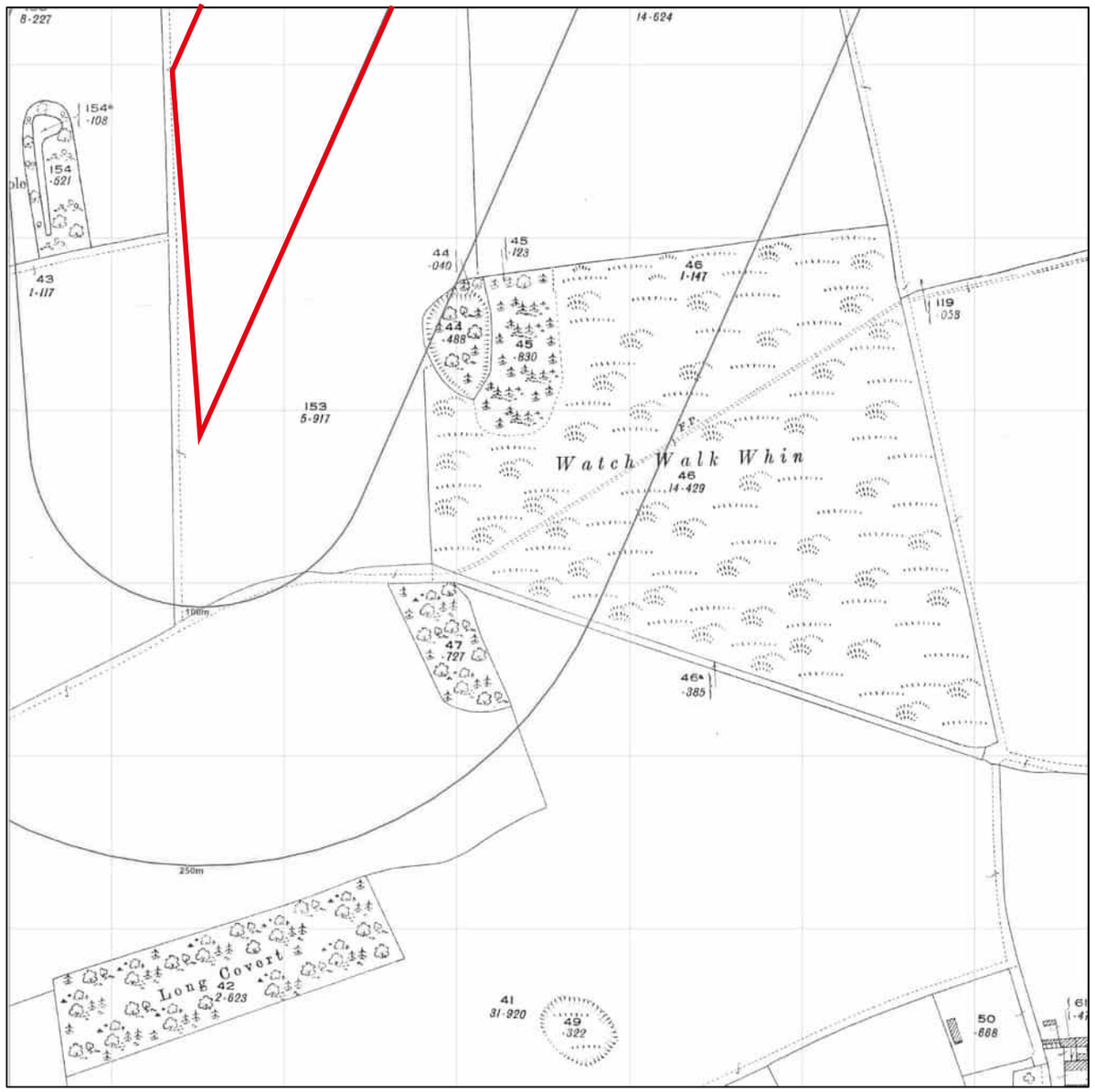
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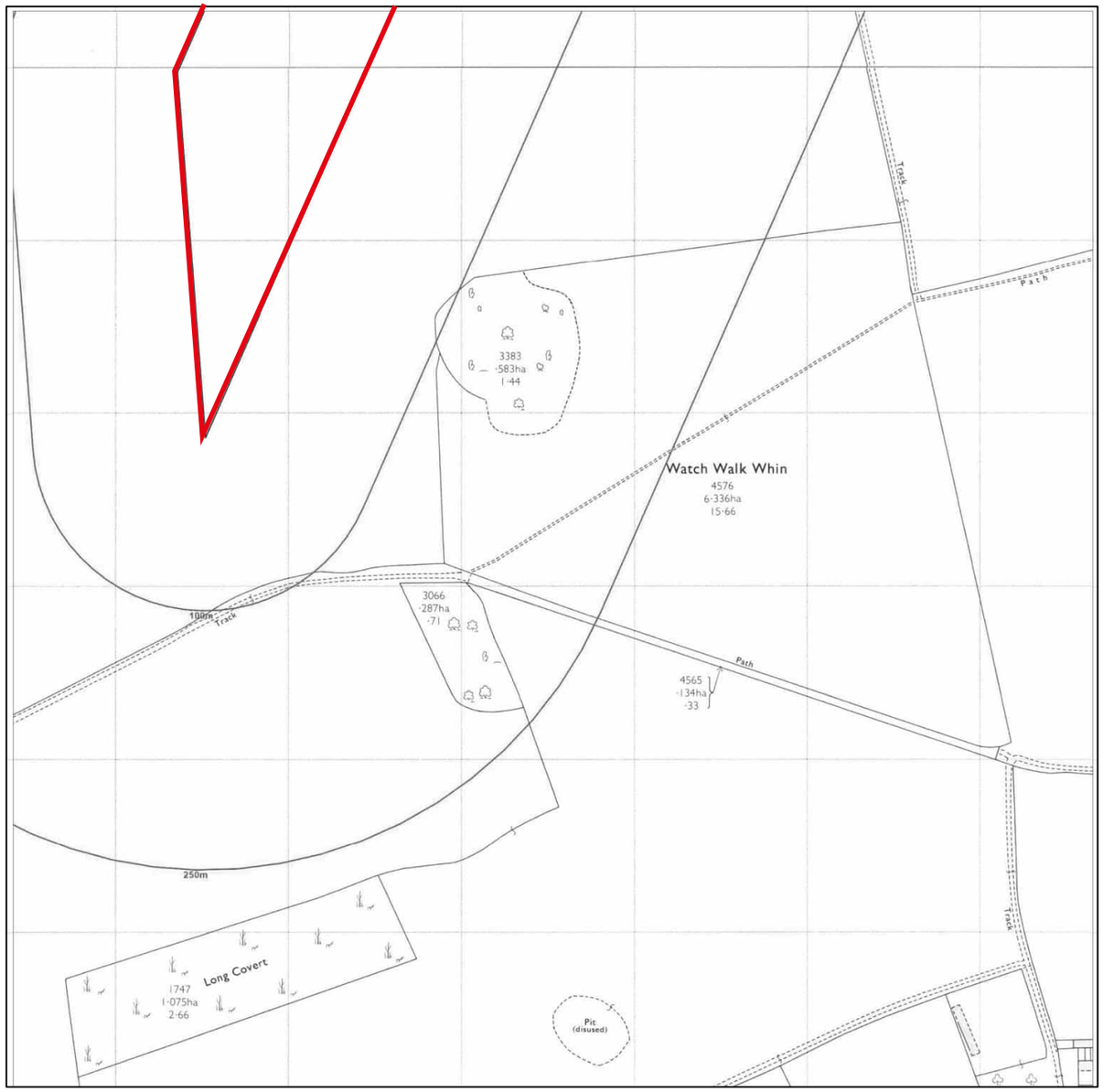
Approximate site boundary Clearance

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1970



Approximate site boundary

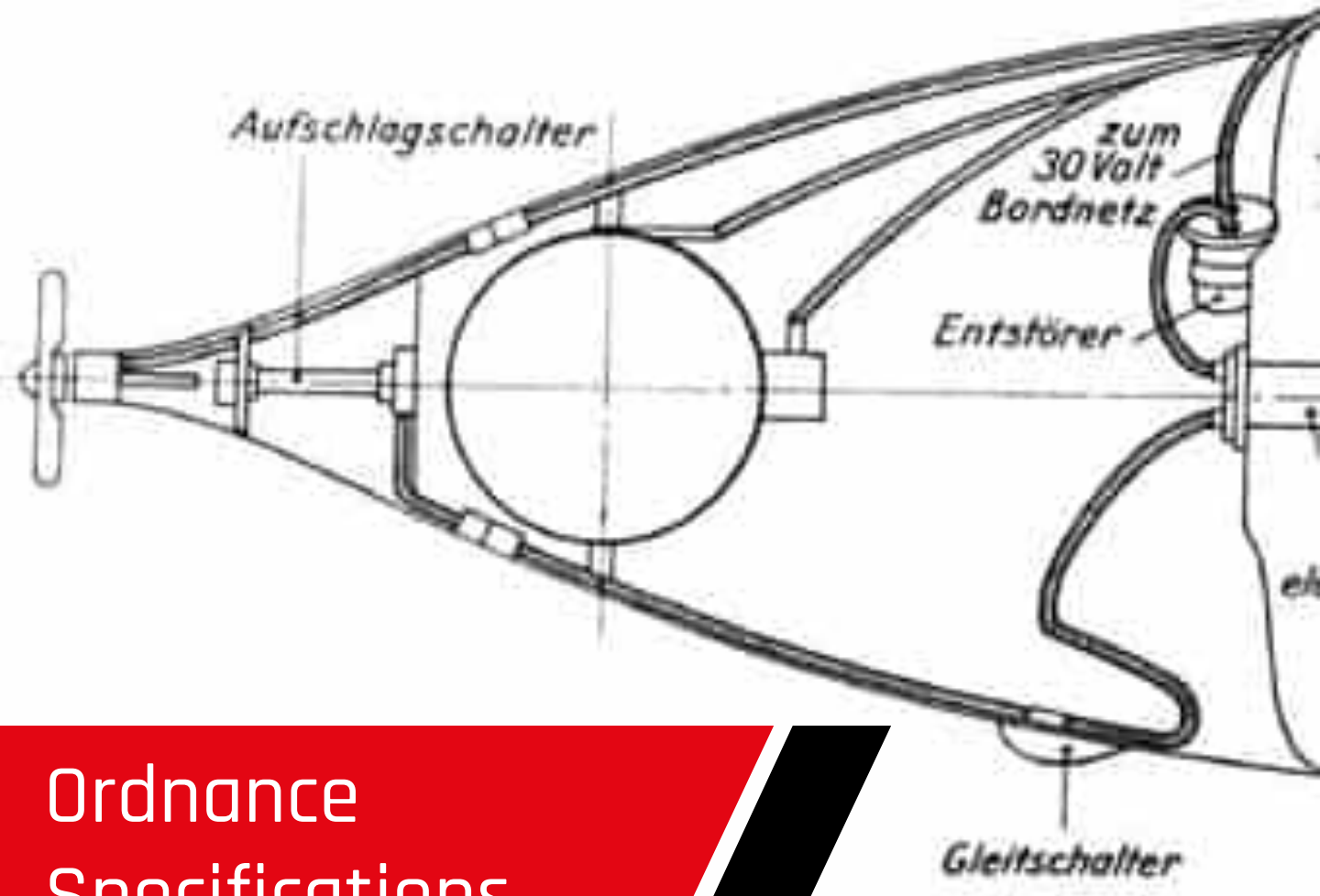
WWII-era RAF Aerial Photography – 28th July 1946



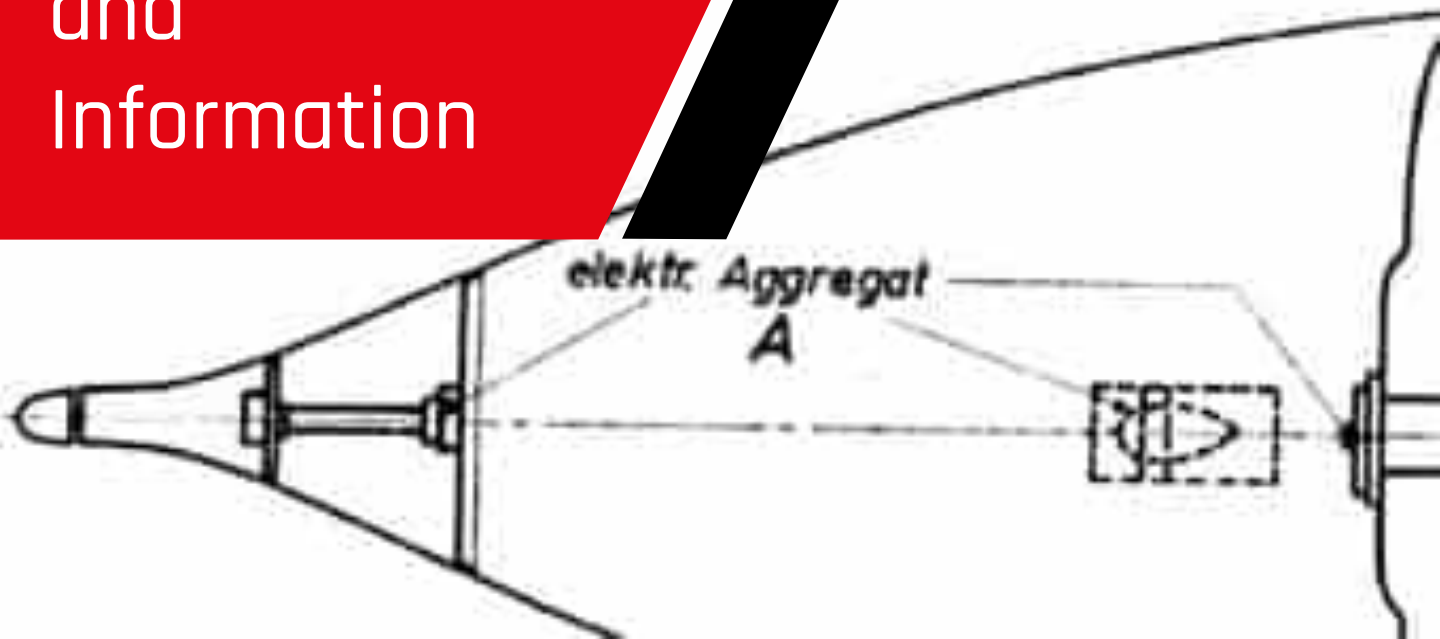
Approximate site boundary

RAF Aerial Collection

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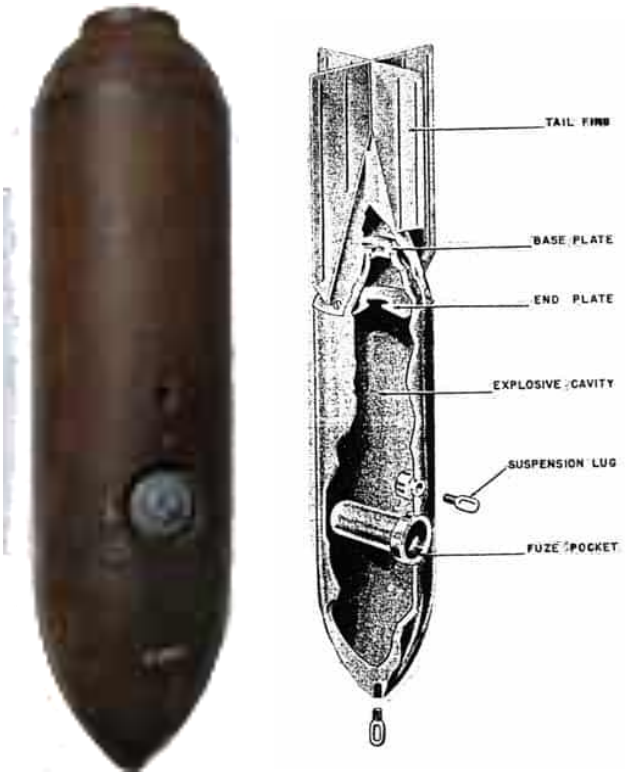


Ordnance Specifications and Information





German Ordnance





Sprengbombe Cylindrisch 50

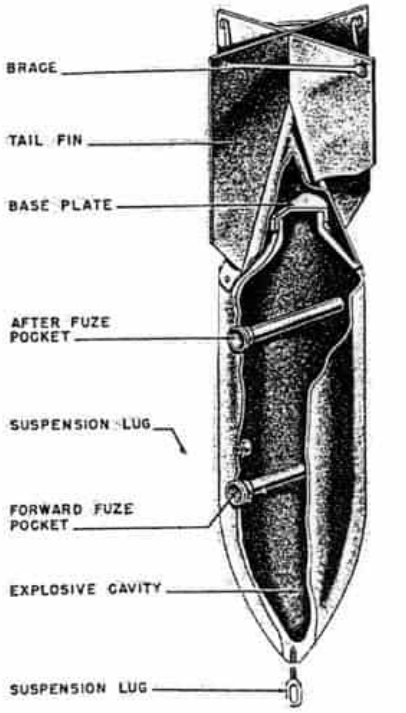
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

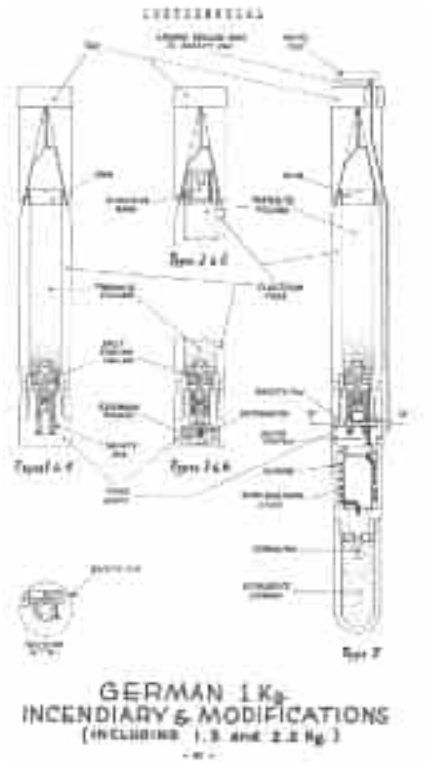
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









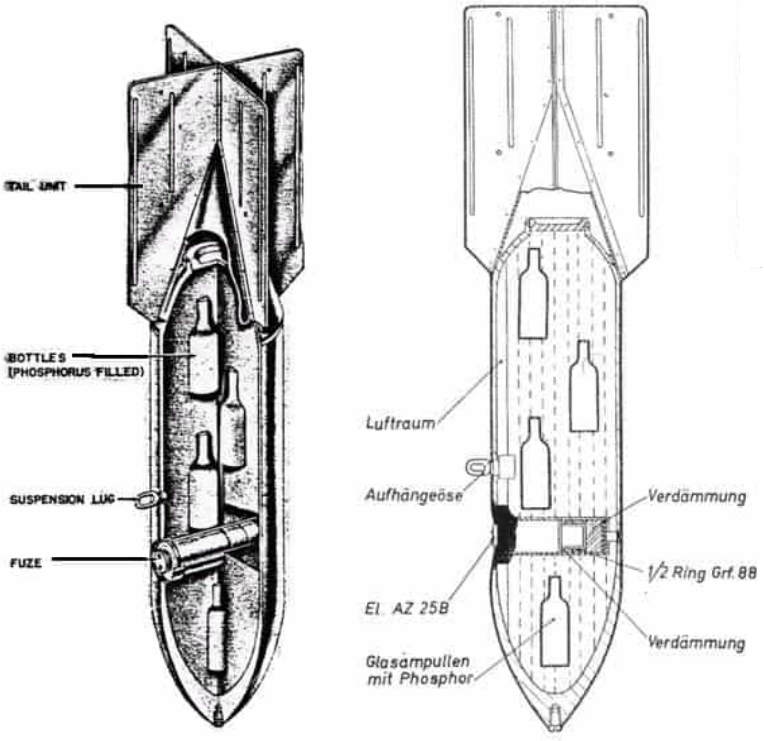
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

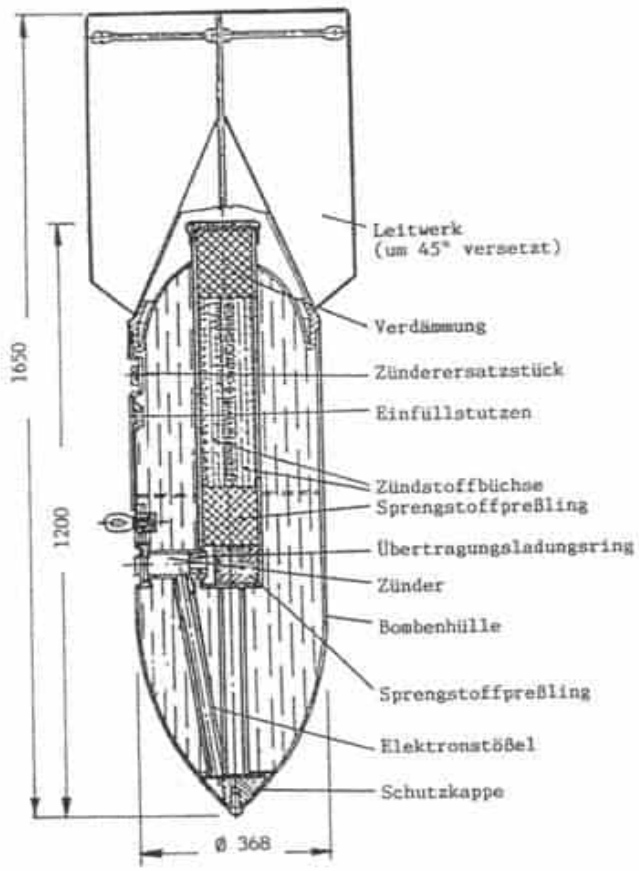






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

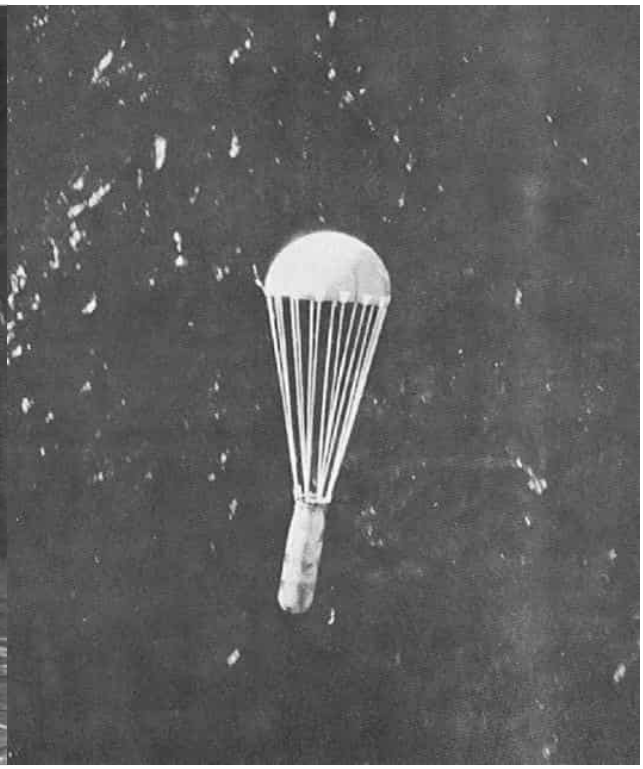




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration





Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg

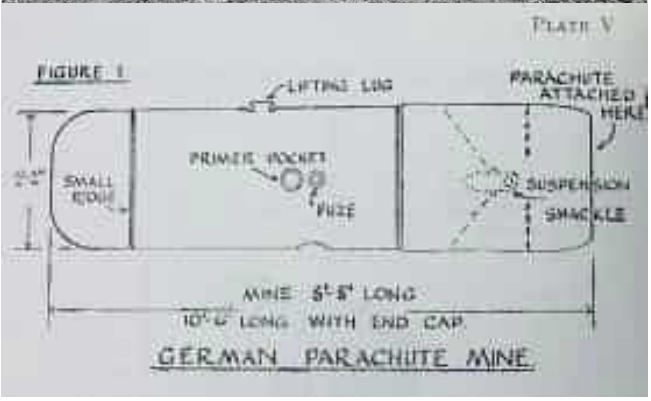
Fuze Type: Mechanical clockwork fuze

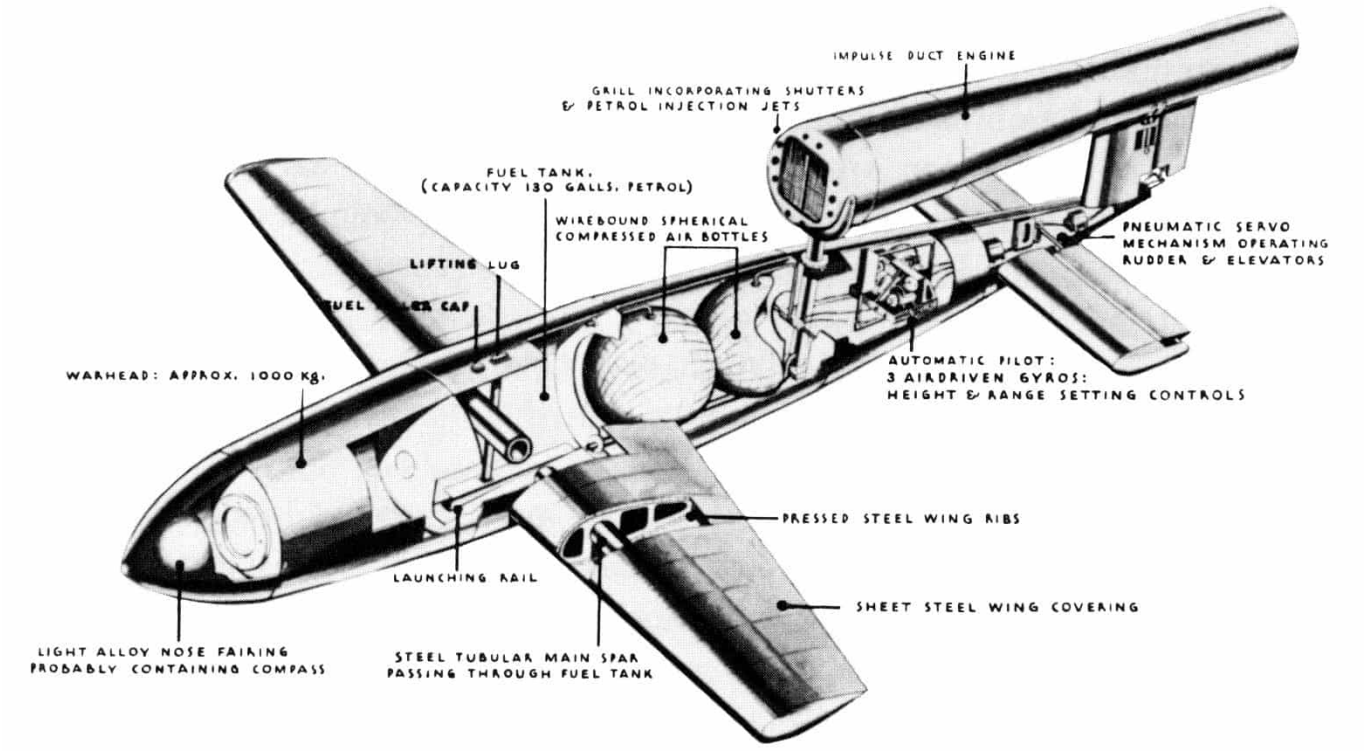
Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

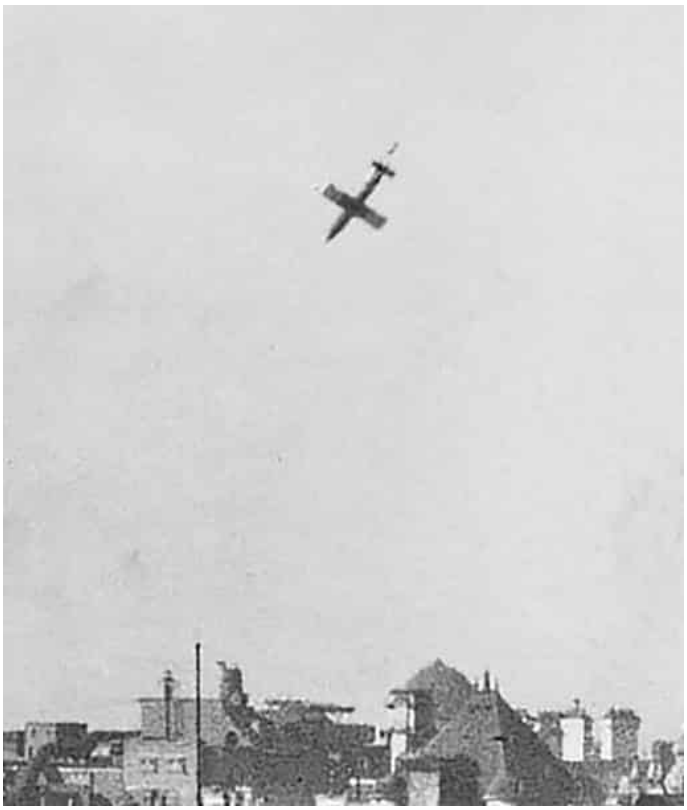




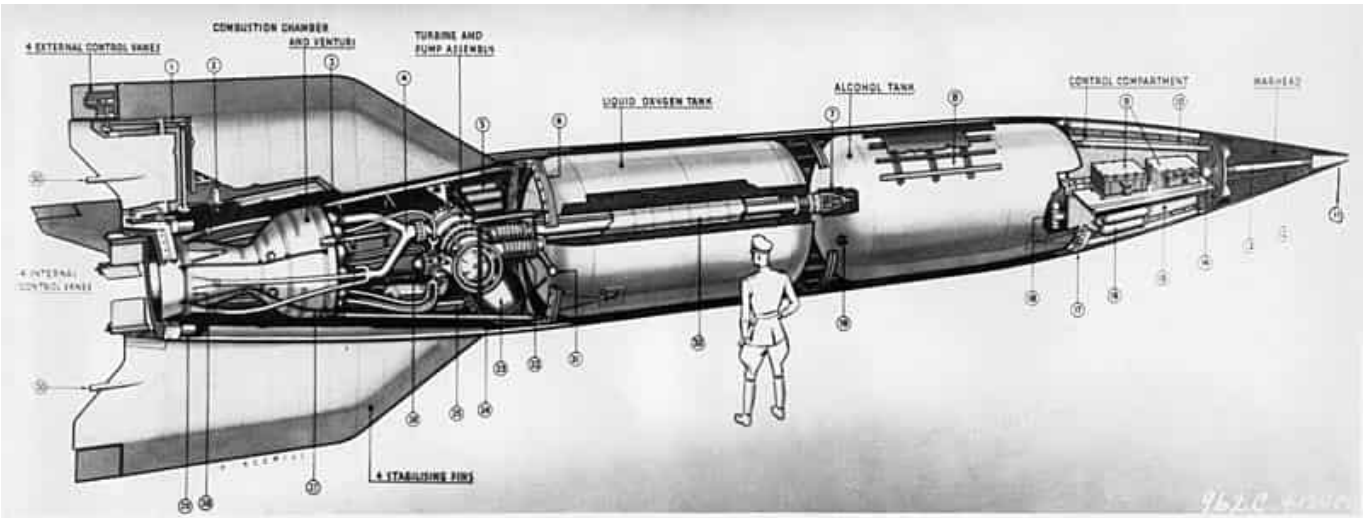


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

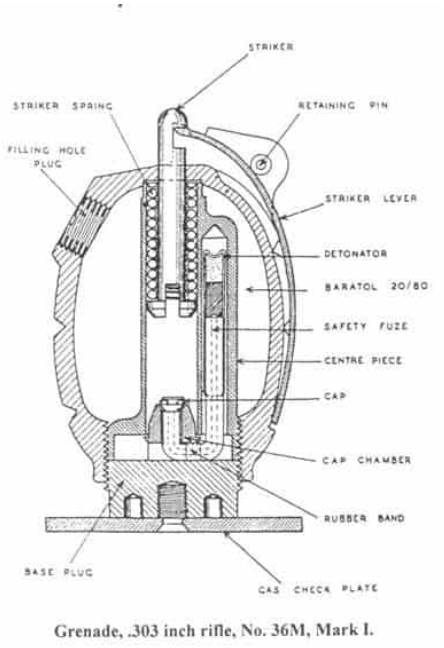
Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.





British & Allied Ordnance



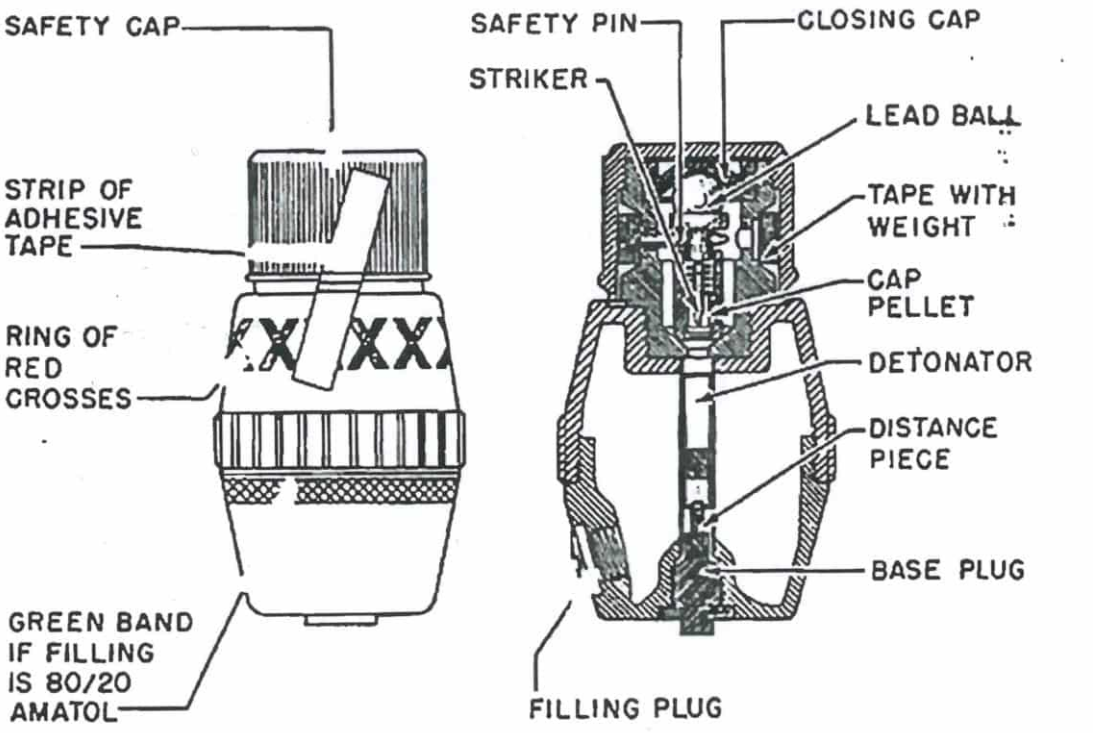


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



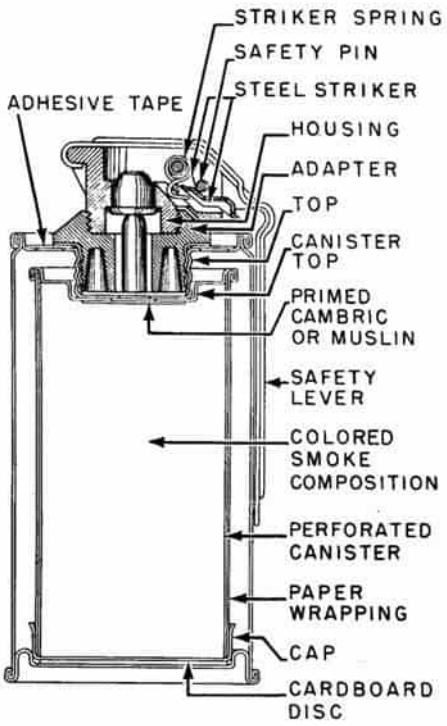


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





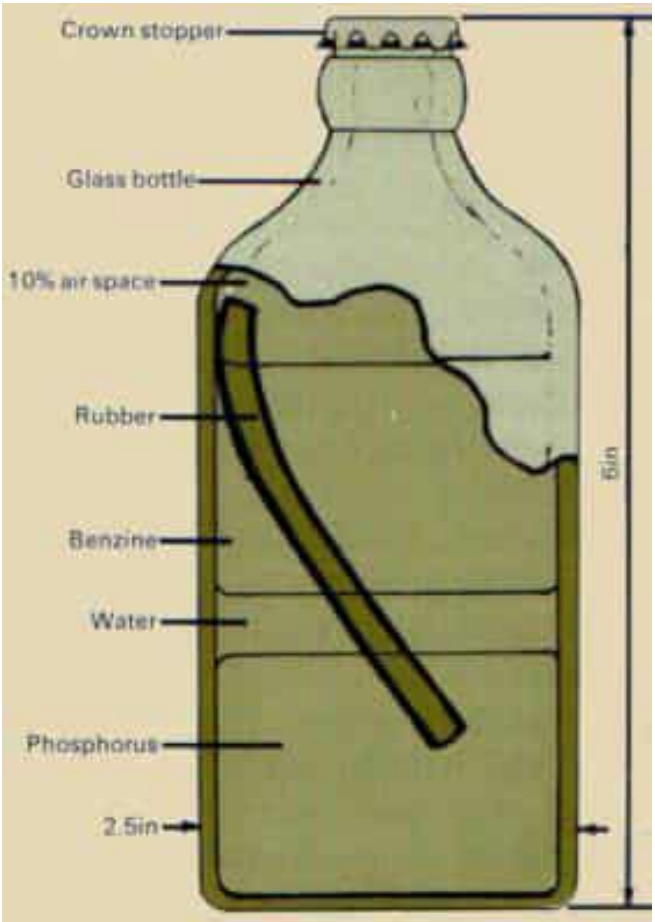


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

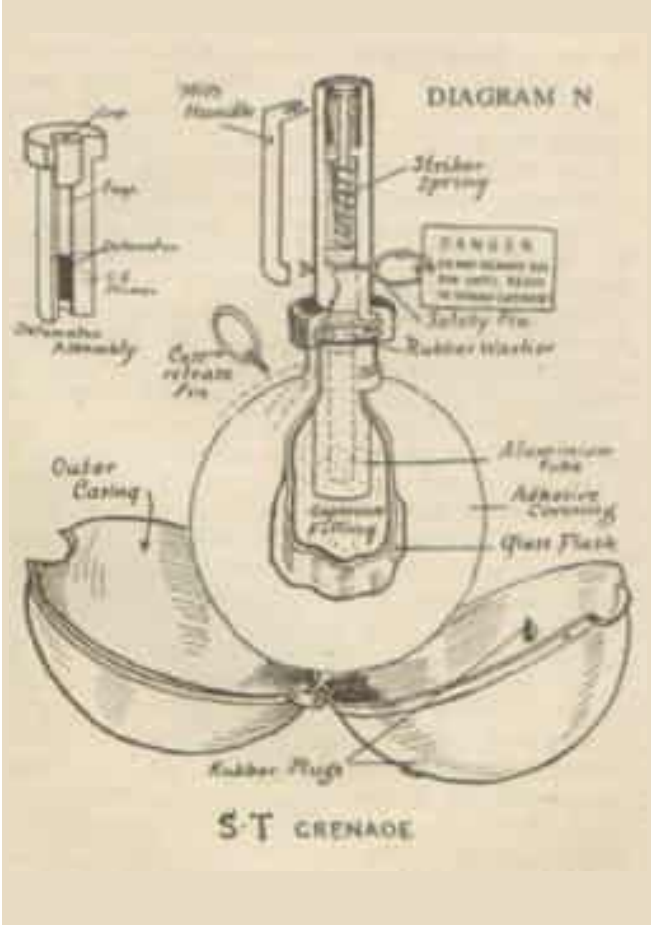






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

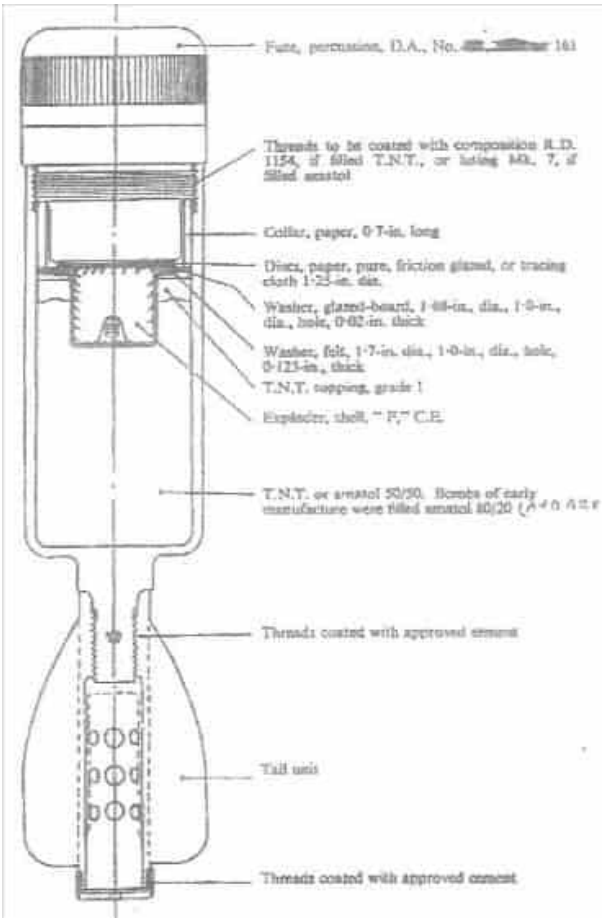






Typical 2" High Explosive Mortar

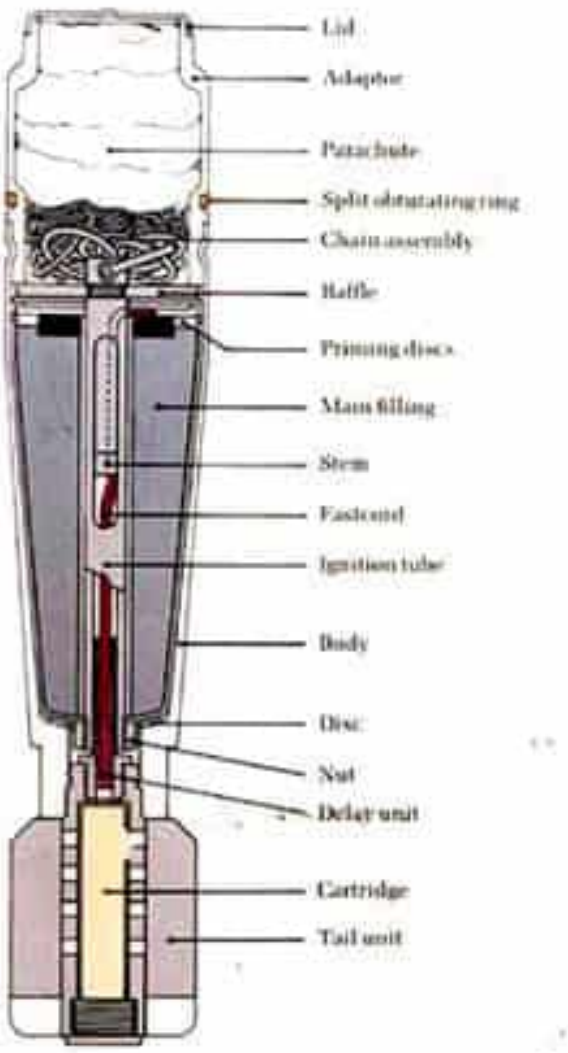
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







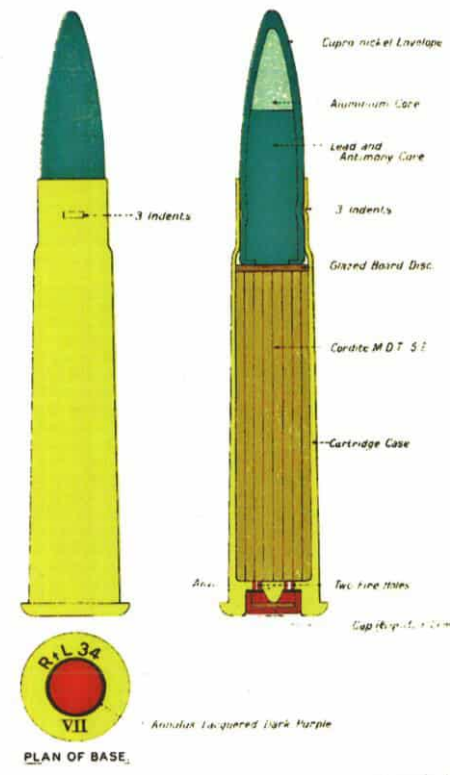


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



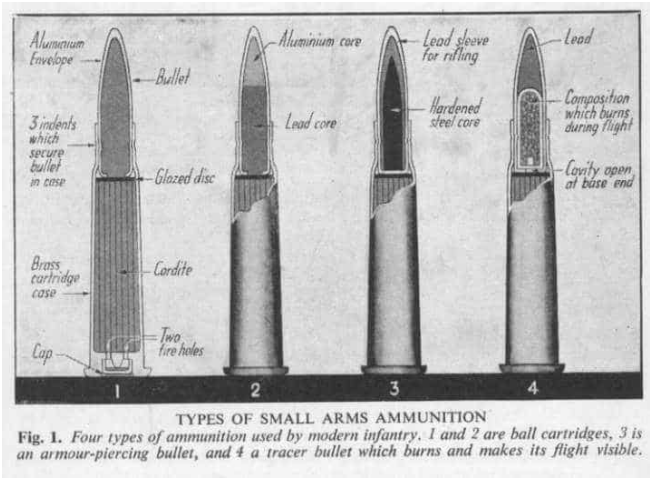




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



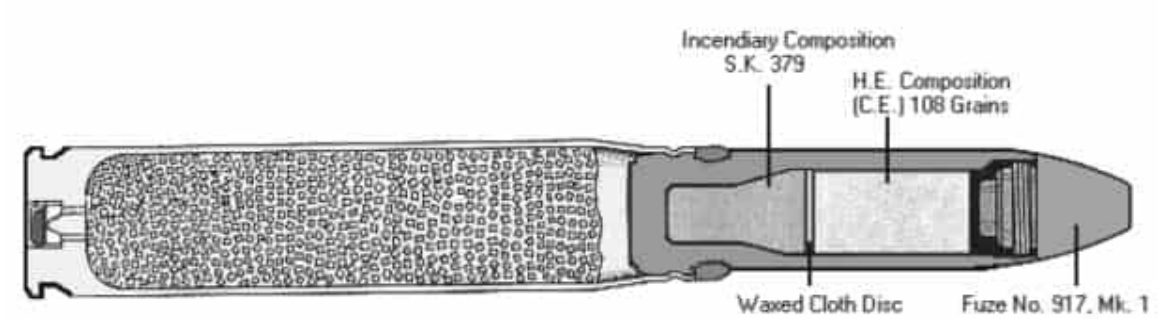


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

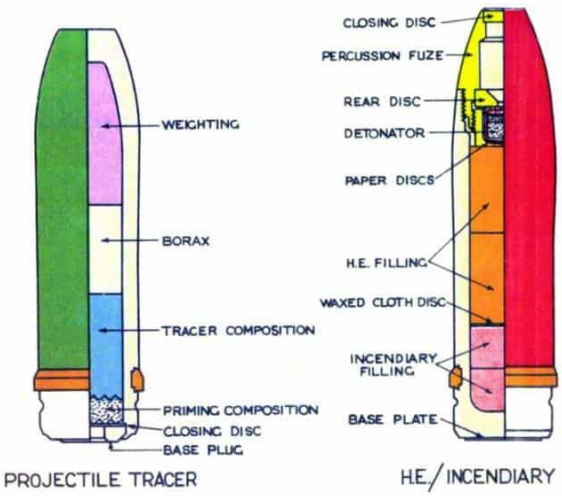






20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



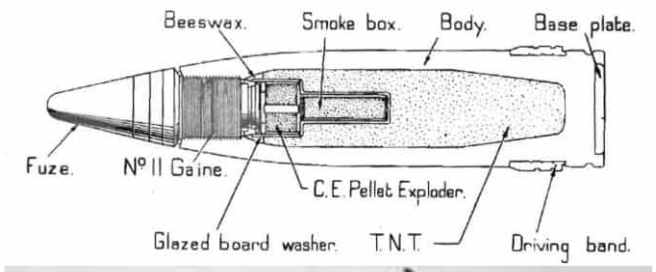
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	



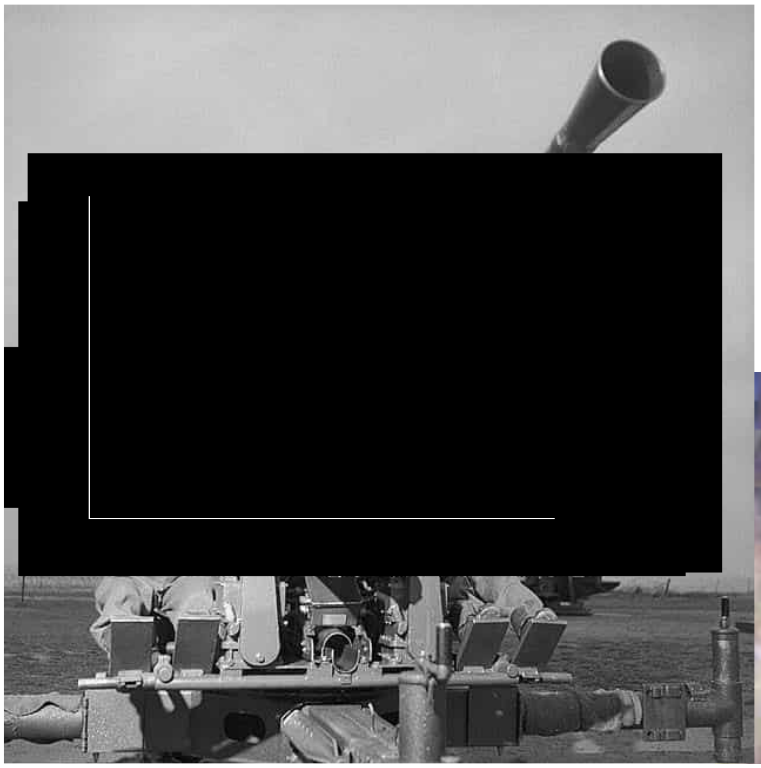
3.7" Anti-Aircraft Projectile

Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.







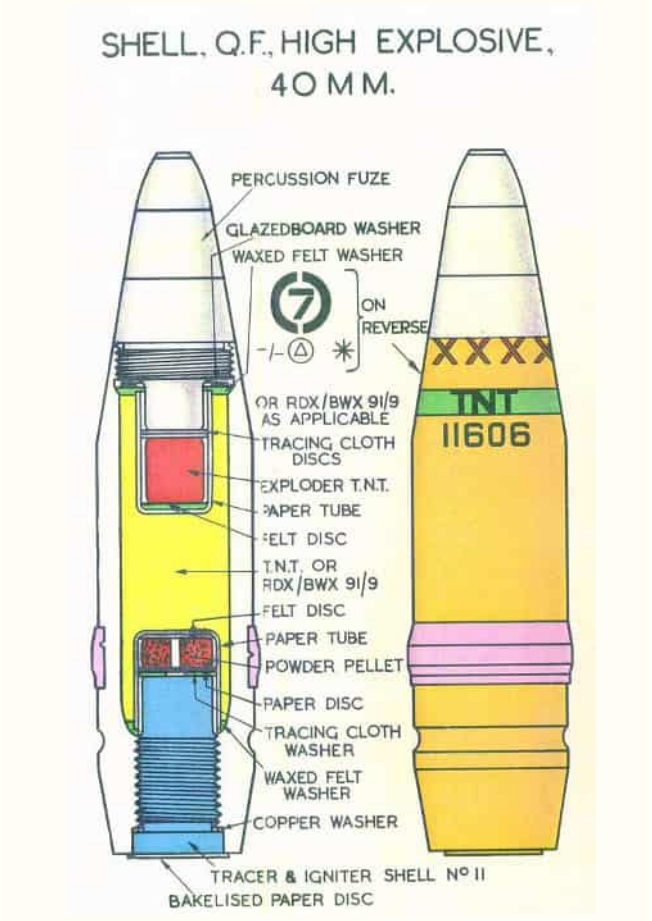




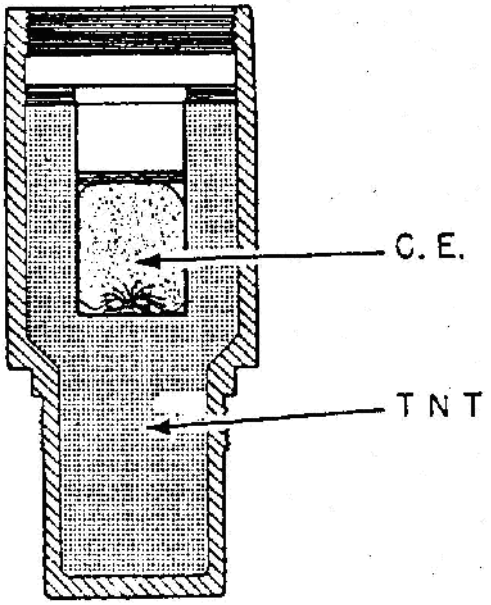


40mm Bofors Gun Projectile

Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

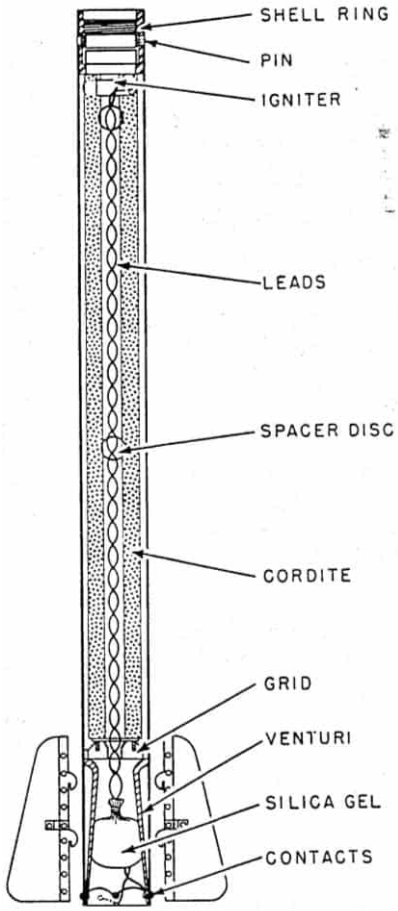






Rockets / Un-rotating Projectiles

Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery



SAFELANE
GLOBAL



Detailed Unexploded Ordnance
Risk Assessment

In Respect Of:
Richborough Option No.1

For:
Mott Macdonald

Report Reference:
9251-4 RA



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1	PDF Copy	Mott MacDonald	OA	RL	NB	18/05/22

This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry. This report has been compiled using all due diligence and expertise and having made all proper but reasonable enquiries within given time limitations. However, in accepting and implementing the recommendations contained in this report, the client does so strictly at his own risk.

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VAT Registration No. GB 171 628 112

Executive Summary

The Site	
Address:	Brook Lane, Minster, Thanet District, Kent, England, CT12 5DN
OS National Grid Reference:	TR 32624 63211
Site Description:	The site is primarily occupied by farmland, comprising of multiple fields. An access road is present at the site's centre, running from the south-eastern to the north-eastern extent. A railway line is adjacent to the western boundary. Two ponds lie on the north-eastern boundary, furthermore, small inlets of rivers akin to an irrigation system encroach multiple areas throughout the site.
Proposed Works	
The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 30m bgl.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**MEDIUM from the following UXO types:** • German Air-Delivered HE bombs • Anti-Aircraft Projectiles
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	
Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **10-12m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Recommended Risk Mitigation		
Risk Level	**Planned Site Activity**	**Recommendations**
Medium	**Shallow Intrusive Works eg excavations**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only)

		• Target Investigation (Required as a follow-on from NI magnetometer survey) • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation (SI)
	Deep intrusive works (eg piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.		

Table of Contents

Distribution i
Executive Summary ii
Table of Contents iv
List of Annexes vi
Appendices vi
Glossary of Terms vii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations *4*
4.5.2 Bombing Records *5*
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Pre and Post-WWII OS Mapping 7
8 The Threat from Aerial Bombing 8
8.1 General Bombing History of Kent 8
8.1.1 First World War *8*
8.1.2 Second World War *8*
8.2 Generic Types of WWII German Air-delivered Ordnance 9
8.3 Second World War Bombing Statistics 10
8.4 Site Specific WWII Bombing Records 10
8.4.1 Kent Bomb Census Maps *10*
8.4.2 Original ARP Bombing Incident Records *11*
8.4.3 Home Office Intelligence Reports *12*
8.4.4 Secondary Source / Anecdotal Evidence *16*
8.4.5 WWII-era RAF Aerial Photography *17*
8.4.6 Abandoned Bombs *17*
8.5 UXB Ground Penetration 18
8.5.1 General Considerations *18*
8.5.2 The "j" Curve Effect *18*
8.5.3 Second World War Bomb Penetration Studies *19*
8.5.4 CIRIA Bomb Penetration Depth Specifications *19*
8.5.5 Site Specific Bomb Penetration Considerations *19*

8.6 Likelihood of Post-raid UXO Detection 20
8.6.1 Density of Bombing *20*
8.6.2 Bomb Damage *20*
8.6.3 Frequency of Access *20*
8.6.4 Ground Cover *21*
8.6.5 German Air-Delivered Ordnance Failure Rate *21*
8.6.6 Site Specific Analysis *22*
9 The Threat from Allied Military Ordnance 26
9.1 Port Richborough 27
9.2 Home Guard Activity 27
9.3 Anti-Aircraft Gun Batteries 29
9.4 Site-Specific Threat from Allied Military Ordnance 29
9.5 Generic Types of WWII British / Allied Unexploded Ordnance 30
9.5.1 Land Service Ammunition (LSA) *30*
9.5.2 Small Arms Ammunition (SAA) *31*
9.5.3 Anti-Aircraft Shells *31*
10 The Overall Unexploded Ordnance Risk Assessment Methodology 33
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance 34
10.1.1 General *34*
10.1.2 Likelihood of Contamination from German UXO *35*
10.1.3 Likelihood of Contamination from British / Allied UXO *36*
10.2 The Likelihood that Unexploded Ordnance Remains on Site 36
10.2.1 General *36*
10.2.2 EOD Bomb Disposal and Clearance Tasks *37*
10.2.3 Post War Redevelopment *37*
10.2.4 Site-Specific Analysis *38*
10.3 The Likelihood that Ordnance may be Encountered during the Works 38
10.4 The Risk that Ordnance may be Initiated 39
10.4.1 Initiation of Unexploded Bombs *39*
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance *39*
10.5 The Consequences of Encountering or Initiating Ordnance 41
11 SafeLane Global's Risk Assessment 45
11.1 Conclusions 45
12 Proposed Risk Mitigation Strategy 46
12.1 Summary 46
12.2 Additional Notes 47
Bibliography 51

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C Pre and Post-WWII OS Maps

Annex D Kent Bomb Census Maps

Annex E WWII ARP Records Bomb Census Map

Annex F WWII-era RAF Aerial Photography

Appendices

Ordnance Specifications and Information

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Richborough Option No.1

1 Introduction

Groundsure Ltd, on the behalf of Mott Macdonald has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Richborough Option No.1site.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Kent History & Library Centre.
- The GeoInformation Group.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Brook Lane, Minster, Thanet District, Kent, England, CT12 5DN	
OS National Grid Reference	TR 32624 63211	
Site Description	The site is primarily occupied by farmland, comprising of multiple fields. An access road is present at the site's centre, running from the south-eastern to the north-eastern extent. A railway line is adjacent to the western boundary. Two ponds lie on the north-eastern boundary, furthermore, small inlets of rivers akin to an irrigation system encroach multiple areas throughout the site.	
Proposed Works	The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 30m bgl.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	Borehole Reference	TR36SW97
	Location	Richborough, located on the south-eastern extent of the site.
	Date	24/02/92
	Recorded Shallow Geology	• 0.4m of Topsoil • 1.7m of Clay (silty and soft) • 3.0m of Clay (soft) • 19.0m of Clay (becomes stiff towards 8.50m to very stiff at the end of the borehole)
British Geological Survey Mapping	Superficial Deposits	Thanet Formation – Sand, Silt, and Clay.
	Bedrock	Tidal Flat Deposits – Clay and Silt.

7 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1938	• The site is occupied by open ground with no apparent use, likely to be farmland, indicated by two small structures in the site's centre. • Numerous irrigation channels can be identified on site. • A railway runs adjacent to the site's western boundary.	Annex C-1	Groundsure Ltd
Post-WWII	1957	• The site and surrounding vicinity appear consistent with conditions present in pre-war OS mapping. • There appears to be no evidence of clearance, redevelopment, or ruins within the vicinity of the site. • These factors can often be indicators of bomb damage on historical OS mapping. • However, due to the lack of development within the area it is unlikely that these indicators would be present.	Annex C-2	Groundsure Ltd

8 The Threat from Aerial Bombing

8.1 General Bombing History of Kent

8.1.1 First World War

During WWI, Kent suffered extensive aerial bombardment from zeppelin airships and fixed-wing aircraft. The first attack by the German Air Force was launched against Dover on the 21st December 1914 using naval seaplanes.

Bombing continued in Kent throughout the war; areas such as Ashford, Canterbury, Dover, Folkestone, Gravesend, Margate, Maidstone and Sheerness suffered particularly severe raids. The last raid on the county was on the night of the 19th May 1918 when a total of 14.55 tonnes of bombs were dropped on London, Faversham and Dover. Ramsgate is situated approximately 3km east of the site and gained the reputation as the most bombed seaside town in WWI. The town suffered from both aerial bombing and naval bombardment during WWI, with Zeppelin's scattering a number of bombs in all districts in the area.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Kent played a key role in the defence of Britain in WWII. It was at the frontline during the Battle of Britain during which the Luftwaffe attempted to destroy the RAF and its airfields in order to gain air superiority over the south-east of England ahead of the planned German invasion. Bombing raids began in July 1940 from German-occupied France and in the following months many of the towns and cities in Kent were subjected to bombing attacks.

Within Kent, Manston airfield was a key target for the Luftwaffe especially during the Battle of Britain, where RAF Manston sustained serious bomb damage. Most of the staff dispersed into the surrounding houses due to the destruction. The site is located just 1.6km south-east of the airfield.

By May 1941, concentrated attacks were reduced as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa', the invasion of Russia. Note however that Canterbury was heavily bombed in mid-1942 as part of the Baedeker Blitz.

During 1942 and 1943, there were a number of minor raids carried out by small formations of fighter bombers and then between January and May 1944 the Luftwaffe returned to London en masse, for Operation Steinbock. These raids were executed by inexperienced Luftwaffe crews and were less frequent when compared to the original Blitz of 1940/41. Poor navigation and improved defences resulted in unsustainable Luftwaffe losses and many raids were unsuccessful.

Cliffsend was situated within 'Hellfire Corner'; an area of Kent where aerial 'dog fights' and 'tip and run' bombing incidents were frequent during the Battle of Britain. The region was also under artillery

bombardment from the coastal batteries located at Calais and Cap-Gris-Nez in occupied France. These batteries, including the *Lindemann* and *Todt Batteries*, bombarded the south coast until they were captured after the Allied D-Day Landings in 1944. The batteries covered an arc stretching from Ramsgate to Hythe and fired shells weighing approximately 1 ton each.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe. Totals of 2,419 V1s and 517 V2s were recorded in the London Civil Defence region.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Municipal Borough of Ramsgate between 1940 and 1945.

Record of German Ordnance Dropped on the Municipal Borough of Ramsgate	
Area Acreage	3,624
High Explosive Bombs (all types)	771
Parachute Mines	5
Oil Bombs	3
Phosphorus Bombs	-
Fire Pots	-
Pilotless Missile (V1)	-
Long Range Rocket (V2)	-
Total	774
Items Per 1,000 Acres	**213.6**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Kent Bomb Census Maps

A review was conducted of the Kent Bomb Census Maps, obtained from the National Archives. Those showing incidents on or close to the site are listed below. Note, the maps are small in scale and lack any clear geographical indicators, therefore the site and distance(s) listed below can be considered an approximate.

Date	Weapon	Details
9th July 1940	Incendiary and HE bombs	Approximately on or adjacent to the site.
27th October 1940	2 x HE bombs	Approximately 1.8km to the north-east of the site.
29th October 1940	HE bomb	Approximately on or adjacent to the site.
6th December 1940	Incendiary bomb	Approximately 200m south to the site.
Reference		**Annex D**

8.4.2 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records. Sections of these ARP records (with map references) have been plotted in **Annex E**.

Written ARP records were reviewed for	Ramsgate
Source	Kent History & Library Centre
Records of bombing on / near the site were found	✓

Date	Weapon	Details
18th September 1940	Unspecified	"Unexploded bomb located in St. Augustine's Golf Links about 30 yards from Ramsgate – Sandwich Road." Map reference 780/820. Approximately 1.8km north-east of the site.
20th October 1940	Unspecified	Bomb dropped in open ground in Ramsgate. Location of incident unknown.
24th October 1940	HE bombs	An enemy aircraft dropped HE bombs at Pegwell End and Cliffsend Ramsgate. Proximity to site potentially on or adjacent.
6th November 1940	HE bombs	West of Ebbsfleet Farmhouse. Map reference – 770/810 Approximately 800m north-west of the site.
6th February 1941	10 x HE bombs	10 x 50KG HE's were dropped in a line from Map reference 788/839 – 789/819.

		Approximately 2.0km north of the site.
4th May 1941	1 x HE bomb	Cottington Hill, Minister. Map reference 776/819. Approximately 1.5km north-west of the site.
4th May 1941	1 x HE bomb	South of Cottington Hill, Minister. Map reference 775/817. Approximately 1.2km north-west of the site.

8.4.3 Home Office Intelligence Reports

The Home Office Intelligence reports document enemy action on British domestic soil and were prepared twice a day for the Home Security War Room. The summaries were prepared by intelligence staff, who compiled reports received from the twelve civil defence regions.

However, available records only document time and general location of attack and numbers of casualties. The intelligence officials generally only recorded locations on municipal level (town, village, or city), rarely providing specific addresses.

Date	Location	Details
5th July 1940	Ramsgate	0 casualties
8th/9th July 1940	Ramsgate	0 casualties
12th August 1940	Manston, Ramsgate	12 casualties
14th August 1940	Manston, Ramsgate	0 casualties
16th/17th August 1940	Manston, Ramsgate	0 casualties
22nd/23rd August 1940	Manston, Ramsgate	0 casualties
24th August 1940	Ramsgate	65 casualties
24th August 1940	Manston, Ramsgate	0 casualties
28th August 1940	Ramsgate	1 casualty
13th September 1940	Ramsgate	0 casualties

16th September 1940	Ramsgate	0 casualties
28th September 1940	Ramsgate	Unspecified
7th October 1940	Ramsgate	0 casualties
8th October 1940	Ramsgate	0 casualties
11th October 1940	Ramsgate	4 casualties
20th October 1940	Ramsgate	0 casualties
27th October 1940	Ramsgate	1 casualty
2nd November 1940	Ramsgate	29 casualties
10th November 1940	Ramsgate	4 casualties
11th November 1940	Ramsgate	9 casualties
12th November 1940	Ramsgate	2 casualties
13th November 1940	Ramsgate	1 casualty
18th November 1940	Ramsgate	4 casualties
29th November 1940	Ramsgate	0 casualties
5th December 1940	Ramsgate	0 casualties
29th December 1940	Ramsgate	0 casualties
3rd/4th January 1941	Ramsgate	17 casualties
11th January 1941	Ramsgate	2 casualties
15th January 1941	Ramsgate	1 casualty

17th/18th January 1941	Ramsgate	0 casualties
3rd February 1941	Ramsgate	4 casualties
12th February 1941	Ramsgate	0 casualties
22nd February 1941	Ramsgate	0 casualties
3rd March 1941	Ramsgate	4 casualties
13th/14th March 1941	Ramsgate	0 casualties
18th March 1941	Ramsgate	2 casualties
20th March 1941	Ramsgate	12 casualties
9th/10th April 1941	Ramsgate	2 casualties
4th/5th May 1941	Ramsgate	0 casualties
7th May 1941	Ramsgate	0 casualties
10th/11th May 1941	Ramsgate	0 casualties
13th/14th June 1941	Ramsgate	16 casualties
6th/7th August 1941	Ramsgate	1 casualty
16th/17th August 1941	Ramsgate	0 casualties
30th/31st August 1941	Ramsgate	3 casualties
7th/8th September 1941	Ramsgate	26 casualties
9th/10th November 1941	Ramsgate	6 casualties
27th November 1941	Ramsgate	1 casualty

29th/30th May 1942	Ramsgate	0 casualties
4th September 1942	Ramsgate	0 casualties
31st October 1942	Ramsgate	0 casualties
26th January 1943	Ramsgate	6 casualties
9th February 1943	Ramsgate	0 casualties
2nd March 1943	Ramsgate	0 casualties
3rd/4th March 1943	Ramsgate	0 casualties
18th/19th May 1943	Ramsgate	0 casualties
19th/20th May 1943	Ramsgate	0 casualties
28th/29th May 1943	Ramsgate	3 casualties
12th/13th June 1943	Ramsgate	0 casualties
15th/16th June 1943	Ramsgate	5 casualties
16th/17th August 1943	Ramsgate	5 casualties
17th August 1943	Ramsgate	5 casualties
22nd/23rd August 1943	Ramsgate	0 casualties
3rd/4th October 1943	Ramsgate	12 casualties
4th/5th November 1943	Ramsgate	0 casualties
19th/20th January 1944	Ramsgate	0 casualties
21st/22nd January 1944	Ramsgate	0 casualties

21st/22nd January 1944	Ramsgate	0 casualties
24th/25th January 1944	Ramsgate	0 casualties
29th June 1944	Ramsgate	0 casualties
31st/1st August/September 1944	Ramsgate	20 casualties

8.4.4 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
August 1940	150> HE Bombs	Multiple attacks were made on RAF Manston during the Battle of Britain over the course of a few months, particularly in August. 12th August – "About 150 bombs were dropped, leaving some 100 craters. Two hangars were damaged and a workshop destroyed. Unfortunately, a civilian clerk in the workshop was killed. …some craters remained near the edge of the airfield, which were close to unexploded bombs."[1] Approximately 2.5km north of the site.
31st August 1940	Aircraft crash	A fighter plane crash landed in Sandwich Flats in Pegwell Bay. Proximity to site potentially within 2.5km.

[1] https://www.bbc.co.uk/history/ww2peopleswar/stories/17/a6812417.shtml

8.4.5 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	Circa. 1946
Source	The GeoInformation Group
Image Type	Aerial
Image quality	Low resolution and low scale
Observations	• The site remains accurate to historical OS mapping, the fields are largely covered in soft vegetation. • There are several small circular holes that are indicative of possible bomb damage located in and within the site's immediate vicinity. These have been highlighted on the Annex. • There is limited evidence to corroborate bombs landing on site, but due to its rural location, it is possible that these would have gone undetected. • Approximately 200m south of the study area there are craters in the field, these are indictive of localised bombing and bomb damage.
Reference	**Annex E**

8.4.6 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✓
Additional Comments	• 2 items of unknown ordnance in a field approximately 180m north-east of the site, within close proximity to the railway embankment. • 2 items of unknown ordnance in a field approximately 220m north of the site, south of Brook Lane, adjacent to the two ponds. • 1 item of unknown ordnance in the marshes near Brook Lane, approximately 550m north-east of the site.

8.5 UXB Ground Penetration

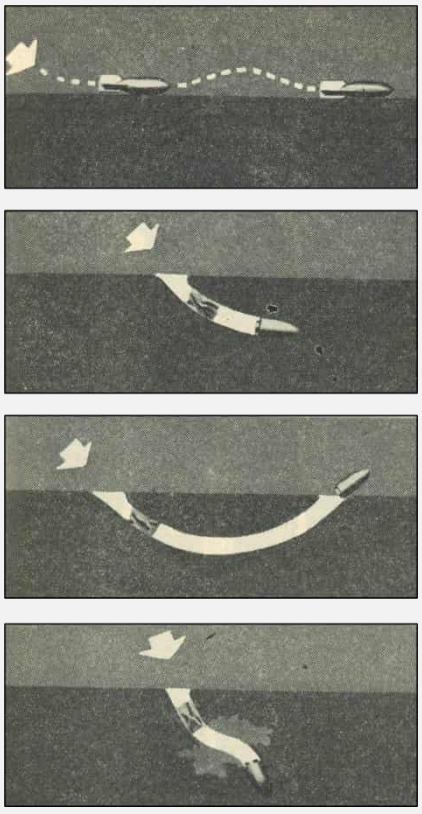
8.5.1 General Considerations

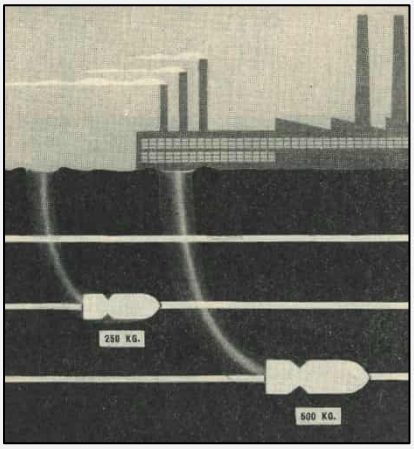
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

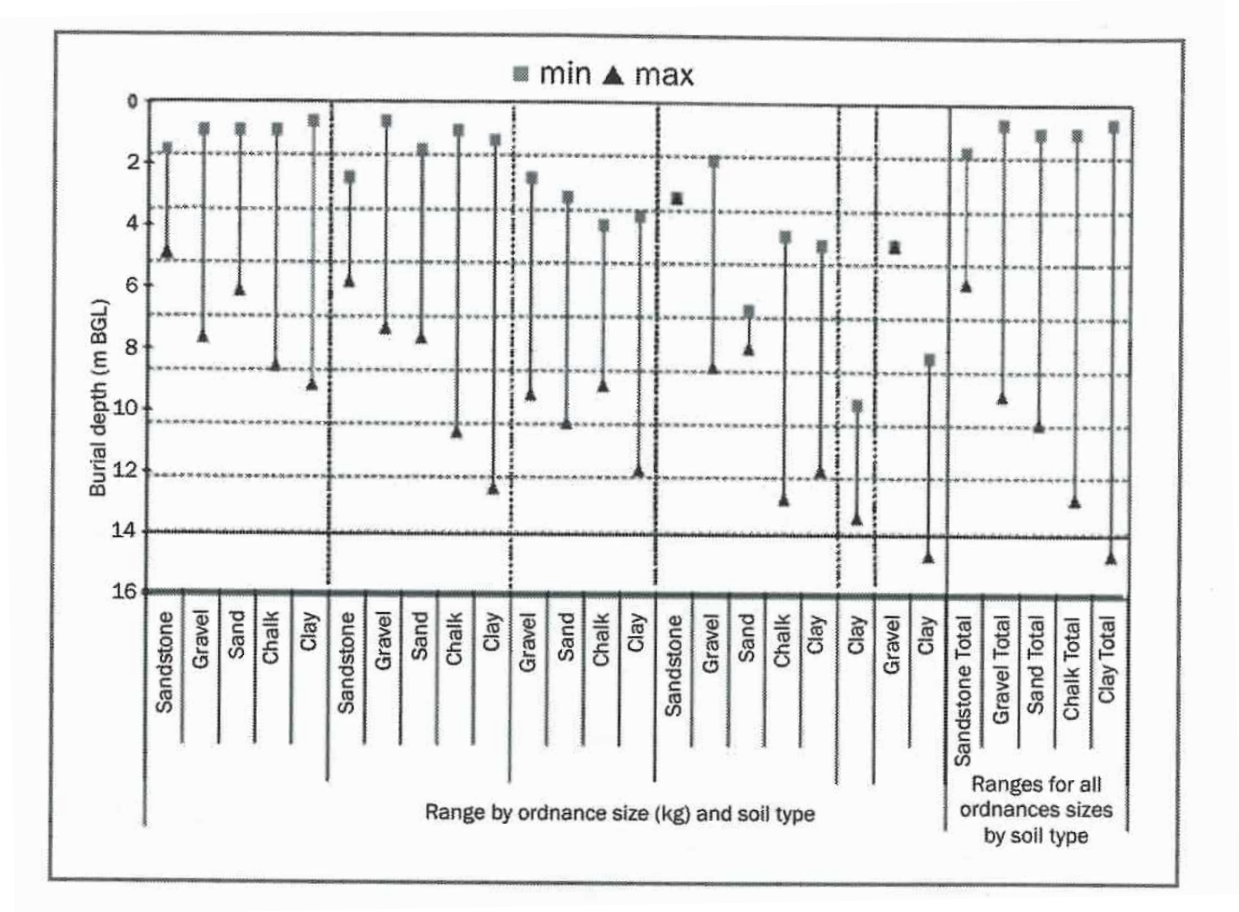
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 0.4m of Topsoil and >24m of Clay.

- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-

aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.

- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.6.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	High	The site is within close proximity to Manston airfield and a small port (Richborough). Ramsgate experienced a bombing density of 213.6 items per 1000 acres. 5 x abandoned bombs are recorded within 500m of the site.
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✓	Kent Bomb Census Maps highlight a HE bomb landed within the immediate vicinity of the site. However, due to the scale of the mapping, it is difficult to accurately identify the exact location of these strikes.
	What is the distance between the site boundary and the closest recorded large bomb strike?	On / adjacent	
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot	1	

	bombs (large bombs) were recorded within a 300m radius of the site?		
	Were any nearby sticks of large bombs recorded in line with the site?	✗	
	Were any 1kg incendiary bomb showers recorded over the site?	✓	
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✗	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	Possibly	Ground disturbance has been highlighted on and to the south of the site.
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✗	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	✗	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✗	
	The site was exclusively or partially developed during WWII.	✗	
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	n/a	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	*Brook Lane* encroaches through the site. It's possible that this would have been accessed.
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗	
	The site was occupied by a school during WWII.	✗	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✗	

	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✖	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✖	
	The site was occupied by a graveyard which would have experienced limited access.	✖	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	Historical aerial and OS mapping has illustrated that the site appears to be used for agricultural purposes.
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✖	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✖	The fields within the western section of the site lie adjacent to the railway line.
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	n/a	
	The site was occupied by dense, inaccessible vegetation during WWII.	✖	
	The site may have been susceptible to waterlogged conditions during WWII.	✓	The irrigation system present on site may have caused waterlogged conditions.
	The site was occupied by (possibly) unmaintained grass field during WWII.	Possibly	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✖	Multiple irrigation channels are present on site.
	The site was occupied by tidal mud or marshland during WWII.	✖	

	The site was occupied by railway tracks crossing soft ground during WWII.	Adjacent	
	The site was occupied by stockpiled material during WWII.	n/a	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	n/a	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	n/a	
	The site was occupied by well-maintained, manicured lawn during WWII.	✗	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	Had a bomb impacted the soft vegetation on site, it is possible that the J-curve effect would have to come into consideration.
Bomb Failure Rate Assessment	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✗
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✗
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✗
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 Port Richborough

Port Richborough, nicknamed port "Q", was established in 1914 on the banks of the River Stour. The facility was kept a secret and served as a significant military outpost. Throughout WWI, the port was used for manning and arming barges being sent to Dover and subsequently France.[2] The port became militarised during the First World War, with multiple stores for equipment used for supplying the barges erected in and around the banks. Moreover, defensive positions were established around the Port especially on the flats towards the mouth of the river Stour.

During WWII the port still served a purpose as a military outpost for the Royal Marines in 1942, named H.M.S Robertson. The Port was considered "a hive of industry" in preparation for D-Day, with many troops stationed in the nearby Richborough Camp. In addition, factory workers would work throughout the blackout in the port factory.[3] The port was located approximately 1.2km south-east of the site.

9.2 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[4]

[2] [redacted]

[4] Various News Sources

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.3 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.4 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Nearest Home Guard Battalion to the site	6th Kent (Thanet) Battalion.
Home Guard Activity on site	• The Thanet battalion primarily operated out of Margate, approximately 7.0km from the site. However, the exact locations of their HQs or training areas were not found. • Typically, HG soldiers would take part in training exercises in areas occupied by open countryside such as the fields on site. However, there is no evidence to corroborate training activity within the study area. • HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. • The HG were active within defensive features within the vicinity of Richborough Port approximately 1.6km south-east, but there is no evidence to suggest such activity in the study area.
Defensive features within the vicinity	• 1 Pillbox is located within approximately 1.2km east on *Sandwich Road*. • "Port Richborough & machine gun position" located approximately 1.1km to the site.[5]

[5] https://storymaps.arcgis.com/stories/336078a0a78f474ba05e74bf25c6c49a

	• Nissen Hut – a prefabricated shelter used by the military, approximately 1.5km to the site.[6] • Slit trench or PAD trench – A small v-shaped dugout feature remains in the port area, approximately 1.6km to the site.[7] • WWII gun emplacement that is circular, pictured in military photographs (not annexed) approximately 1.2km south.
Number of HAA batteries within 5km of the site	4
Threat to the site from unexploded AA shells	• The nearest HAA battery was approximately 1.45km south-east to the site, located on the open ground near Richborough Port. This lay adjacent to the Nissen Hut and other recorded defensive features.[8] • The other HAA's were located around RAF Manston, approximately 3.0km to the north-east. • RAF Manston was targeted and attacked by the Luftwaffe several times during WWII. During such attacks, it is likely that a degree of AA fire would have occurred over the site. • One anecdotal account notes that "the intensity of the anti-aircraft fire put up around Manston and Hawkinge airfields during the raids of 15th August 1940" led to the towns of Ramsgate getting bombed more frequently.[9] • During the height of the Battle of Britain, several LAA positions may have been established in open fields within the site's proximity. Secondary sources have confirmed the likelihood of an LAA battery being established adjacent to the HAA.[10] • Had an exploded shell landed onto the soft vegetation on site, it is conceivable it could have remained undetected.

9.5 Generic Types of WWII British / Allied Unexploded Ordnance

9.5.1 Land Service Ammunition (LSA)

9.5.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

[6] [redacted]

[9] Hylton, Stuart, *Kent and Sussex 1940: Britain's Front Line,* (Barnsley, Pen & Sword Books Limited, 2004)

[10] [redacted]

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

9.5.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.5.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

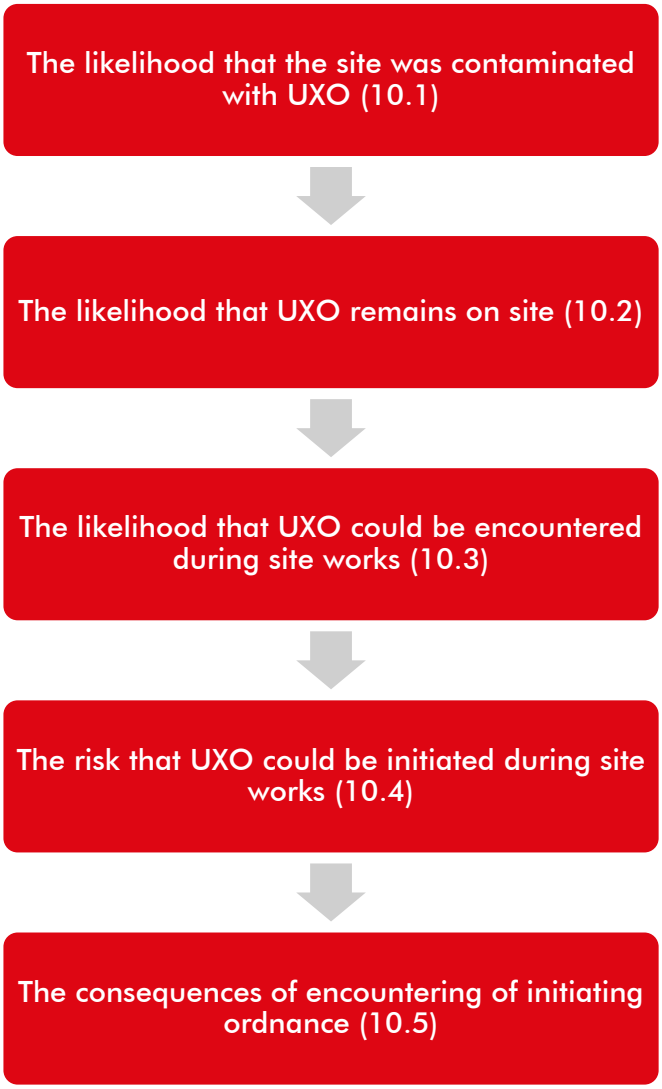
The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• Situated in an area of high bombing density • 1 x HE bomb within the immediate vicinity of the site. • 1 x Incendiary bomb within proximity to the site • 5 abandoned bombs were discovered to the north of the site
Bomb Damage	• Possible ground disturbances located on and to the south of the study area. • There is no clear evidence of bomb damage on the site.
Ground Conditions	• Soft vegetation across the whole site. • Irrigation ditches present across the site.
Frequency of Access	• The site was mainly agricultural, it is unclear how often it was accessed during WWII. • The western site boundary was adjacent to railway sidings.
J-Curve Effect	• Had any UXB landed within the soft ground and vegetation on site, it could have come to rest beneath the study area.
Other considerations	n/a
Overall Likelihood of Contamination	**Medium**

10.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• Evidence suggests that the HG were very active in the area surrounding the port and Sandwich Road. • No evidence has been found to suggest that the site formerly had any British / Allied military occupation or usage that could have led to contamination with items of UXO.
Anti-Aircraft Projectiles	• 4 HAA batteries were located within 5km of the site. • The nearest HAA battery was approximately 1.45km south-east to the site, located on the open ground near Richborough Port. • Several LAA batteries may have been established in open fields within the site's proximity during WWII. • Had an exploded shell landed onto the soft vegetation on site, it is conceivable it could have remained undetected.
Overall Likelihood of Contamination	**Medium**

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	None
Local tasks undertaken by SafeLane Global	None

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✘
Further Details	Historical OS mapping has highlighted that land-use on site has remained consistent since WWII, the site has remained agricultural.

10.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	The site has remained undeveloped since the end of WWII.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. As no such works appear to have taken place post-WWII, this is considered unlikely. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. As no bulk excavations have been carried out onsite, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works are expected to consist of site investigation works, comprising boreholes and trial pits etc

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.
Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions,

	particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

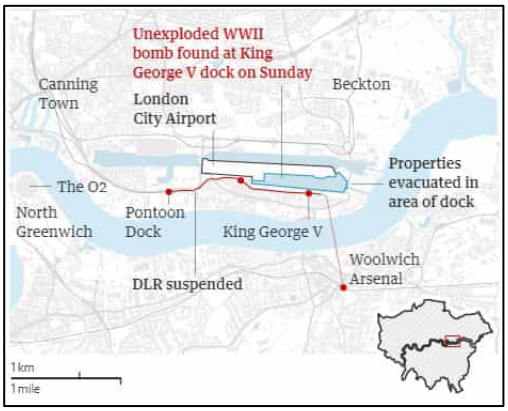
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be **Medium.**

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Low	Low	Low	Not Significant	**Low**
Land Service Ammunition	Low	Low	Low	Moderate	**Low**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
Medium	Shallow Intrusive Works eg. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation (SI) • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of

	an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required.

	The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iii. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

iv. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

v. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

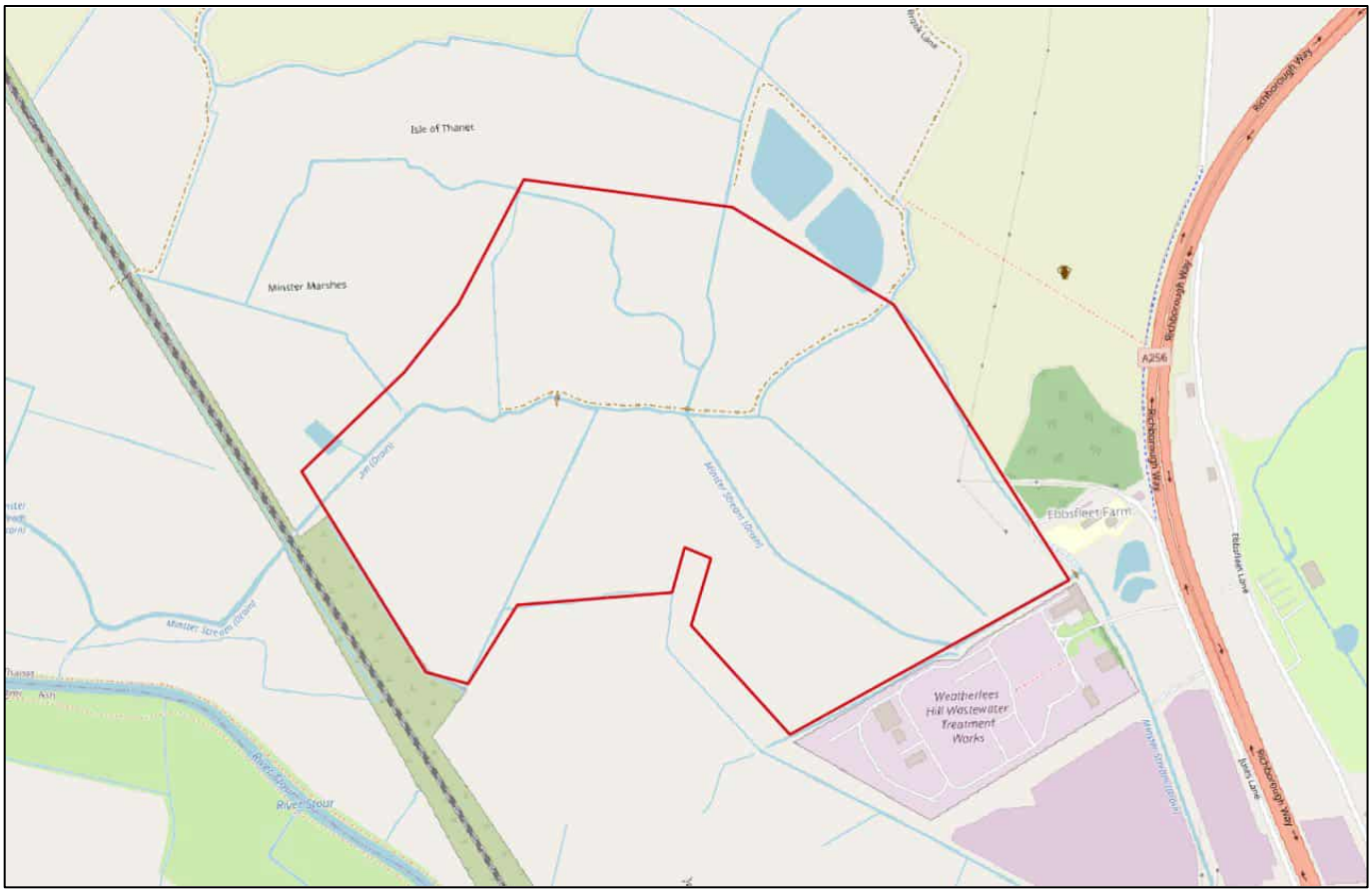
vi. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

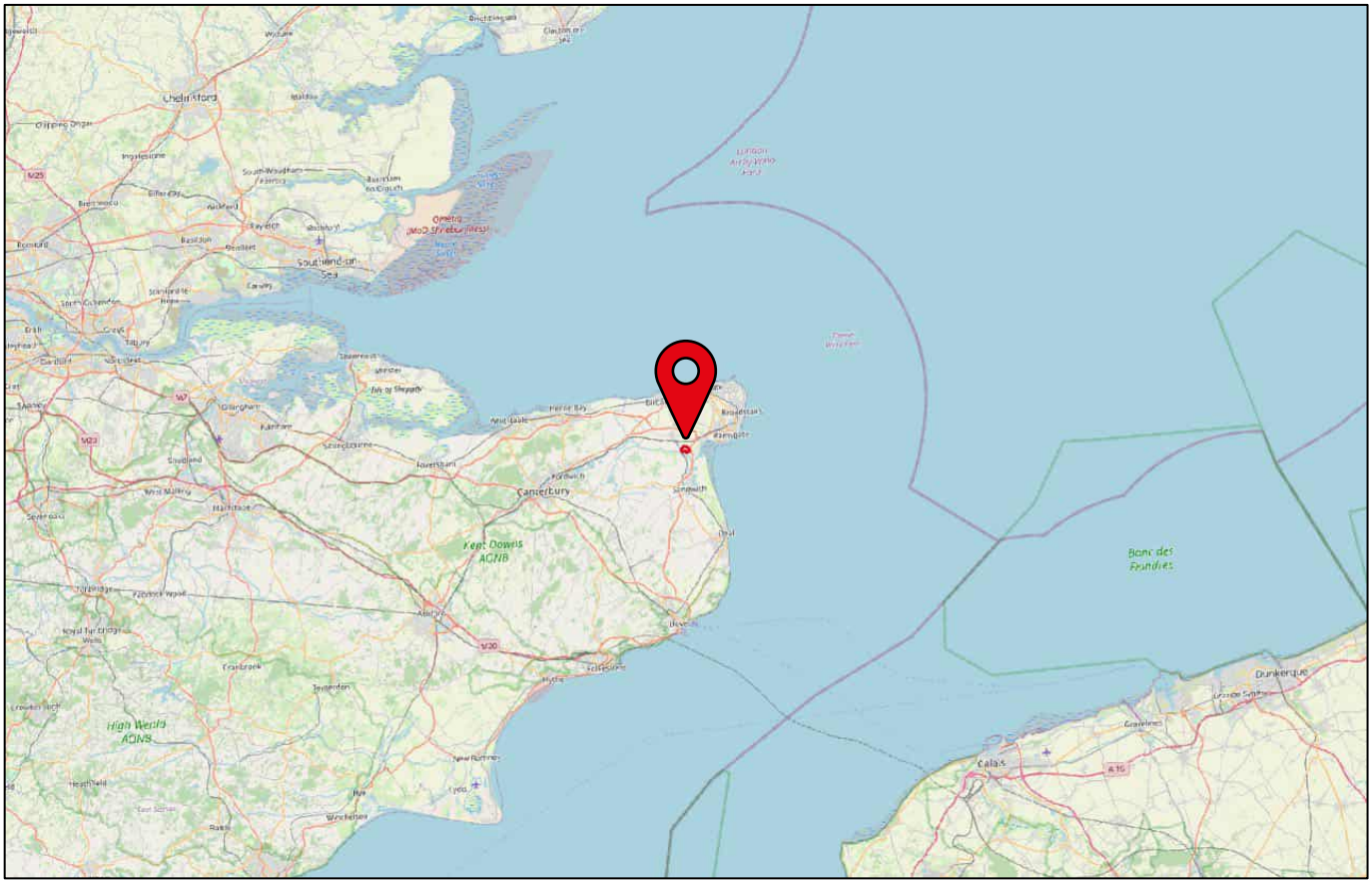
vii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

viii. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

ix. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

x. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).





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Recent Aerial Photograph

Annex B
9251-4 RA

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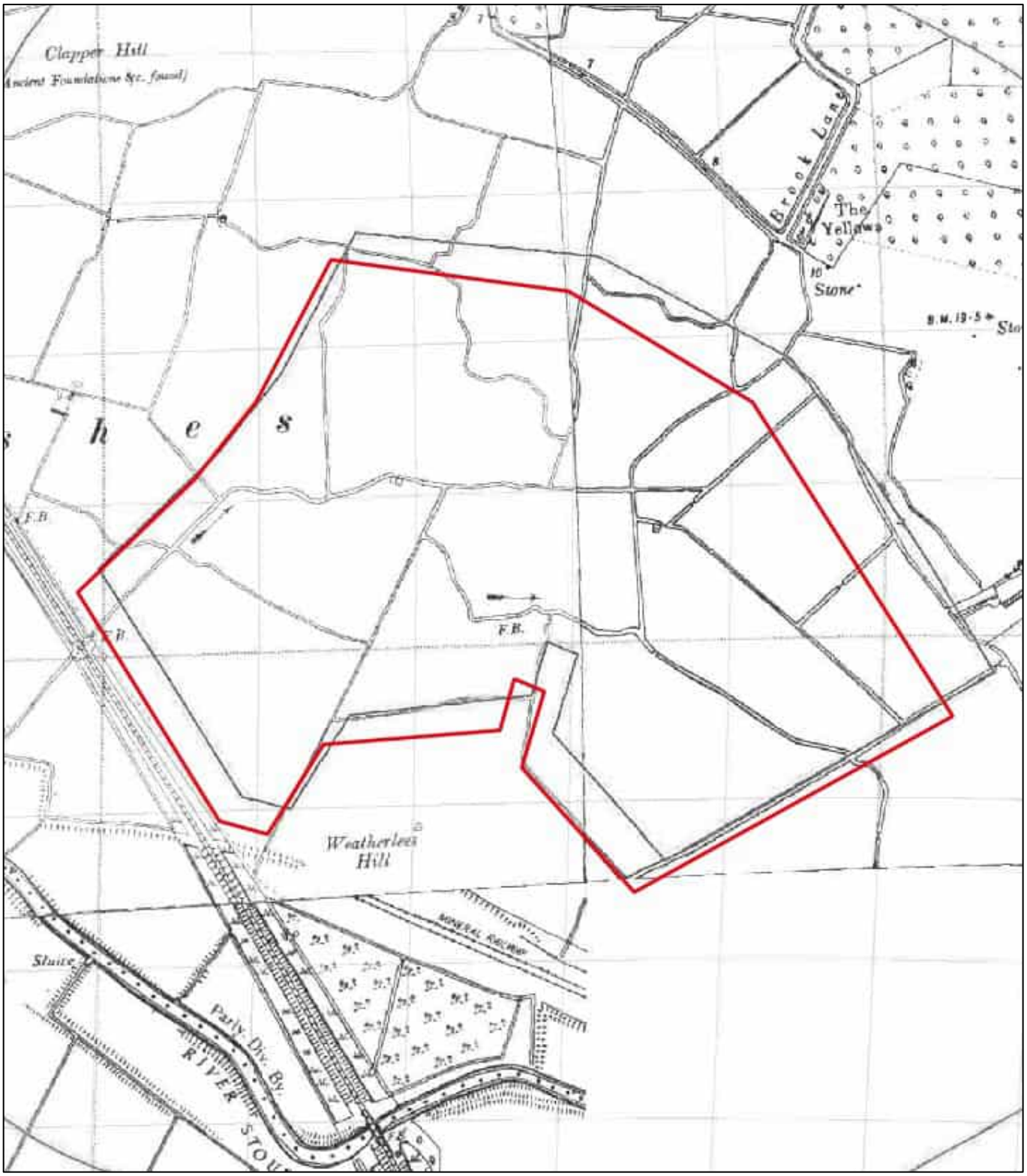


Approximate site boundary

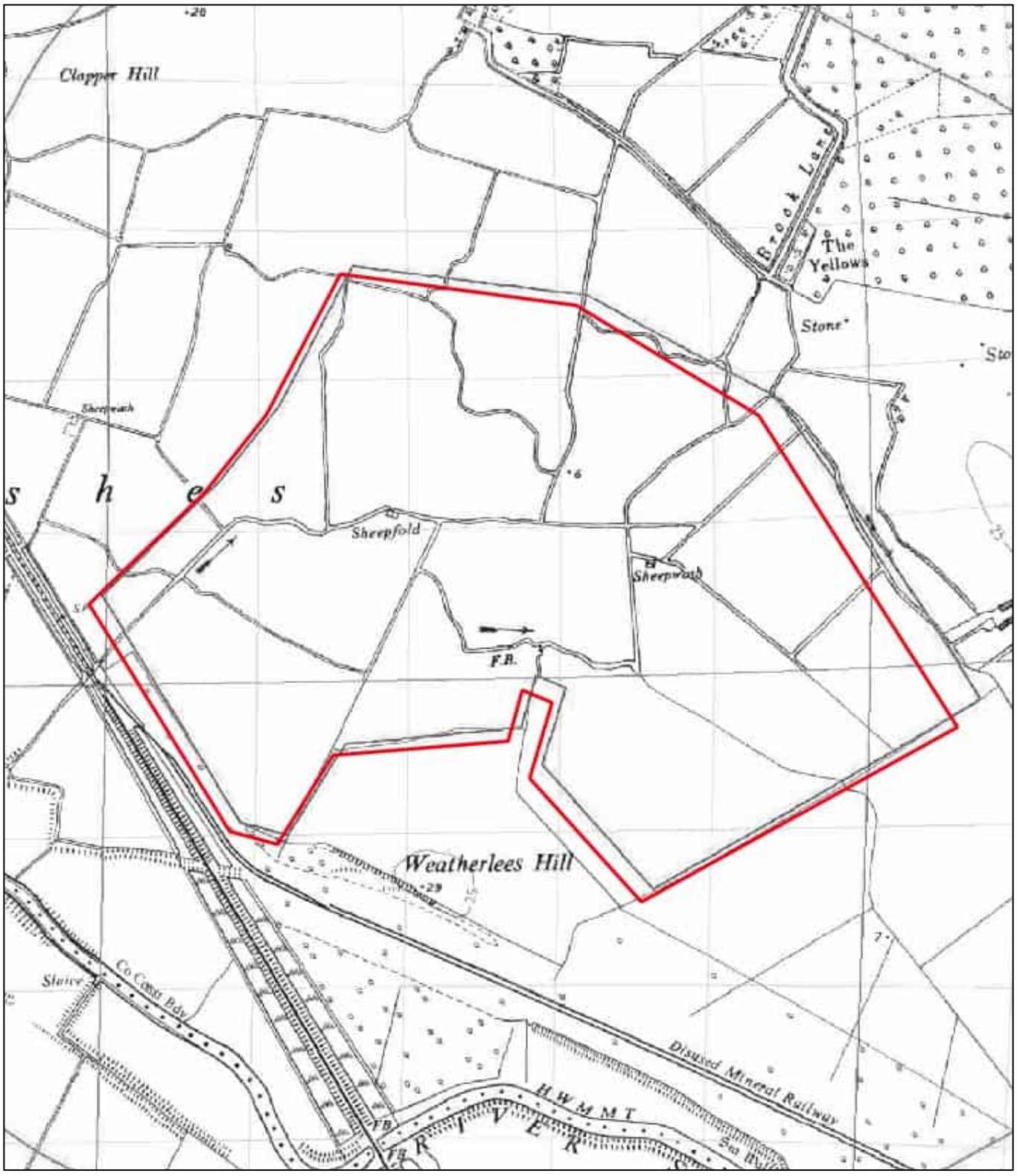
Google Earth™ Mapping Services

1938 OS Map

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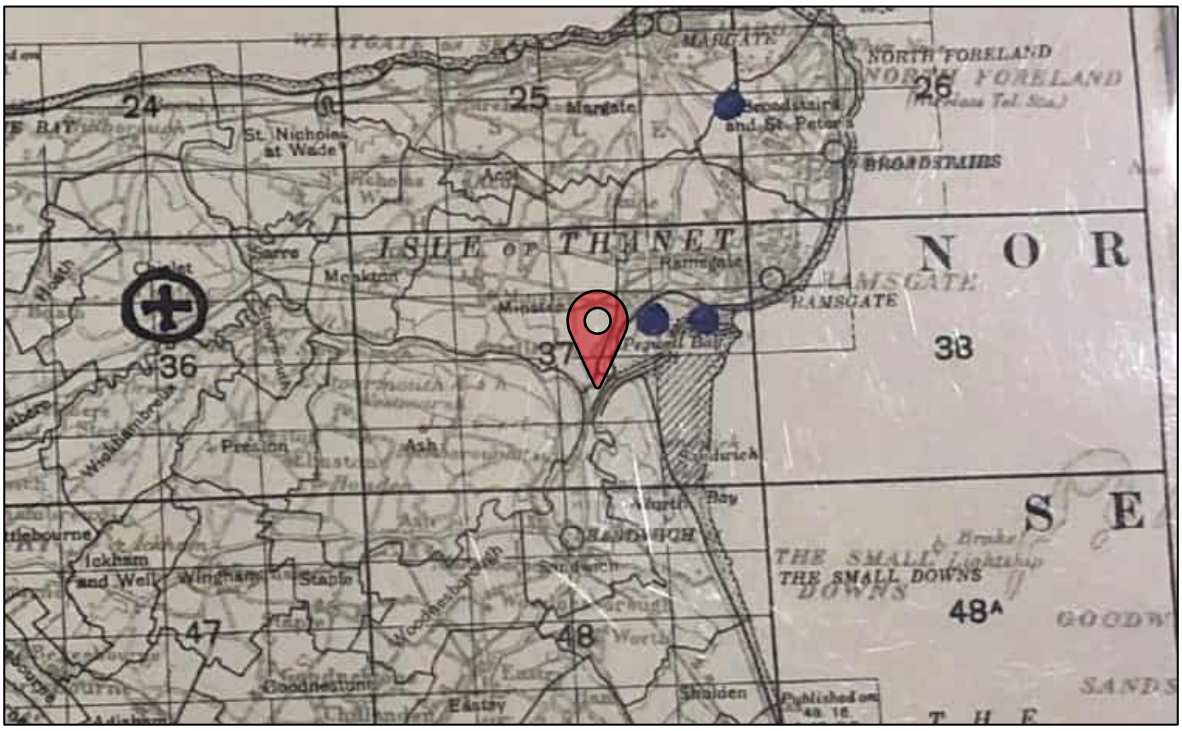
Approximate site boundary



Approximate site boundary



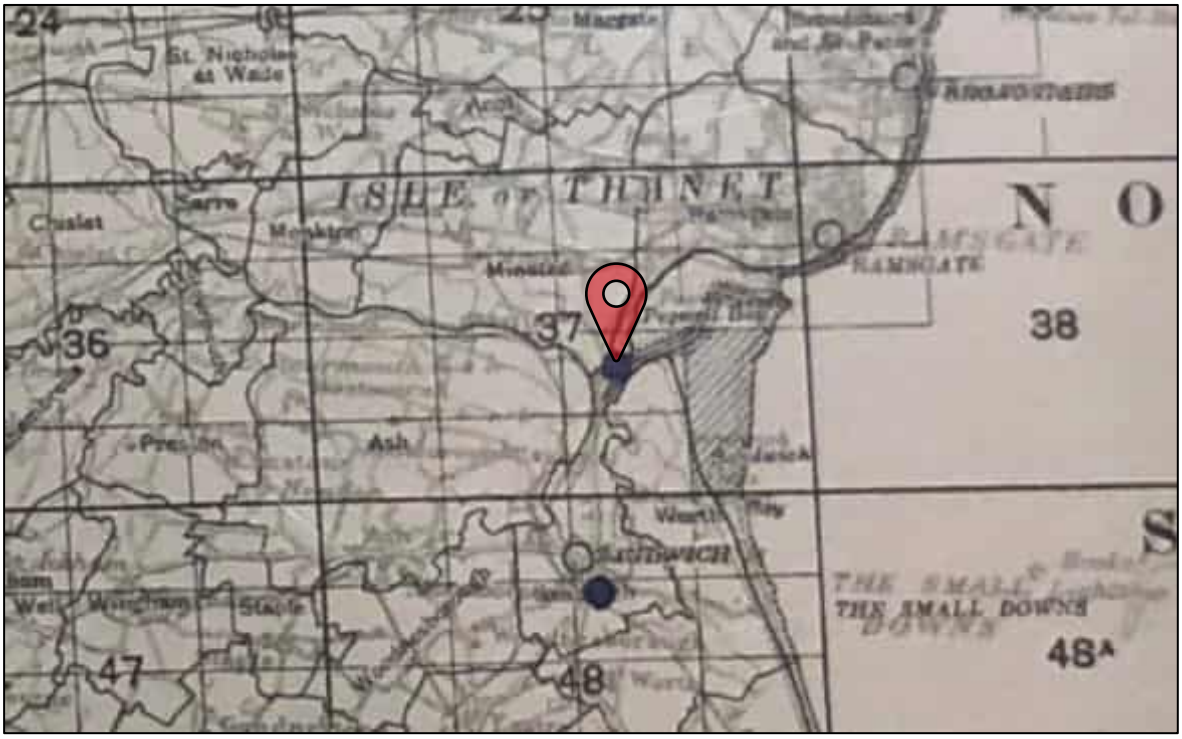
9th July 1940



27th October 1940

Approximate site location | HE bomb strike | Incendiary shower | HE bomb area

Kent History & Library Centre



29th October 1940



6th December 1940

Approximate site location

HE bomb strike

Incendiary bomb

RAF Fighter

Kent ARP Records Bomb Census Map

N



Approximate site boundary

HE bomb

Unexploded bomb

(Numbers in circles denote quantity of explosive ordnance recorded)

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WWII-era RAF Aerial Photography - Circa. 1946

Annex F
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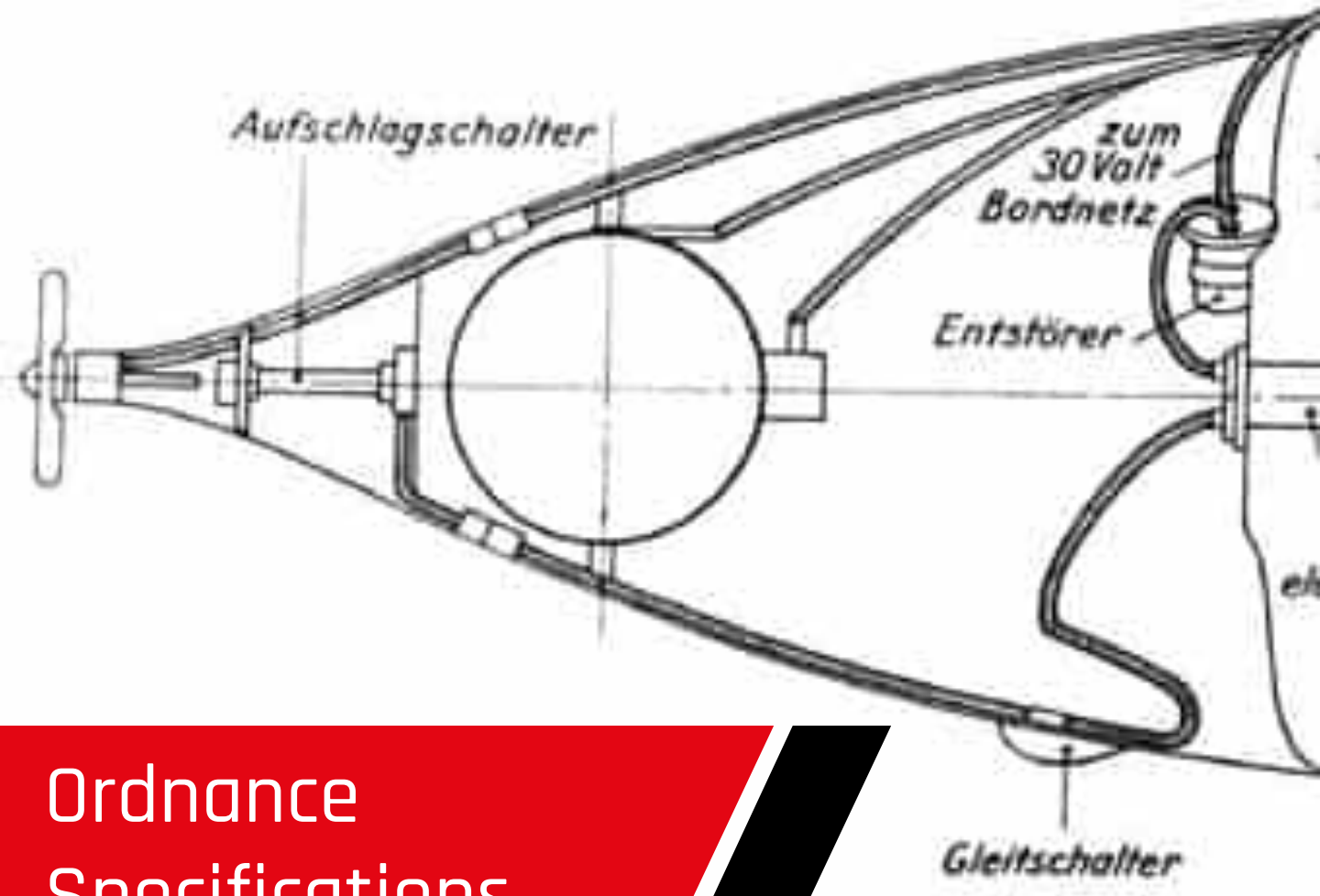
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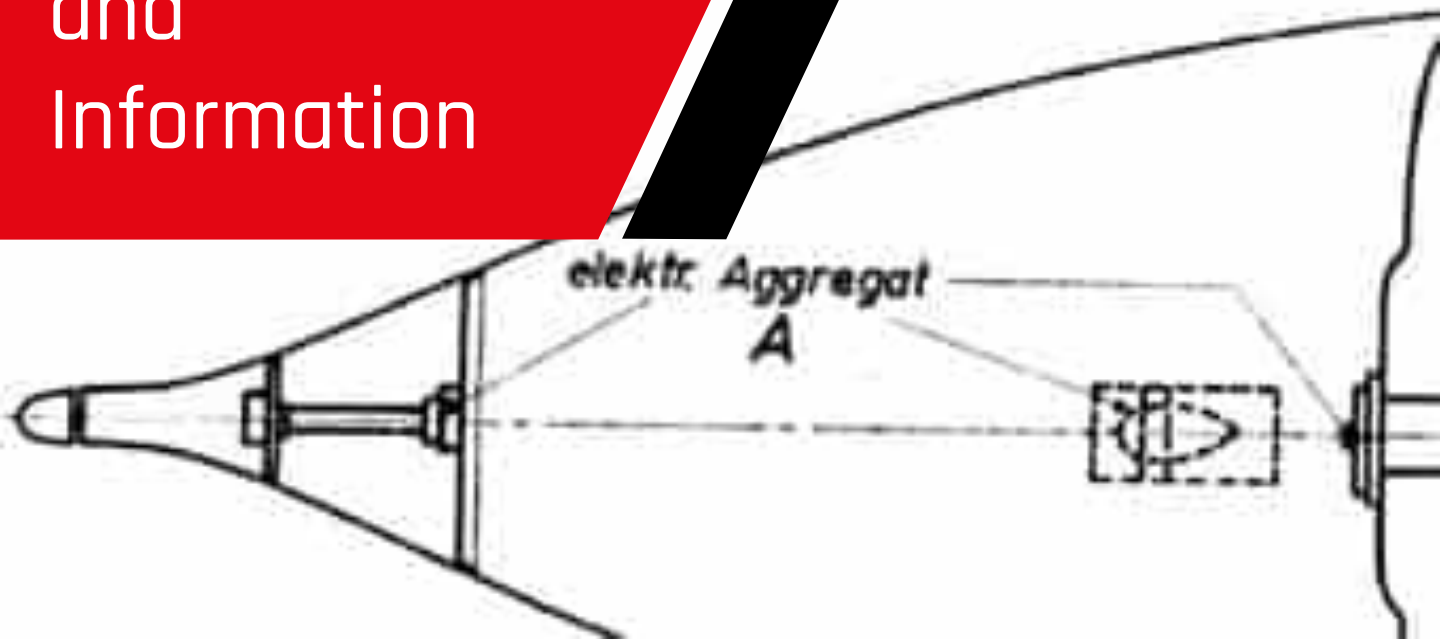
Approximate site boundary

Possible Ground disturbance

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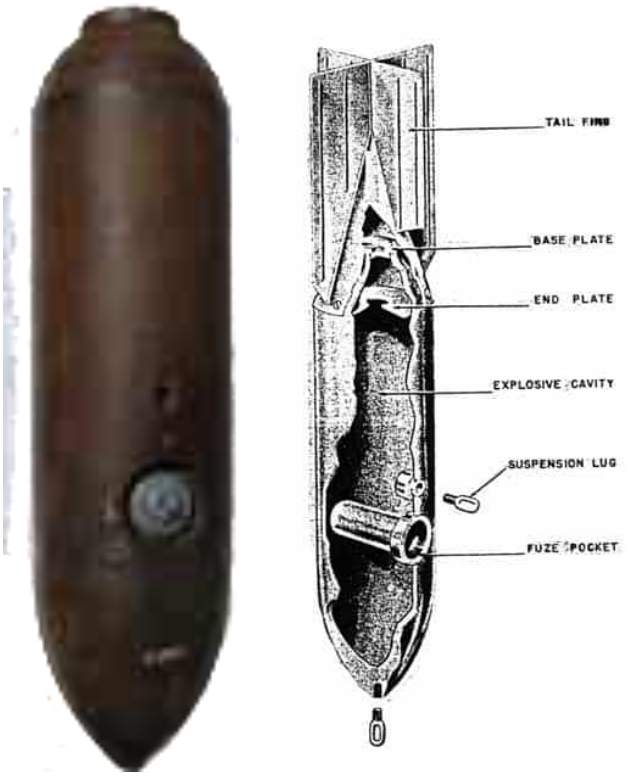


Ordnance Specifications and Information





German Ordnance





Sprengbombe Cylindrisch 50

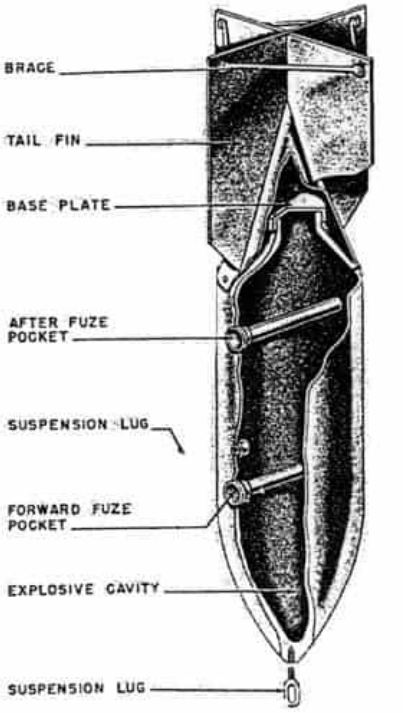
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

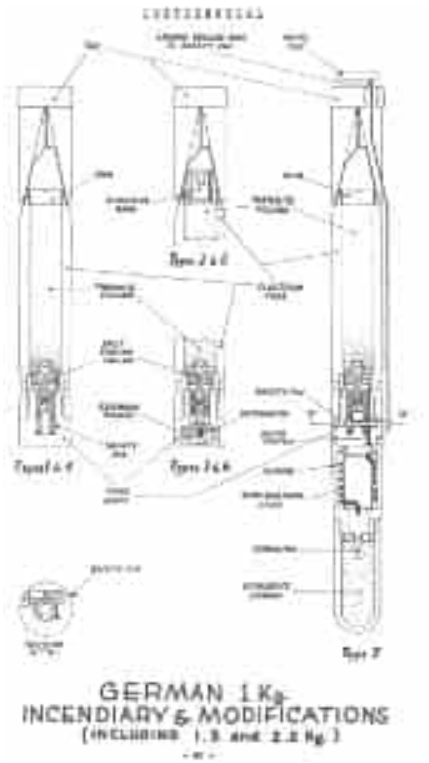
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









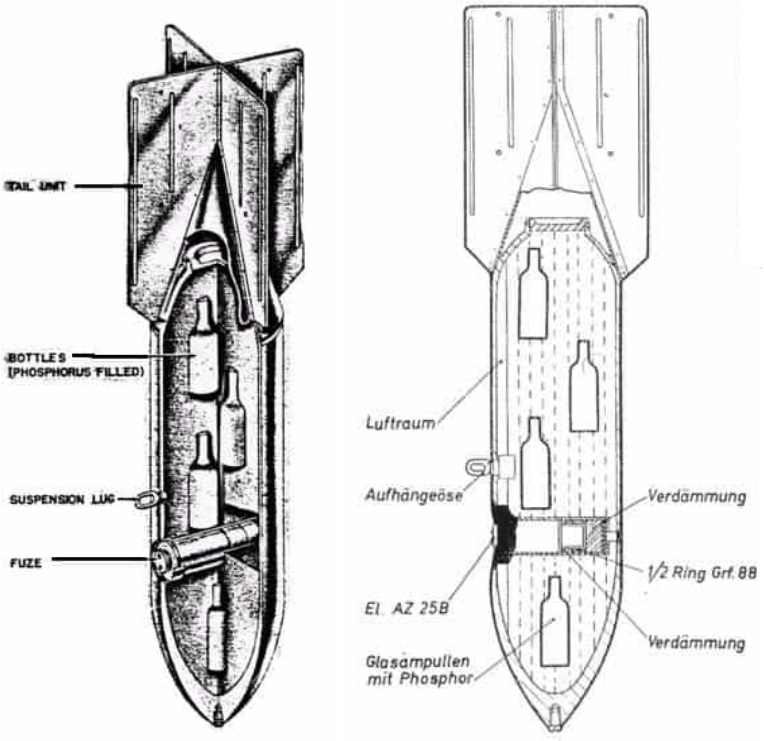
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

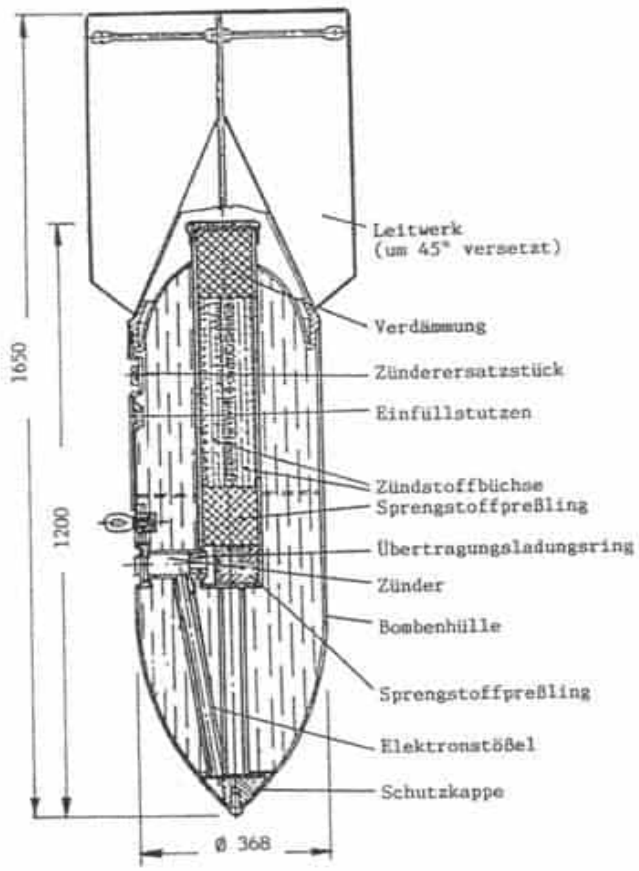






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

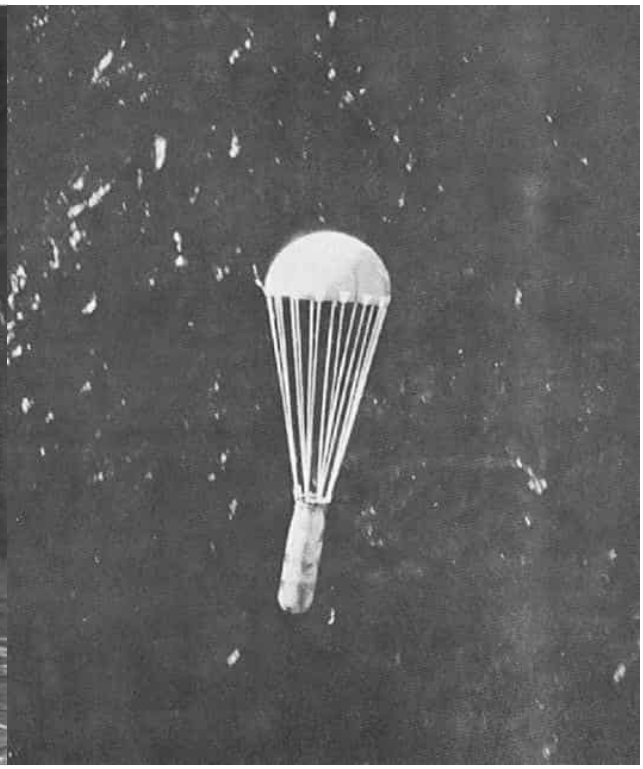




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration

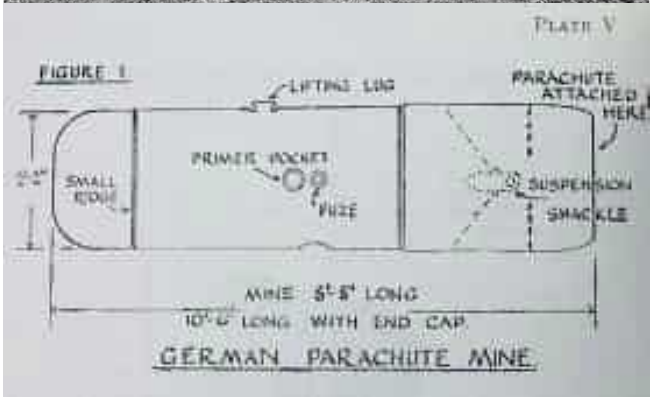

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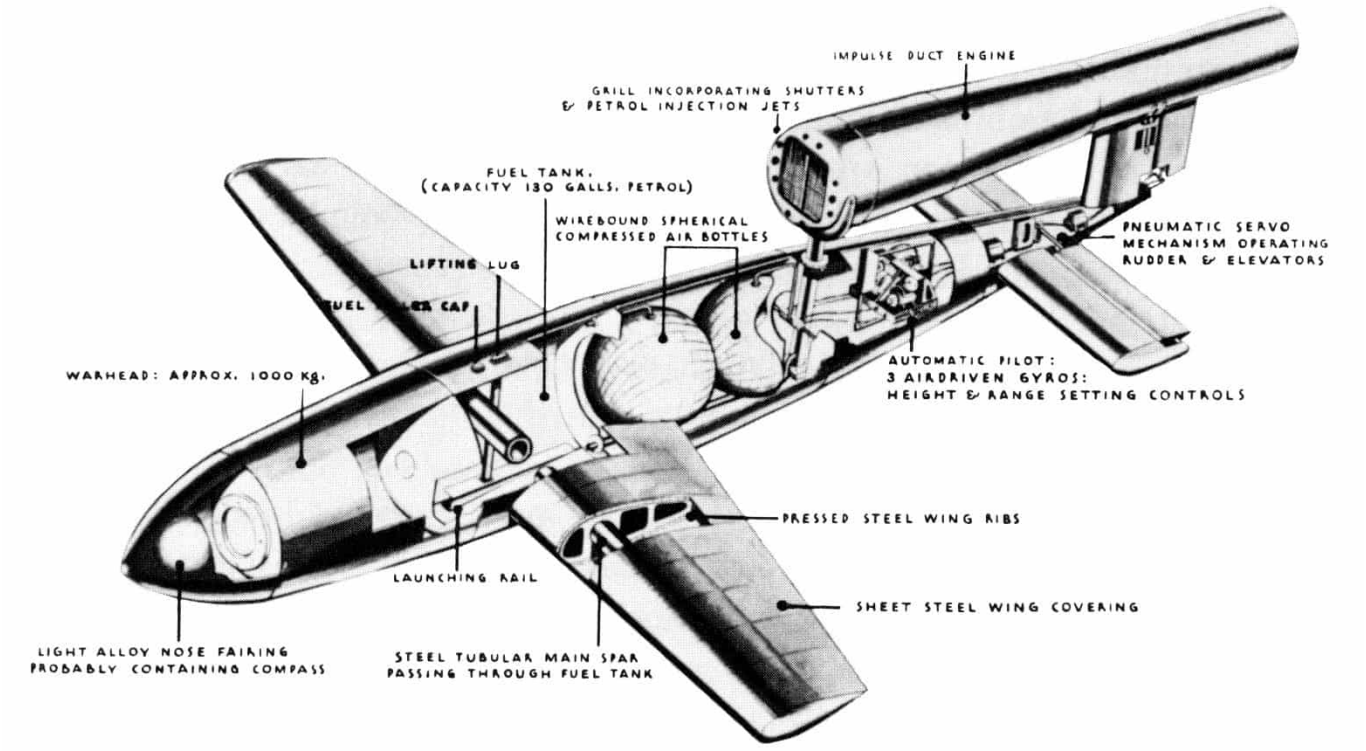


Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg
Fuze Type: Mechanical clockwork fuze
Bomb Dimensions: A – 1768mm, B – 2682mm
Use: Capable of creating severe blast damage in built-up areas.
Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

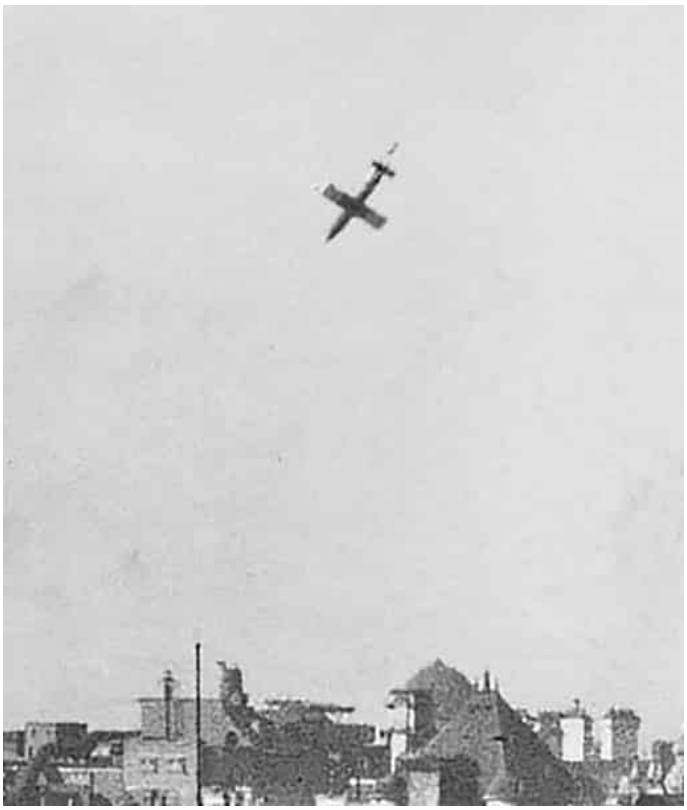

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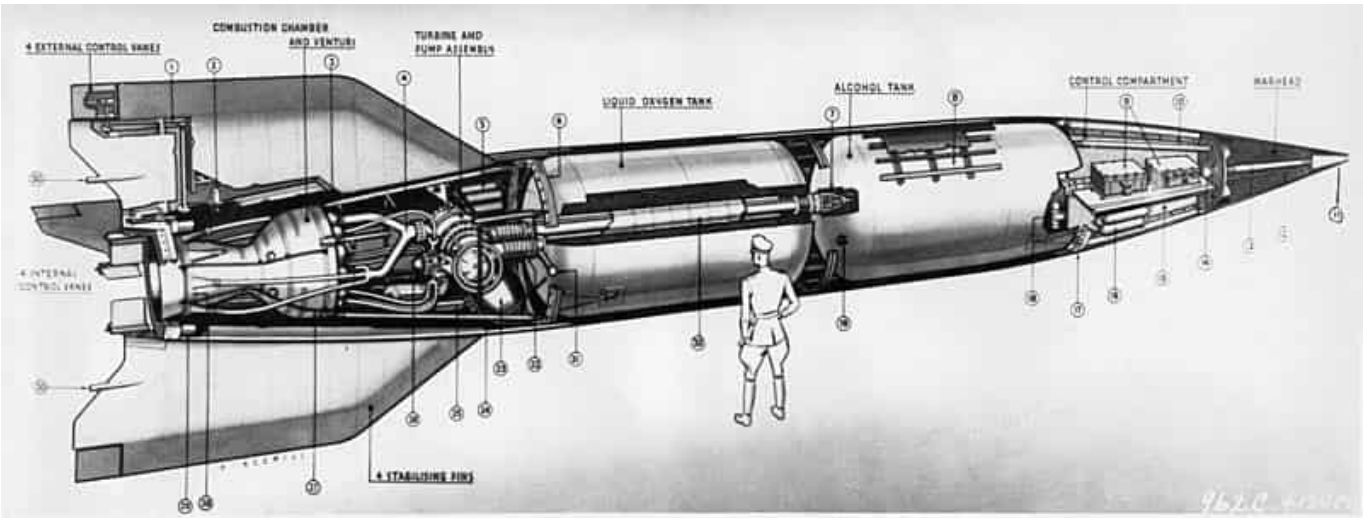


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

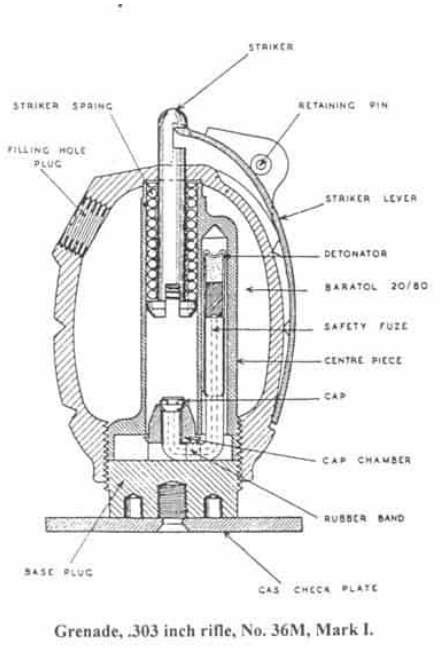
Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.





British & Allied Ordnance



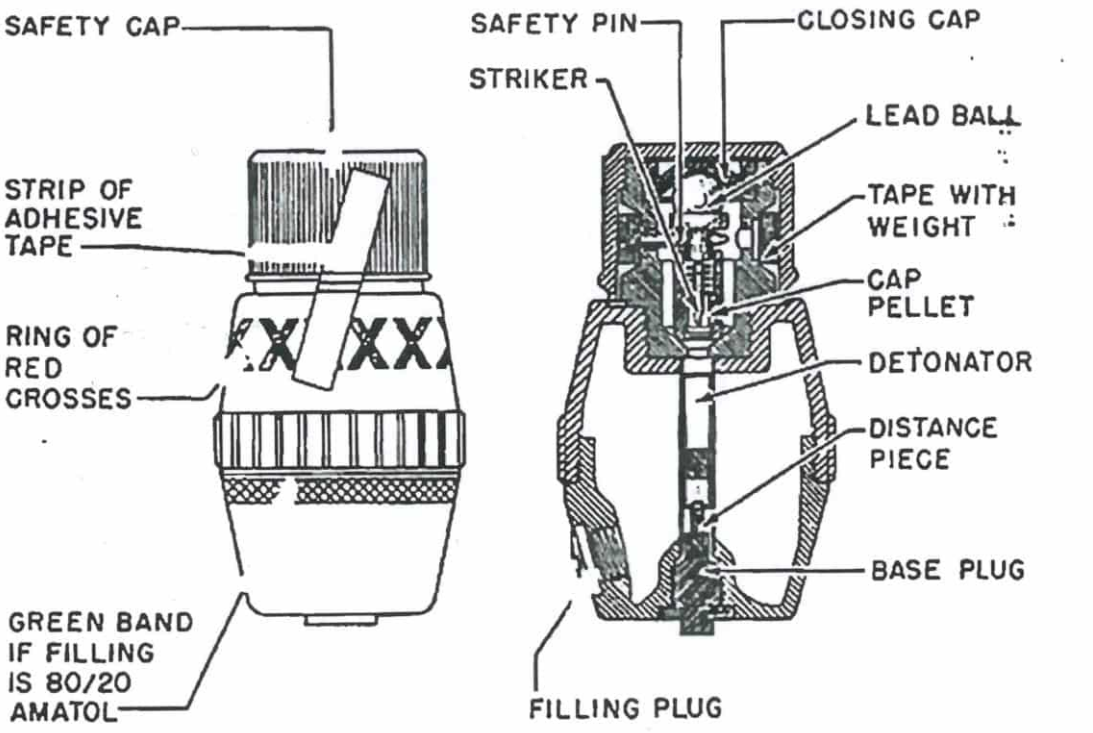


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



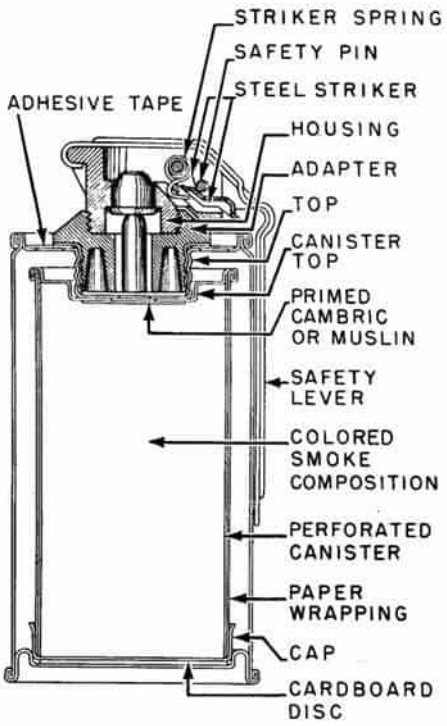


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





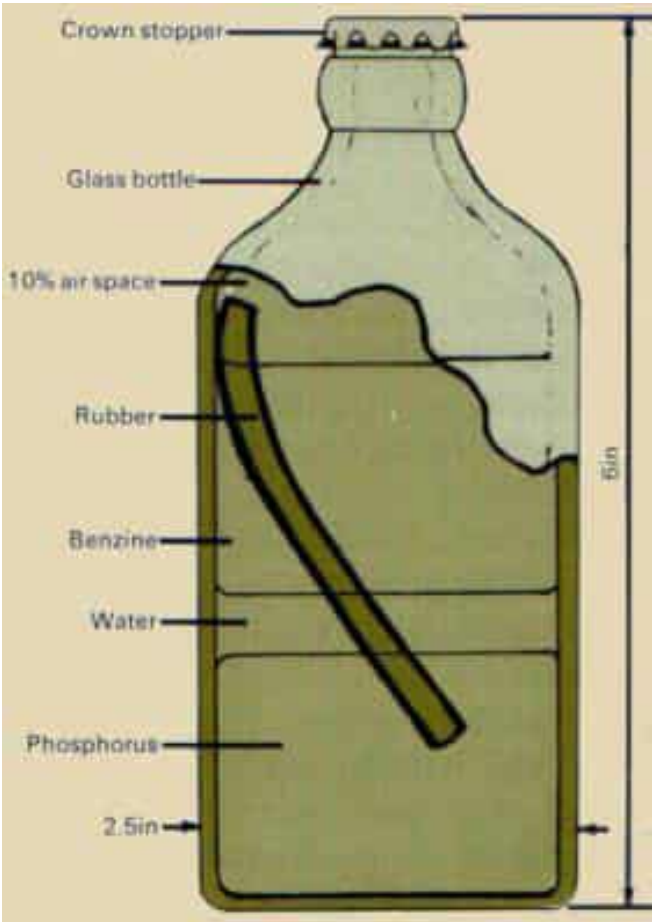


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

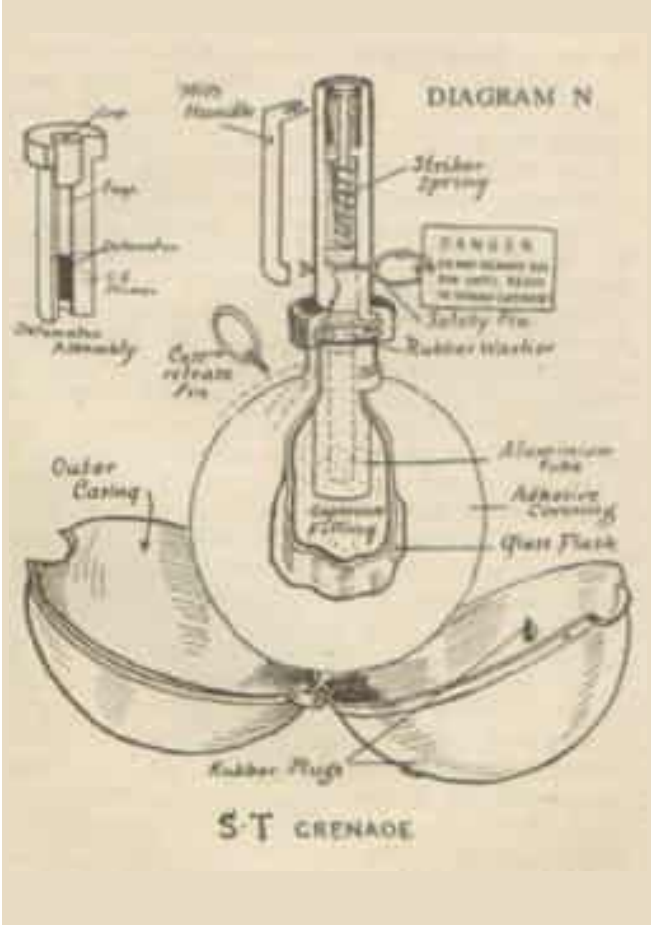






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

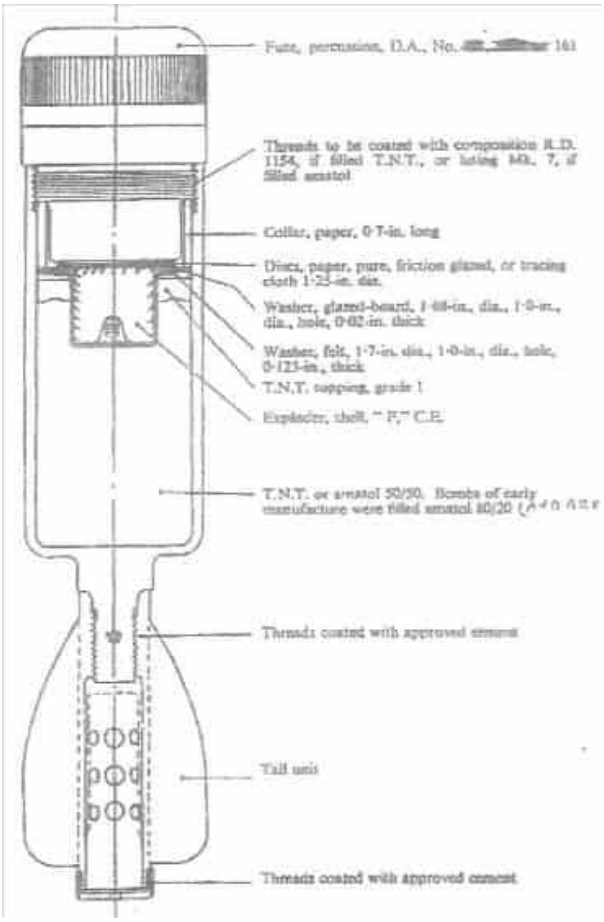






Typical 2" High Explosive Mortar

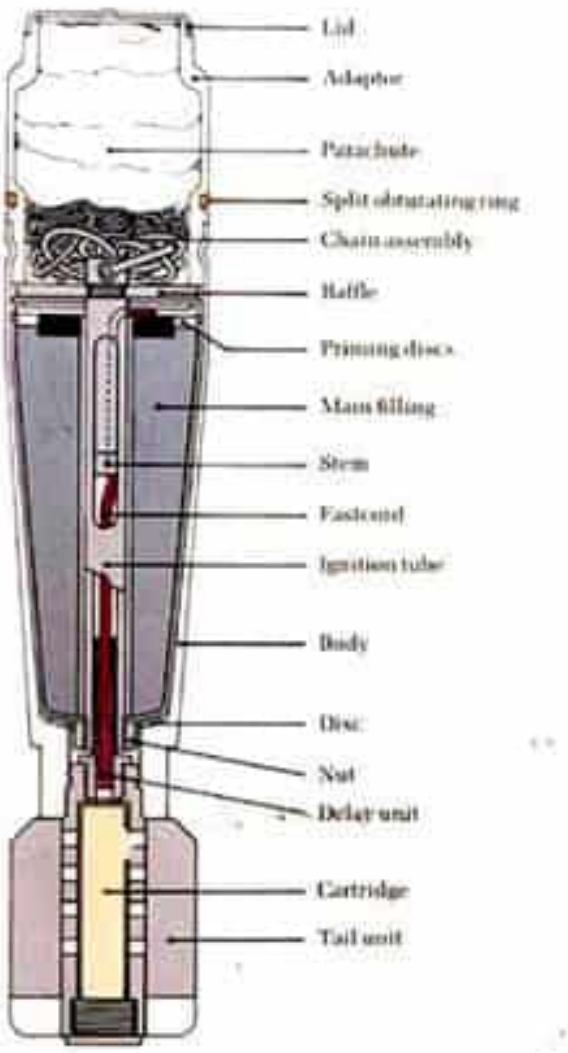
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







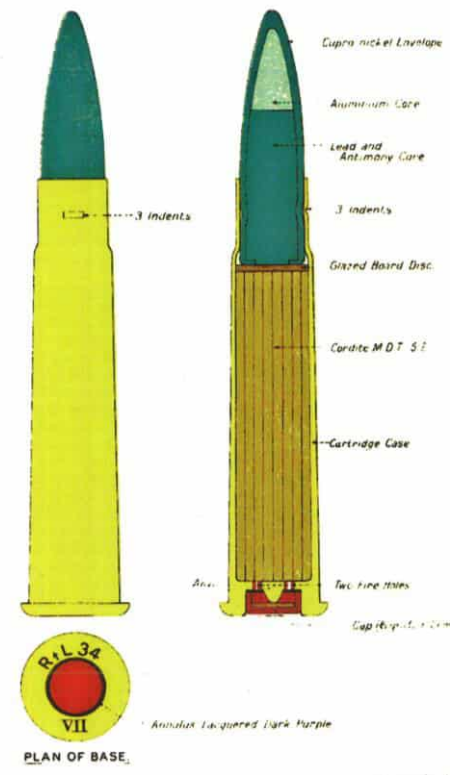


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



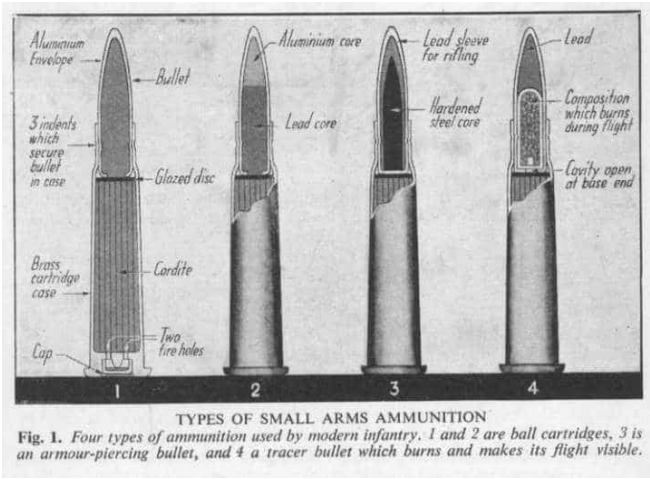




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



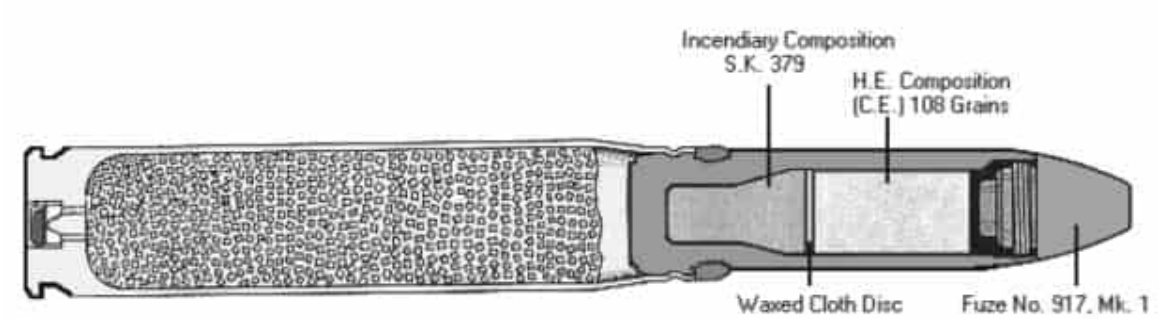


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

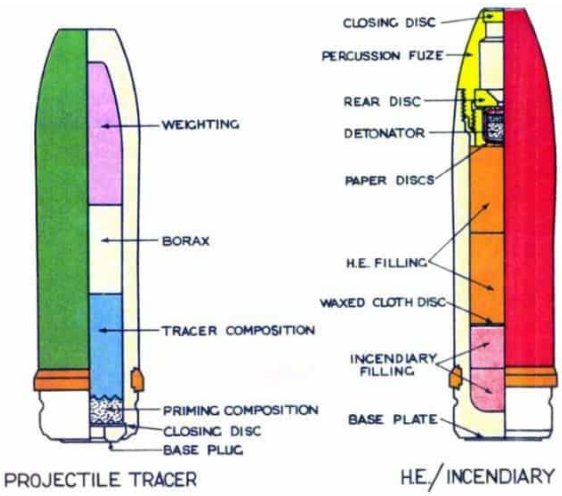






20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



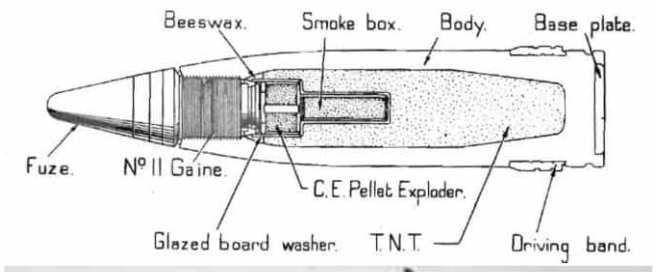
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	



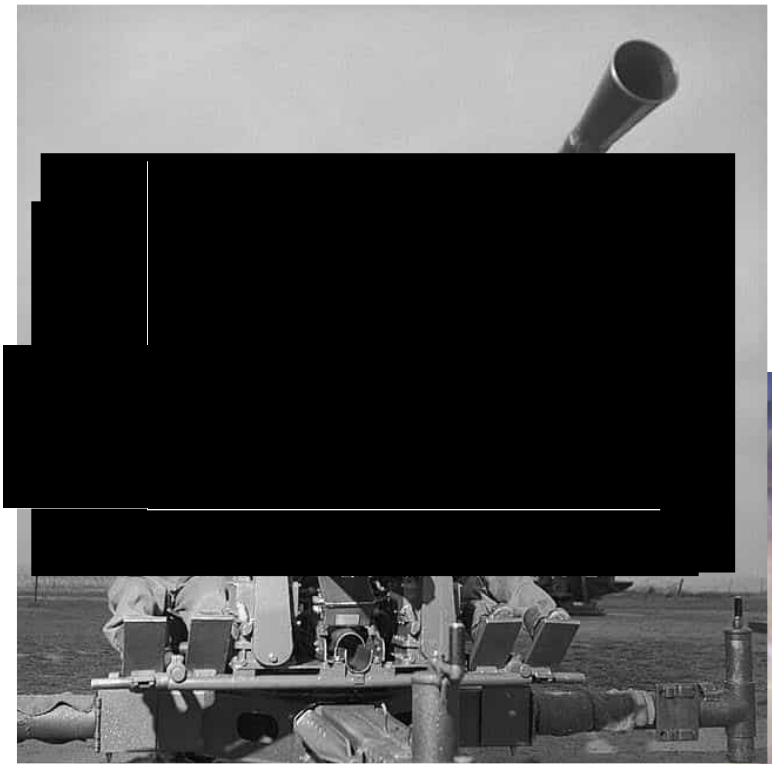
3.7" Anti-Aircraft Projectile

Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.







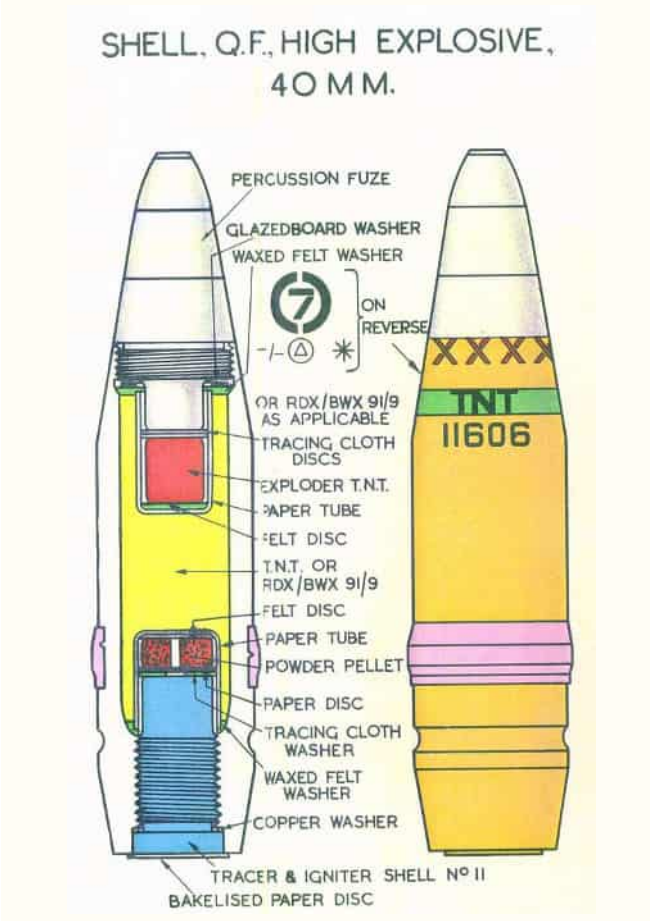




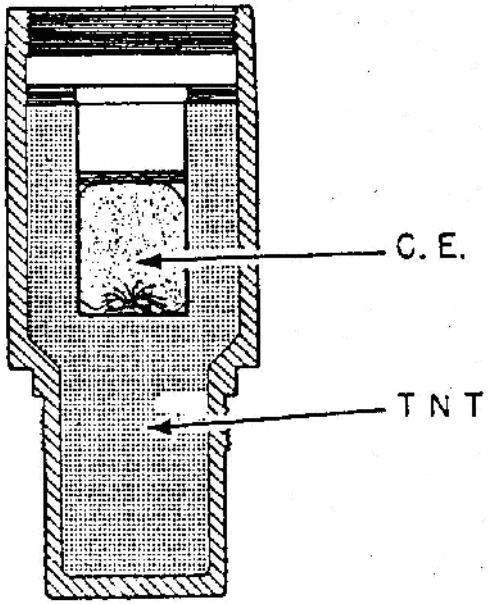


40mm Bofors Gun Projectile

Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

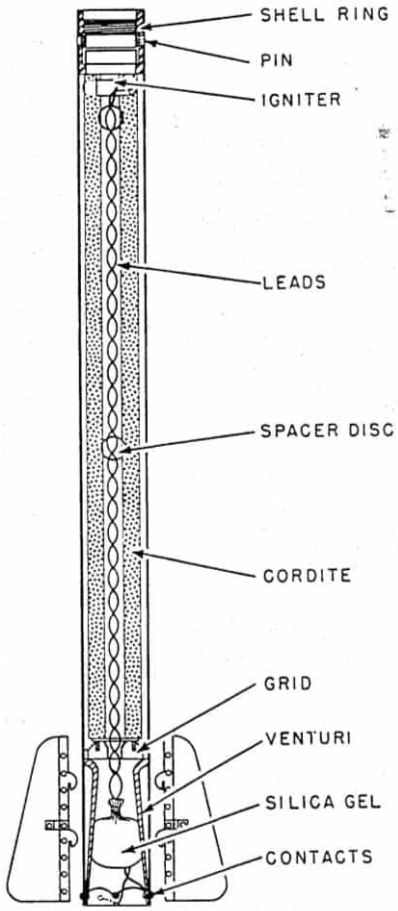






Rockets / Un-rotating Projectiles

Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery



SAFELANE
GLOBAL



Detailed Unexploded Ordnance
Risk Assessment

In Respect Of:
Richborough Alternative Area 4 Cable Route Revision

For:
Mott Macdonald

Report Reference:
9758-3 RA



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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry. This report has been compiled using all due diligence and expertise and having made all proper but reasonable enquiries within given time limitations. However, in accepting and implementing the recommendations contained in this report, the client does so strictly at his own risk.

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Executive Summary

The Site	
Address:	Cliffsend, Ramsgate, CT12 5LJ
OS National Grid Reference:	TR 34156 63747
Site Description:	The site is predominantly occupied by the grounds of St. Augustine Golf Links and Stonelees Golf Centre, constituting multiple holes. The golf courses are largely occupied with soft vegetation, with several clusters of trees in the central northern extent and towards the south-western extent. Access to the site is gained by the golf club located to the north-west through multiple paths that encroach onto the site. Sandwich Road encroaches through sites eastern boundary. Extension area: Comprises a section of foreshore, grassy ground, mature trees and hard-surfaced areas.
Proposed Works	
The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**HIGH from the following UXO types:** • German Air-Delivered HE bombs • Land Service Ammunition
	MEDIUM from the following UXO types: • Allied Anti-Aircraft Shells • British / Allied Small Arms
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	
Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of

	that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.	
Recommended Risk Mitigation		
Risk Level	**Planned Site Activity**	**Recommendations**
High	**Shallow Intrusive Works eg excavations**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Search & Clear • Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey)
	Deep intrusive works (eg piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
	Offshore works	Appropriate risk mitigation measures can be provided for any works taking place in marine (coastal or offshore) parts of the project site if necessary. These can usually include the following: • UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Client threat briefing • Authorities' engagement where required • Non-Intrusive (NI) High-Resolution Marine Survey – Area specific to each project module • Assessment and production of a Master Target List • Target Investigation (Required as a follow-on from NI Marine Survey) • ROV/Diver Investigation / Survey • Disposal if requested
In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.		

Table of Contents

Distribution i
Executive Summary ii
Table of Contents iv
List of Annexes vi
Appendices vi
Glossary of Terms vii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations *4*
4.5.2 Bombing Records *5*
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Pre and Post-WWII OS Mapping 7
8 The Threat from Aerial Bombing 7
8.1 General Bombing History of Kent 7
8.1.1 First World War *7*
8.1.2 Second World War *8*
8.2 Generic Types of WWII German Air-delivered Ordnance 8
8.3 Second World War Bombing Statistics 10
8.4 Site Specific WWII Bombing Records 11
8.4.1 Kent Bomb Census Maps *11*
8.4.2 Original ARP Bombing Incident Records *11*
8.4.3 Home Office Intelligence Reports *13*
8.4.4 Secondary Source / Anecdotal Evidence *16*
8.4.5 WWII-era RAF Aerial Photography *17*
8.4.6 Abandoned Bombs *17*
8.5 UXB Ground Penetration 18
8.5.1 General Considerations *18*
8.5.2 The "j" Curve Effect *18*
8.5.3 Second World War Bomb Penetration Studies *19*
8.5.4 CIRIA Bomb Penetration Depth Specifications *19*
8.5.5 Site Specific Bomb Penetration Considerations *19*

8.6 Likelihood of Post-raid UXO Detection 20
8.6.1 Density of Bombing *20*
8.6.2 Bomb Damage *20*
8.6.3 Frequency of Access *20*
8.6.4 Ground Cover *21*
8.6.5 German Air-Delivered Ordnance Failure Rate *21*
8.6.6 Site Specific Analysis *22*
9 The Threat from Allied Military Ordnance 26
9.1 Port Richborough 26
9.2 Home Guard Activity 27
9.3 Anti-Aircraft Gun Batteries 28
9.4 Site-Specific Threat from Allied Military Ordnance 29
9.5 Generic Types of WWII British / Allied Unexploded Ordnance 31
9.5.1 Land Service Ammunition (LSA) *31*
9.5.2 Small Arms Ammunition (SAA) *32*
9.5.3 Anti-Aircraft Shells *32*
10 The Overall Unexploded Ordnance Risk Assessment Methodology 33
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance 34
10.1.1 General *34*
10.1.2 Likelihood of Contamination from German UXO *35*
10.1.3 Likelihood of Contamination from British / Allied UXO *36*
10.2 The Likelihood that Unexploded Ordnance Remains on Site 37
10.2.1 General *37*
10.2.2 EOD Bomb Disposal and Clearance Tasks *37*
10.2.3 Post War Redevelopment *38*
10.2.4 Site-Specific Analysis *38*
10.3 The Likelihood that Ordnance may be Encountered during the Works 39
10.4 The Risk that Ordnance may be Initiated 39
10.4.1 Initiation of Unexploded Bombs *39*
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance *40*
10.5 The Consequences of Encountering or Initiating Ordnance 41
11 SafeLane Global's Risk Assessment 45
11.1 Conclusions 45
12 Proposed Risk Mitigation Strategy 46
12.1 Summary 46
12.2 Additional Notes 47
Bibliography 51

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C Pre and Post-WWII OS Maps

Annex D Kent Bomb Census Maps

Annex E Kent ARP Records Bomb Census Map

Annex F WWII-era RAF Aerial Photography

Appendices

Ordnance Specifications and Information

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Richborough Alternative Area 4 Cable Route Revision

1 Introduction

Groundsure Limited, on behalf of Mott Macdonald has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of Richborough Alternative Area 4 Cable Route Revision.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC – Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Kent History & Library Centre.
- Kent Historic Environment Record.
- National Collection of Aerial Photography (NCAP).
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Cliffsend, Ramsgate, CT12 5LJ	
OS National Grid Reference	TR 34156 63747	
Site Description	The site is predominantly occupied by the grounds of St. Augustine Golf Links and Stonelees Golf Centre, constituting multiple holes. The golf courses are largely occupied with soft vegetation, with several clusters of trees in the central northern extent and towards the south-western extent. Access to the site is gained by the golf club located to the north-west through multiple paths that encroach onto the site. Sandwich Road encroaches through sites eastern boundary. Extension area: Comprises a section of foreshore, grassy ground, mature trees and hard-surfaced areas.	
Proposed Works	The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	**Borehole Reference**	None recorded within 500m of the site.
British Geological Survey Mapping	**Superficial Deposits**	Thanet Formation (occupies majority of the site) - None recorded. Thanet formation (occupies the south-eastern and eastern extent) – Tidal Flat Deposits consisting of Clay and Silt.
	Bedrock	Thanet Formation – Sand, Silt, and Clay.
Client Provided Data	**Document Name**	Groundsure Ltd – Superficial geology (50k)
Groundsure Ltd	**Superficial Deposits**	• Beach and Tidal Flat deposits – Sand and Gravel (constitutes the eastern corner). • Tidal Flat Deposits – Clay and Silt (constitutes majority of the site). • Storm Beach Deposits – Sand and Gravel (occupies the eastern-most boundary).

7 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1938	• The site is occupied by a *St. Augustine's* golf course in the northern extent and identified greenfield in the south. • A road encroaches onto the site's eastern boundary. • The site and surrounding area is rural/coastal in nature. • Extension area: Extends into the foreshore, comprising *Saltings, Sand and Mud*.	Annex C-1	Groundsure Ltd
Post-WWII	1948	• The site and surrounding area appear consistent with conditions present in pre-war OS mapping. • There appears to be no evidence of clearance, redevelopment, or ruins within the vicinity of the site. • These features can be the indicators of bomb damage on historical OS mapping. However, due to the lack of development within the area, it is unlikely that these indicators would be present. • Extension area: No changes are noted within its boundary.	Annex C-2	Groundsure Ltd

8 The Threat from Aerial Bombing

8.1 General Bombing History of Kent

8.1.1 First World War

During WWI, Kent suffered extensive aerial bombardment from zeppelin airships and fixed-wing aircraft. The first attack by the German Air Force was launched against Dover on the 21st December 1914 using naval seaplanes.

Bombing continued in Kent throughout the war; areas such as Ashford, Canterbury, Dover, Folkestone, Gravesend, Margate, Maidstone and Sheerness suffered particularly severe raids. The last raid on the county was on the night of the 19th May 1918 when a total of 14.55 tonnes of bombs were dropped on London, Faversham and Dover. Ramsgate is situated approximately 3km north-east of the site and gained the reputation as the most bombed seaside town in WWI. The town suffered from both aerial bombing and naval bombardment during WWI, with Zeppelin's scattering a number of bombs in all districts in the area.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of

attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Kent played a key role in the defence of Britain in WWII. It was at the frontline during the Battle of Britain during which the Luftwaffe attempted to destroy the RAF and its airfields in order to gain air superiority over the south-east of England ahead of the planned German invasion. Bombing raids began in July 1940 from German-occupied France and in the following months many of the towns and cities in Kent were subjected to bombing attacks.

Within Kent, Manston airfield was a key target for the Luftwaffe especially during the Battle of Britain, where RAF Manston sustained serious bomb damage. Most of the staff dispersed into the surrounding houses due to the destruction. The site is located just 1.6km south-east of the airfield.

By May 1941, concentrated attacks were reduced as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa', the invasion of Russia. Note however that Canterbury was heavily bombed in mid-1942 as part of the Baedeker Blitz.

During 1942 and 1943, there were a number of minor raids carried out by small formations of fighter bombers and then between January and May 1944 the Luftwaffe returned to London en masse, for Operation Steinbock. These raids were executed by inexperienced Luftwaffe crews and were less frequent when compared to the original Blitz of 1940/41. Poor navigation and improved defences resulted in unsustainable Luftwaffe losses and many raids were unsuccessful.

Cliffsend was situated within 'Hellfire Corner'; an area of Kent where aerial 'dog fights' and 'tip and run' bombing incidents were frequent during the Battle of Britain. The region was also under artillery bombardment from the coastal batteries located at Calais and Cap-Gris-Nez in occupied France. These batteries, including the *Lindemann* and *Todt Batteries*, bombarded the south coast until they were captured after the Allied D-Day Landings in 1944. The batteries covered an arc stretching from Ramsgate to Hythe and fired shells weighing approximately 1 ton each.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe. Totals of 2,419 V1s and 517 V2s were recorded in the London Civil Defence region.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Municipal Borough of Ramsgate between 1940 and 1945.

Record of German Ordnance Dropped on the Municipal Borough of Ramsgate	
Area Acreage	3,624
High Explosive Bombs (all types)	771
Parachute Mines	5
Oil Bombs	3
Phosphorus Bombs	-
Fire Pots	-
Pilotless Missile (V1)	-
Long Range Rocket (V2)	-
Total	774
Items Per 1,000 Acres	**213.6**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Kent Bomb Census Maps

A review was conducted of the Kent Bomb Census Maps, obtained from the National Archives. Those showing incidents on or close to the site are listed below. Note, the maps are small in scale and lack any clear geographical indicators, therefore the site and distance(s) listed below can be considered an approximate.

Date	Weapon	Details
09/07/1940	Incendiary bombs HE bombs	On or adjacent to the site.
27/10/1940	3 x HE bombs	1 x HE bomb immediately to the west of the site.
29/10/1940	2 x HE bombs	Approximately 1.1km south-west of the site.
05/12/1940	1 x Incendiary bomb	800m north-east.
Reference		**Annex D**

8.4.2 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records. Sections of these ARP records (with map references) have been plotted in **Annex E**.

Written ARP records were reviewed for	Sandwich		
Source	Kent History & Library Centre		
Records of bombing on / near the site were found			✓
Date	**Weapon**	**Map Reference**	**Details**
19/09/1940	2 x HE bombs	n/a	"2 small HEs on Golf Course." – Sandwich Proximity to site potentially on or adjacent.
06/10/1940	"Salvo" of HE bombs	n/a	"Dropped in Sea off Pegwell Bay". Approximately within 700m of the site.
24/08/1942	HE Bomb	n/a	"Just West of Ramsgate – Sandwich Road." Proximity to site potentially on or adjacent.

Written ARP records were reviewed for	Ramsgate		
Source	Kent History & Library Centre		
Records of bombing on / near the site were found			✓
Date	**Weapon**	**Map Reference**	**Details**
13/09/1940	2 x HE bombs	n/a	Foads Hill, Cliffsend. Approximately 800m north of the site.
18/09/1940	1 x UXB	n/a	St Augustine's Golf Links about 30 yards from Ramsgate-Sandwich Road. Bomb believed to have resulted from enemy action on 17/09/1940. Approximately 200m north-west of the site.
	1 x UX HE 2 x Hes	780820	St Augustine's Golf Course. 320m north.
14/10/1940	1 x Mine	n/a	Mine stranded by the tide 200 yards from shore. Pegwell Bay, Ramsgate. Precise location not known.
27/10/1940	4 x HE bombs	n/a	An enemy aircraft dropped 2 x HE bombs at Pegwell and 2 x HE bombs at Cliffsend. Precise location not known.
08/12/1940	2 x Incendiary bombs	795821	In open field at Cliffsend. Approximately 1.2km north-east.
05/02/1941	4 x HE bombs	n/a	Fell in open ground at Cliffsend, Ramsgate. Eight bungalows slightly damaged. Precise location not known.
06/02/1941	10 x 50 kg HE bombs	788839 to 789819	10 x 50kg HE's were dropped in a line from map reference 788/839 to 789/819. Approximately 600m north-east of the site.
04/05/1941	1 x HE bomb	n/a	Lavender Road, Golf Link Road. Approximately within 300m of the site.
	1 x HE bomb	776819	Cottington Hill, Minister.

			Approximately 350m north-west of the site.
	1 x HE bomb	775817	South of Cottington Hill, Minister. Approximately 400m west of the site.
13/08/1941	Unspecified UXBs	796828	Search on open ground Approximately 1.4km north-east of the site.
19/05/1943	1 x HE	n/a	In Pegwell Bay (in sea). Precise location not known.

9.1.1 Home Office Intelligence Reports

The Home Office Intelligence reports document enemy action on British domestic soil and were prepared twice a day for the Home Security War Room. The summaries were prepared by intelligence staff, who compiled reports received from the twelve civil defence regions.

However, available records only document time and general location of attack and numbers of casualties. The intelligence officials generally only recorded locations on municipal level (town, village, or city), rarely providing specific addresses.

Date	Location	Details
05/07/1940	Ramsgate	0 casualties
08-09/07/1940	Ramsgate	0 casualties
12/08/1940	Manston, Ramsgate	12 casualties
14/08/1940	Manston, Ramsgate	0 casualties
16-17/08/1940	Manston, Ramsgate	0 casualties
22-23/08/1940	Manston, Ramsgate	0 casualties
24/08/1940	Ramsgate	65 casualties
	Manston, Ramsgate	0 casualties
28/08/1940	Ramsgate	1 casualty
13/09/1940	Ramsgate	0 casualties
16/09/1940	Ramsgate	0 casualties
28/09/1940	Ramsgate	Unspecified
07/10/1940	Ramsgate	0 casualties

08/10/1940	Ramsgate	0 casualties
11/10/1940	Ramsgate	4 casualties
20/10/1940	Ramsgate	0 casualties
27/10/1940	Ramsgate	1 casualty
02/11/1940	Ramsgate	29 casualties
10/11/1940	Ramsgate	4 casualties
11/11/1940	Ramsgate	9 casualties
12/11/1940	Ramsgate	2 casualties
13/11/1940	Ramsgate	1 casualty
18/11/1940	Ramsgate	4 casualties
29/11/1940	Ramsgate	0 casualties
05/12/1940	Ramsgate	0 casualties
29/12/1940	Ramsgate	0 casualties
03-04/01/1941	Ramsgate	17 casualties
11/01/1941	Ramsgate	2 casualties
15/01/1941	Ramsgate	1 casualty
17-18/01/1941	Ramsgate	0 casualties
03/02/1941	Ramsgate	4 casualties
12/02/1941	Ramsgate	0 casualties
22/02/1941	Ramsgate	0 casualties
03/03/1941	Ramsgate	4 casualties
13-14/03/1941	Ramsgate	0 casualties
18/03/1941	Ramsgate	2 casualties
20/03/1941	Ramsgate	12 casualties

09-10/04/1941	Ramsgate	2 casualties
04-05/05/1941	Ramsgate	0 casualties
07/05/1941	Ramsgate	0 casualties
10-11/05/1941	Ramsgate	0 casualties
13-14/06/1941	Ramsgate	16 casualties
06-07/08/1941	Ramsgate	1 casualty
16-17/08/1941	Ramsgate	0 casualties
30-31/08/1941	Ramsgate	3 casualties
07-08/09/1941	Ramsgate	26 casualties
09-10/11/1941	Ramsgate	6 casualties
27/11/1941	Ramsgate	1 casualty
29-30/05/1942	Ramsgate	0 casualties
04/09/1942	Ramsgate	0 casualties
31/10/1942	Ramsgate	0 casualties
26/01/1943	Ramsgate	6 casualties
09/02/1943	Ramsgate	0 casualties
02/03/1943	Ramsgate	0 casualties
03-04/03/1943	Ramsgate	0 casualties
18-19/05/1943	Ramsgate	0 casualties
19-20/05/1943	Ramsgate	0 casualties
28-29/05/1943	Ramsgate	3 casualties
12-13/06/1943	Ramsgate	0 casualties
15-16/06/1943	Ramsgate	5 casualties
16-17/08/1943	Ramsgate	5 casualties

17/08/1943	Ramsgate	5 casualties
22-23/08/1943	Ramsgate	0 casualties
03-04/10/1943	Ramsgate	12 casualties
04-05/11/1943	Ramsgate	0 casualties
19-20/01/1944	Ramsgate	0 casualties
21-22/01/1944	Ramsgate	0 casualties
	Ramsgate	0 casualties
24-25/01/1944	Ramsgate	0 casualties
29/06/1944	Ramsgate	0 casualties
31/08/1944 – 01/09/1944	Ramsgate	20 casualties

9.1.2 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
24/08/1940	HE and Incendiary bombs.	Ramsgate town centre was hit by over 250 bombs.[1] Approximately 3.2km north-west of the site.
31/08/1940	Aircraft crash	A fighter-plane crash landed in Sandwich Flats in Pegwell Bay. Incident possibly on or adjacent to the site.
17/09/1940	Unidentified UXB	"One unexploded bomb at St Augustine's golf course." Incident possible on or adjacent to the site.
02/03/1943	4 x Shells	Pegwell Bay. [2] No further details provided.
1940-1945	HE Bombs	A news article dating from 18th December 1945 (not annexed) details how farmland in the surrounding area of Cliffsend, particularly Bethlehem Farm (~ 600m north-east of the site) sustained bombing in WWII. At least 22 bombs fell in fields and nine RAF planes either crashed or made forced landings.

[1] Ogley, Bob, *Kent at War,* (Kent, Froglets Publications Ltd, 1994)
[2] https://www.britishnewspaperarchive.co.uk/viewer/bl/0001699/19450622/056/0003

9.1.3 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	3rd March 1942
Source	National Collection of Aerial Photography (NCAP)
Image Type	Aerial
Image quality	High resolution, small scale
Observations	• The site remains accurate to historical OS mapping, the golf course is largely covered in soft vegetation. • There seems to be irregularity on the ground approximately 40m to the north of the site, however, it is unclear whether this is a bunker or a crater from a bomb. • The low resolution makes it difficult to see in great detail, therefore any smaller bomb entry points or craters cannot be identified. • WWII bomb craters have been identified in additional aerial photography (not annexed) from 1944, it measured 10.5m by 8.4m.[3] • Extension area: The image confirms the extension area comprised an area of the foreshore. No evidence of bomb damage is apparent within its boundary.
Reference	**Annex F**

9.1.4 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✓
Additional Comments	An abandoned 50kg HE bomb is recorded on the golf course within the site boundary.

[3] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43187

9.2 UXB Ground Penetration

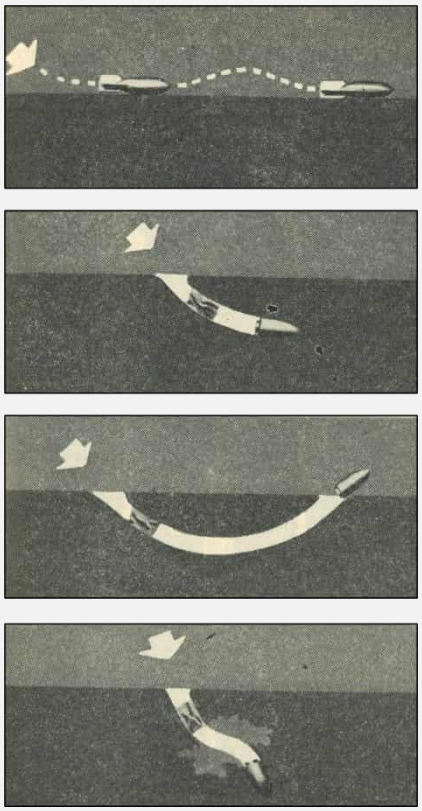
9.2.1 General Considerations

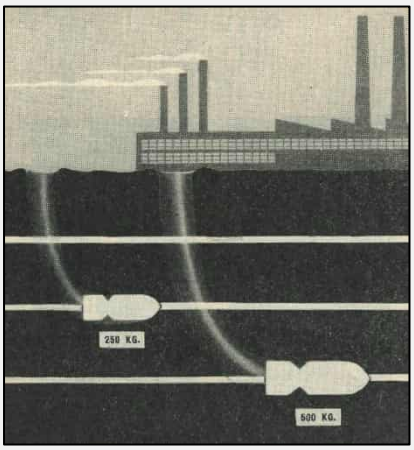
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

9.2.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

9.2.3 Second World War Bomb Penetration Studies

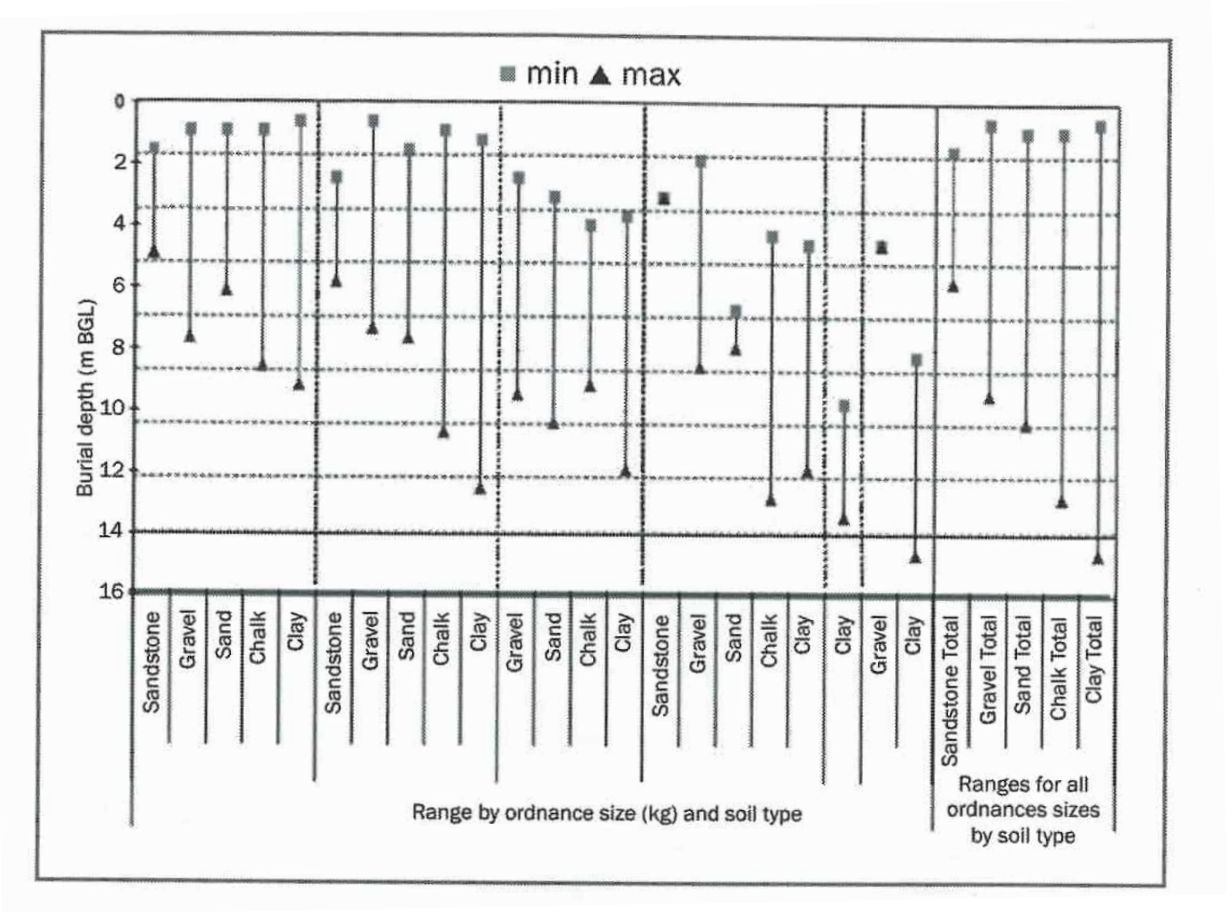
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

9.2.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



9.2.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – While no publicly available boreholes are recorded in the area, information provided by the client has shown the superficial deposits are and tidal consist of Clay, Silt, and Sand.
- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

9.3 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

9.3.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

9.3.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

9.3.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-

aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

9.3.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

9.3.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.

- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

9.3.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	High	The site's proximity to an airfield and to a harbour town resulted in a high bombing density over the local area. Ramsgate borough experienced a bombing density of 213.6 items per 1000 acres.
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✓	
	Were any HE bomb strikes recorded on site?	✓	An abandoned 50kg HE bomb is plotted on site.
	What is the distance between the site boundary and the closest recorded large bomb strike?	On site	
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	~ 4	
	Were any nearby sticks of large bombs recorded in line with the site?	✓	Kent Bomb Census Mapping plotted two HE bombs plotted within

			the vicinity of the site, indicating a possible stick.
	Were any 1kg incendiary bomb showers recorded over the site?	✓	Kent Bomb Census Mapping illustrates an incendiary shower encompassing the site.
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✗	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) have been found.	✗	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✗	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	✗	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✗	
	The site was exclusively or partially developed during WWII.	✓	However, the site was predominantly undeveloped.
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✗	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	Sandwich Road would have still been used during the war, according to ARP reports it was closed and traffic was stopped when a UXO was found on the golf course.
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗	
	The site was occupied by a school during WWII.	✗	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✗	

	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✖	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	Possibly	During WWII, the golf course was requisitioned by the military (see Section 9.3) and covered with defensive fortifications, including barbed wire. It is unclear however, when these were constructed and if the site was still being used recreationally during the early part of WWII.
	The site was occupied by a graveyard which would have experienced limited access.	✖	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✖	
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✖	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✖	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖	
	The site was occupied by dense, inaccessible vegetation during WWII.	✖	
	The site may have been susceptible to waterlogged conditions during WWII.	✓	
	The site was occupied by (possibly) unmaintained grass field during WWII.	✖	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✖	

	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✗	
	The site was occupied by stockpiled material during WWII.	✗	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✗	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✗	
	The site was occupied by well-maintained, manicured lawn during WWII.	✗	It is unlikely the golf course would have been well maintained.
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	
Bomb Failure Rate	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

10 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✓
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✓
Locations of Army Explosive Ordnance Clearance Tasks	✓
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

10.1 Port Richborough

Port Richborough, nicknamed port "Q", was established in 1914 on the banks of the River Stour, the facility was kept a secret and served as a significant military outpost. Throughout WWI, the port was used for manning and arming barges being sent to Dover and subsequently France.[4] The port became militarised during the First World War, with multiple stores for equipment used for supplying the barges erected in and around the banks. Moreover, defensive positions were established around the Port, especially on the flats towards the mouth of the river Stour.

During WWII, the port still served a purpose as a military outpost for the Royal Marines in 1942, named H.M.S Robertson. The Port was considered "a hive of industry" in preparation for D-Day, with many troops stationed in the nearby Richborough Camp, and factory workers working throughout the blackout in the port factory.[5] The port was located approximately 1.2km south-east of the site.

[4] https://blog.railwaymuseum.org.uk/port-of-richborough-and-the-birth-of-the-cross-channel-train-ferry/
[5] http://www.open-sandwich.co.uk/town_history/richborough_port.htm

10.2 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[6]

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019

[6] Various News Sources

	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

10.1 Coastal Defences

10.1.1 General

Following the evacuation of troops from Dunkirk in June 1940, Britain was at threat of invasion from occupied France. Several strategies were considered and developed but largely the emphasis was placed upon coastal fortifications. As a result the south-east witnessed the construction of a continuous coastal defence comprising: coast batteries, hardened field defences including weapon emplacements and concrete anti-tank obstacles, anti-tank ditches, anti-tank scaffolding, fire trenches and barbed wire entanglements.

Members of the HG (and probably Army) personnel that would have manned defensive positions along the coast will have been issued with land service and small arms ammunition and therefore there is a slightly increased risk of localised UXO contamination.

The HG deployed a range of both conventional and unconventional weapons throughout the war. These included conventional rifles, machine guns, mortars and grenades and the more unconventional Northover Projector (a grenade launcher), Spigot Mortar, the Smith Gun, SIP grenades and Fougasse bombs.

10.1.2 Defensive Minefields

In addition to an extensive network of coastal defences, key points, such as road junctions, bridges and airfields, were prepared for demolition at short notice. Canadian pipe mines (known as McNaughton Tubes) were also commonly used to create an instant tank obstacle in order to hamper enemy progress.

Furthermore, the mining of the beaches along the south coast was started in great haste following June 1940. These minefields were combined with other previously mentioned obstacles.

The Corps of Royal Engineers Journal states that "the laying of minefields was the first large scale practical experience the British Army had had in this branch of warfare. Lack of experience, and hurried operation, led to many mistakes being made which were to cause much trouble to units and members of the Corps later."

This may also be the reason why the practice of fencing off and accurately recording mine locations was not as universal as desired. Inaccuracies in record keeping, combined with changes caused by the tides, inhibited some of the later clearance efforts.

While the risk from a dislodged mine migrating and being washed up onshore is considered unlikely it cannot be entirely discounted.

10.2 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

10.3 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Nearest Home Guard Battalion to the site	6th Kent (Thanet) Battalion.
Home Guard Activity on site	• The Thanet battalion primarily operated out of Margate, approximately 7.0km from the site. However, the exact locations of their HQs or training areas were not found.

	• The Kent Historic Environment Record shows a number of WWII defences occupying St Augustine's Golf Course. These include a machine gun post, slit trench and pillbox which are positioned on or in close proximity to the site.[7] • The Thanet Advertiser from 1945 also states that the golf course was also covered with barbed wire and other obstructions.[8] • Further defensive features in close proximity to the extension area included a coast battery observation post and fougasse (anti-tank weapon system) approximately 60m to the north. Pegwell Bay beach was also protected by anti-boat landing obstacles, comprising anti-tank blocks, barbed wire and fencing. • HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Due to the area being heavily fortified, it is possible that arms were buried on or adjacent to the site. • Marshy land between Minster and Pegwell Bay was used as a mortar training range during WWII, however no details regarding the full extent of the training area could be located. • Furthermore, during May 1943, Spigot Mortars were fired into Pegwell Bay as part of the Thanet Battalions 3rd birthday parade celebrations. [9] Such activity is likely to account for some of the UXO finds in Pegwell Bay, some of which were discovered in close proximity to the extension area, in the post-war period (see Section 10.2.2). • Given the strong military / HG presence in the area and the site comprising undeveloped ground, the possibility the site was used for training purposes cannot be discounted. • Beaches across the Kent coast were mined as an anti-invasion defence measure, for example the shoreline between Deal and Sandwich was mined during WWII. [10] • Furthermore, a newspaper article reported that mines were laid across farmland at Cliffsend when enemy invasion appeared to be imminent. This included Bethlehem Farm 750m north of the site[11]. The full extent of these minefields is unknown. • Pegwell Bay was considered to be a likely landing beach for invading forces and was therefore likely protected with mines. However, no further details could be located.
Number of HAA batteries within 5km of the site	5
Threat to the site from unexploded AA shells	• The nearest HAA battery was approximately 2.0km north-east from the site, situated close to RAF Manston. • However, the Kent Historic Environment Record and historical aerial photography also indicates the presence of an anti-aircraft battery on St Augustine's Golf Course, approximately 200m to the north of the site. [12]

[7] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43191
[8] https://www.britishnewspaperarchive.co.uk/viewer/bl/0001699/19450313/043/0003
[9] https://www.britishnewspaperarchive.co.uk/viewer/bl/0001698/19430518/020/0001
[10] https://issuu.com/cisr-journal/docs/journal21-1/s/103656
[11] Thanet Advisor – 18th December 1945
[12] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43192

	• RAF Manston was targeted and attacked by the Luftwaffe several times during WWII. During such attacks, it is likely that a degree of AA fire would have occurred over the site. • One anecdotal account notes that "the intensity of the anti-aircraft fire put up around Manston and Hawkinge airfields during the raids of 15th August 1940" led to the towns of Ramsgate getting bombed more frequently.[13] • Furthermore, as a consequence of the site's position to Ramsgate harbour, it is possible that many temporary LAA batteries were established on the course and in open fields within close proximity to the site.[14] A Kent County Council source has confirmed. • Had an exploded shell landed onto the soft ground on site, it is conceivable it could have remained undetected.

10.4 Generic Types of WWII British / Allied Unexploded Ordnance

10.4.1 Land Service Ammunition (LSA)

10.4.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10.4.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

[13] Hylton, Stuart, Kent and Sussex 1940:Britain's Front Line, (Barnsley, Pen & Sword Books Limited, 2004)
[14] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43191

10.4.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

10.4.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10.4.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

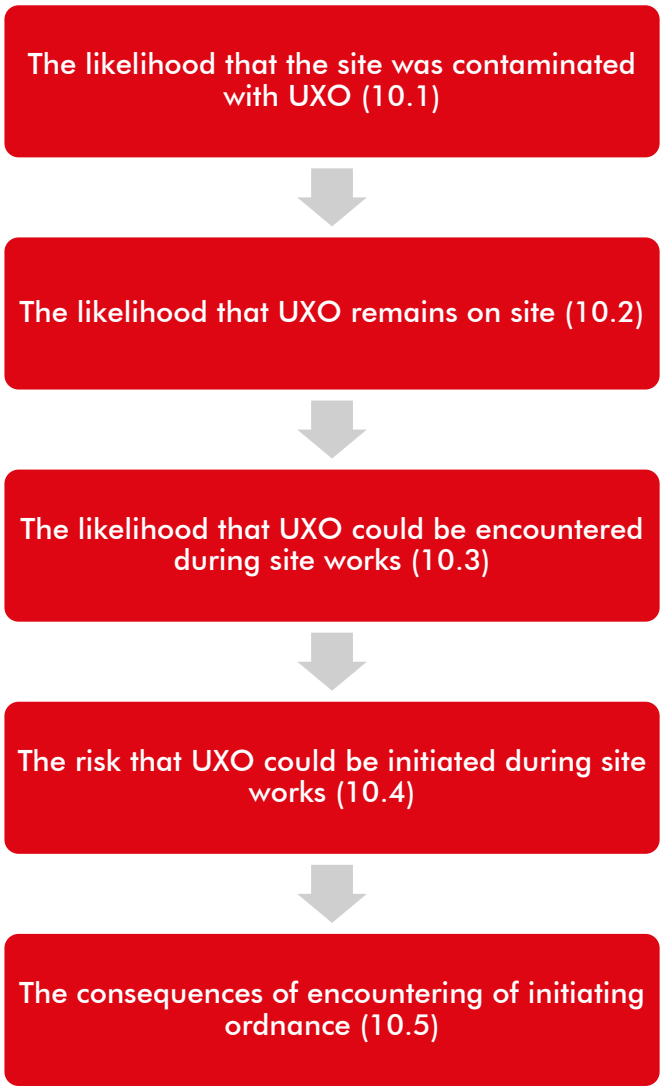
The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

11 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

11.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

11.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

11.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• High localised bombing density (213.3 items per 1000 acres). • 1 x abandoned 50kg HE bomb plotted on site. • 1x Incendiary bomb shower plotted adjacent to the site. • 1 x stick of bombs in line with the site.
Bomb Damage	• No evidence of bomb damage on site. • Possible HE bomb crater 40m north.
Ground Conditions	• Soft vegetation across the whole site. • Hard surface in the eastern extent. • Extension area comprised foreshore.
Frequency of Access	• It is unclear whether the site was used recreationally throughout the war. • The site was likely accessed by the military. • Extension area unlikely to have been accessed frequently.
J-Curve Effect	• Had any UXB landed within the soft ground / marshland / mud on / adjacent to the site, it could have come to rest beneath the study area.
Other considerations	n/a
Overall Likelihood of Contamination	**High**

11.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• St. Augustine's Golf Course was requisitioned by the military. A machine gun post, slit trench and pillbox were positioned on or in close proximity to the site. • A coastal battery observation post and fougasse (anti-tank weapon system) were located 60m to the north of the extension area. • Pegwell Bay beach was also protected by anti-boat landing obstacles, comprising anti-tank blocks, barbed wire and fencing. • HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Due to the area being heavily fortified, it is possible that arms were buried on or adjacent to the site. • Marshy land between Minster and Pegwell Bay was used as a mortar training range during WWII. Therefore, the possibility of such training taking place on site cannot be discounted. • Spigot Mortars were fired into Pegwell Bay as part of the Thanet Battalions 3rd birthday parade celebrations. Such activity is likely to account for a number of the UXO finds in the area (see Section 10.2.2). • Pegwell Bay was considered to be a likely landing beach for invading forces and was therefore likely protected with mines. However, no further details could be located.
Anti-Aircraft Projectiles	• Five HAA batteries were situated within a 5km radius of the site during WWII, the closest of which was approximately 2.0km north-east. • A smaller AA battery was also located approximately 200m to the north of the site. • Had an exploded shell landed onto the soft ground on site, it is conceivable it could have remained undetected. Therefore, the study area is susceptible to contamination from anti-aircraft ordnance.
Overall Likelihood of Contamination	**High**

11.2 The Likelihood that Unexploded Ordnance Remains on Site

11.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

11.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	• November 1960 – An unidentified UXB was discovered on the sand of Pegwell Bay (precise location not known but potentially within the extension area).[15] • December 1960 – A 3-inch mortar was discovered in the mud at Pegwell Bay (precise location not known but potentially within the extension area).[16] • November 1962 – A mortar was dug up at Pegwell Bay. [17] • October 1965 – A smoke bomb was found on the beach at Pegwell Bay (precise location not known but potentially within the extension area). [18] • October 1968 – A bait digger unearthed a mortar on the sands of Pegwell Bay, next to the then construction site of the international hoverport. [19] The former hoverport site is located approximately 420m to the north-east of the site. It is likely the incident occurred on or in close proximity to the extension area. • April 1969 – A 4.5in shell was found in the mud on the Pegwell Bay hovercraft flight path. [20] • January 1970 – A mortar was found by bait diggers in the flight path of the international hoverport, Pegwell Bay. At the same time a bomb disposal team searched for a German 1,000lb bomb in the same area, however no evidence could be found. [21] • March 1970 – A 250lb RAF HE bomb was found on the mud flats of Pegwell Bay, approximately half a mile from the hovercraft flight path. It was believed that the bomb was jettisoned by an RAF plane after it got into difficulties. [22]

[15] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19601130/244/0015
[16] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19601223/054/0003
[17] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19621130/293/0008
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[21] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19700123/009/0001
[22] https://www.britishnewspaperarchive.co.uk/viewer/bl/0002513/19700317/014/0001

	• September 1970 – A 3-inch shell was found in the mud on the foreshore at Cliffsend (precise location not known but potentially within the extension area).[23] • September 1976 – A UXB, approximately 16in long, was found on the beach at Pegwell Bay, near the car park of Cliffsend Garage (approximately 1.1km north-east of the site). [24] • July 2017 - A UXB was found in Pegwell Bay Country Park. An Army disposal team carried out a controlled detonation.[25] Pegwell Bay County Park is located approximately 200m south of the site. • An unidentified UXB was discovered in the marshes near Brook Lane, approximately 900m to the west.
Local tasks undertaken by SafeLane Global	During intrusive works within Pegwell Bay (outside of the extension area), SafeLane Global discovered several mortars.

11.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✓
Further Details	• It appears that much of the site has remained largely undeveloped in the post-war period. However, the south of the site has seen landscaping works with the construction of Stonelees Golf Centre. • The area of the site still occupied by St Augustine's Golf Links is unlikely to have undergone any bulk excavations. • However, it is likely that the course will have been renovated throughout the years post war. • The extension area has not been subject to significant redevelopment works.

11.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	There is limited evidence that the site has been redeveloped, due to its current state it is likely that the site would have only been subject to shallow excavations.
Further comments	Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations/boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. As no known

[23] https://www.britishnewspaperarchive.co.uk/viewer/bl/0002513/19700902/263/0001
[24] https://www.britishnewspaperarchive.co.uk/viewer/bl/0002514/19760914/284/0028
[25] https://theisleofthanetnews.com/the-army-has-carried-out-another-controlled-explosion-of-war-time-bombs-at-cliffsend/

	bulk excavations have been carried out onsite, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth.

11.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works are expected to consist of intrusive works. Therefore, the risk of encountering UXO remains elevated.

11.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

11.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.

Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

11.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

11.5 The Consequences of Encountering or Initiating Ordnance

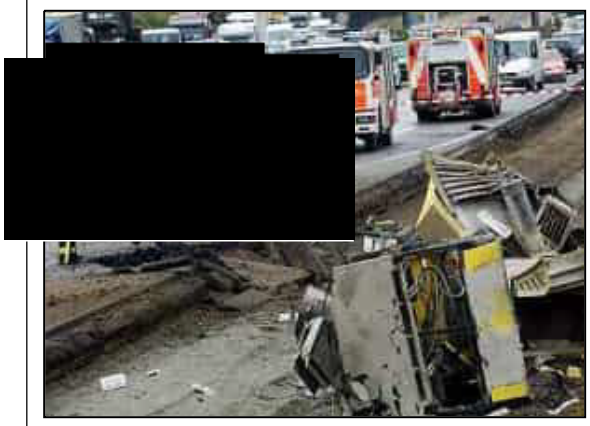
Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

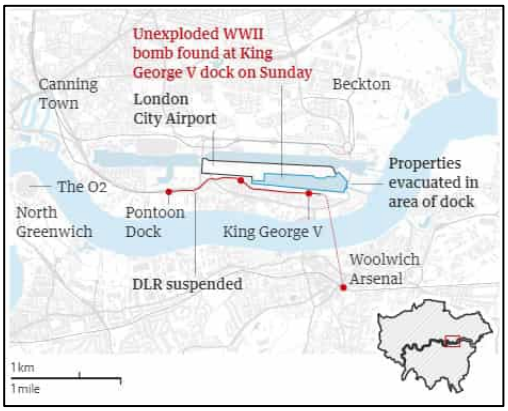
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

12 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

12.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be **High**.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	High	Medium	Medium	Severe	**High**
German 1kg Incendiary Bombs	Medium	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Medium	Medium	Medium	Not Significant	**Medium**
Land Service Ammunition	High	Medium	Medium	Moderate	**High**
Landmines	Medium	Medium	Medium	Severe	**Medium**

13 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

13.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
High	**Shallow Intrusive Works eg. excavations**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Explosive Ordnance Disposal (EOD) Engineer Watching Brief (for brownfield areas unsuitable for NI magnetometer survey) • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation (SI)
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions
	Offshore works	Appropriate risk mitigation measures can be provided for any works taking place in marine (coastal or offshore) parts of the project site if necessary. These can usually include the following: • UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Client threat briefing • Authorities' engagement where required • Non-Intrusive (NI) High-Resolution Marine Survey – Area specific to each project module • Assessment and production of a Master Target List • Target Investigation (Required as a follow-on from NI Marine Survey) • ROV/Diver Investigation / Survey • Disposal if requested

13.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of

	an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required.

	The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iii. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

iv. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

v. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

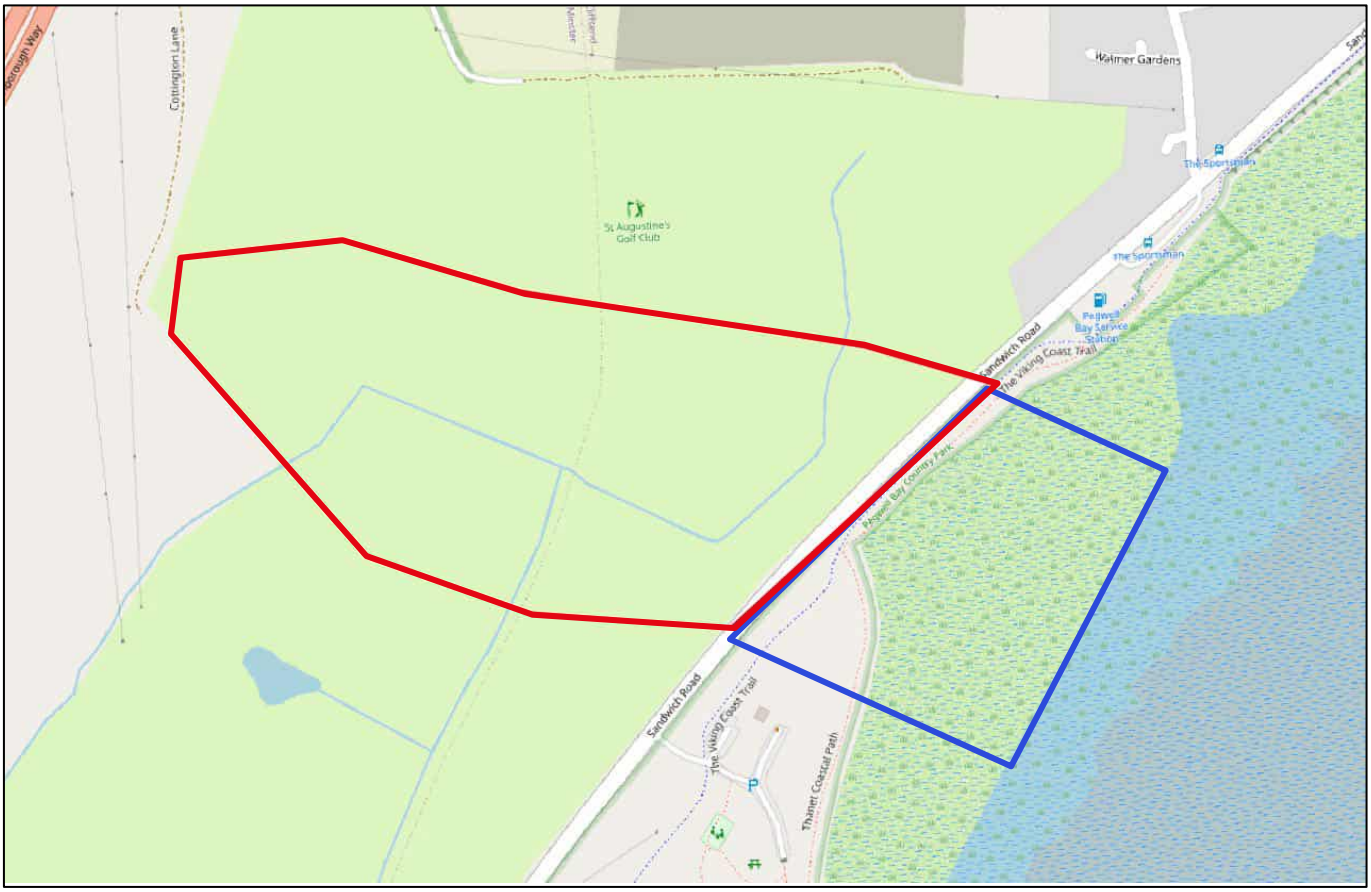
vi. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

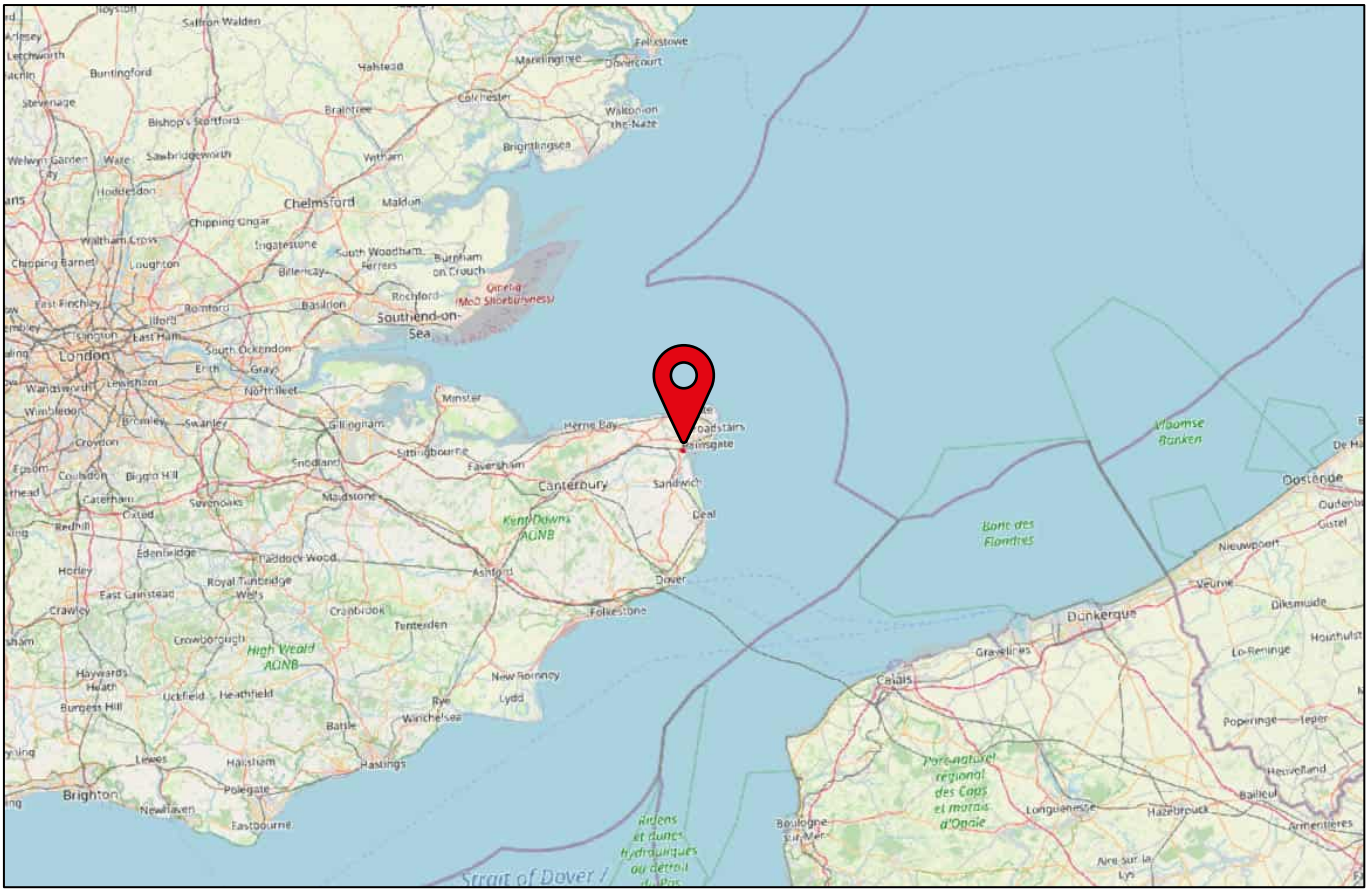
vii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

viii. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

ix. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

x. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).





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Recent Aerial Photograph

Annex B
9758-3 RA

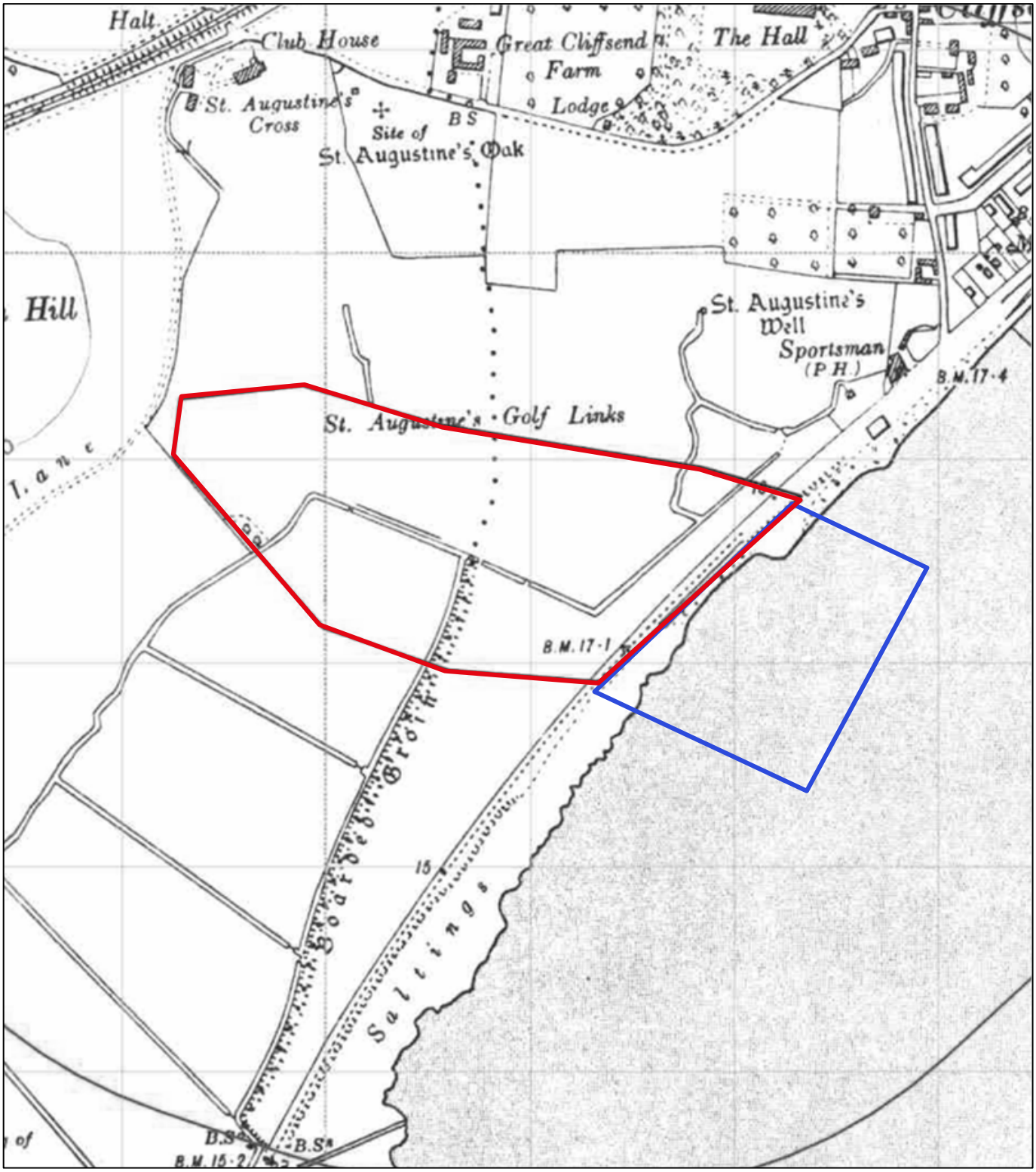
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Approximate site boundary Approximate extension area

Google Earth™ Mapping Services

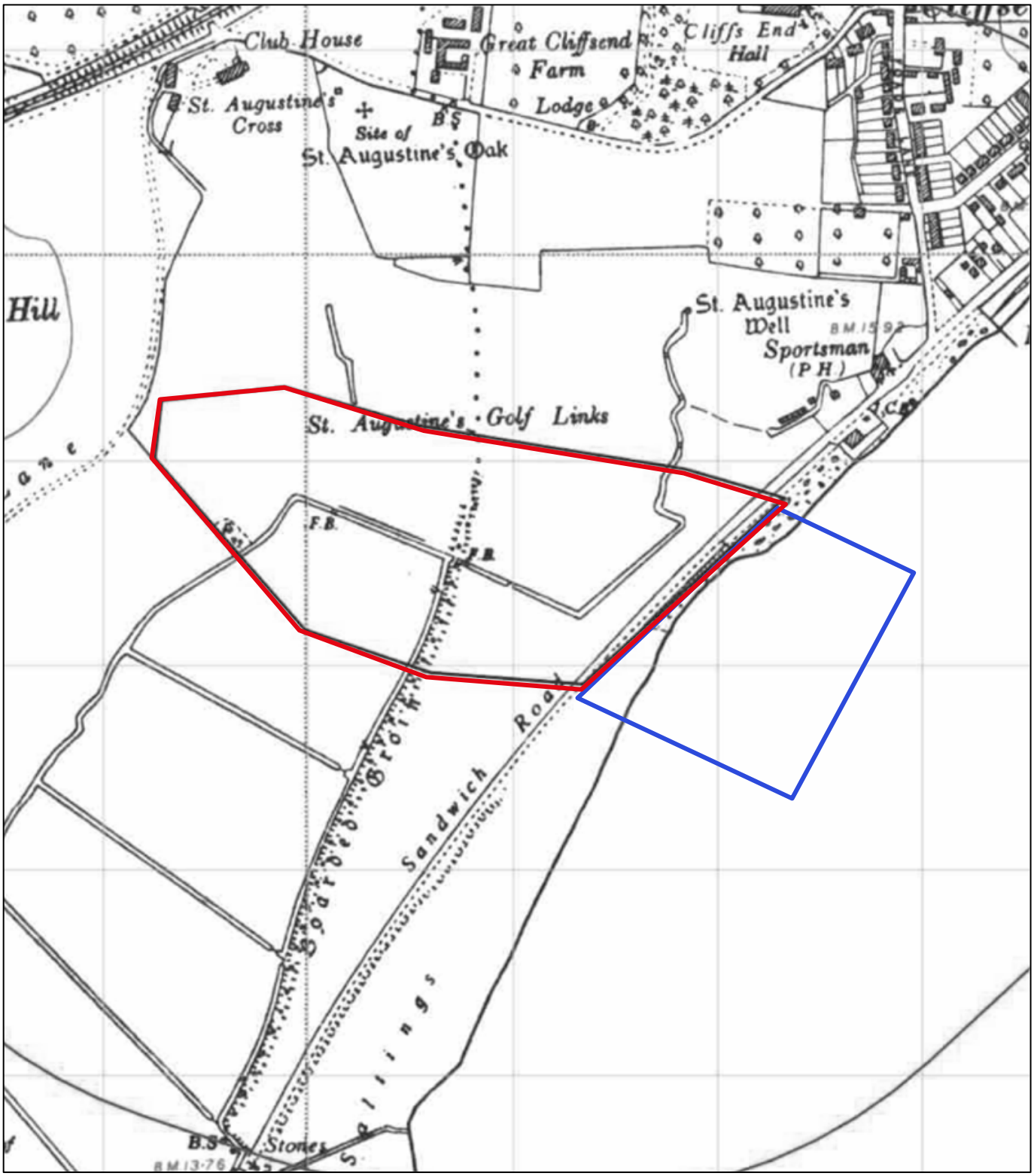
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Approximate site boundary

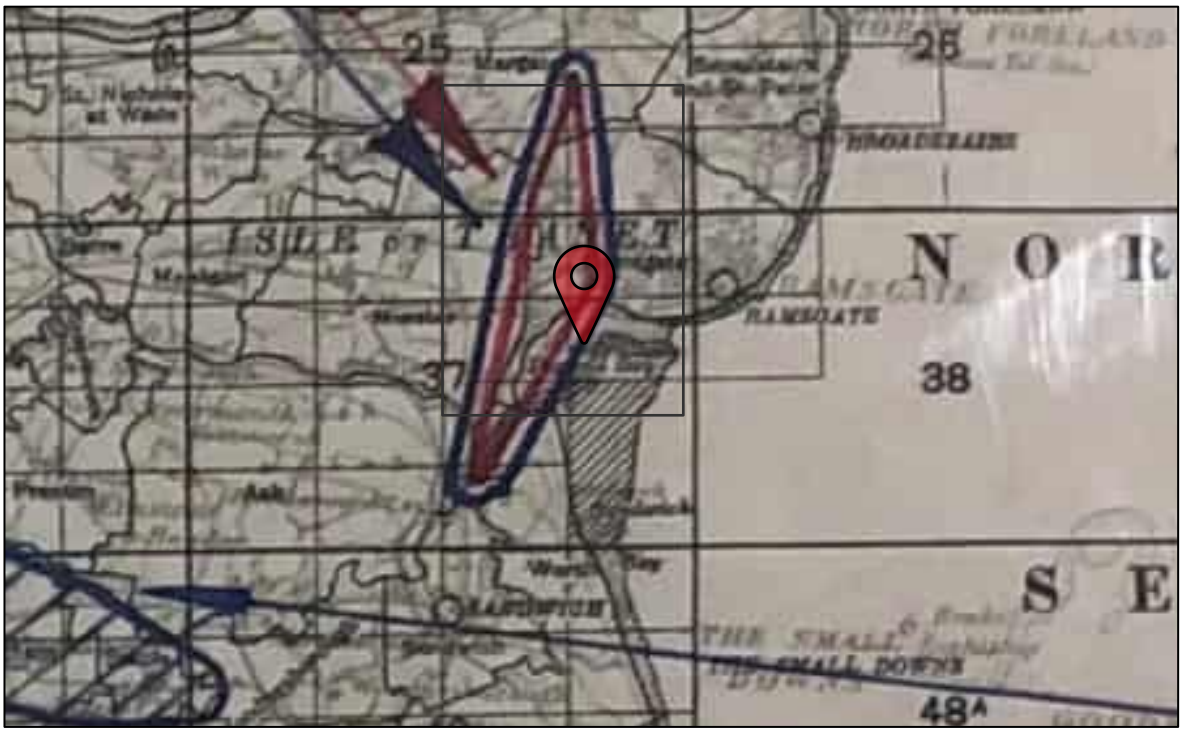
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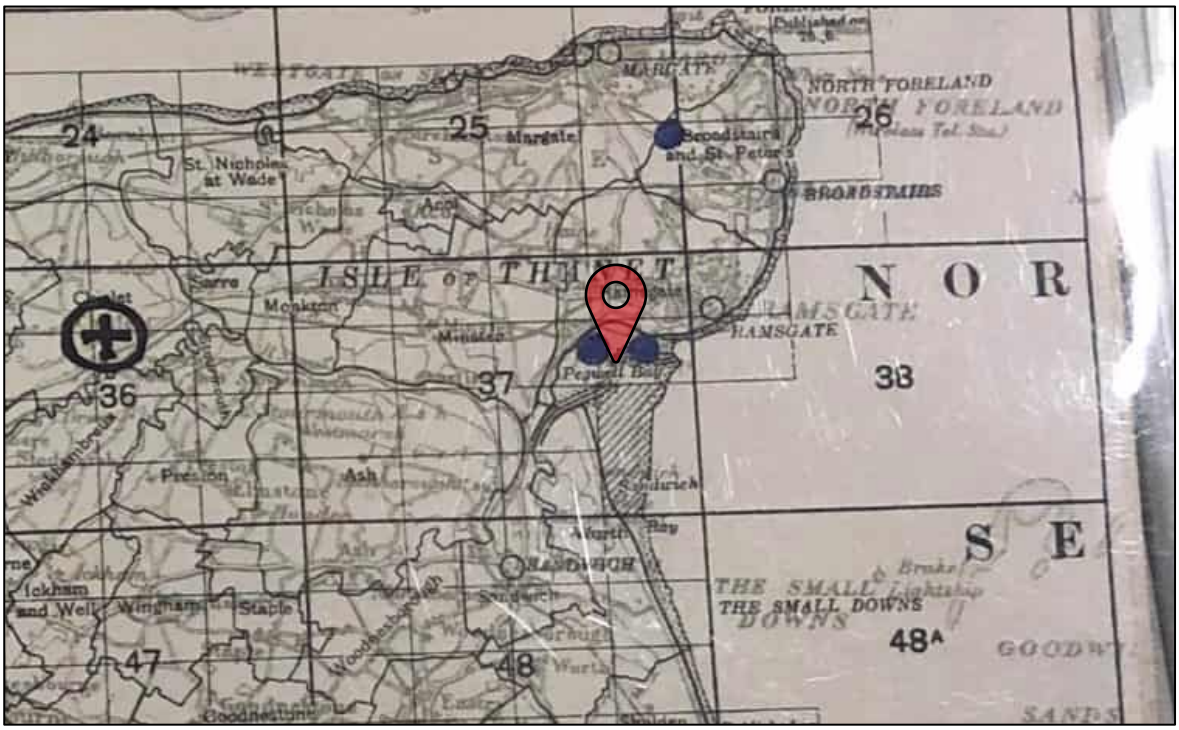


Approximate site boundary

Approximate extension area



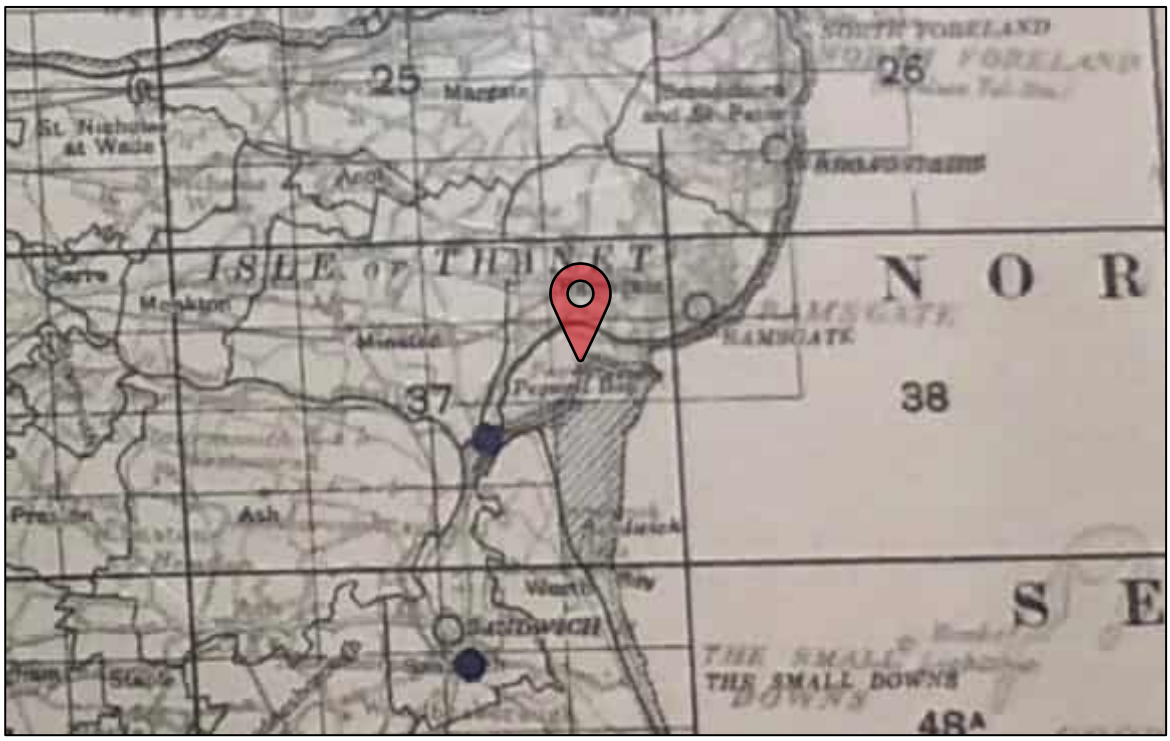
9th July 1940



27th October 1940

Approximate site location | HE bomb strike | Incendiary shower | HE bomb area

Kent History & Library Centre



29th October 1940



5th December 1940

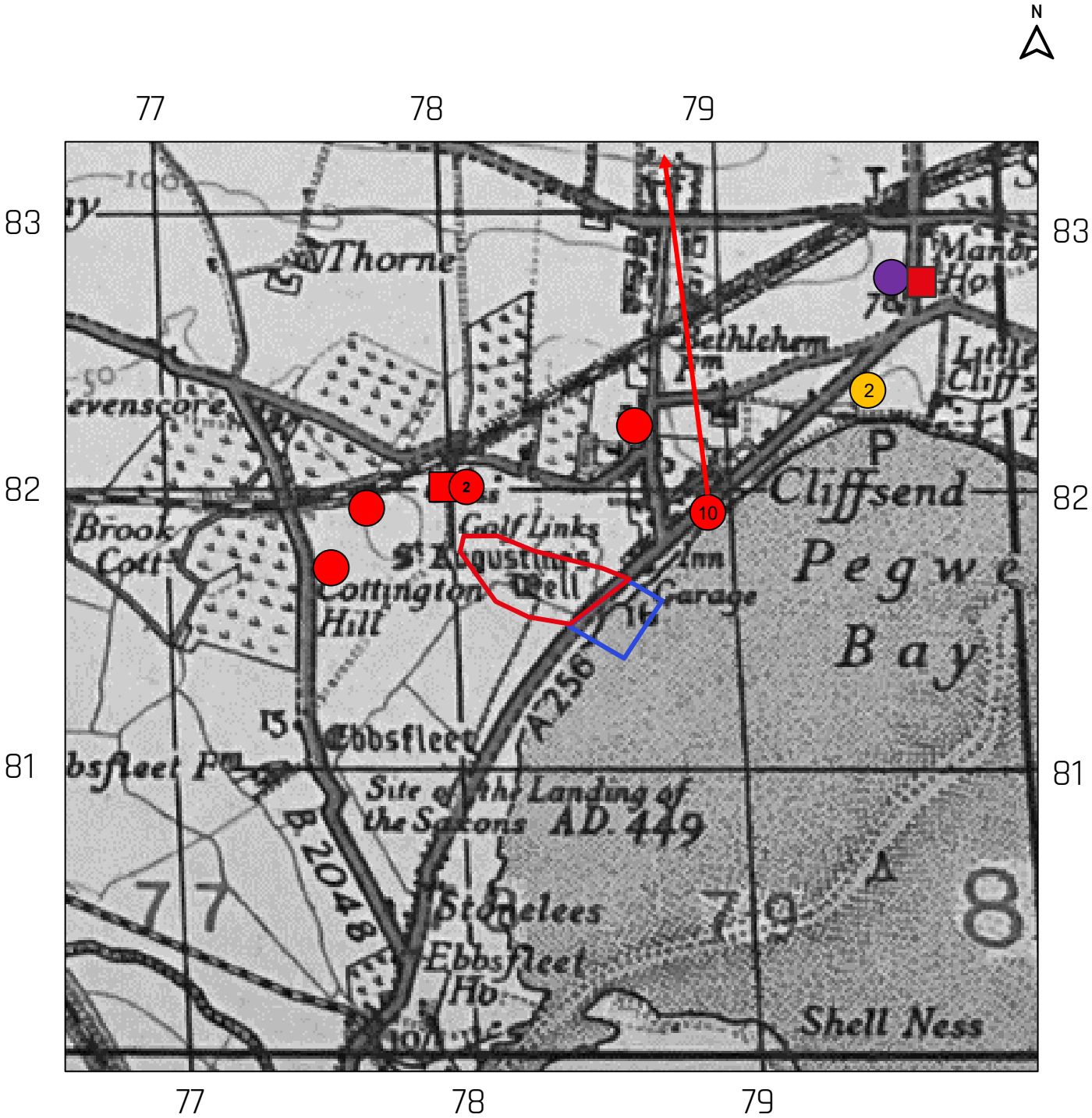
Approximate site location HE bomb strike Incendiary bomb

Kent History & Library Centre

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Kent ARP Records Bomb Census Map

Annex E
9758-3 RA



Approximate site boundary

HE bomb

Incendiary bomb

Unidentified weapon

Unexploded bomb

(Numbers in circles denote quantity of explosive ordnance recorded)

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WWII-era RAF Aerial Photography – 3rd March 1942

Annex F
9758-3 RA



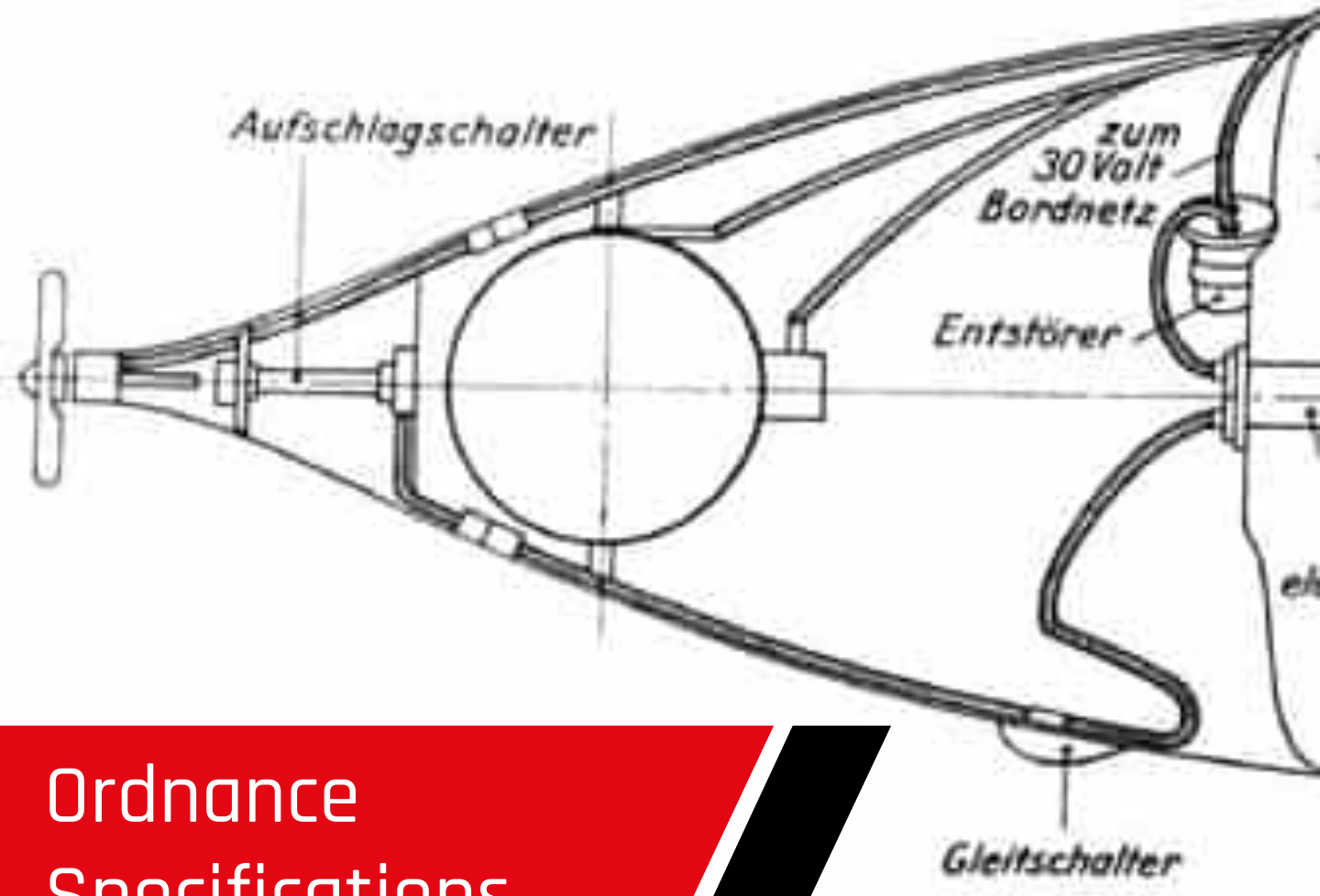
Approximate site boundary

Approximate extension area

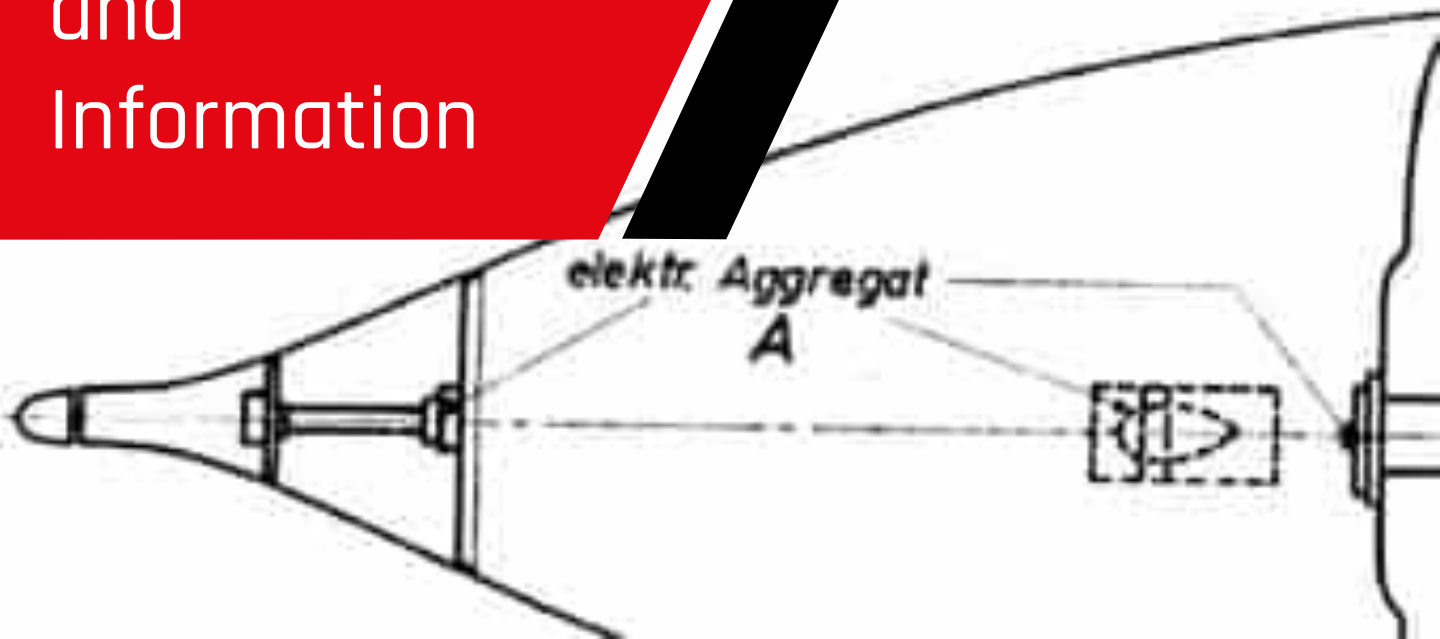
Possible ground disturbance

NCAP

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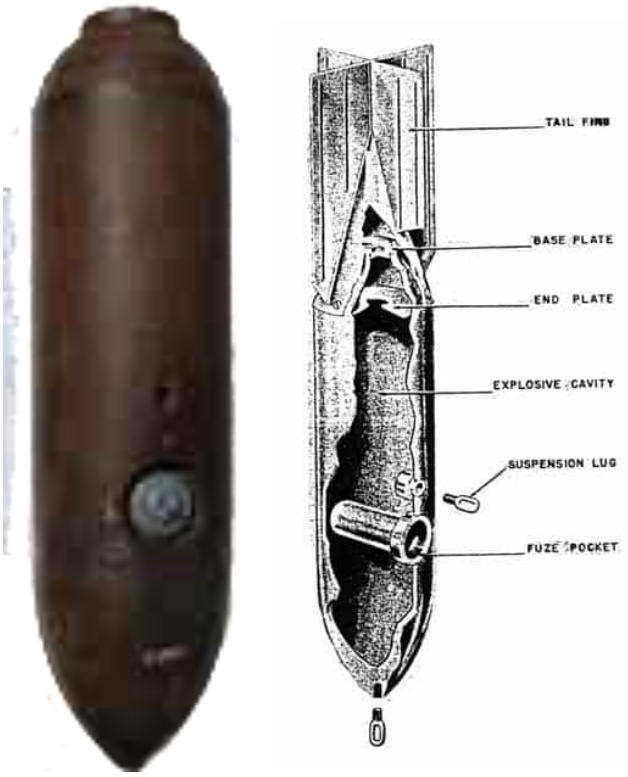


Ordnance Specifications and Information





German Ordnance





Sprengbombe Cylindrisch 50

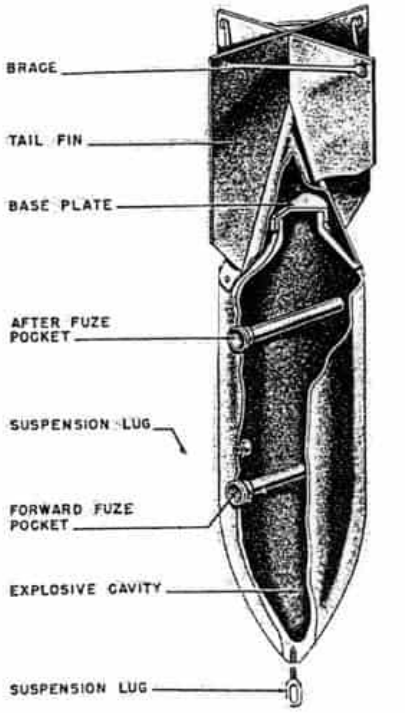
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

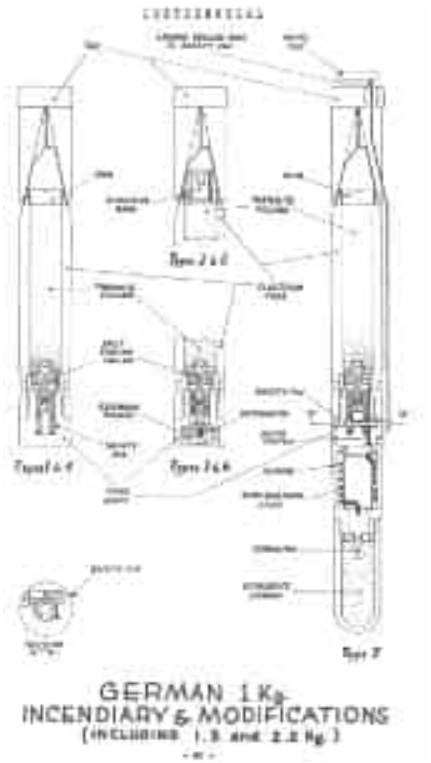
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









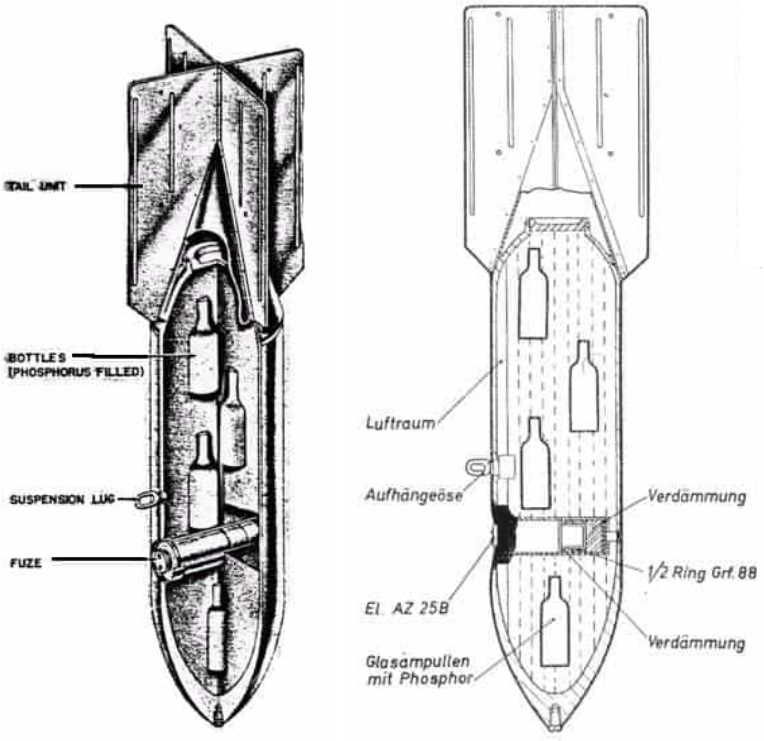
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

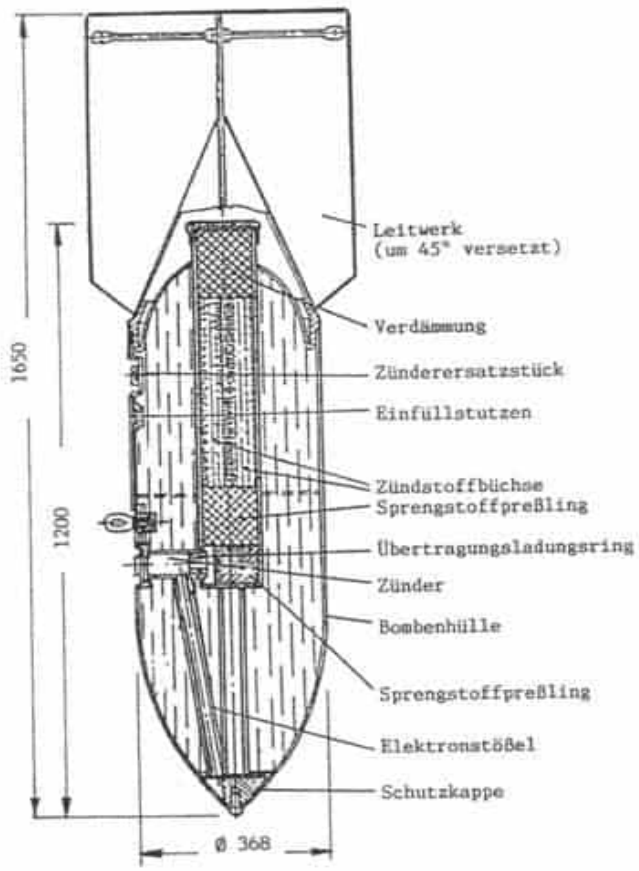






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

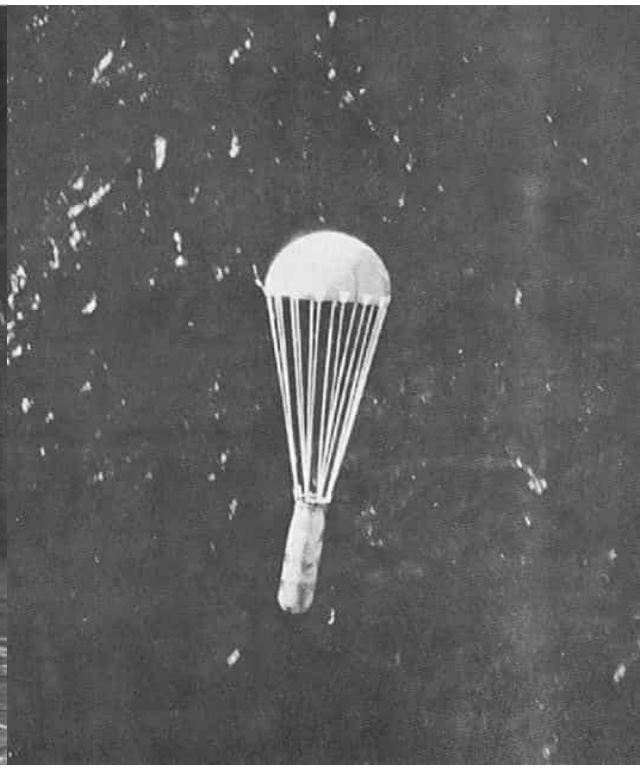




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration





Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg

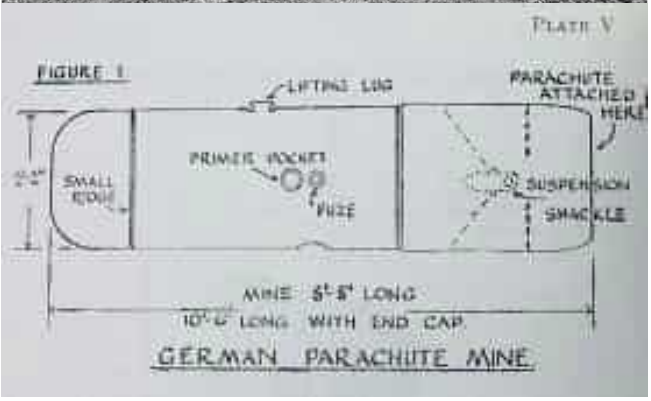
Fuze Type: Mechanical clockwork fuze

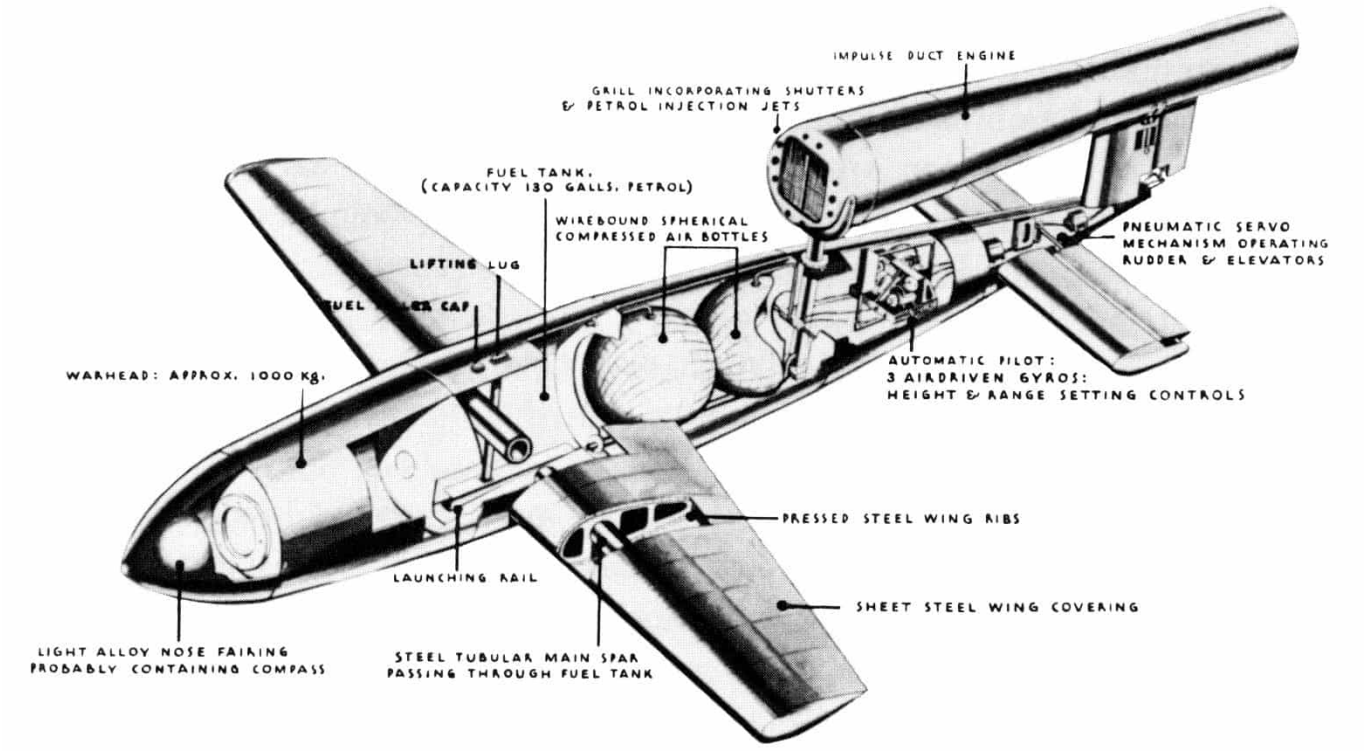
Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

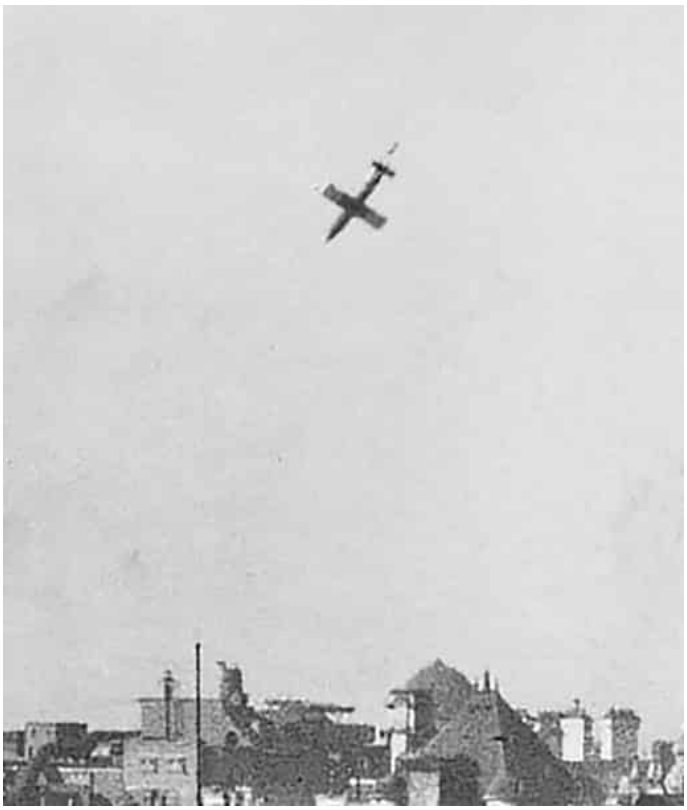




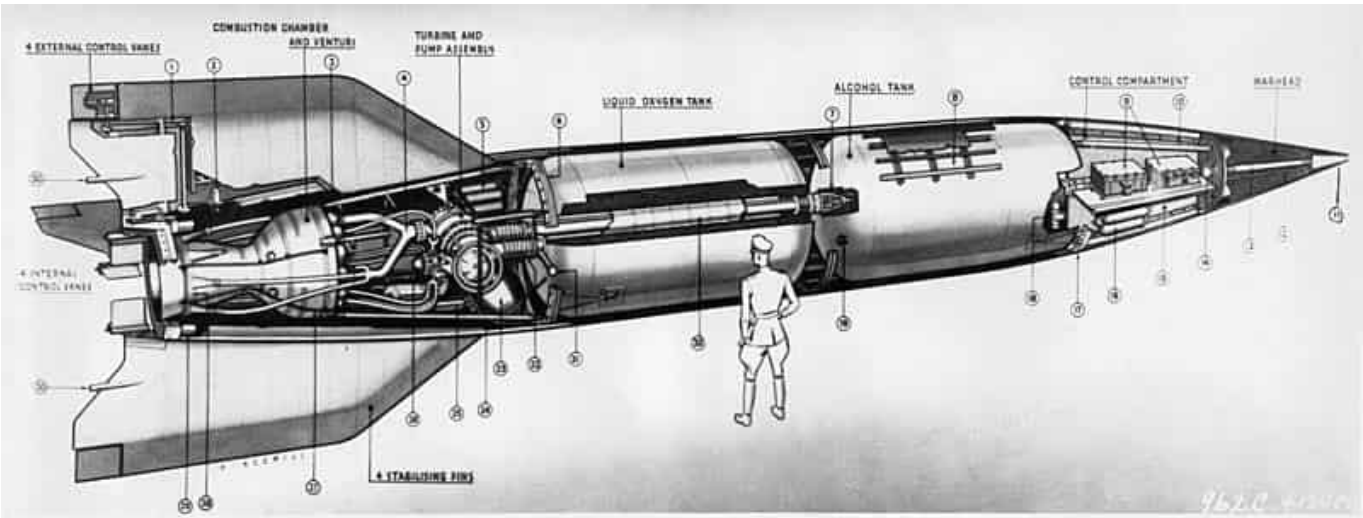


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

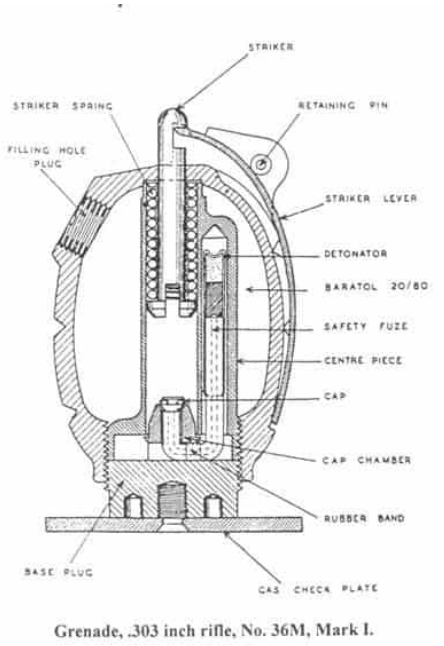
Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.





British & Allied Ordnance



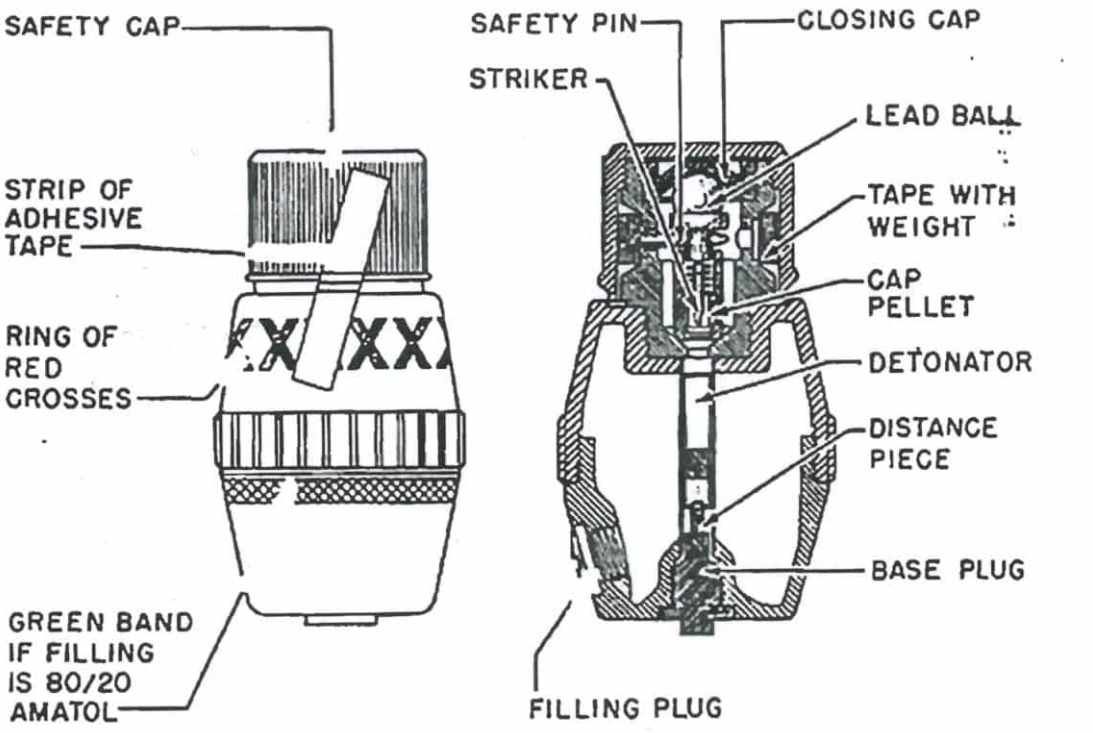


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



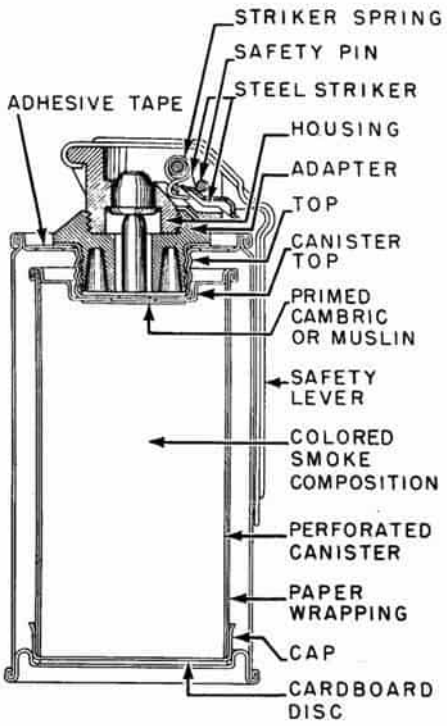


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





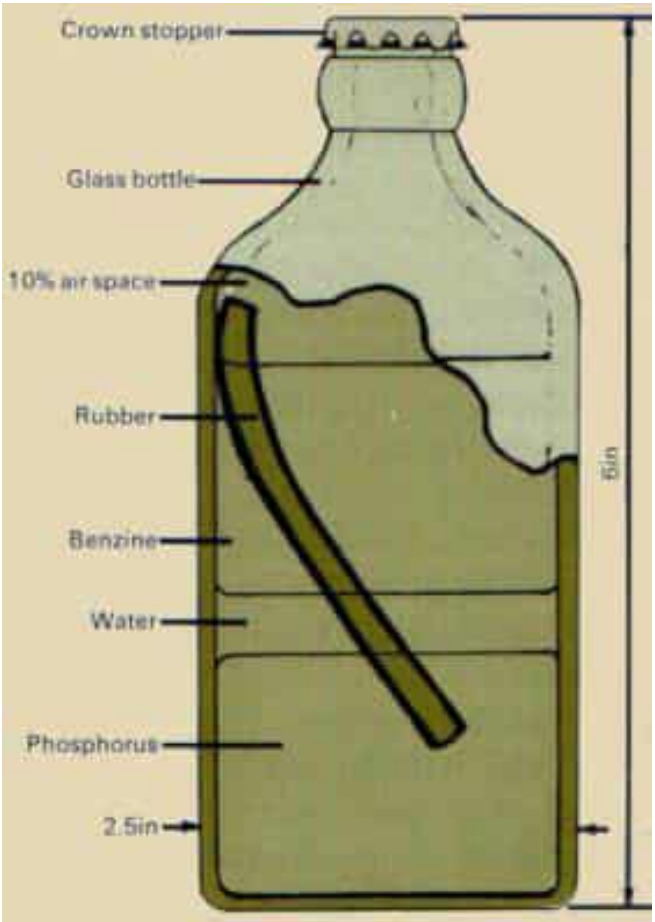


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

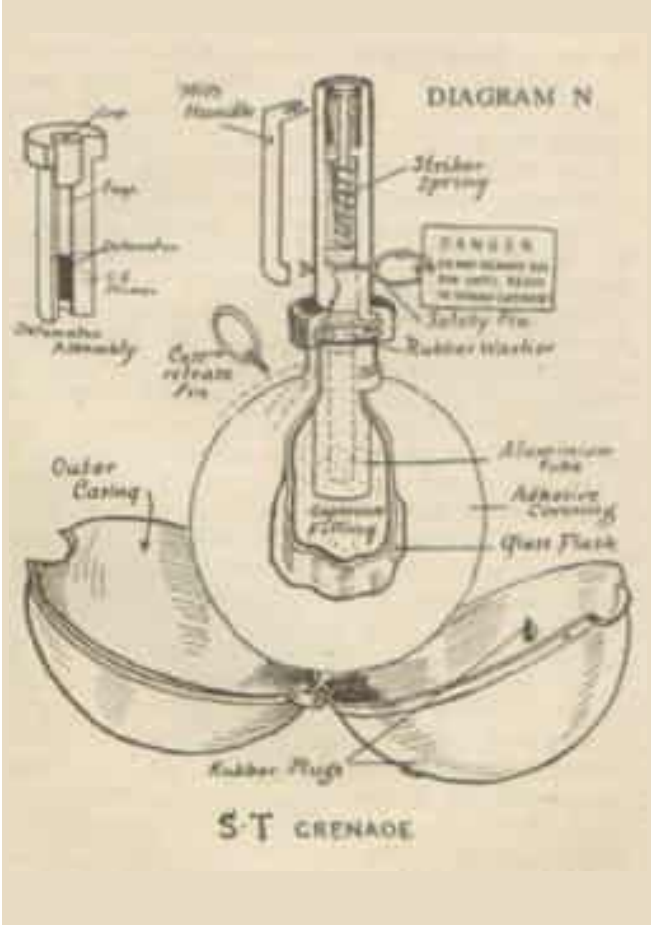






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

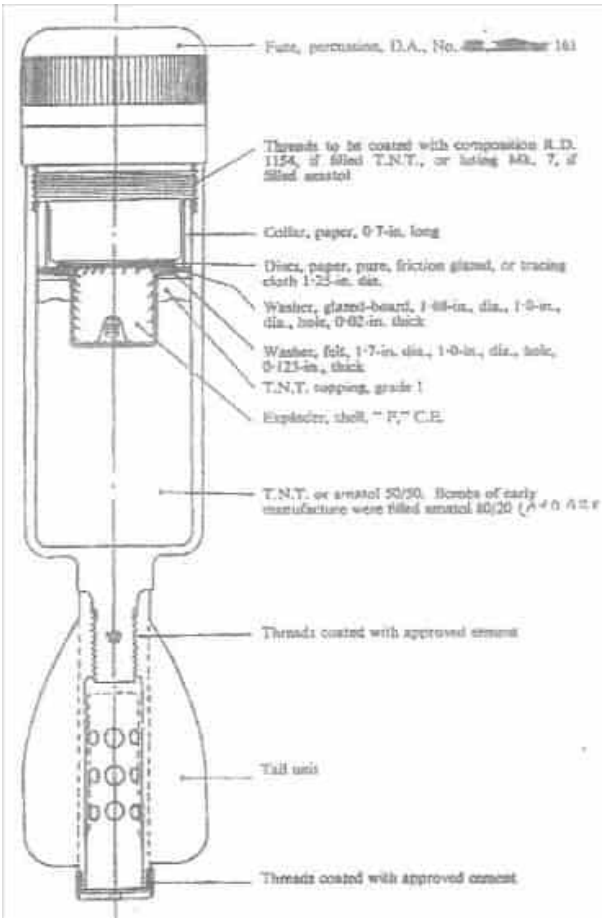






Typical 2" High Explosive Mortar

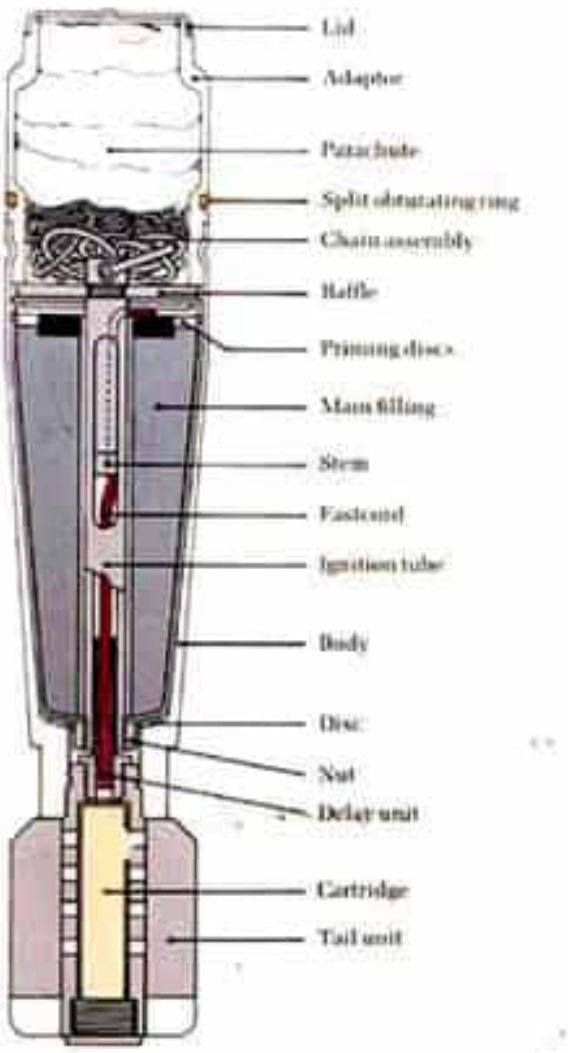
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







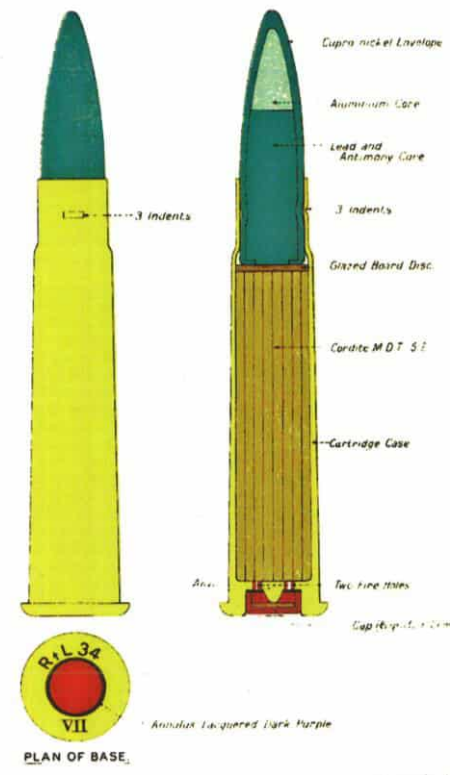


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



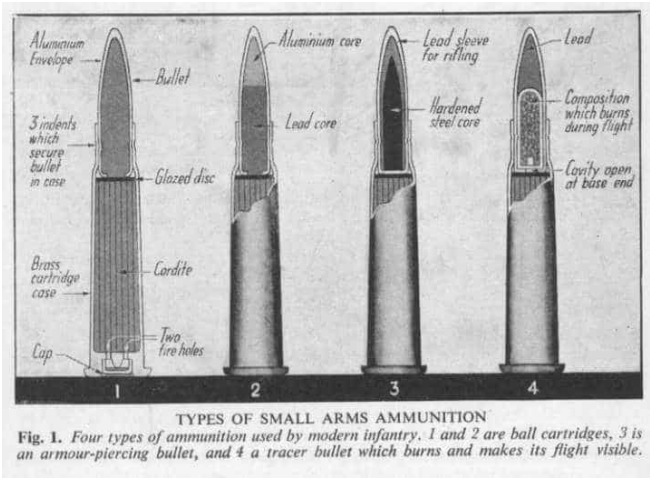




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



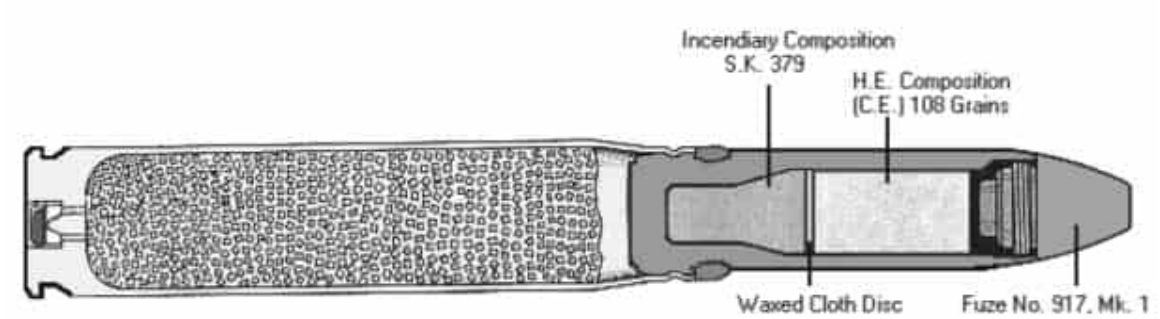


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

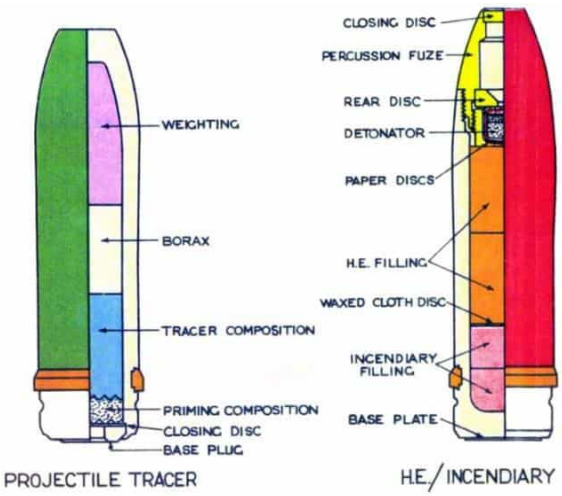






20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



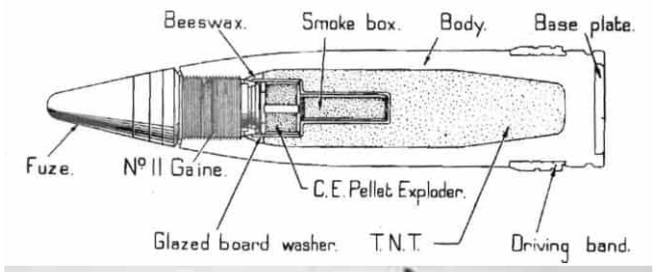
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	



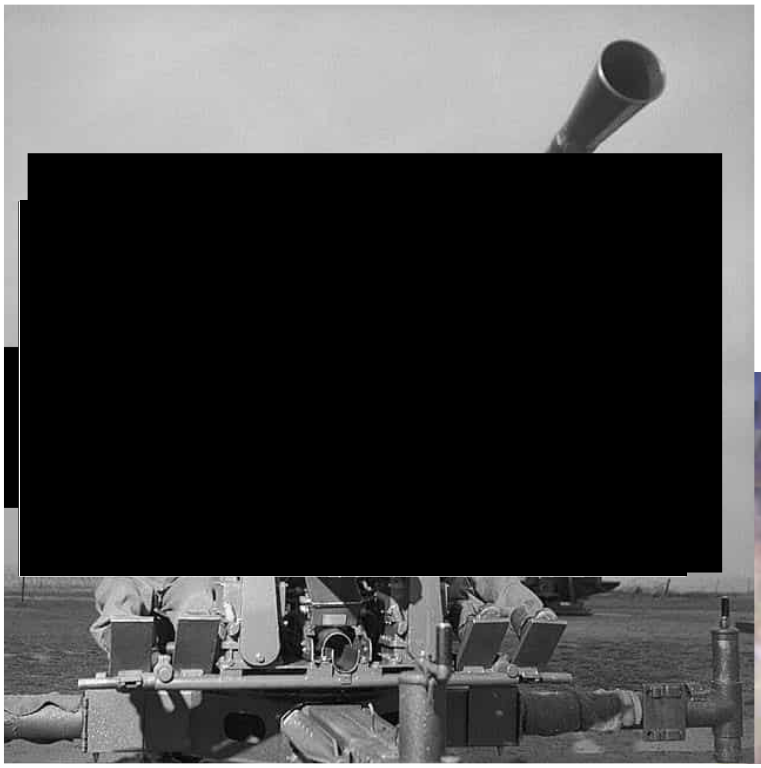
3.7" Anti-Aircraft Projectile

Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.







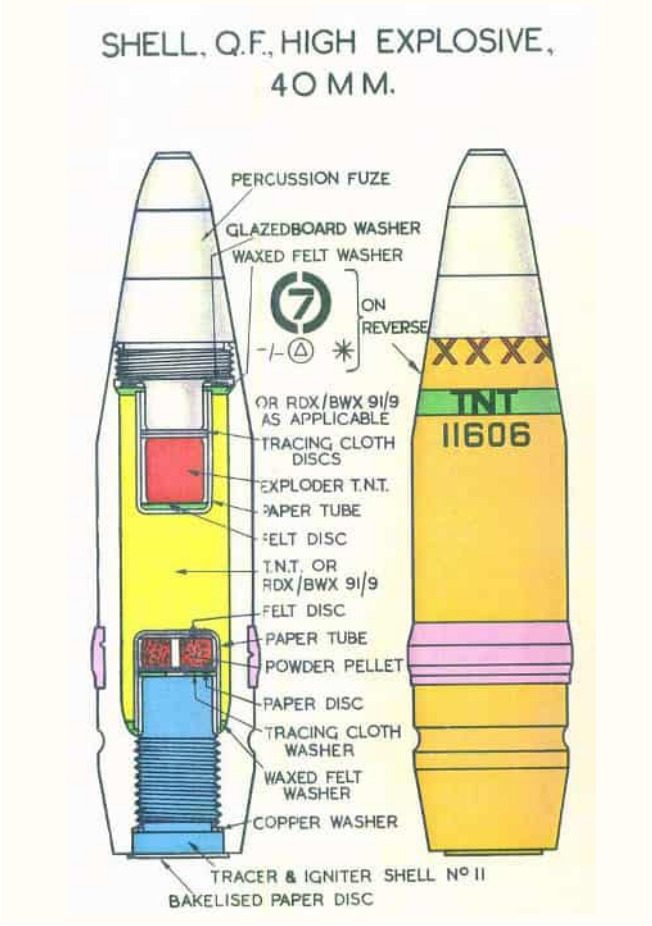




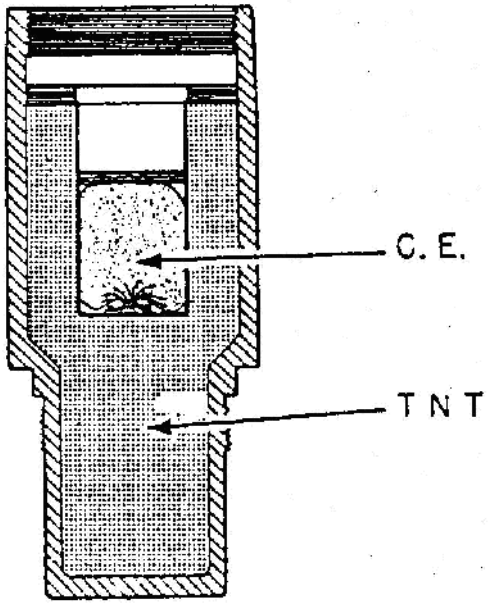


40mm Bofors Gun Projectile

Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

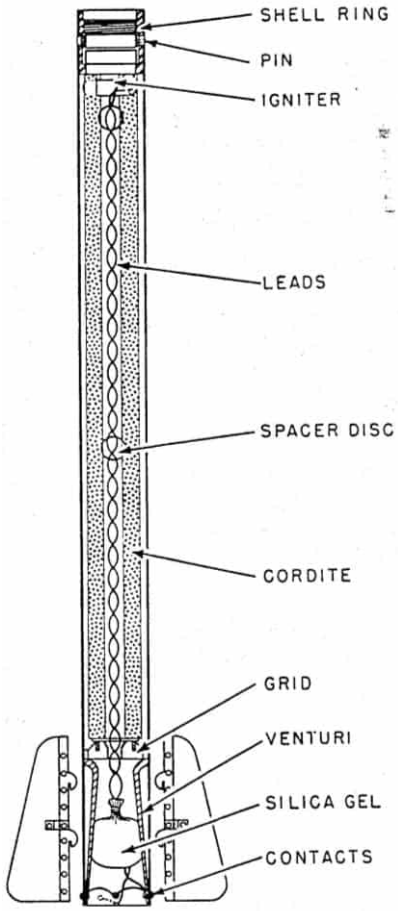






Rockets / Un-rotating Projectiles

Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery



SAFELANE
GLOBAL



Detailed Unexploded Ordnance
Risk Assessment

In Respect Of:
Richborough – Cable Route and Construction
Compounds Revision

For:
Mott MacDonald

Report Reference:
9758-4 RA



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1	PDF Copy	Mott MacDonald	KB	ED	NB	23/06/2023

This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry. This report has been compiled using all due diligence and expertise and having made all proper but reasonable enquiries within given time limitations. However, in accepting and implementing the recommendations contained in this report, the client does so strictly at his own risk.

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Registered in England No. 03431843.

VAT Registration No. GB 171 628 112

Executive Summary

The Site	
Address:	Cottington Lane, Cliffsend, Ramsgate, CT12 5JN
OS National Grid Reference:	TR 33680 63702
Site Description:	The majority of the site comprises open ground. The northern section of the site is occupied by the northern extent of St. Augustine's Golf Course and associated infrastructure. These facilities are served by Cottington Lane, which enters the site from the north. Richborough Way (A256) crosses the south-western extent, north to south. This area of the site is also occupied by a small wooded area and a warehouse. Extension area: The extension is immediately to the north-west of the main area. It comprises open, agricultural fields, mature hedgerows and a section of Richborough Way.
Proposed Works	
The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**MEDIUM from the following UXO types:** • German Air-Delivered HE bombs • Anti-Aircraft Projectiles • Land Service Ammunition • Small Arms Ammunition
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	

Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Recommended Risk Mitigation

Risk Level	Planned Site Activity	Recommendations
Medium	Shallow Intrusive Works eg excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.

Table of Contents

Distribution i
Executive Summary ii
Table of Contents iv
List of Annexes vi
Appendices vi
Glossary of Terms vii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations 4
4.5.2 Bombing Records 5
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Pre and Post-WWII OS Mapping 6
8 The Threat from Aerial Bombing 7
8.1 General Bombing History of Kent 7
8.1.1 First World War 7
8.1.2 Second World War 7
8.2 Generic Types of WWII German Air-delivered Ordnance 8
8.3 Second World War Bombing Statistics 9
8.4 Site Specific WWII Bombing Records 10
8.4.1 Kent Bomb Census Maps 10
8.4.2 Kent V1 Bomb Census Map 10
8.4.3 Original ARP Bombing Incident Records 10
8.4.4 Secondary Source / Anecdotal Evidence 13
8.4.5 WWII-era RAF Aerial Photography 13
8.4.6 Abandoned Bombs 14
8.5 UXB Ground Penetration 15
8.5.1 General Considerations 15
8.5.2 The "j" Curve Effect 15
8.5.3 Second World War Bomb Penetration Studies 16
8.5.4 CIRIA Bomb Penetration Depth Specifications 16
8.5.5 Site Specific Bomb Penetration Considerations 16

8.6 Likelihood of Post-raid UXO Detection 17
8.6.1 Density of Bombing *17*
8.6.2 Bomb Damage *17*
8.6.3 Frequency of Access *17*
8.6.4 Ground Cover *18*
8.6.5 German Air-Delivered Ordnance Failure Rate *18*
8.6.6 Site Specific Analysis *19*
9 The Threat from Allied Military Ordnance 22
9.1 Port Richborough 23
9.2 Home Guard Activity 23
9.3 Anti-Aircraft Gun Batteries 25
9.4 Site-Specific Threat from Allied Military Ordnance 25
9.5 Generic Types of WWII British / Allied Unexploded Ordnance 26
9.5.1 Land Service Ammunition (LSA) *26*
9.5.2 Small Arms Ammunition (SAA) *27*
9.5.3 Anti-Aircraft Shells *27*
10 The Overall Unexploded Ordnance Risk Assessment Methodology 29
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance 30
10.1.1 General *30*
10.1.2 Likelihood of Contamination from German UXO *31*
10.1.3 Likelihood of Contamination from British / Allied UXO *31*
10.2 The Likelihood that Unexploded Ordnance Remains on Site 32
10.2.1 General *32*
10.2.2 EOD Bomb Disposal and Clearance Tasks *32*
10.2.3 Post War Redevelopment *33*
10.2.4 Site-Specific Analysis *33*
10.3 The Likelihood that Ordnance may be Encountered during the Works 34
10.4 The Risk that Ordnance may be Initiated 34
10.4.1 Initiation of Unexploded Bombs *34*
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance *35*
10.5 The Consequences of Encountering or Initiating Ordnance 35
11 SafeLane Global's Risk Assessment 39
11.1 Conclusions 39
12 Proposed Risk Mitigation Strategy 40
12.1 Summary 40
12.2 Additional Notes 40
Bibliography **45**

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C Pre and Post-WWII OS Maps

Annex D Kent Bomb Census Maps – Night Raids

Annex E Kent ARP Records Bomb Census Map

Annex F WWII-era RAF Aerial Photography

Appendices

Ordnance Specifications and Information

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Richborough – Cable Route and Construction Compounds Revision

1 Introduction

Groundsure Limited, on behalf of Mott MacDonald, has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Richborough – Cable Route and Construction Compounds.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Kent Library and History Centre.
- National Collection of Aerial Photography (NCAP).
- Kent County Council.
- Kent Historic Environment Record.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed

level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Cottington Lane, Cliffsend, Ramsgate, CT12 5JN	
OS National Grid Reference	TR 33680 63702	
Site Description	The majority of the site comprises open ground. The northern section of the site is occupied by the northern extent of St. Augustine's Golf Course and associated infrastructure. These facilities are served by Cottington Lane, which enters the site from the north. Richborough Way (A256) crosses the south-western extent, north to south. This area of the site is also occupied by a small, wooded area and a warehouse. Extension area: The extension is immediately to the north-west of the main area. It comprises open, agricultural fields, mature hedgerows and a section of Richborough Way.	
Proposed Works	The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	Borehole Reference	TR36SW99
	Location	On site
	Date	Not known
	Recorded Shallow Geology	• 0.3m of Topsoil • 1.21 of Thanet Sand (sand and stone) • 3.04m of Thanet Sand (loamy sand and shells) • 3.96m of Thanet Sand (loamy sand) • 18.89m of Thanet Sand (sandy clay)
British Geological Survey Mapping	Superficial Deposits	None recorded
	Bedrock	Thanet Formation – Sand, Silt and Clay

7 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1933-38	• The majority of the site comprises open ground, forming part of *Cottington Hill*. • The northern section of the site is occupied by *St Augustine's Cross, Club House* with associated infrastructure. A railway embankment also encroaches into the northern extent. • Two roadways cross the site, including *Cottington Lane*. • Extension area: Comprises multiple fields and an orchard, an area of which is labelled *The Yellows*. • *Brook Lane* encroaches into the north-western extent while another road passes north to south through the eastern section.	Annex C-1	Groundsure Limited

Post-WWII	**1948-66**	• A small area of clearance is apparent in the northern section of the site, within the area of the *Club House*. • Typically, evidence of ruins, clearance and redevelopment is often indicative of bomb damage on early post-WWII OS mapping. • No further changes are noted on site or across the immediate surrounding area. Note, there is no coverage of the south-western section of the site. • Extension area: No significant changes are noted within the extension area.	**Annex C-2**	**Groundsure Limited**

8 The Threat from Aerial Bombing

8.1 General Bombing History of Kent

8.1.1 First World War

During WWI, Kent suffered extensive aerial bombardment from Zeppelin airships and fixed-wing aircraft. The first attack by the German Air Force was launched against Dover on the 21st December 1914 using naval seaplanes.

Bombing continued in Kent throughout the war; areas such as Ashford, Canterbury, Dover, Folkestone, Gravesend, Margate, Maidstone and Sheerness suffered particularly severe raids. The last raid on the county was on the night of the 19th May 1918 when a total of 14.55 tonnes of bombs were dropped on London, Faversham and Dover. Ramsgate, situated approximately 3km north-east of the site, gained the reputation as the most bombed seaside town in WWI. The town suffered from both aerial bombing and naval bombardment during WWI, with Zeppelin's scattering a number of bombs in all districts in the area.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Kent played a key role in the defence of Britain in WWII. It was at the frontline during the Battle of Britain during which the Luftwaffe attempted to destroy the RAF and its airfields in order to gain air superiority over the south-east of England ahead of the planned German invasion. Bombing raids began in July 1940 from German-occupied France and in the following months many of the towns and cities in Kent were subjected to bombing attacks.

Within Kent, Manston Airfield, located 1km north of the site, was a key target for the Luftwaffe especially during the Battle of Britain, where RAF Manston sustained serious bomb damage. Most of the staff dispersed into the surrounding houses due to the destruction.

By May 1941, concentrated attacks were reduced as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa', the invasion of Russia. Note however, that Canterbury, 14.5km south-west, was heavily bombed in mid-1942 as part of the Baedeker Blitz.

During 1942 and 1943, there were a number of minor raids carried out by small formations of fighter bombers and then between January and May 1944 the Luftwaffe returned to London en masse, for Operation Steinbock. These raids were executed by inexperienced Luftwaffe crews and were less frequent when compared to the original Blitz of 1940/41. Poor navigation and improved defences resulted in unsustainable Luftwaffe losses and many raids were unsuccessful.

Minster was situated within 'Hellfire Corner'; an area of Kent where aerial 'dog fights' and 'tip and run' bombing incidents were frequent during the Battle of Britain. The region was also under artillery bombardment from the coastal batteries located at Calais and Cap-Gris-Nez in occupied France. These batteries, including the *Lindemann* and *Todt Batteries*, bombarded the south coast until they were captured after the Allied D-Day Landings in 1944. The batteries covered an arc stretching from Ramsgate to Hythe and fired shells weighing approximately 1 ton each.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive

charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.

- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Rural District of Eastry and Municipal Borough of Ramsgate between 1940 and 1945. While the majority of the site was located in the Rural District of Eastry, the north-eastern extent fell within the Municipal Borough of Ramsgate.

Record of German Ordnance Dropped		
Area	RD of Eastry	MB of Ramsgate
Area Acreage	54,276	3,624
High Explosive Bombs (all types)	646	771
Parachute Mines	14	5
Oil Bombs	11	3
Phosphorus Bombs	8	-
Fire Pots	38	-
Pilotless Missile (V1)	8	-
Long Range Rocket (V2)	1	-
Total	726	774
Items Per 1,000 Acres	**13.4**	**213.6**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Kent Bomb Census Maps

A review was conducted of the Kent Bomb Census Maps. Those showing incidents on or close to the site are listed below. Note, the maps are small in scale and lack any clear geographical indicators, therefore the site and distance(s) listed below can be considered an approximate.

Date	Weapon	Details
09/07/1940	HE bombs Incendiary bombs	Over the site
06/11/1940	2 x HE bombs	Immediately to the west of the extension area
Reference		**Annex D**

8.4.2 Kent V1 Bomb Census Map

Following the beginning of the V1 campaign in mid-1944, a series of maps showing where these weapons fell was produced for the London Civil Defence region and these were updated as the war progressed.

V1 Strike Recorded on Site (or in Vicinity)	✘
Distance from Site	None recorded in Minster Parish
Reference	**Not annexed**

8.4.3 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

Records which include Map References have been plotted onto a map presented in **Annex E**.

Written ARP records were reviewed for	Ramsgate, Sandwich and Rural District of Eastry		
Source	Kent History & Library Centre		
Records of bombing on / near the site were found			✓
Date	**Weapon**	**Map Reference**	**Details**
08-09/04/1940	4 x HEs	n/a	Minster.
19-20/07/1940	13 x HEs 1 x UX HE	n/a	Minster.
14/08/1940	5 x HEs	n/a	Minster.
22/08/1940	1 x HE	n/a	Minster.
22-23/08/1940	10 x HEs 2 x UX HEs	n/a	Minster and Ash.
13/09/1940	2 x HEs	n/a	Foads Hill, Cliffsend. Foads Hill is located approximately 770m north-east.
16-17/09/1940	1 x HE	n/a	Minster.
17/09/1940	1 x UX HE	776830	North of Thorne. 1km north-west.
18/09/1940	1 x UXB	n/a	St Augustine's Golf Links about 30 yards from Ramsgate-Sandwich Road. Bomb believed to have resulted from enemy action on 17/09/1940. On or in close proximity to the site.
	1 x UX HE 2 x HEs	780820	St Augustine's Golf Course. On site.
18-19/09/1940	2 x HEs 1 x UX HE	n/a	Minster.
26/09/1940	1 x UX HE	767819	Minster – 500yrds south of Brook Cottages. 460m north-west.

27/10/1940	2 X HEs	n/a	Cliffsend.
30/10/1940	1 x UX HE	771815	Near Brook Cottage. On site (extension area).
	1 x HE	n/a	Near Ramsgate, Sandwich Road. Two and a half miles north-east of Sandwich.
06/11/1940	1 x UX HE	770824	North-west of Sevenscore Railway Crossing. 8400m north.
	1 x UX HE	770810	West of Ebbsfleet Farm House. 200m south-west.
08/12/1940	2 x IBs	795821	In open field at Cliffsend. 930m north-east.
	1 x HE	774823	Sevenscore Farm. 570m north-west.
	2 x IBs	768826	Sandwich Road. 1.2km north-west.
05/02/1941	4 x HEs	n/a	Cliffsend, Ramsgate. Eight bungalows slightly damaged.
21/03/1941	1 x UX HE	n/a	Minster.
04/05/1941	1 x HE	773821	North-west of Sevenscore Railway Crossing. 600m west.
	1 x HE	776819	Cottington Hill. 190m west.
	1 x HE	775817	Cottington Hill. On/immediately adjacent with site boundary.
05/05/1941	3 x HEs	n/a	Minster.
19/03/1942	1 x UXB	775828	Thorne Farm. 820m north.

8.4.4 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. The following references to incidents on site or in the surrounding area were found.

Date	Weapon	Details
13th September 1940	2 x HEs 2 x IBs	*"Two high explosive bombs and two incendiary bombs at Foadshill, Cliffs End."* Foads Hill is located approximately 770m north-east.
17th September 1940	UXB	*"One unexploded bomb at St Augustine's golf course."* Possibly on or adjacent to the site.
1940-1945	HE Bombs	A news article dating from 18th December 1945[1] details how farmland in the surrounding area of Cliffsend, particularly Bethlehem Farm (~ 600m north-east of the site) sustained bombing in WWII. At least 22 bombs fell in fields and nine RAF planes either crashed or made forced landings.

8.4.5 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	3rd March 1942
Source	National Collection of Aerial Photography (NCAP)
Image Type	Aerial
Image quality	High resolution and small scale, partial coverage
Observations	• The aerial image confirms the site predominantly comprised open ground, agricultural ground and a golf course. • Within the north-eastern section of the site a small AA gun site is apparent, including a Nissen hut. • A crater-like feature, consistent with a HE bomb strike, has been highlighted approximately 180m south of the site. • The structures on site appear to have survived WWII largely intact. However, due to the small scale of the image an accurate assessment for any structural damage is not possible.
Reference	**Annex F-1**

[1] Thanet Advisor and Echo – 18th December 1945.

Date	Circa 1946
Source	Kent County Council
Image Type	Aerial
Image quality	Moderate resolution and small scale
Observations	• The aerial image shows the entirety of the site. The south-western extent is a mixture of agricultural land, orchards and marshland. • Another crater-like feature has been highlighted approximately 230m south-west of the southern extent of the site. • It appears that the structures occupying the site have survived WWII largely intact. However, like the previous image, an accurate assessment for any structural damage is not possible. • The AA battery in the northern section of the site has been cleared. • Extension area: This area largely comprised open ground, including a large orchard and smaller wooded area in the northern half. Several small drainage ditches are apparent in the south-western corner. No evidence of significant bomb damage is apparent within its boundary.
Reference	**Annex F-2**

8.4.6 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✓
Additional Comments	• 1 x 50kg HE bomb – St Augustine's Golf Course (approximately 220m south of the north-eastern extent of the site). • 1 x unknown UXB – In marshes near Brook Lane, Minster (approximately 90m north of the extension area). • 2 x unknown UXBs – south of Brook Lane, Minster (approximately 270m west of the extension area).

8.5 UXB Ground Penetration

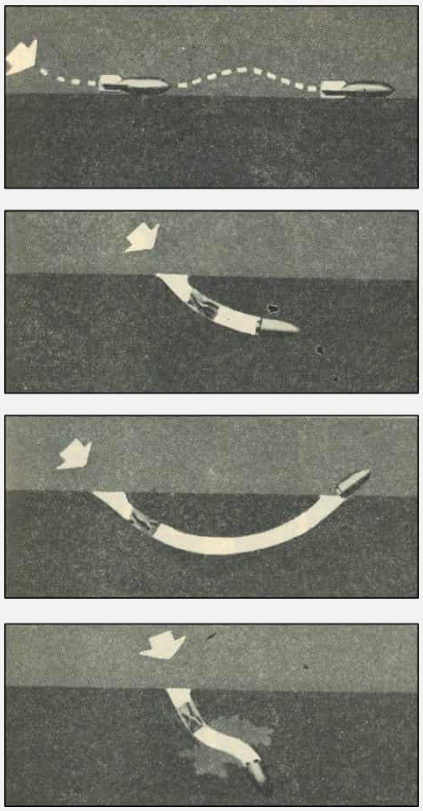
8.5.1 General Considerations

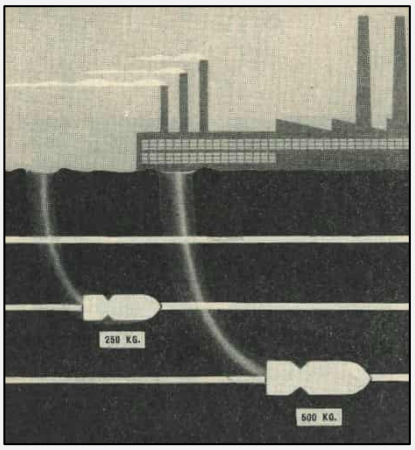
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

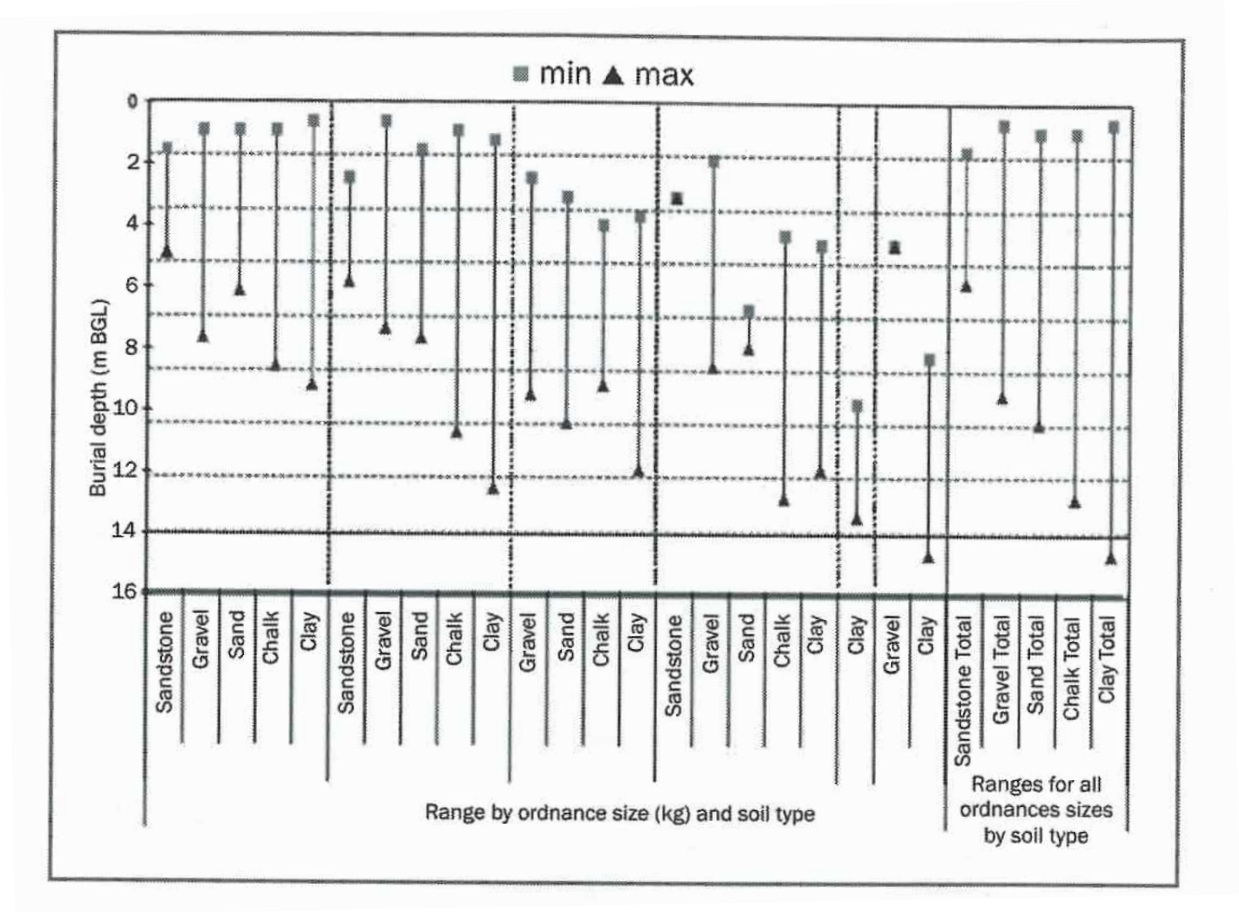
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 0.3m of Topsoil and > 27.1m of Thanet Sand (sand, silt and clay)

- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.

- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.6.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Moderate	While the overall bombing density of the Rural District of Eastry was low, the Parish of Minster sustained a comparatively higher density of bombing due to the presence of RAF Manston.
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✓	The following were recorded on site: 2 x HE bombs and 2 x UXBs. The following were recorded on site/immediately adjacent with its boundary: 1 x HE bomb.
	What is the distance between the site boundary and the closest recorded large bomb strike?	On site	
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	5	
	Were any nearby sticks of large bombs recorded in line with the site?	✓	

	Were any 1kg incendiary bomb showers recorded over the site?	✗	
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✓	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✗	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✗	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✗	
	The site was exclusively or partially developed during WWII.	✓	A number of farm and Golf Club buildings were present on site.
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗	
	The site was occupied by a school during WWII.	✗	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✓	It is possible the AA battery on site was subjected to post-raid searches for UXO.
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✓	

	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✓	
	The site was occupied by a graveyard which would have experienced limited access.	✗	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✗	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✓	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✗	
	The site was occupied by dense, inaccessible vegetation during WWII.	Possibly	
	The site may have been susceptible to waterlogged conditions during WWII.	✓	
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓	
	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✓	
	The site was occupied by stockpiled material during WWII.	✗	

	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✗	
	The site was occupied by well-maintained, manicured lawn during WWII.	✓	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	
Bomb Failure Rate	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✓
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✓
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 Port Richborough

Port Richborough, nicknamed port "Q", was established in 1914 on the banks of the River Stour, was kept a secret and served as a significant military outpost. Throughout WWI, the port was used for manning and arming barges being sent to Dover and subsequently France.[2] The port became militarised during WWI, multiple stores for equipment used for supplying the barges were erected in and around the banks. Moreover, defensive positions were established around the Port especially on the flats towards the mouth of the River Stour.

During WWII the port served as a military outpost for the Royal Marines in 1942, named H.M.S Robertson. The Port was considered "a hive of industry" in preparation for D-Day, with many troops were stationed in the nearby Richborough Camp and factory workers working throughout the blackout in the port factory.[3] The port was located approximately 900m south of the site.

9.2 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[4]

[2] *https://blog.railwaymuseum.org.uk/port-of-richborough-and-the-birth-of-the-cross-channel-train-ferry/*

[3] *http://www.open-sandwich.co.uk/town_history/richborough_port.htm*

[4] Various News Sources

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.3 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.4 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Nearest Home Guard Battalion to the site	6th Kent (Thanet) Home Guard Battalion
Home Guard Activity on site	• The Thanet Battalion primarily operated out of Margate, approximately 7km north-east from the site. However, the exact locations of their HQ or training areas were not found. • A number of defensive positions were located on and in close proximity to the site (see below). These points would have been manned by HG / military personnel armed with LSA / SAA. • Typically, HG soldiers would take part in training exercises in areas occupied by open countryside. Furthermore, HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. • Marshy land between Minster and Pegwell Bay was used as a mortar training range during WWII, however no details regarding the full extent of the training area could be located. Therefore the possibility of such training taking place on site cannot be discounted. • Given the strong military / HG presence in the area and the site comprising undeveloped ground, the possibility the site was used for training purposes cannot be discounted.

Defensive features within the vicinity	• St Augustine's Golf Course was covered in anti-invasion defences including barbed wire, trenches and gun pits[5]. • A newspaper article reported that mines were laid across farmland at Cliffsend when enemy invasion appeared to be imminent. This included Bethlehem Farm 550m north-east of the site[6]. The full extent of these minefields is unknown. • 4 x Pillboxes were located within 460m of the site, the closest of which was approximately 100m east. • A WWII road block was established across Ebsfleet Lane, approximately 130m east[7].
Number of HAA batteries within 5km of the site	6
Threat to the site from unexploded AA shells	• The nearest HAA battery was approximately 1.9km north-east from the site, situated close to RAF Manston. • Furthermore, a number of light AA batteries were established across the area. This included Bethlehem Battery, situated within the north-eastern section of the site. This Battery was armed with 6in breech loading guns. However, by May 1942 the AA emplacement was backfilled and replaced with two gun pits on either side of where the gun emplacement previously stood[8]. Provision for the storage and possibly the disposal of munitions would have been made on site. • RAF Manston and the surrounding area was targeted and attacked by the Luftwaffe several times during WWII. During such attacks, it is likely that a significant degree of AA fire would have occurred over the site. • The site was occupied by open ground during WWII. In such ground conditions, an unexploded AA shell could go unnoticed.

9.5 Generic Types of WWII British / Allied Unexploded Ordnance

9.5.1 Land Service Ammunition (LSA)

9.5.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

[5] Thanet Advisor – 13th March 1945
[6] Thanet Advisor – 18th December 1945
[7] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43194
[8] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MKE39272

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

9.5.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.5.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

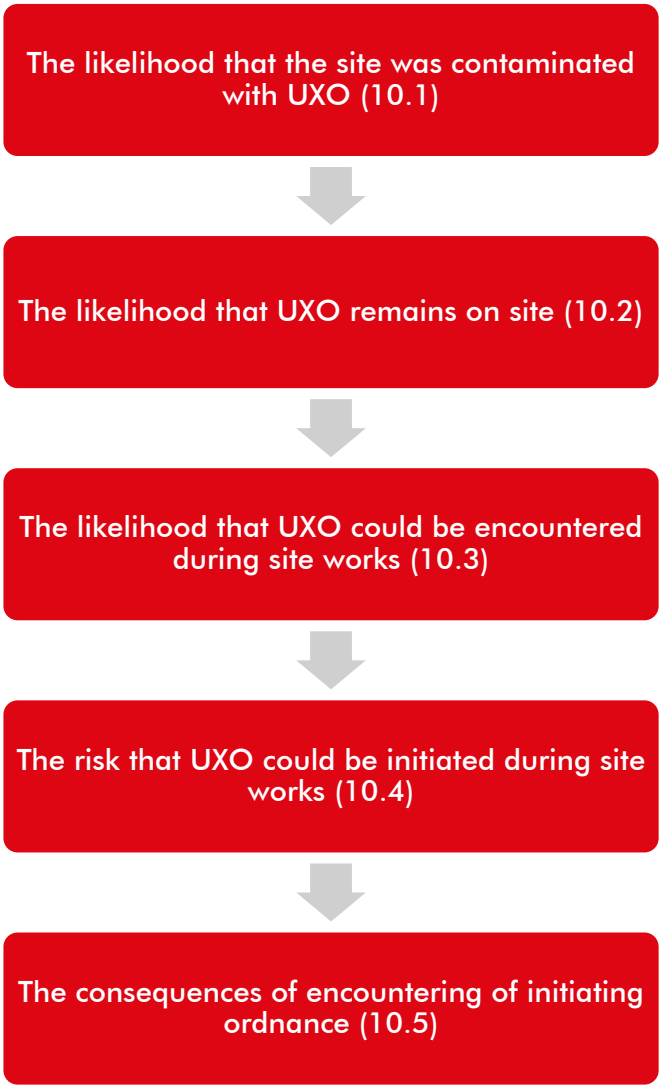
The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• Moderate bombing density. • 2 x HE bombs plotted on site. • 2 x UXBs plotted on site. • 2 x HE bombs plotted on/immediately adjacent to the site.
Bomb Damage	• One building appears to have sustained bomb damage.
Ground Conditions	• Majority of the site comprised open ground, including a golf course, agricultural land and marshland. • A golf club and farm buildings occupied the site. • A railway embankment encroached into northern extent.
Frequency of Access	• Likely infrequent access to marshland. • Infrequent access to the golf course. • Likely seasonal access to farmland.
J-Curve Effect	• Had any UXB landed within the soft ground on site, it could have come to rest beneath the adjacent undamaged areas.
Other considerations	• 4 x abandoned bombs reported within 300m of the site. • A UXB was found in Pegwell Bay Country Park, approximately 420m south-east of the site, in 2017.
Overall Likelihood of Contamination	**Medium**

10.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• Several Platoons of the Thanet Home Guard Battalion operated in the area. • St Augustine's Golf Course was covered in anti-invasion defences including barbed wire, trenches and gun pits.

	• 4 x Pillboxes within 460m of the site, closest of which was 100m east. • Marshy land between Minster and Pegwell Bay used as a mortar training range during WWII. • Given the strong military / HG presence in the area and the site comprising undeveloped ground, the possibility the site was used for training purposes cannot be discounted.
Anti-Aircraft Projectiles	• Six HAA batteries were situated within a 5km radius of the site during WWII, the closest of which was approximately 1.9km north-east from the site. • Bethlehem Battery, situated within the north-eastern section of the site. This was replaced by May 1942 with two gun pits. Provision for the storage and possibly the disposal of munitions would have been made on site. • The site was occupied by open ground during WWII. In such ground conditions, an unexploded AA shell could go unnoticed.
Overall Likelihood of Contamination	**Medium**

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	• July 2017 - A UXB was found in Pegwell Bay Country Park. An Army disposal team carried out a controlled detonation.[9] Pegwell Bay County Park 420m south-east of the site.

[9] https://theisleofthanetnews.com/the-army-has-carried-out-another-controlled-explosion-of-war-time-bombs-at-cliffsend/

	• 1st July 2017 – A UXB was discovered near Sandwich Road, Cliffsend. The precise location of where this UXB was discovered is unknown.[10]
Local tasks undertaken by SafeLane Global	None

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✓
Further Details	• The majority of the site has not been subject to significant redevelopment works in the post-war period. • Between 1964 and 1990 Cottington Lane was removed from the centre of the site. During this same period the orchard was also cleared from the south-western extent. • By 1990 a large warehouse was constructed at Ebbsfleet Farm, in the southern extent of the site. Between 2009 and 2013 this warehouse was downsized and the present day A256 constructed. • Extension area: Beyond the clearance of the orchard and the construction of Richborough Way, no significant redevelopment works have been carried out.

10.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	Beyond the creation of the A256, and minor redevelopment works at the Golf Course and Ebbsfleet Farm, much of the site has not been subject to significant intrusive works.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. At any location on site where no known bulk excavations have been carried out, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth

[10] Kent Live – 1st July 2017

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works comprise ground investigations including machine excavated trial bits and cable percussion boreholes. There is an elevated likelihood of UXO being encountered during these works.

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.
Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-	This is the most likely scenario resulting in the bomb detonating.

sensitive) fuze explosive	

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

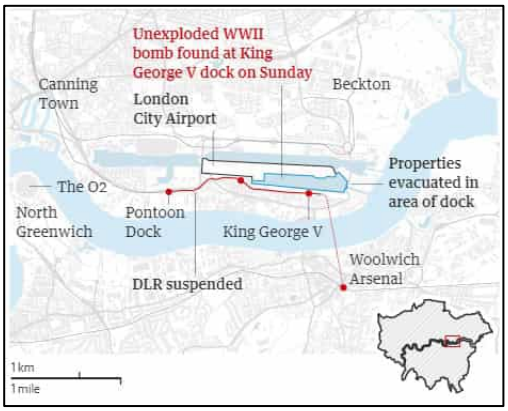
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be Medium.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Medium	Medium	Medium	Severe	**Medium**
German 1kg Incendiary Bombs	Medium	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Medium	Medium	Medium	Not Significant	**Medium**
Land Service Ammunition	Medium	Medium	Medium	Moderate	**Medium**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
Medium	Shallow Intrusive Works eg. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation (SI) • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. • Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer.

	• Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard.

	• Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).

Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required. The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation**

	If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iii. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

iv. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

v. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

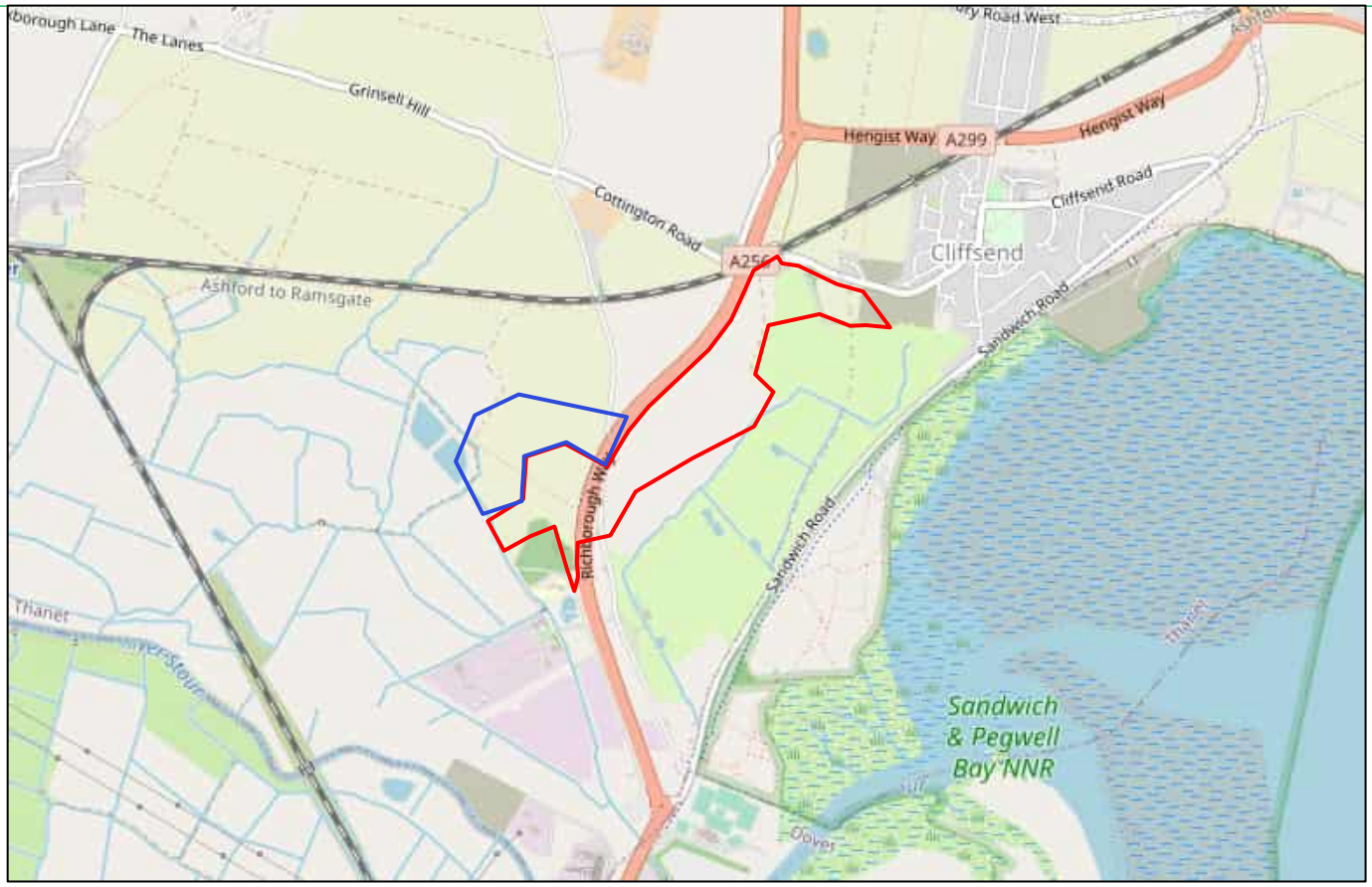
vi. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

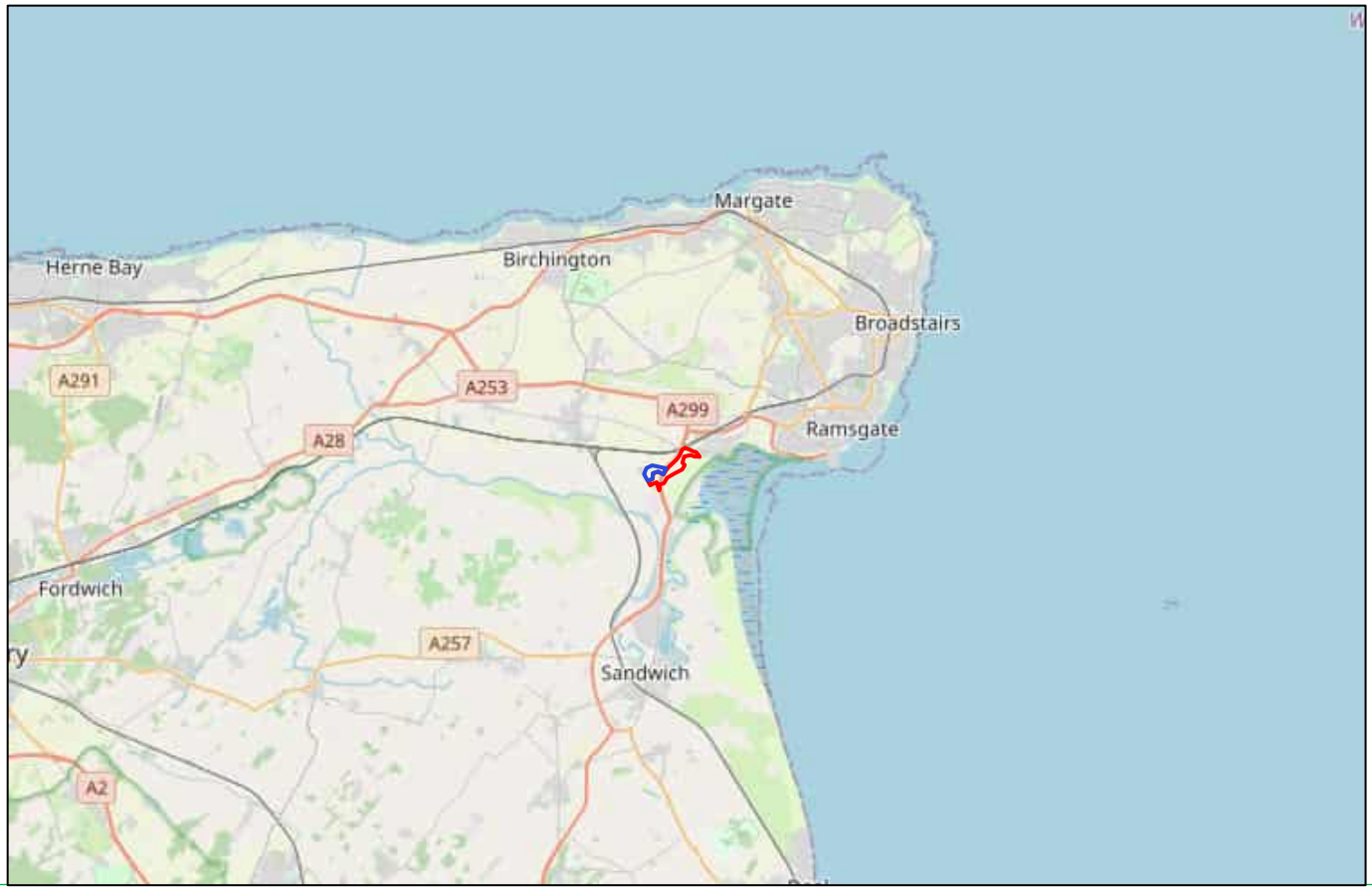
vii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

viii. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

ix. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

x. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).





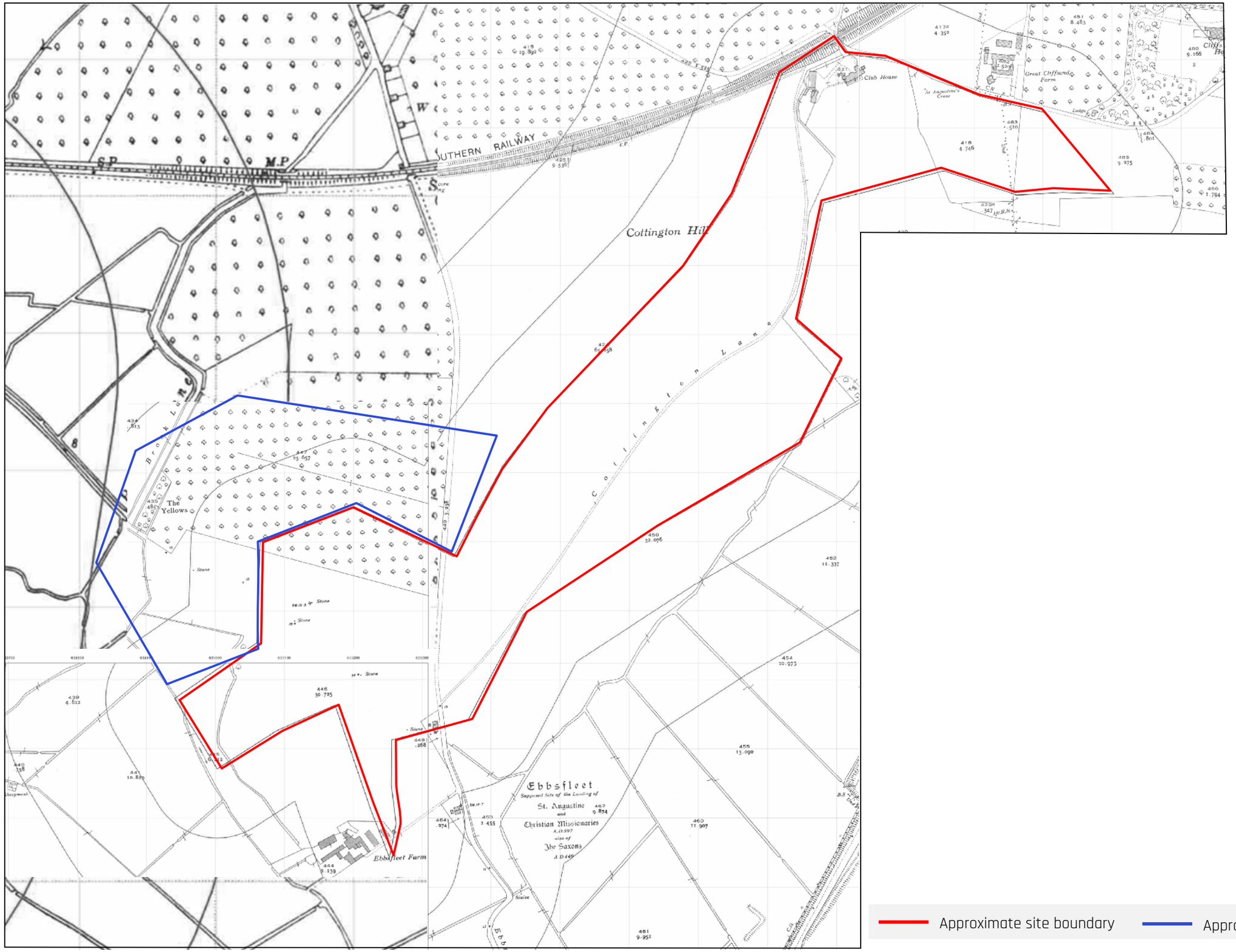
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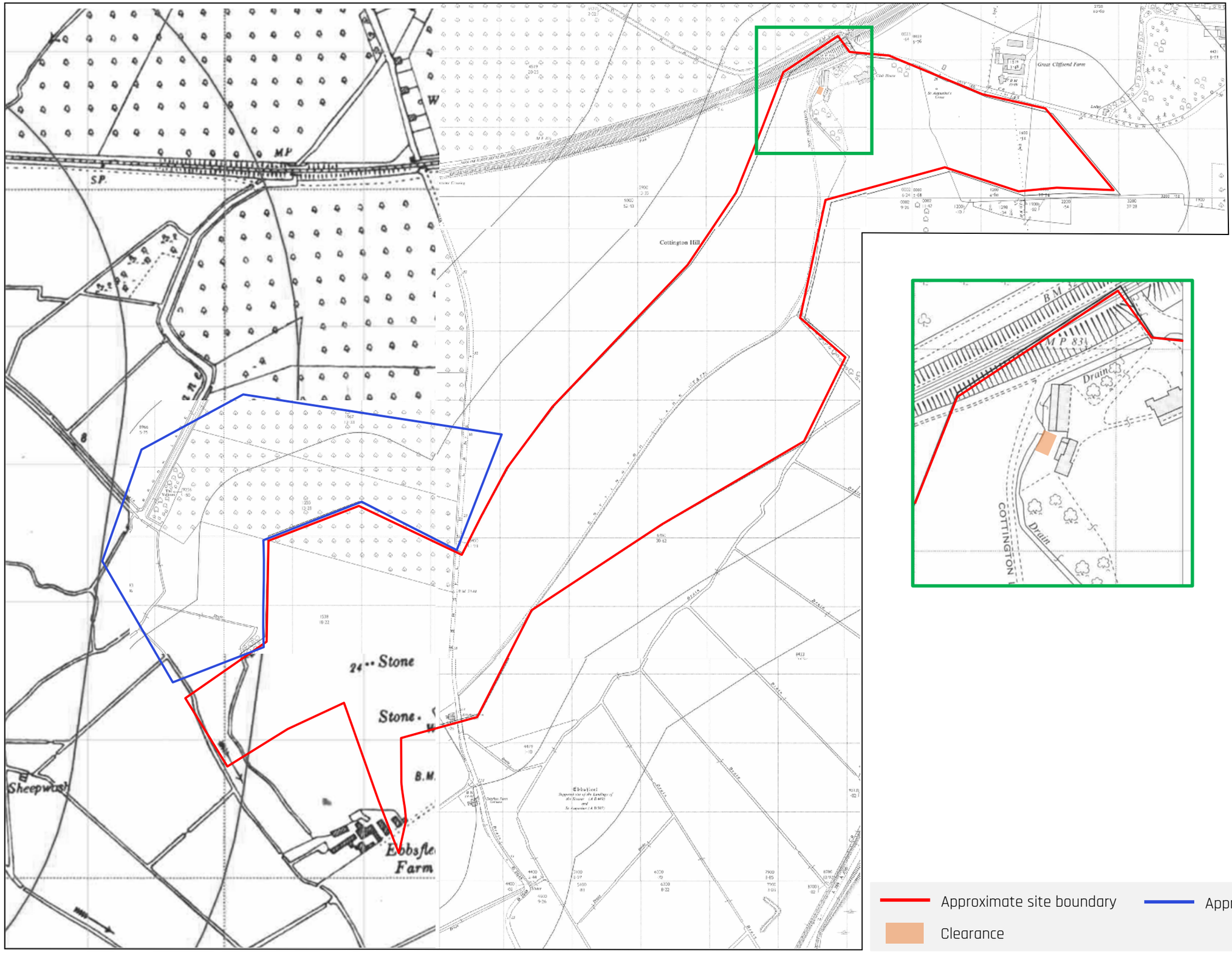


Approximate site boundary

Approximate extension area


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S.P
M.P
Cottington Hill
Club House
St Augustine's Cross
Great Cliffsend Farm
Cliffs End
Collington Lane
Broad Lane
The Yellows
Stone
Ebbsfleet
Supposed Site of the Landing of
St. Augustine
and
Christian Missionaries
A.D.597
also of
The Saxons
A.D.449
Ebbsfleet Farm
Statue
Approximate site boundary
Approximate extension area

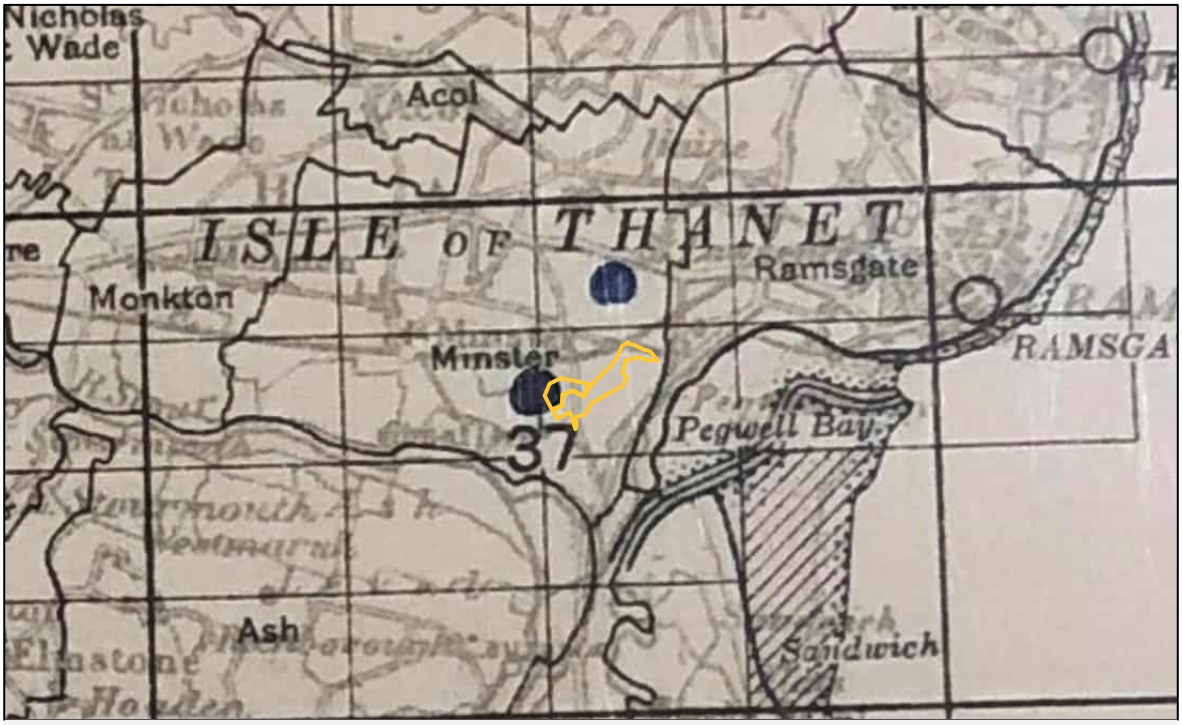
N



Approximate site boundary
Approximate extension area
Clearance



9th July 1940



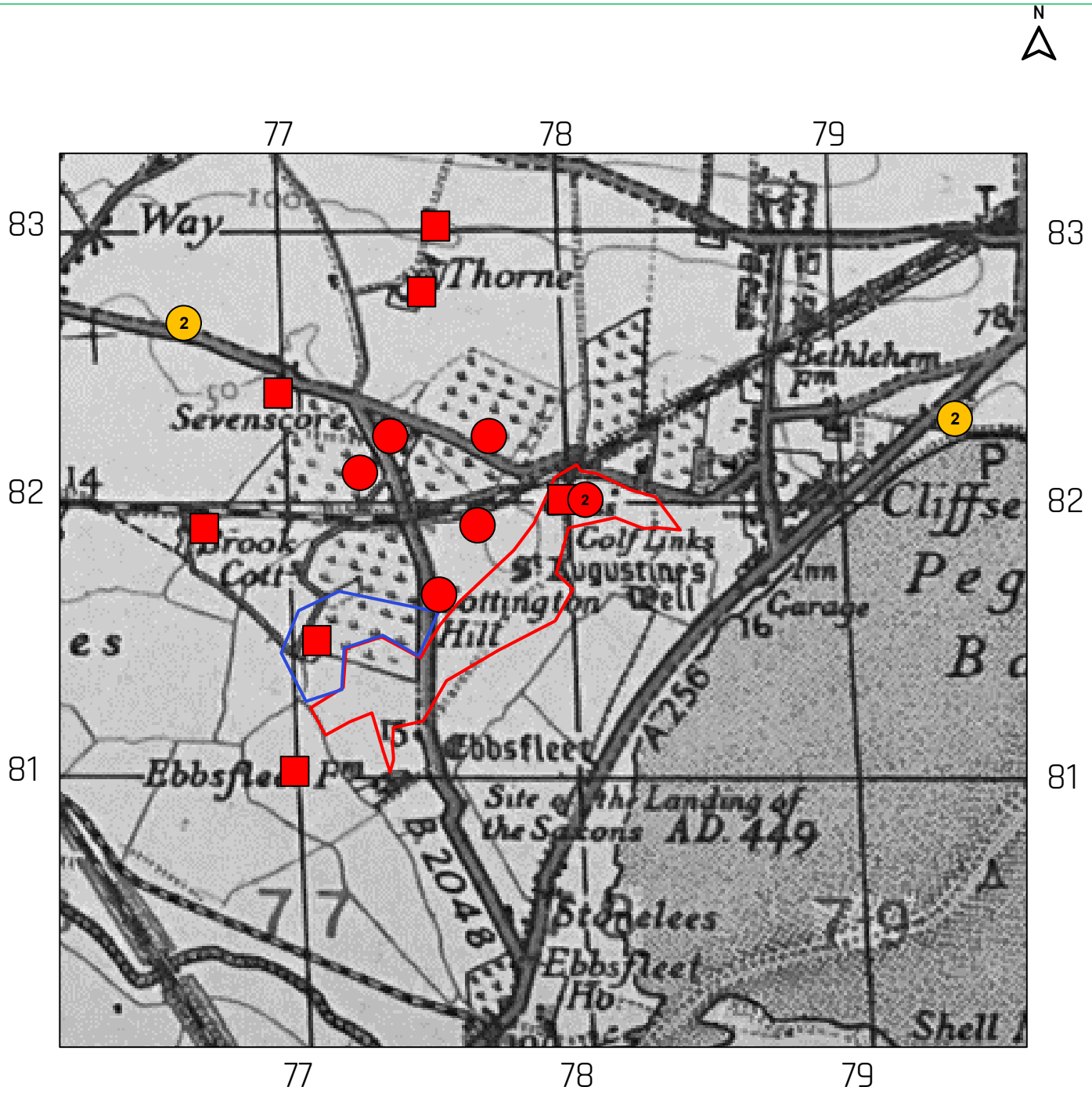
6th November 1940

Approximate site boundary

HE bomb strike

Incendiary shower

HE bomb area



Approximate site boundary

Approximate extension area

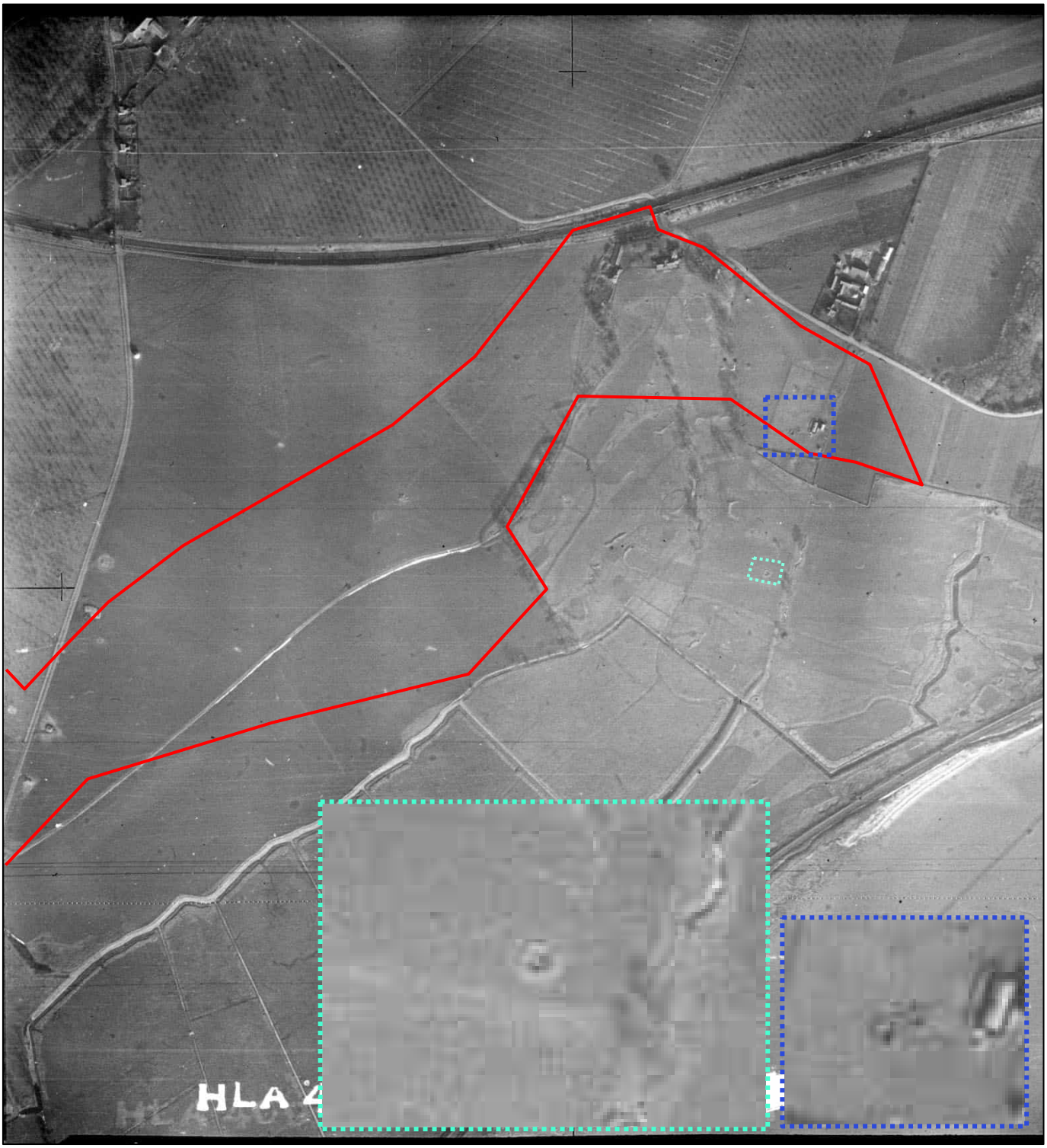
HE bomb

Unexploded HE bomb

Incendiary bomb

(Numbers in circles denote quantity of explosive ordnance recorded)

WWII-era RAF Aerial Photography – 3rd March 1942



Approximate site boundary Potential ground disturbance AA gun site

WWII-era RAF Aerial Photography – Circa 1946

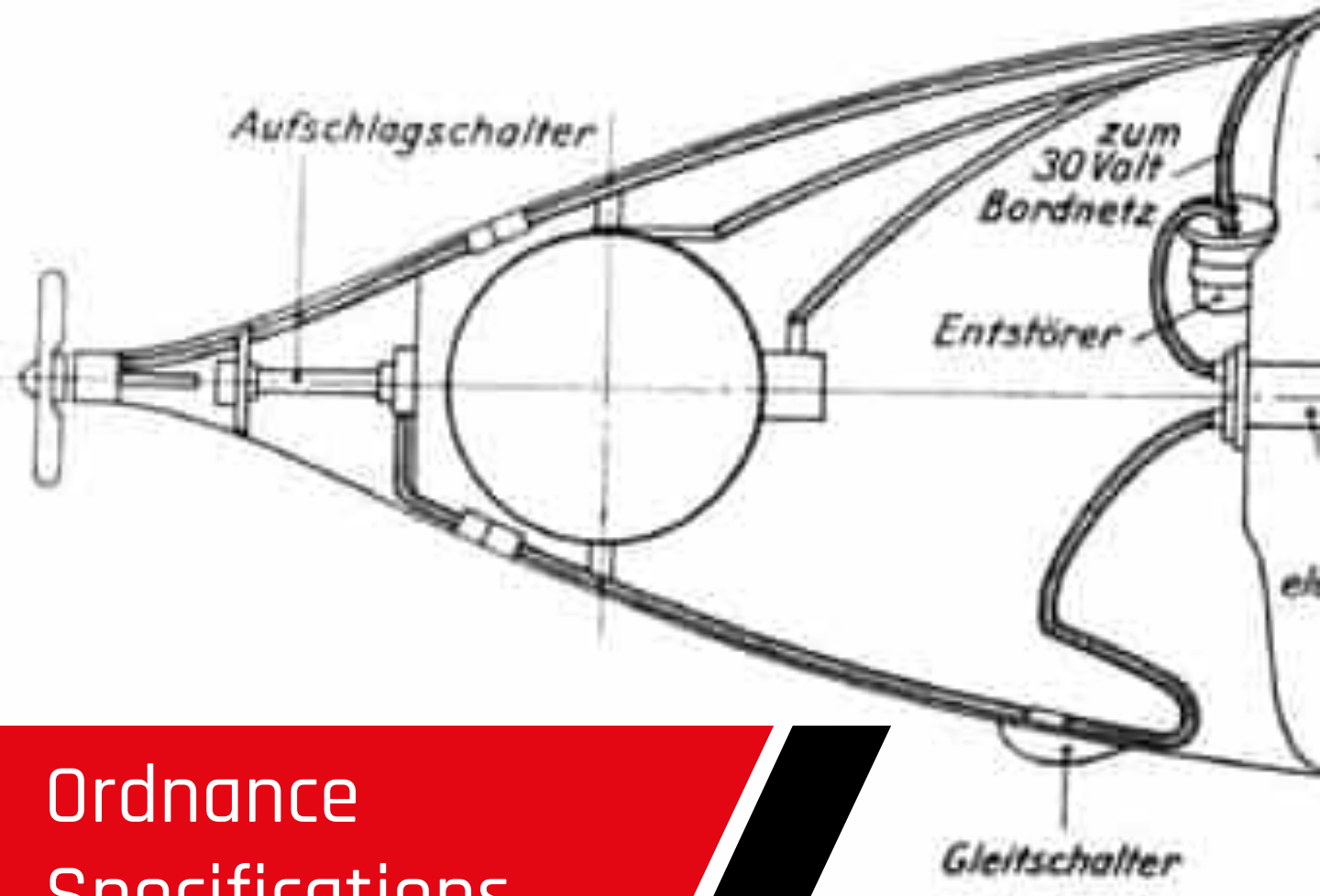
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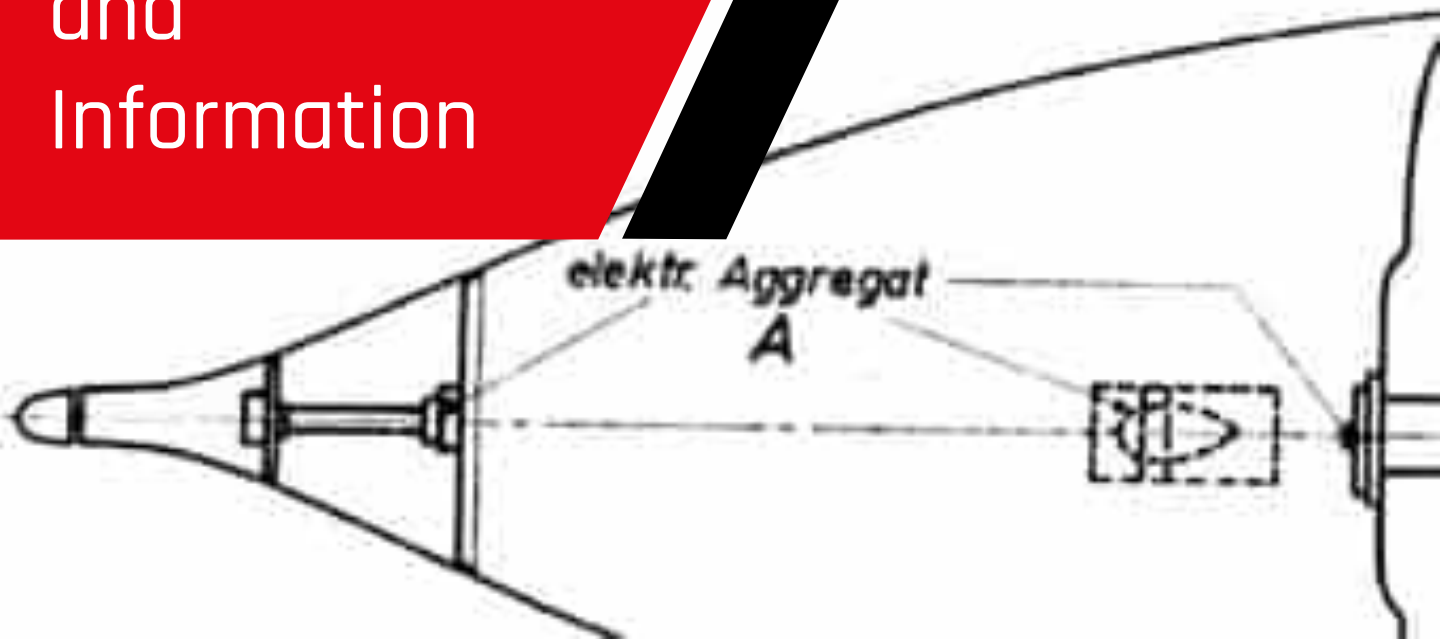
Approximate site boundary

Potential ground disturbance

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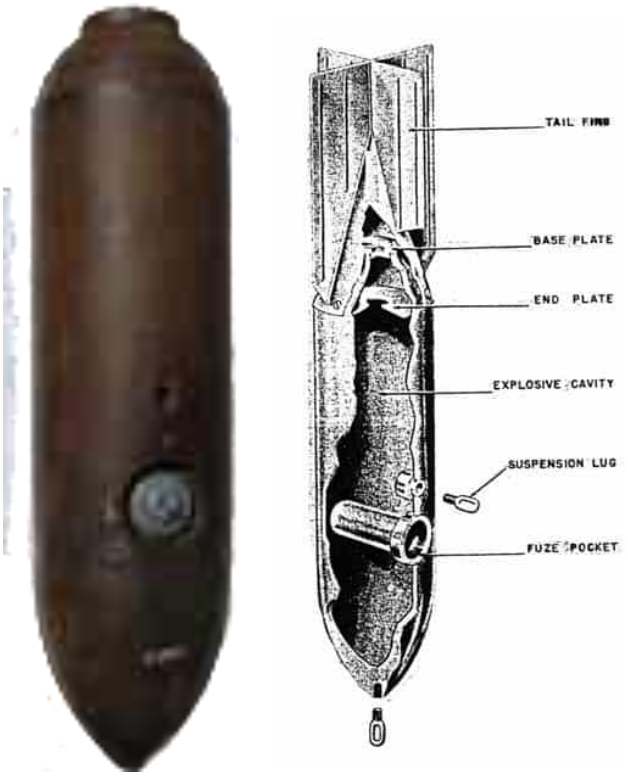


Ordnance Specifications and Information





German Ordnance





Sprengbombe Cylindrisch 50

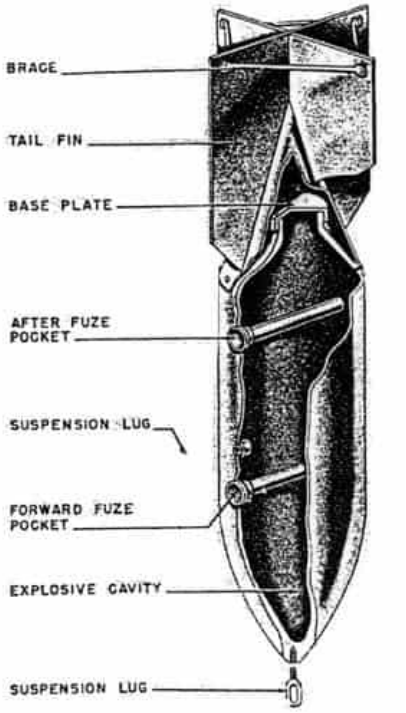
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

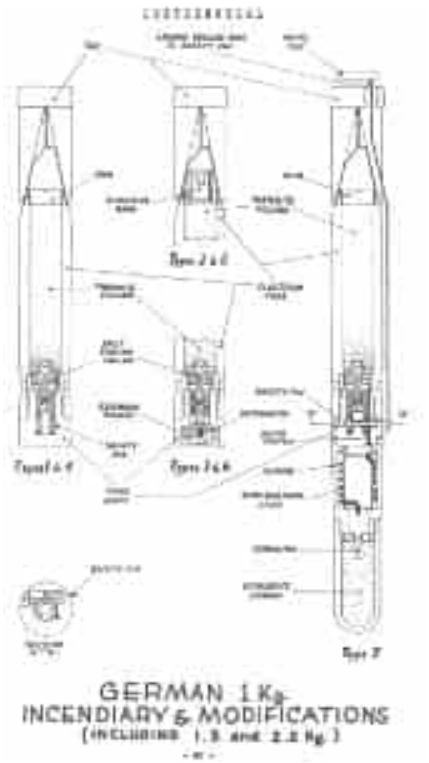
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









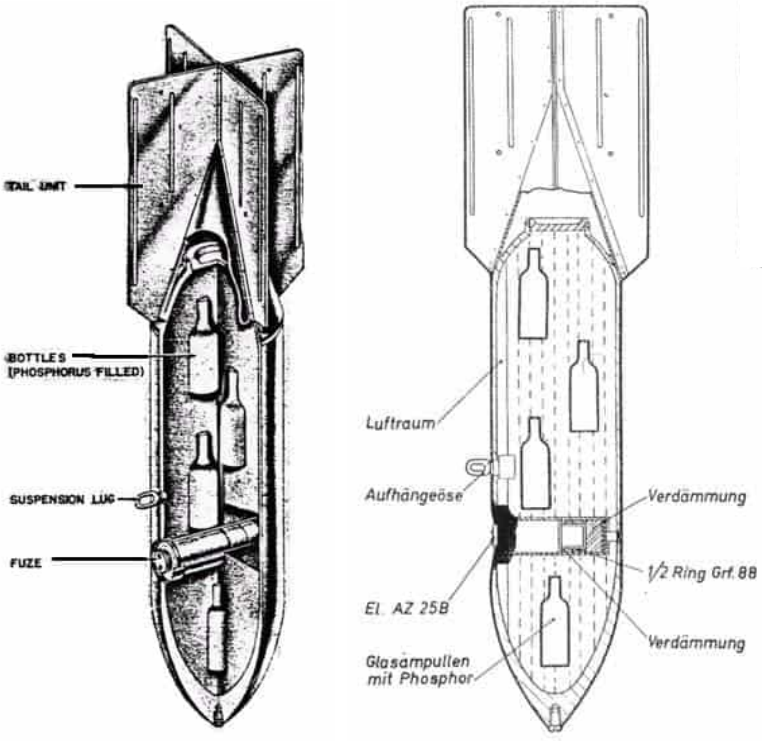
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

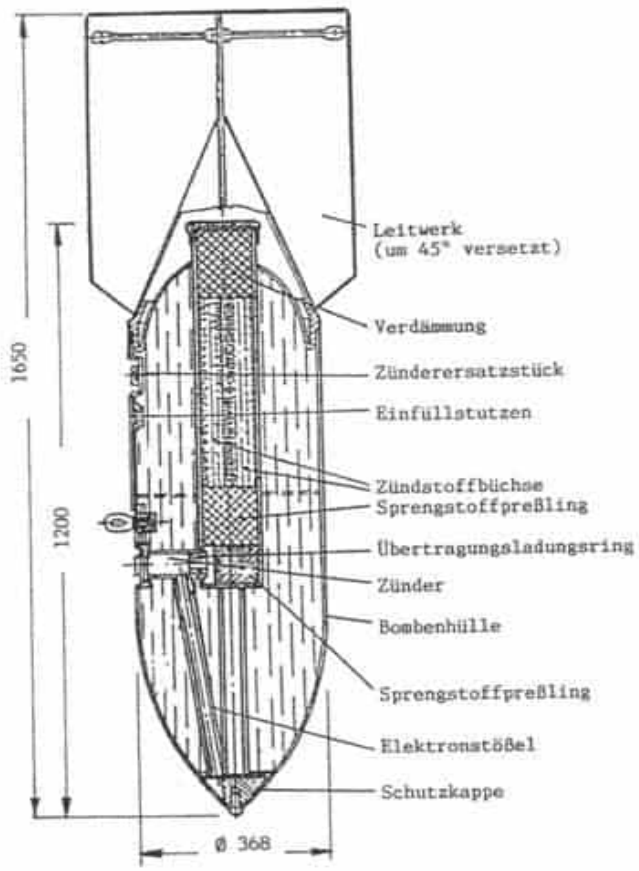






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

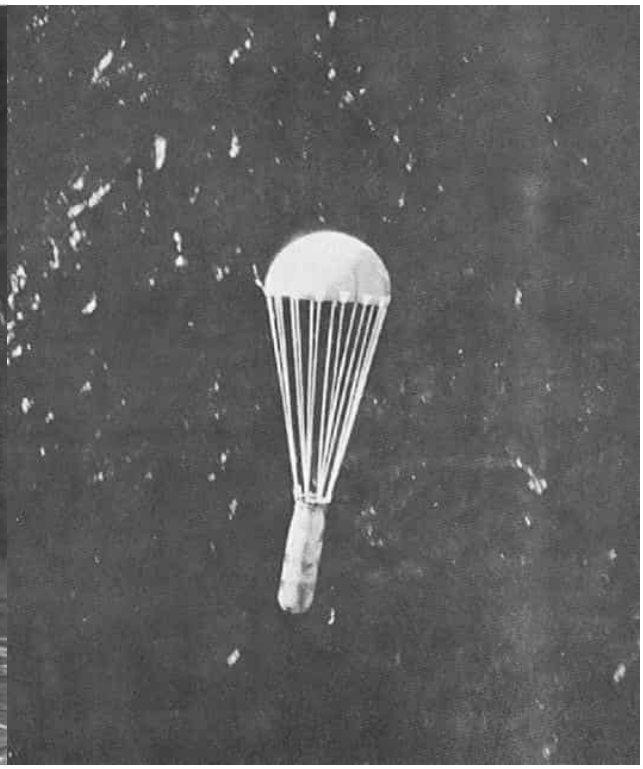




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration





Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg

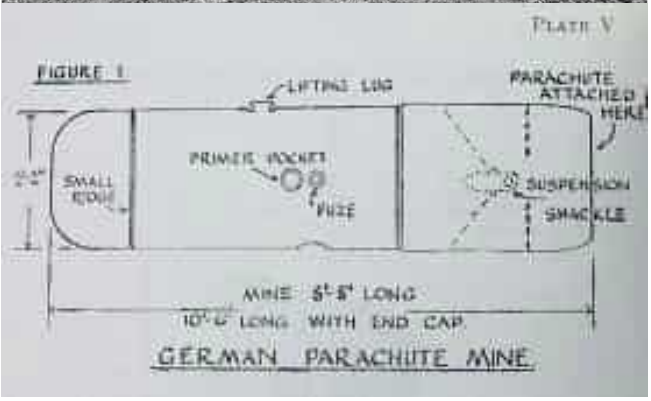
Fuze Type: Mechanical clockwork fuze

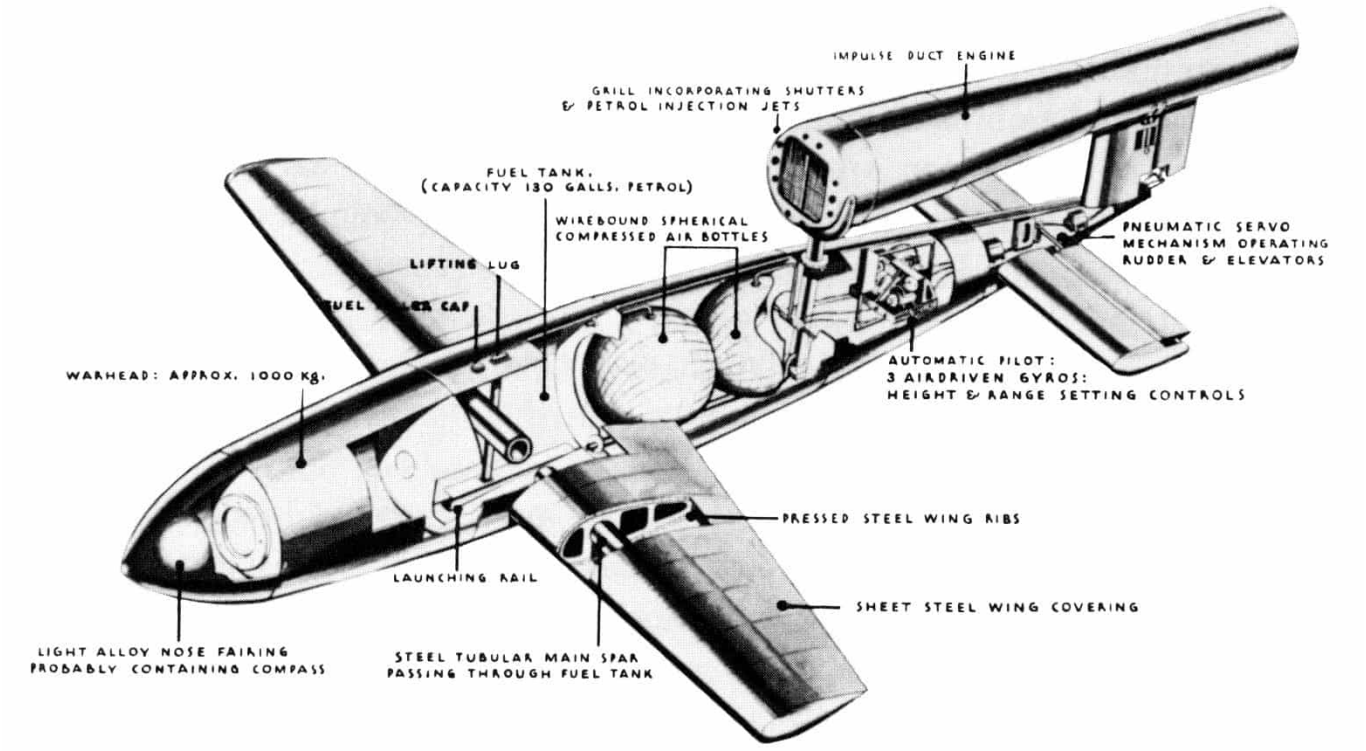
Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

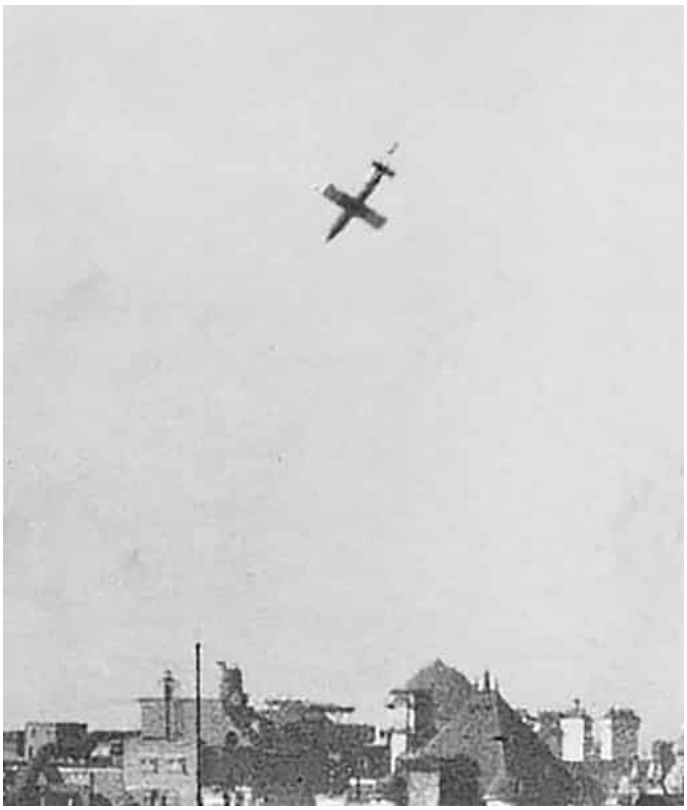




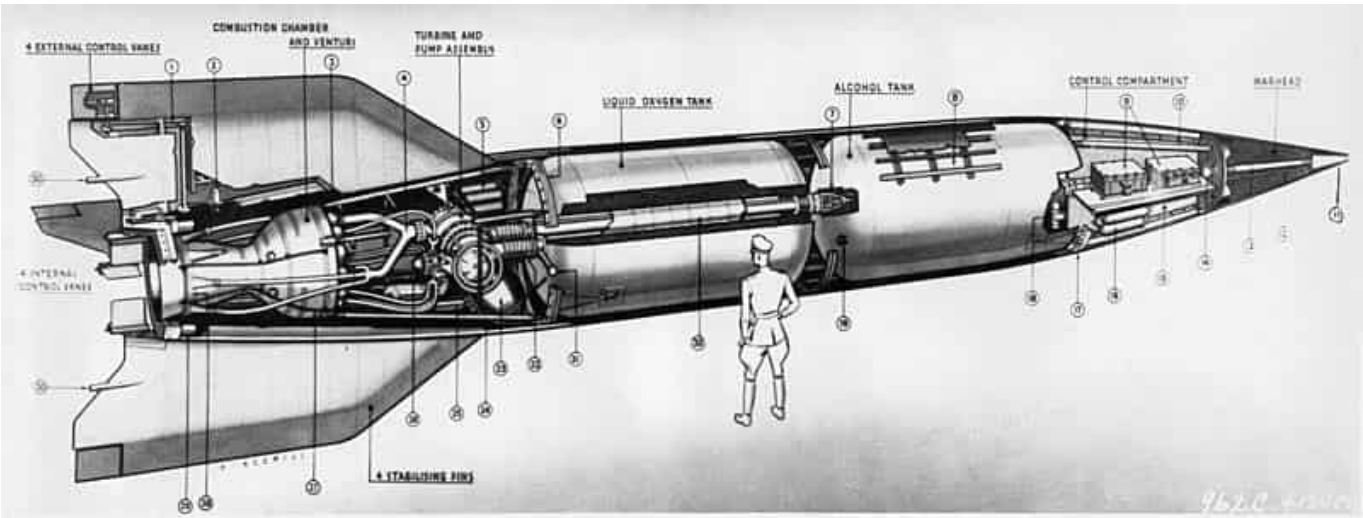


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

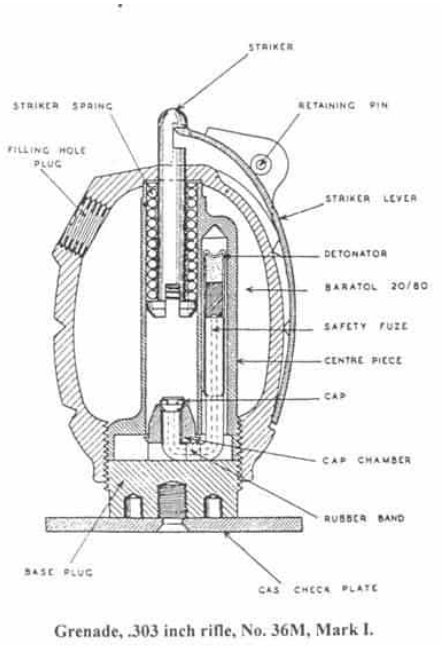
Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.





British & Allied Ordnance



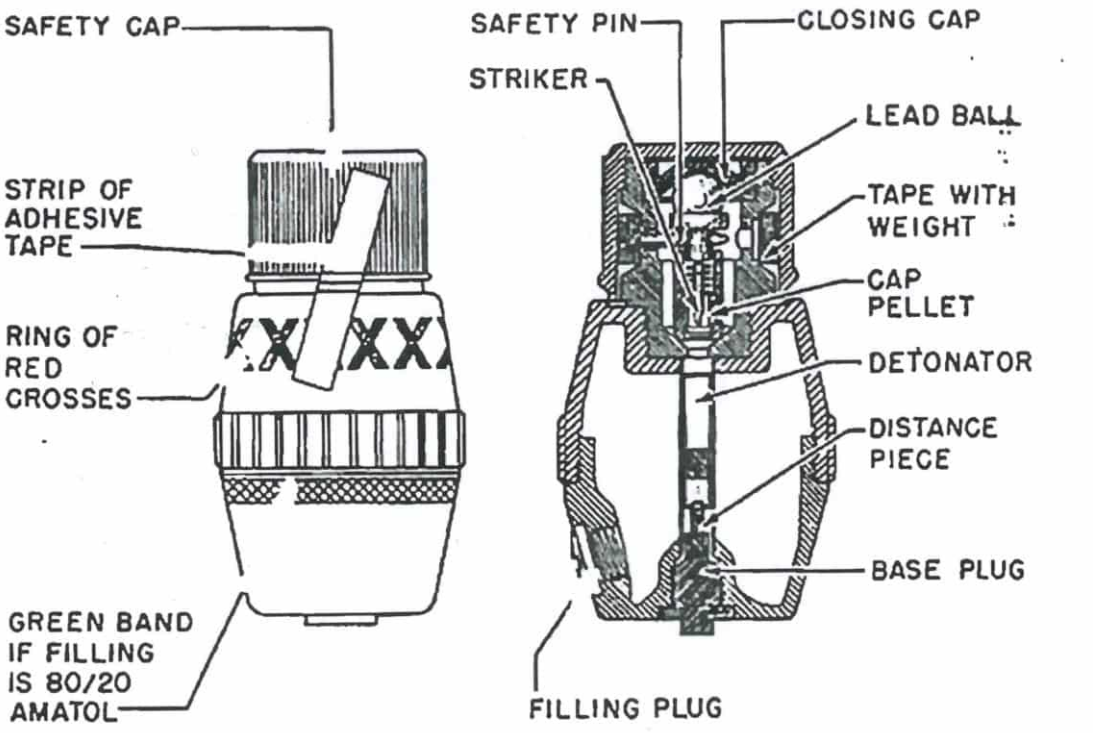


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



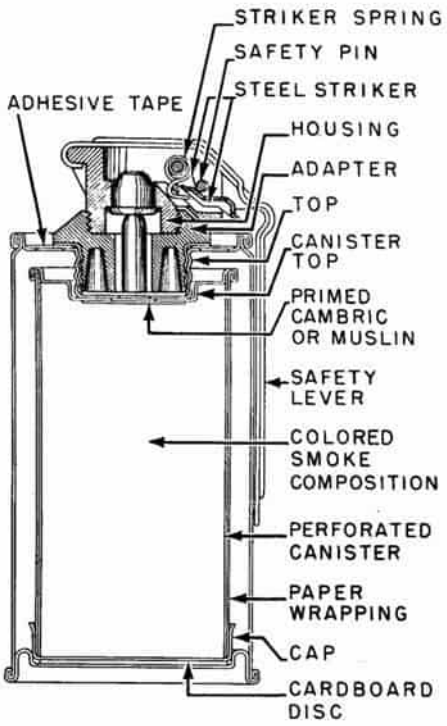


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





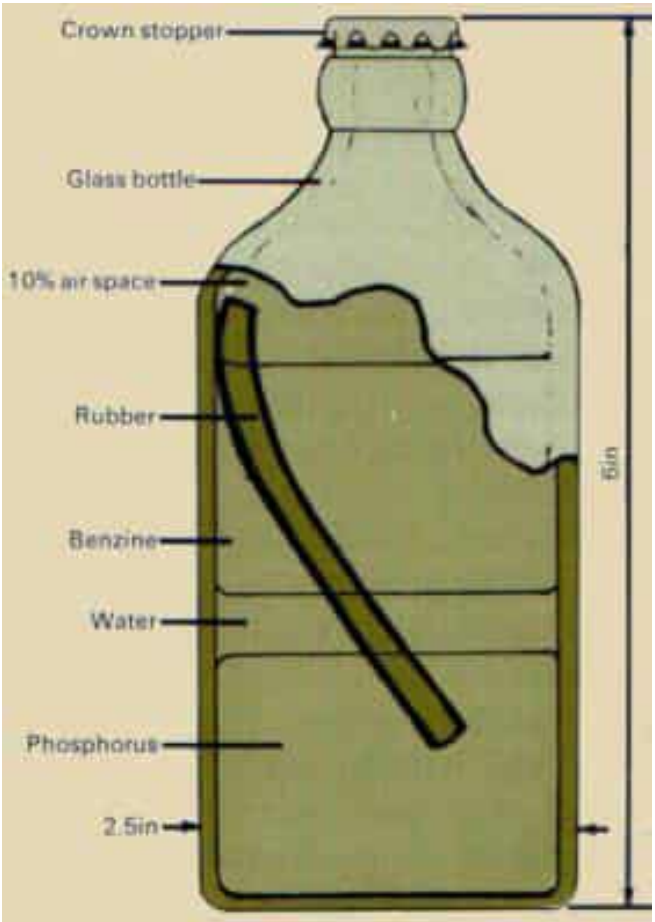


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

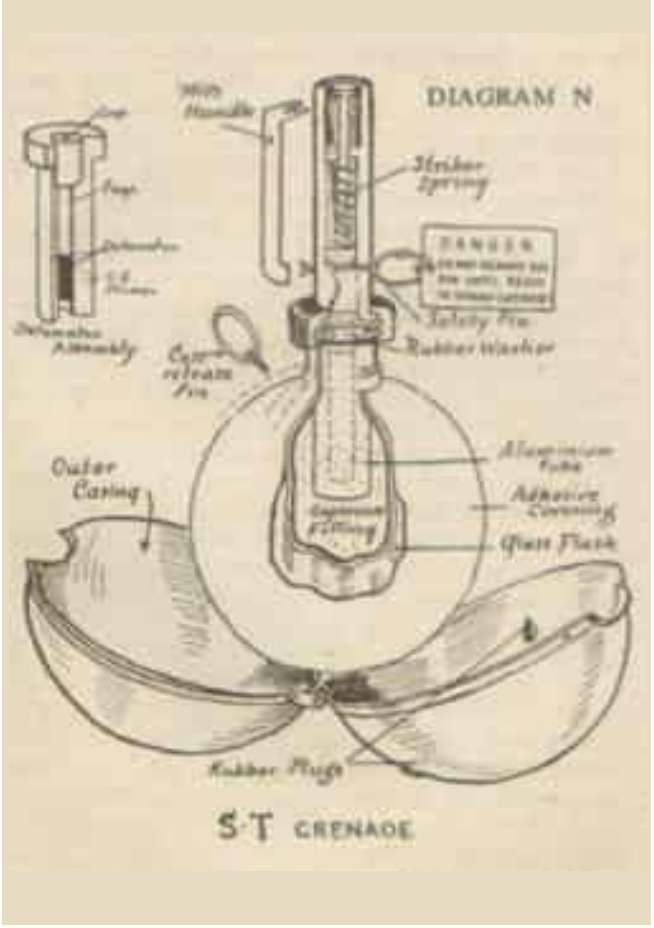






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

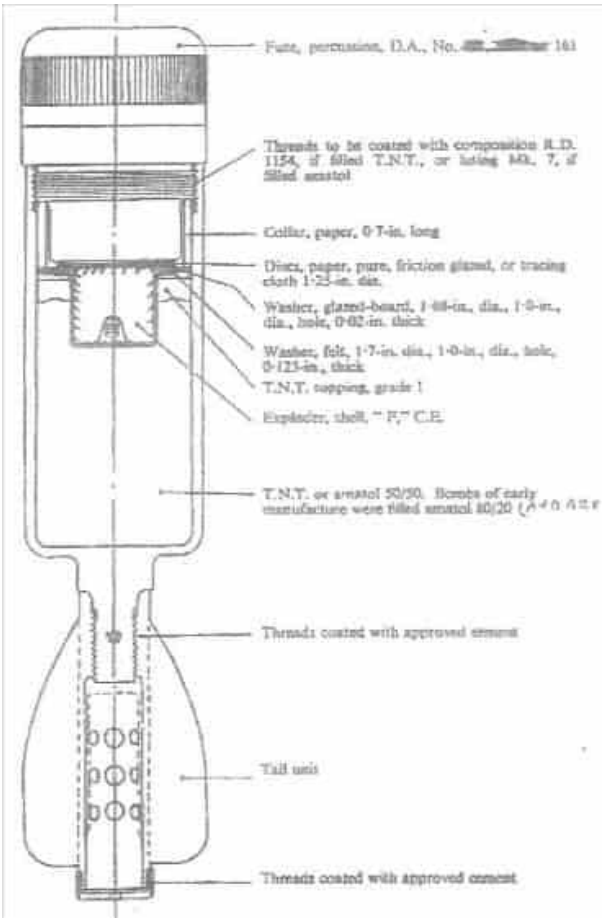






Typical 2" High Explosive Mortar

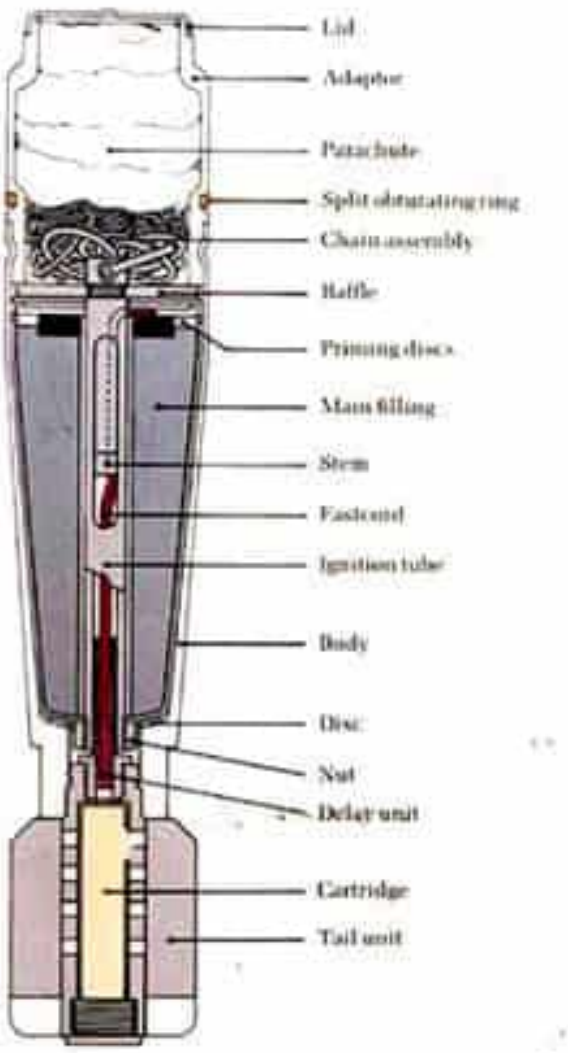
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







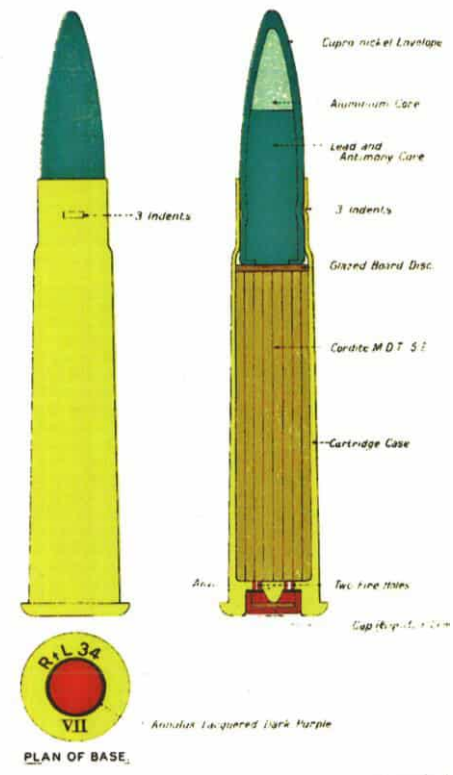


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



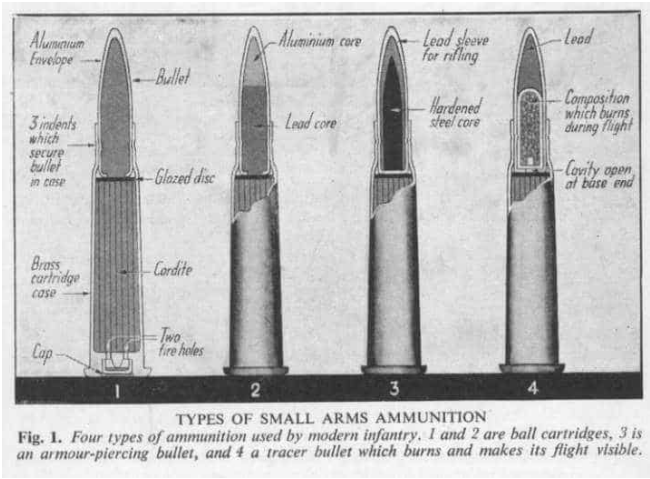




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



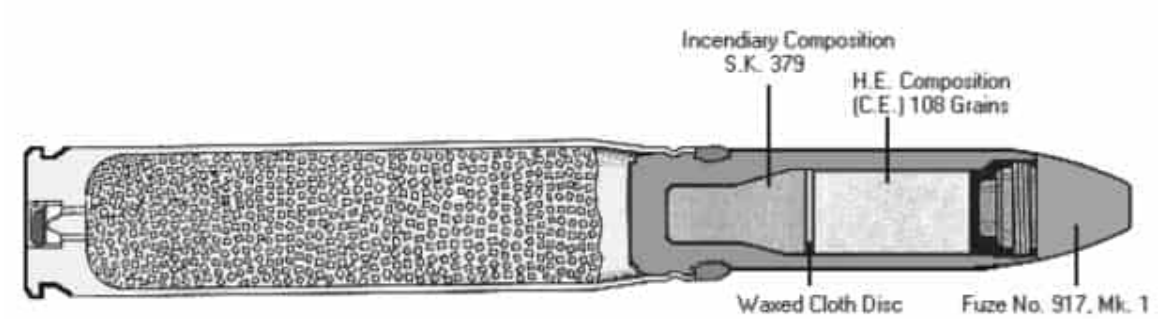


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

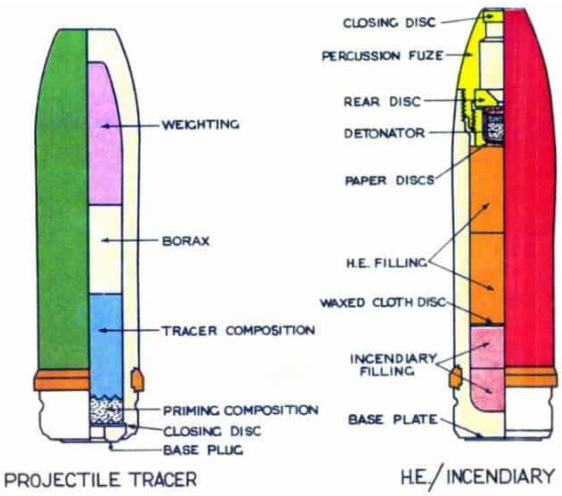






20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



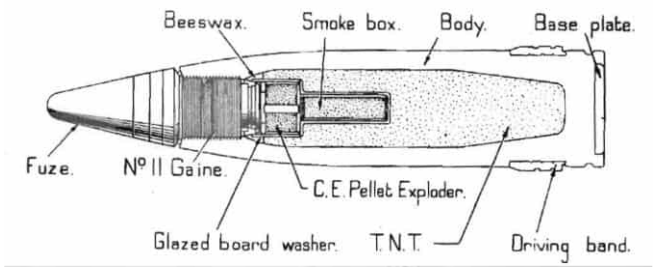
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	



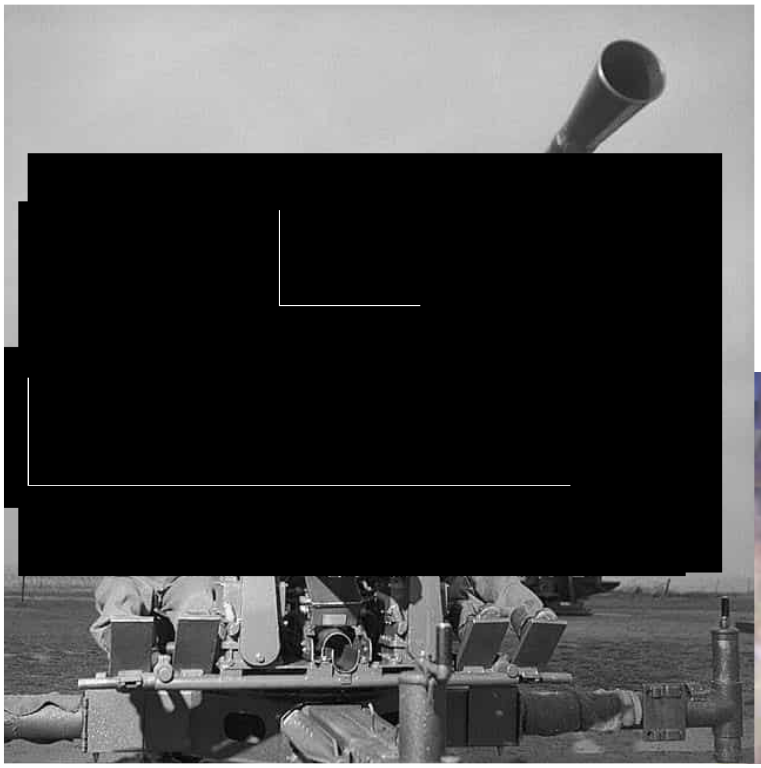
3.7" Anti-Aircraft Projectile

Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.







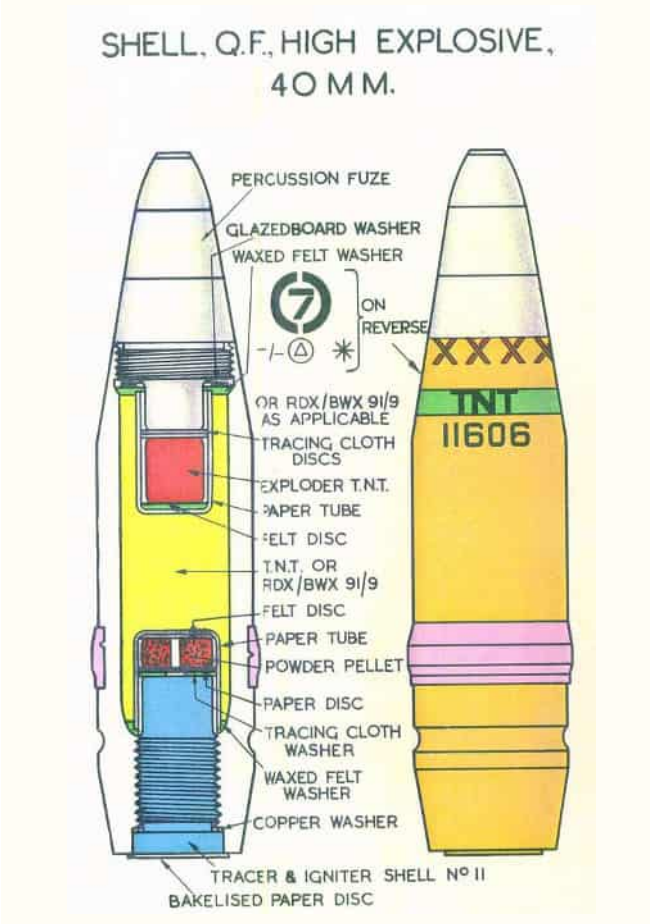




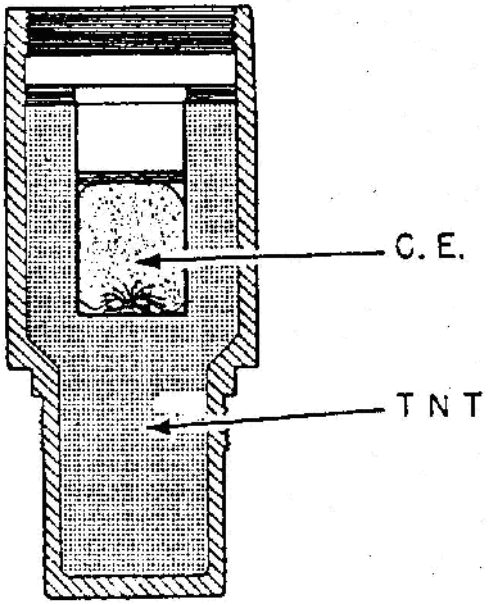


40mm Bofors Gun Projectile

Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

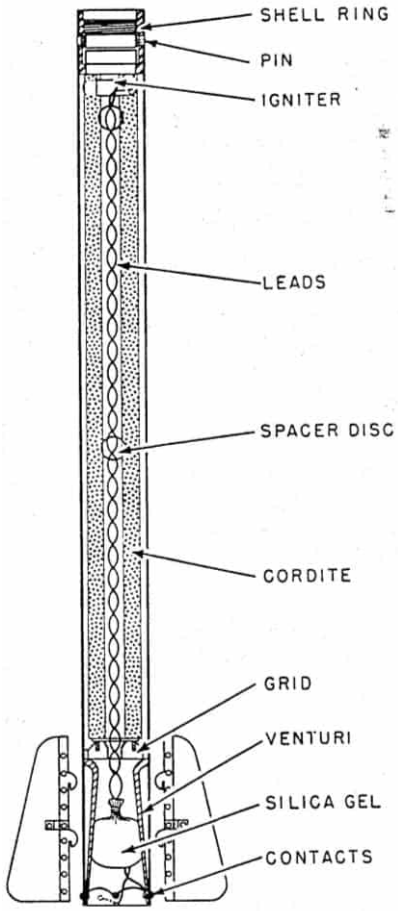






Rockets / Un-rotating Projectiles

Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery



SAFELANE
GLOBAL



Detailed Unexploded Ordnance
Risk Assessment

In Respect Of:
Richborough – Alternate Option No. 3 for Connection to
OHL Richborough Revision

For:
Mott MacDonald

Report Reference:
9758-5 RA



safelaneglobal.com

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Executive Summary

The Site	
Address:	Minster Marshes, Minster, Ramsgate, CT12 4DD
OS National Grid Reference:	TR 31162 63307
Site Description:	The majority of the site comprises open ground, some of which forms Minster Marshes. A Sewage Works is located in the centre of the site, served by Marsh Farm Road from the north. A railway track crosses the eastern extent of the site while a section of the River Stour passes through the southern section. Extension area: Largely comprises open, agricultural ground, crossed by drainage ditches and a trackway.
Proposed Works	
The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**HIGH from the following UXO types:** • German Air-Delivered HE bombs
	MEDIUM from the following UXO types: • German Air-Delivered Incendiary Bombs • Anti-Aircraft Projectiles • Land Service Ammunition • Small Arms Ammunition
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	

Maximum Bomb Penetration Depth	It has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between **10-12m** below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

Recommended Risk Mitigation

Risk Level	Planned Site Activity	Recommendations
High	**Shallow Intrusive Works eg excavations**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.

Table of Contents

Distribution i
Executive Summary ii
Table of Contents iv
List of Annexes vi
Appendices vi
Glossary of Terms vii
1 Introduction 1
2 Construction Industry Duties and Responsibilities 2
2.1 The UK Regulatory Environment 2
2.2 The Health and Safety at Work Act, 1974 2
2.3 Construction (Design and Management) Regulations 2015 2
2.4 Other Legislation 3
3 The Role of the Authorities and Commercial Contractors 3
3.1 The Authorities 3
3.2 Commercial Contractors 3
4 This Report 3
4.1 Aims and Objectives 3
4.2 Risk Assessment Methodology 3
4.3 Approach 4
4.4 Sources of Information 4
4.5 Reliability of Historical Records 4
4.5.1 General Considerations 4
4.5.2 Bombing Records 5
5 The Site and Scope of Proposed Works 5
6 Ground Conditions 6
7 Pre and Post-WWII OS Mapping 6
8 The Threat from Aerial Bombing 7
8.1 General Bombing History of Kent 7
8.1.1 First World War 7
8.1.2 Second World War 7
8.2 Generic Types of WWII German Air-delivered Ordnance 8
8.3 Second World War Bombing Statistics 9
8.4 Site Specific WWII Bombing Records 10
8.4.1 Kent Bomb Census Maps 10
8.4.2 Kent V1 Bomb Census Map 10
8.4.3 Original ARP Bombing Incident Records 10
8.4.4 Secondary Source / Anecdotal Evidence 13
8.4.5 WWII-era RAF Aerial Photography 13
8.4.6 Decoy Bombing Sites 14
8.4.7 Abandoned Bombs 14
8.5 UXB Ground Penetration 15
8.5.1 General Considerations 15
8.5.2 The "j" Curve Effect 15
8.5.3 Second World War Bomb Penetration Studies 16
8.5.4 CIRIA Bomb Penetration Depth Specifications 16

8.5.5 Site Specific Bomb Penetration Considerations *17*
8.6 Likelihood of Post-raid UXO Detection 17
8.6.1 Density of Bombing *17*
8.6.2 Bomb Damage *17*
8.6.3 Frequency of Access *18*
8.6.4 Ground Cover *18*
8.6.5 German Air-Delivered Ordnance Failure Rate *18*
8.6.6 Site Specific Analysis *19*
9 The Threat from Allied Military Ordnance 23
9.1 Port Richborough 23
9.2 Home Guard Activity 23
9.3 Anti-Aircraft Gun Batteries 25
9.4 Site-Specific Threat from Allied Military Ordnance 25
9.5 Generic Types of WWII British / Allied Unexploded Ordnance 27
9.5.1 Land Service Ammunition (LSA) *27*
9.5.2 Small Arms Ammunition (SAA) *28*
9.5.3 Anti-Aircraft Shells *28*
10 The Overall Unexploded Ordnance Risk Assessment Methodology 29
10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance 30
10.1.1 General *30*
10.1.2 Likelihood of Contamination from German UXO *31*
10.1.3 Likelihood of Contamination from British / Allied UXO *31*
10.2 The Likelihood that Unexploded Ordnance Remains on Site 32
10.2.1 General *32*
10.2.2 EOD Bomb Disposal and Clearance Tasks *32*
10.2.3 Post War Redevelopment *33*
10.2.4 Site-Specific Analysis *33*
10.3 The Likelihood that Ordnance may be Encountered during the Works 34
10.4 The Risk that Ordnance may be Initiated 34
10.4.1 Initiation of Unexploded Bombs *34*
10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance *35*
10.5 The Consequences of Encountering or Initiating Ordnance 35
11 SafeLane Global's Risk Assessment 39
11.1 Conclusions 39
12 Proposed Risk Mitigation Strategy 40
12.1 Summary 40
12.2 Additional Notes 40
Bibliography 45

List of Annexes

Annex A Site Location Maps

Annex B Recent Aerial Photograph

Annex C Pre and Post-WWII OS Maps

Annex D Kent Bomb Census Maps – Night Raids

Annex E Kent ARP Records Bomb Census Map

Annex F WWII-era RAF Aerial Photography

Appendices

Ordnance Specifications and Information

Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Richborough – Alternate Option No.3 for Connection to OHL Richborough Revision

1 Introduction

Groundsure Limited, on behalf of Mott MacDonald, has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Richborough - Alternative Option No.3 for Connection to OHL Richborough Revision site.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.

- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- Kent Library and History Centre.
- Kent County Council.
- Kent Historic Environment Record.
- Groundsure Limited.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

Site Address	Minster Marshes, Minster, Ramsgate, CT12 4DD	
OS National Grid Reference	TR 31162 63307	
Site Description	The majority of the site comprises open ground, some of which forms Minster Marshes. A Sewage Works is located in the centre of the site, served by Marsh Farm Road from the north. A railway track crosses the eastern extent of the site while a section of the River Stour passes through the southern section. Extension area: Largely comprises open, agricultural ground, crossed by drainage ditches and a trackway.	
Proposed Works	The proposed ground investigation would include machine excavated trial pits to 4m bgl and cable percussion boreholes, maximum 35m bgl. Construction will comprise Horizontal Directional Drilling from offshore to onshore where the cable will be installed in an open cut trench to a max depth of 2m bgl. There will be some shallow earthworks carried out for temporary construction compounds and construction of the permanent substation/ convertor station platform. Piled foundations are also anticipated.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Borehole	Borehole Reference	TR36SW/7
	Location	On site
	Date	11/09/1959
	Recorded Shallow Geology	• 0.23m of Topsoil, Ballast, Roots and Ashes • 1.50m of firm Clay • 4.06m of soft Clay • 3.66m of sandy Clay • 1.17m of clayey Silt
British Geological Survey Mapping	Superficial Deposits	Tidal Flat Deposits – Clay and Silt
	Bedrock	Thanet Formation – Sand, Silt and Clay

7 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1938	• The majority of the site comprises open ground labelled *Minster Marshes*. This includes a network of drainage ditches, footpaths and footbridges. • A number of small unlabelled structures are present across the site, likely for farming. • A *Sewage Works* is located in the southern half of the site. • A railway line crosses the eastern section of the site while the *River Stour* passes west to east through the southern extent. • The site also encompasses a *Sea Wall* and *Sluices*. • The surrounding area is rural in nature with *Minster Junction* located approximately 200m north. • Extension area: Comprises open ground and drainage ditches.	Annex C-1	Groundsure Limited

Post-WWII	**1948-57**	• Evidence of minor redevelopment, primarily on areas of farming infrastructure, are apparent across the site. Typically, evidence of ruins, clearance and redevelopment is often indicative of bomb damage on early post-WWII OS mapping. • The *Sewage Works* has expanded with the construction of additional *Tanks*. • An additional railway siding has been constructed to the north of the site. • No further changes are noted across the surrounding area. • Extension area: No changes are noted within the extension area.	**Annex C-2**	**Groundsure Limited**

8 The Threat from Aerial Bombing

8.1 General Bombing History of Kent

8.1.1 First World War

During WWI, Kent suffered extensive aerial bombardment from Zeppelin airships and fixed-wing aircraft. The first attack by the German Air Force was launched against Dover on the 21st December 1914 using naval seaplanes.

Bombing continued in Kent throughout the war; areas such as Ashford, Canterbury, Dover, Folkestone, Gravesend, Margate, Maidstone and Sheerness suffered particularly severe raids. The last raid on the county was on the night of the 19th May 1918 when a total of 14.55 tonnes of bombs were dropped on London, Faversham and Dover. Ramsgate, situated approximately 4km north-east of the site, gained the reputation as the most bombed seaside town in WWI. The town suffered from both aerial bombing and naval bombardment during WWI, with Zeppelin's scattering a number of bombs in all districts in the area.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress. For these reasons, there is a limited risk that UXBs passed undiscovered. When combined with the relative infrequency of attacks and an overall low bombing density the risk from WWI UXBs is considered low and will not be further addressed in this report.

8.1.2 Second World War

At the start of WWII, the Luftwaffe planned to destroy key military installations, including RAF airfields and Royal Navy bases, during a series of daylight bombing raids. After the Battle of Britain these tactics were modified to include both economic and industrial sites. Targets included dock facilities, railway infrastructure, power stations, weapon manufacturing plants and gas works. As a result of aircraft losses, daylight raids were reduced in favour of attacking targets under the cover of darkness.

Kent played a key role in the defence of Britain in WWII. It was at the frontline during the Battle of Britain during which the Luftwaffe attempted to destroy the RAF and its airfields in order to gain air superiority over the south-east of England ahead of the planned German invasion. Bombing raids

began in July 1940 from German-occupied France and in the following months many of the towns and cities in Kent were subjected to bombing attacks.

Within Kent, Manston airfield, located 1.7km north of the site, was a key target for the Luftwaffe especially during the Battle of Britain, where RAF Manston sustained serious bomb damage. Most of the staff dispersed into the surrounding houses due to the destruction.

By May 1941, concentrated attacks were reduced as the Luftwaffe was diverted east to prepare for 'Operation Barbarossa', the invasion of Russia. Note however, that Canterbury, 14.5km south-west, was heavily bombed in mid-1942 as part of the Baedeker Blitz.

During 1942 and 1943, there were a number of minor raids carried out by small formations of fighter bombers and then between January and May 1944 the Luftwaffe returned to London en masse, for Operation Steinbock. These raids were executed by inexperienced Luftwaffe crews and were less frequent when compared to the original Blitz of 1940/41. Poor navigation and improved defences resulted in unsustainable Luftwaffe losses and many raids were unsuccessful.

Minster was situated within 'Hellfire Corner'; an area of Kent where aerial 'dog fights' and 'tip and run' bombing incidents were frequent during the Battle of Britain. The region was also under artillery bombardment from the coastal batteries located at Calais and Cap-Gris-Nez in occupied France. These batteries, including the *Lindemann* and *Todt Batteries*, bombarded the south coast until they were captured after the Allied D-Day Landings in 1944. The batteries covered an arc stretching from Ramsgate to Hythe and fired shells weighing approximately 1 ton each.

From mid-1944 the "V-weapon" (for Vengeance) campaign, using unmanned cruise missiles and rockets, represented Hitler's final attempt to reverse Germany's imminent defeat. The V1 (Flying Bomb or Doodlebug) and the V2 (Long Range Rocket) were launched from bases in Germany and occupied Europe.

Although these weapons caused considerable destruction, their relatively low numbers allowed accurate records of strikes to be maintained and these records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since, even if an unexploded 1,000kg warhead had survived impact, the remains of the munition's body would have left incontrovertible evidence of the strike and would have been dealt with at the time.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.

- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.
- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Rural District of Eastry between 1940 and 1945.

Record of German Ordnance Dropped on the Rural District Eastry	
Area Acreage	54,276
High Explosive Bombs (all types)	646
Parachute Mines	14
Oil Bombs	11
Phosphorus Bombs	8
Fire Pots	38
Pilotless Missile (V1)	8
Long Range Rocket (V2)	1
Total	726
Items Per 1,000 Acres	**13.4**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Kent Bomb Census Maps

A review was conducted of the Kent Bomb Census Maps. Those showing incidents on or close to the site are listed below. Note, the maps are small in scale and lack any clear geographical indicators, therefore the site and distance(s) listed below can be considered an approximate.

Date	Weapon	Details
09/07/1940	HE bombs Incendiary bombs	650m east
06/11/1940	2 x HE bombs	500m east
05/12/1940	1 x Incendiary bomb 1 x Aerial mine	Incendiary bomb 500m south-east
Reference		**Annex D**

8.4.2 Kent V1 Bomb Census Map

Following the beginning of the V1 campaign in mid-1944, a series of maps showing where these weapons fell was produced for the London Civil Defence region and these were updated as the war progressed.

V1 Strike Recorded on Site (or in Vicinity)	**✘**
Distance from Site	None recorded in Minster Parish
Reference	**Not annexed**

8.4.3 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

Records which include Map References have been plotted onto a map presented in **Annex E**.

Written ARP records were reviewed for	Rural District of Eastry	
Source	Kent History & Library Centre	
Records of bombing on / near the site were found		✓

Date	Weapon	Map Reference	Details
08-09/04/1940	4 x HEs	n/a	Minster.
19-20/07/1940	13 x HEs 1 x UX HE	n/a	Minster.
14/08/1940	5 x HEs	n/a	Minster.
22/08/1940	1 x HE	n/a	Minster.
22-23/08/1940	10 x HEs 2 x UX HEs	n/a	Minster and Ash.
26/08/1940	17 x HEs 1 x UX HE	752814	Minster and Ash – Between Iron Rly Bridge and Sewage Works and South Side of Stour. On site.
16-17/09/1940	1 x HE	n/a	Minster.
18-19/09/1940	2 x HEs 1 x UX HE	n/a	Minster.
	14 x HEs		Ash.
24/09/1940	1 x UX HE	761818	Minster – South of Brook Cottages. 120m north.
26/09/1940	1 x Oil bomb	750812	Minster – Marsh Farm. On site.
	2 x HEs	750810	Minster – south of Marsh Farm, north of River Stour. On site.
	1 x HE	750806	Minster – south of River Stour. On western boundary of extension area.

	1 x UX HE	767819	Minster – 500yrds south of Brook Cottages. 320m north-east.
13/11/1940	1 x HE	n/a	Ash.
04-05/12/1940	1 x UX PM	n/a	Ash.
28/01/1941	40 x IBs	750811	Minster – east of Marsh Farm. On site.
	7 x HEs	739809	Ash – Goldstone Marshes. 380m south-west.
21/03/1941	1 x UX HE	n/a	Minster.
10/04/1941	1 x HE	760820	West of Brook Crossing, Minster. 390m north.
	1 x Oil bomb	759822	Minster – east of Durlock. 610m north.
05/05/1941	3 x HEs	n/a	Minster.
10-11/06/1941	1 x UX HE	n/a	Ash.
31/10/1942	1 x Firepot	756794	Fleet Farm, Ash. 740m south.
	1 x 50kg UX HE	765799	Ash – 10" hole. Marshland. On / immediately adjacent to site.
	1 x 50kg HE	765799	Ash – Camouflet at least 10ft deep. 26 feet from above entry. This may be the result of the bomb of the above entry having "jinked" in exceptionally soft ground. On / immediately adjacent to site.
	1 x UX HE	753795	Bride Farm, Ash. Discovered 01/12/1942. 730m south.
	1 x UX HE	765799	Whitehouse Marsh, Ash. Discovered 02/11/1942.

			On / immediately adjacent to site.
18/01/1943	1 x 250kg HE	758821	Minster – North of Ramsgate, Margate Line. 610m north
06/09/1943	1 x HE	761812	Minster – Exploded in air near signal box. On site.
04/02/1944	1 x 50kg Phosphorus IB	745819	Minster – Marshland at Eden Hall Farm. Land water reaches within 2′ 6″ of surface. Phosphorus remains in hole of entry but no trace can be found after digging to a depth of 6′ 6″. On site.

8.4.4 Secondary Source / Anecdotal Evidence

Anecdotal evidence of local bombing incidents was sought from publications and web resources. No references to incidents on site were found.

8.4.5 WWII-era RAF Aerial Photography

The following WWII-era aerial photography was reviewed for the site:

Date	Circa 1946
Source	Kent County Council
Image Type	Aerial
Image quality	Moderate resolution and small scale
Observations	• The aerial image confirms the site predominantly comprised open ground separated by a series of drainage ditches. • A group of over 20 crater-like features, consistent with HE bomb strikes, has been highlighted in the southern half of the site, to the south and east of the Sewage Works. • More craters are also present in the northern section of the site. • The structures on site have survived WWII largely intact. However, due to the small scale and resolution of the image an accurate assessment for any possible structural damage is not possible. • Extension area: The image confirms the extension area comprised undeveloped fields and drainage ditches. No evidence of bomb damage is apparent within its boundary.

Reference	Annex F

8.4.6 Decoy Bombing Sites

A national decoy authority headed by Colonel John Fisher Turner was set up in July 1940, and following earlier experiments in Glasgow and Sheffield, a system of urban lighting decoys was set up. These were known as "Civil" sites; Civil 'QL' for urban lighting simulation, and Civil 'QF' for dummy fires. "Q" – sites were equipped with assorted electrical and pyrotechnical apparatus to simulate the flare given from furnace doors, steel-making, railway marshalling yards, and light given off by inefficient blackout precautions.

Other sites simulated small fires started by incendiary bombs, with oil-storage area fire simulation being developed near large oil installations. A further variation on fire decoy sites was the "SF", or "Special Fires" sites. A larger, longer-burning type of fire was provided at these sites - known as "Starfish" sites - to draw incendiary bombs, and hopefully as a consequence the full enemy payload, from falling on the larger conurbations and defence installations during heavy air raids. Decoy sites had a good level of success – airfield decoy sites across Britain for example had received 359 attacks by the end of 1941. The real airfields were bombed 358 times.

A bombing decoy site was established in close proximity to the site	✓
Distance from site	1.1km south-west
Additional Comments	• A 'Q' type decoy was constructed 1.1km south-west of the site. This night decoy was established to draw Luftwaffe bombing away from RAF Manston, 1.9km north of the site. • This night decoy, which simulated an active airfield, was in operation from 1st August 1941 to 12th August 1942. However, no records could be found to suggest the decoys level of success.

8.4.7 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✓
Additional Comments	• 2 x 50kg HE bombs – Located on or near Eden Hall Farm, Minster. These are recorded in the north-western extent of the site.

	• 2 x unknown UXBs – Located in field near railway, south-east of Minster Station on Minster Marshes (eastern section of the site).

8.5 UXB Ground Penetration

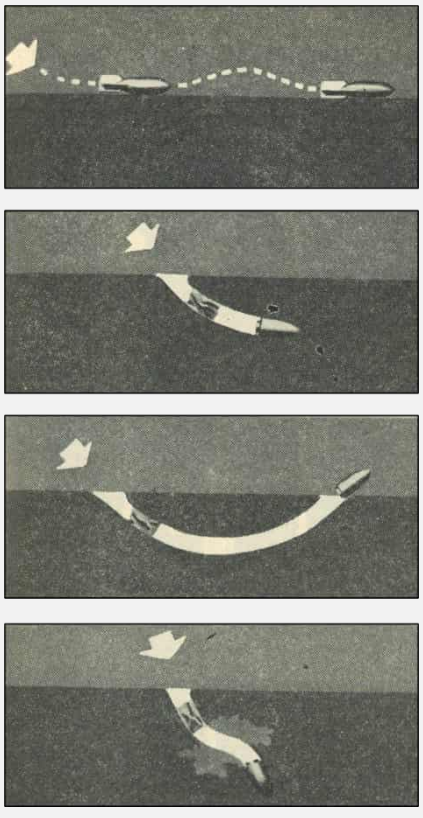
8.5.1 General Considerations

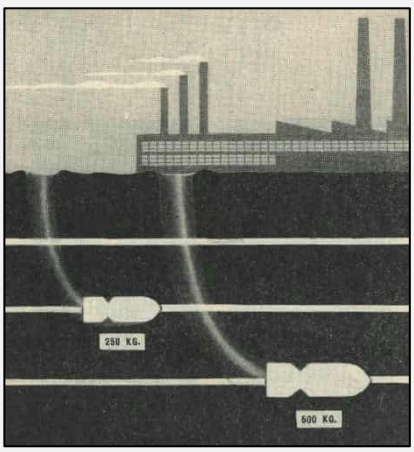
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

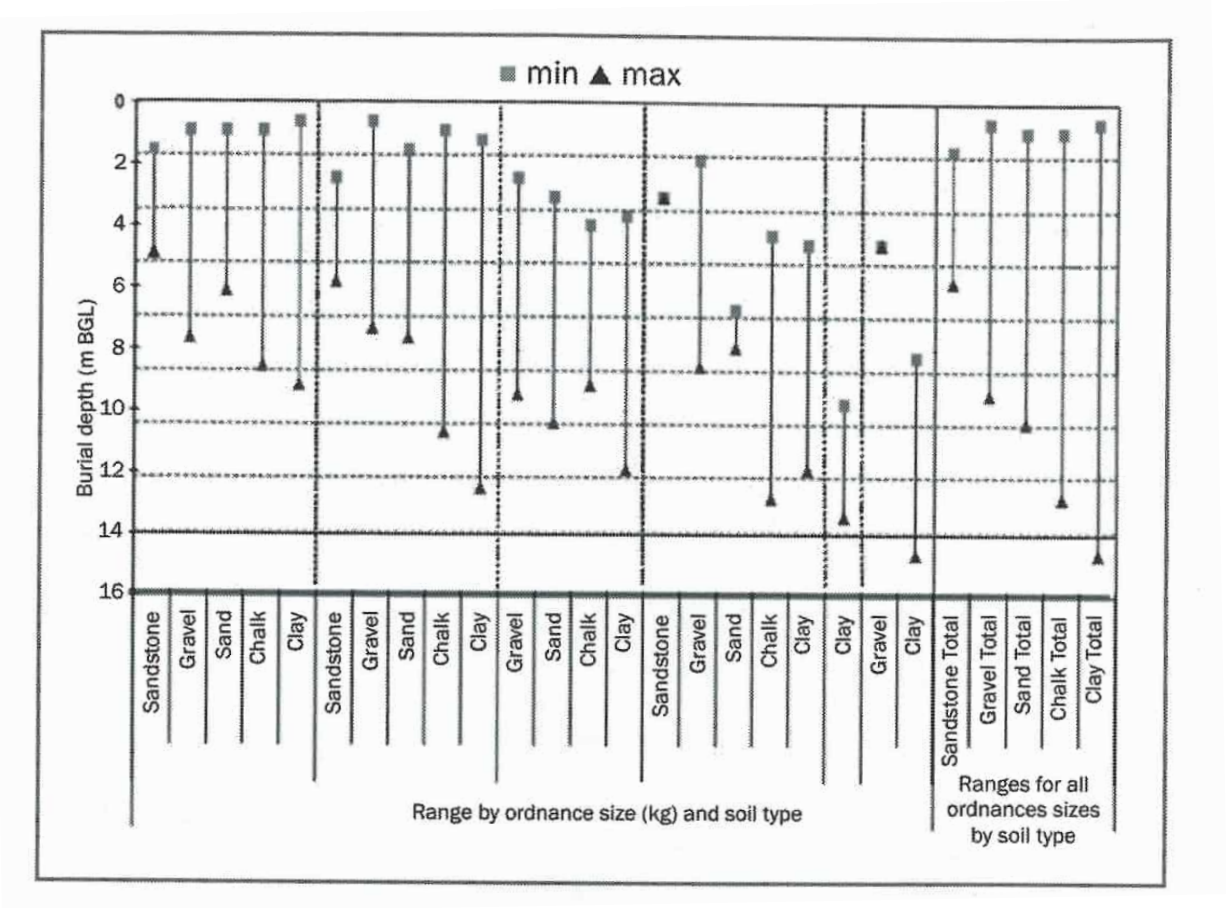
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – 0.23m of Topsoil, Ballast, Roots and Ashes, 1.50m of firm Clay, 4.06m of soft Clay, 3.66m of sandy Clay and 1.17m of clayey Silt
- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 10-12m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.6.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Moderate	While the overall bombing density of the Rural District of Eastry was low, the Parish of Minster sustained a comparatively higher density of bombing due to the presence of RAF Manston.
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✓	The following were recorded on site: 20 x HE bombs, 1 x UXB, 1 x Oil bomb and 41 x IBs
	What is the distance between the site boundary and the closest recorded large bomb strike?	On site	The following were recorded on site/immediately adjacent with its boundary: 1 x HE bomb and 2 x UXBs

	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	2	
	Were any nearby sticks of large bombs recorded in line with the site?	✓	
	Were any 1kg incendiary bomb showers recorded over the site?	✓	41 x IBs recorded on site.
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	✗	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✓	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	✗	
	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✗	
	The site was exclusively or partially developed during WWII.	✓	A number of small farm buildings and a Sewage Works was present on site.
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	✓	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✓	Note however, while the site was occupied by a roadway and footpaths, the site was situated in a rural location. Therefore it is considered unlikely these routes would have been as frequently used as those in urban areas.
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✗	

	The site was occupied by a school during WWII.	✖	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✓	It is possible the Sewage Works was subjected to post-raid searches for UXO.
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	✖	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✖	
	The site was occupied by a graveyard which would have experienced limited access.	✖	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	
	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✖	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✓	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖	
	The site was occupied by dense, inaccessible vegetation during WWII.	Possibly	
	The site may have been susceptible to waterlogged conditions during WWII.	✓	
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✓	

	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✓	
	The site was occupied by stockpiled material during WWII.	✗	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	✓	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	✗	
	The site was occupied by well-maintained, manicured lawn during WWII.	✗	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	
Bomb Failure Rate	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✗
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✓
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 Port Richborough

Port Richborough, nicknamed port "Q", was established in 1914 on the banks of the River Stour, was kept a secret and served as a significant military outpost. Throughout WWI, the port was used for manning and arming barges being sent to Dover and subsequently France.[1] The port became militarised during WWI, multiple stores for equipment used for supplying the barges were erected in and around the banks. Moreover, defensive positions were established around the Port especially on the flats towards the mouth of the River Stour.

During WWII the port served as a military outpost for the Royal Marines in 1942, named H.M.S Robertson. The Port was considered "a hive of industry" in preparation for D-Day, with many troops were stationed in the nearby Richborough Camp and factory workers working throughout the blackout in the port factory.[2] The port was located approximately 840m south-east of the site.

9.2 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas

[1] *https://blog.railwaymuseum.org.uk/port-of-richborough-and-the-birth-of-the-cross-channel-train-ferry/*
[2] *http://www.open-sandwich.co.uk/town_history/richborough_port.htm*

of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[3]

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015

[3] Various News Sources

	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.3 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.4 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Nearest Home Guard Battalion to the site	6th Kent (Thanet) Home Guard Battalion
Home Guard Activity on site	• The Thanet Battalion primarily operated out of Margate, approximately 7km north-east from the site. However, the exact locations of their HQ or training areas were not found.

	• Anecdotal evidence suggests the Minster Platoon of the Thanet HG used a building in the High Street, approximately 700m north of the site, for training purposes[4].
	• Monkton HG Platoon also operated in the area, utilising a chalk pit, approximately 2.9km north-west of the site, for rifle and spigot mortar practice[5].
	• Further military activity in the area included:
	  o The requisition of Walters Hall, 1.3km north-west, by the military.
	  o A camp, built for the construction of Richborough Port, was located approximately 600m south-east[6].
	  o A stores depot for Richborough Port 500m east of the site[7].
	• Typically, HG soldiers would take part in training exercises in areas occupied by open countryside. Furthermore, HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion.
	• Marshy land between Minster and Pegwell Bay was used as a mortar training range during WWII, however no details regarding the full extent of the training area could be located. Therefore the possibility of such training taking place on site cannot be discounted.
	• Note, a mortar was discovered approximately 220m north of the site (see Section 10.2.2), confirming local training activity.
	• Given the strong military / HG presence in the area and the site comprising undeveloped ground, the possibility the site was used for training purposes cannot be discounted.

Defensive features within the vicinity	• WWII road block established across Ebsfleet Lane, approximately 1.1km east[8]. • 3 x anti-tank ditches within 1km. • A WWII-era structure, possibly a lookout post, located 790m east of the site[9]. • A WWI/WWII gun pit located 1.1km south[10]. • Incomplete pillbox 550m east[11]. • Gun emplacement 660m east[12].
Number of HAA batteries within 5km of the site	6

[4] http://sussexhistoryforum.co.uk/index.php?topic=4146.0
[5] http://sussexhistoryforum.co.uk/index.php?topic=7549.0
[6] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MKE42005
[7] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=Mke42007
[8] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43194
[9] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43260
[10] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43481
[11] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43258
[12] https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43259

Threat to the site from unexploded AA shells	• The nearest HAA battery was approximately 2.7km north from the site, situated close to RAF Manston. • Furthermore, a number of light AA batteries were established across the area. This includes a Bofors AA battery 1.5km east, LAA battery 1.6km east, and a machine gun post 2km east[13]. • RAF Manston and the surrounding area was targeted and attacked by the Luftwaffe several times during WWII. During such attacks, it is likely that a significant degree of AA fire would have occurred over the site. • The site was occupied by undeveloped marshy ground / a river / ditches during WWII. In such ground conditions, an unexploded AA shell could go unnoticed.

9.5 Generic Types of WWII British / Allied Unexploded Ordnance

9.5.1 Land Service Ammunition (LSA)

9.5.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars

b. Grenades

c. Projectiles

d. Rockets

e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

[13] *https://webapps.kent.gov.uk/KCC.ExploringKentsPast.Web.Sites.Public/SingleResult.aspx?uid=MWX43191*

9.5.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.5.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.5.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

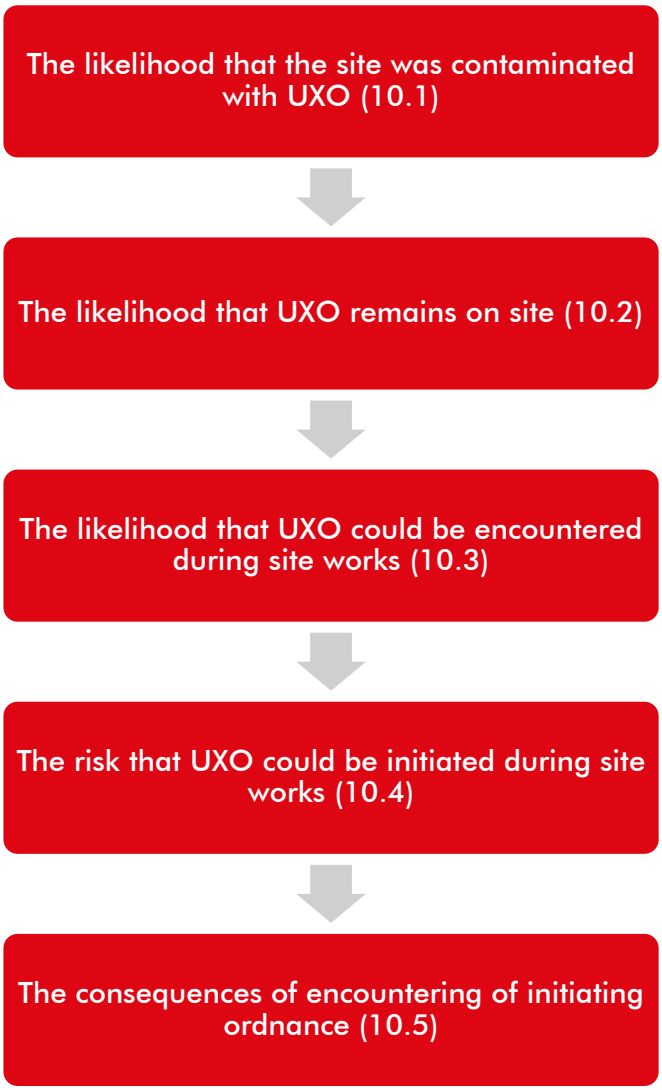
The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

10.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

10.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

10.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• 20 x HE bombs plotted on site • 1 x UXB plotted on site • 1 x Oil bomb plotted on site • 41 x IBs plotted on site • 4 x officially recorded abandoned bombs on site
Bomb Damage	• Over 20 bomb craters present within the site boundary
Ground Conditions	• Majority of the site comprised marshland • A sewage works and multiple small farm buildings on site • Railway line present in the eastern section • River crossing the southern extent
Frequency of Access	• Likely infrequent access to marshland • Likely seasonal access to remote farm structures • Sewage Works likely more frequently accessed
J-Curve Effect	• Had any UXB landed within the soft ground / waterways on site, it could have come to rest beneath the adjacent undamaged areas.
Other considerations	• Bombing decoy site 1.1km south-west
Overall Likelihood of Contamination	**High**

10.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• Several Platoons of the Thanet Home Guard Battalion operated in the area. • Additional military activity in the area included: a military camp 600m south-east and a stores depot 500m east.

	• At least seven defensive features within 1.1km of the site. • Marshy land between Minster and Pegwell Bay used as a mortar training range during WWII. • A mortar was discovered approximately 220m north of the site, confirming local training activity. • Given the strong military / HG presence in the area and the site comprising undeveloped ground, the possibility the site was used for training purposes cannot be discounted.
Anti-Aircraft Projectiles	• Six HAA batteries were situated within a 5km radius of the site during WWII. The closest of which was approximately 2.7km north from the site. • A number of light AA batteries were established across the area including a Bofors AA battery 1.5km east, LAA battery 1.6km east, and a machine gun post 2km east. • The site was occupied by undeveloped marshy ground / a river / ditches during WWII. In such ground conditions, an unexploded AA shell could go unnoticed.
Overall Likelihood of Contamination	**Medium**

10.2 The Likelihood that Unexploded Ordnance Remains on Site

10.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

10.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	• 1st November 1967 – A WWII mortar was recovered from the roadway in close proximity to Minster Railway Station. It was removed and subsequently

	destroyed[14]. Minster Railway Station is located approximately 220m to the north of the site. • 14th November 1962 – A UXB was found at Hoo Farm, Minster[15]. Hoo Farm is located approximately 970m north. • 20th July 1962 – A mortar was discovered at Wayborough Farm, Minster, in a field at the junction of Canterbury Road[16]. Wayborough Farm is located approximately 1.3km north of the site. • 13th October 1954 – A suspected UXB was found in a field adjoining the road leading from Monkton roundabout to Birchington (1.9km north-west)[17].
Local tasks undertaken by SafeLane Global	None

10.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✖
Further Details	No significant redevelopment works have taken place on site in the post-war period.

10.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	No known redevelopment has been undertaken on site.
Further comments	Within the footprints of the post-war redevelopment / ground works, the risk of shallow buried UXO (especially German 1kg incendiaries) remaining will have been partially mitigated since any such items could have been encountered and removed during soil stripping and levelling. As no such works appear to have taken place post-WWII, this is considered unlikely. Only within the volume of any post-war basement level bulk excavations and at the precise locations of any post-war pile foundations / boreholes, will the risk from deeper buried German HE UXBs have been completely mitigated. As no

[14] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19671101/001/0001

[15] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19621114/012/0001
[16] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19620720/003/0001
[17] https://www.britishnewspaperarchive.co.uk/viewer/bl/0003350/19541013/195/0010

	known bulk excavations have been carried out onsite, the risk from deep buried UXO remains unmitigated to the maximum bomb penetration depth

10.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The proposed works comprise ground investigations including machine excavated trial bits and cable percussion boreholes. here is an elevated likelihood of UXO being encountered during these works.

10.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

10.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.

Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

10.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

10.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

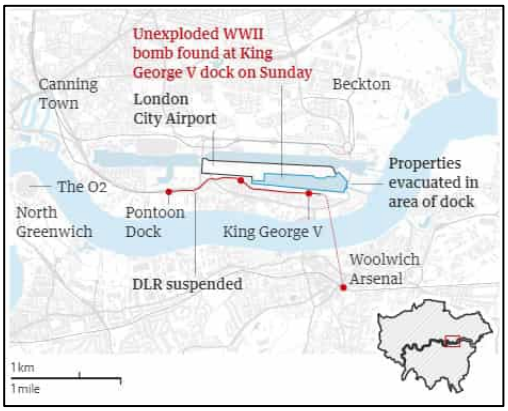
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

11 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

11.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be **High**.

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	High	High	High	Severe	**High**
German 1kg Incendiary Bombs	Medium	Medium	Medium	Severe	**Medium**
Allied Anti-Aircraft Shells	Medium	Medium	Medium	Minor	**Medium**
British / Allied Small Arms	Medium	Medium	Medium	Not Significant	**Medium**
Land Service Ammunition	Medium	Medium	Medium	Moderate	**Medium**

12 Proposed Risk Mitigation Strategy

SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

12.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
High	Shallow Intrusive Works eg. excavations	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Explosive Ordnance Disposal (EOD) Engineer to support Site Investigation (SI) • Non-Intrusive (NI) Magnetometer Survey (Greenfield areas only) • Target Investigation (Required as a follow-on from NI magnetometer survey)
	Deep intrusive works (eg. piling)	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course • Intrusive Magnetometer Survey of pile/borehole positions

12.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. • Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer.

	• Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.
Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard.

	• Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required. • Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).

Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required. The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation**

	If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques. • Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

Bibliography

The key sources consulted during this assessment are listed below;

i. Bates, H, E., *Flying Bombs over England*, (Frogletts Publications Ltd. 1994).

ii. Dobinson, C., *AA Command: Britain's Anti-Aircraft Defences of the Second World War*, (Methuen 2001).

iii. Fegan, T., *The Baby Killers': German Air raids on Britain in the First World War*, (Leo Cooper Ltd. 2002).

iv. Fleischer, W., *German Air-Dropped Weapons to 1945*, (Midland Publishing. 2004).

v. Jappy, M. J., *Danger UXB: The Remarkable Story of the Disposal of Unexploded Bombs during the Second World War*, (Channel 4 Books, 2001).

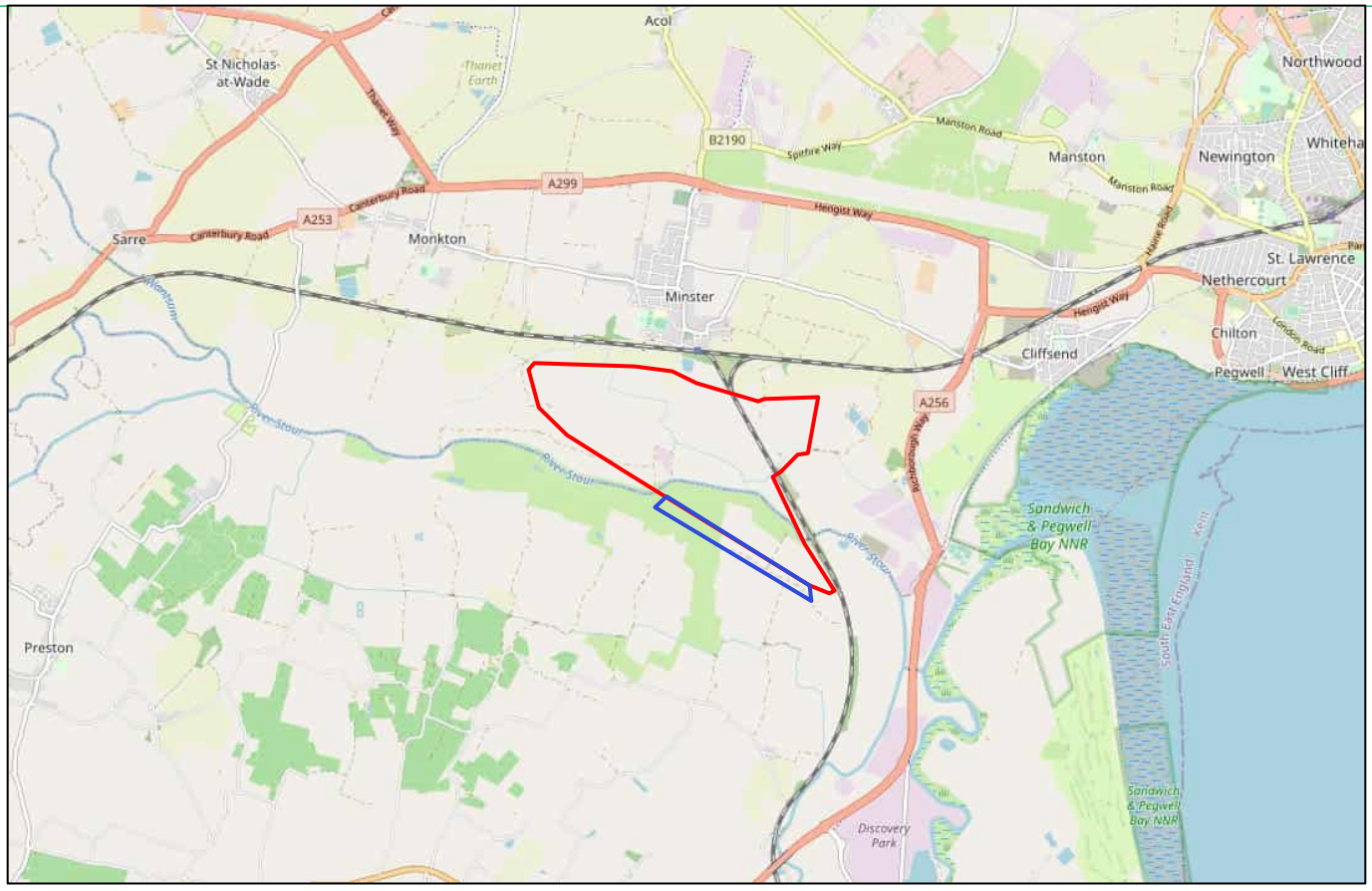
vi. Price, A., *Blitz on Britain, The Bomber Attacks on the United Kingdom 1939 – 1945*, (Purnell Book Services Ltd. 1977).

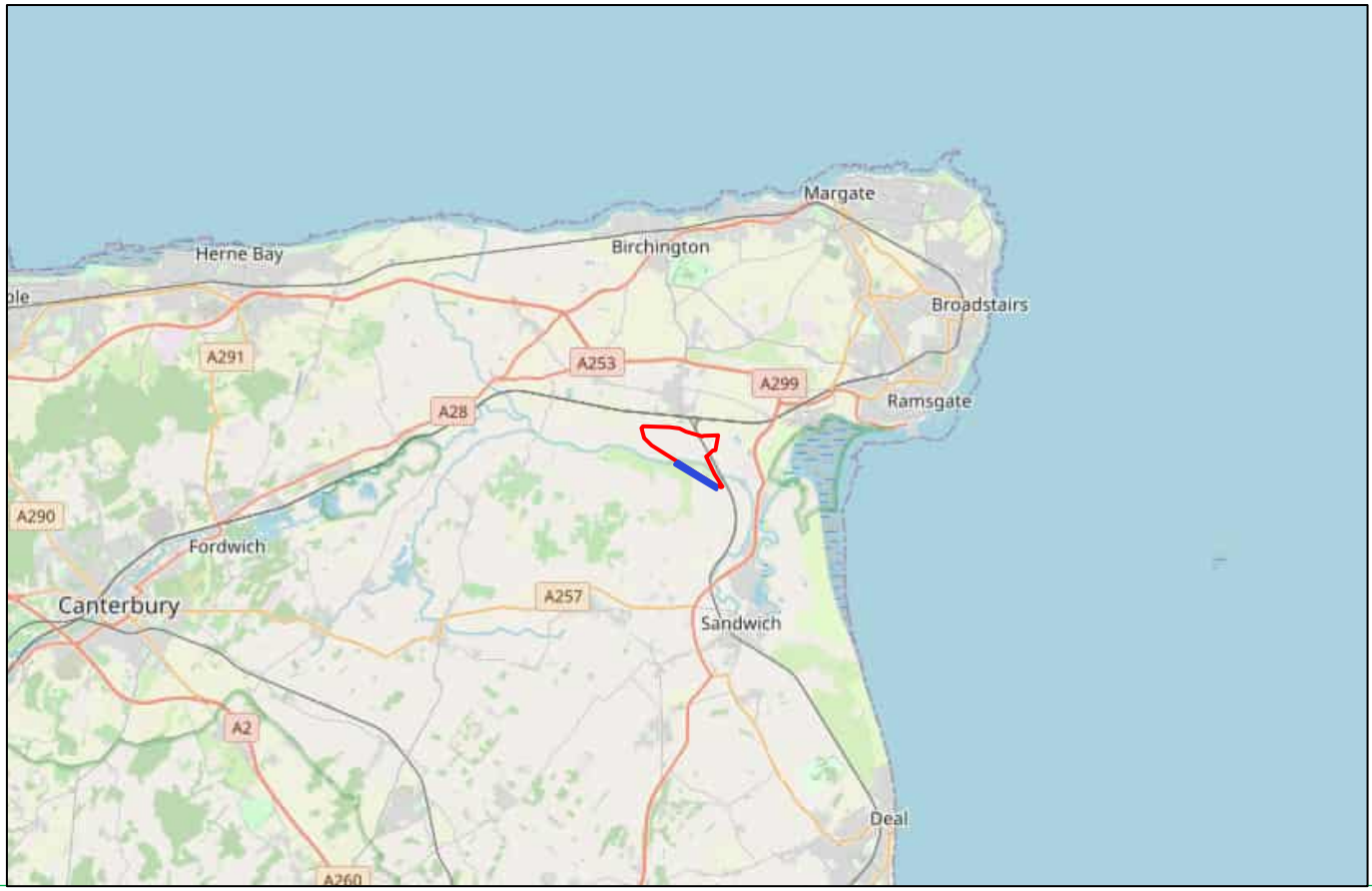
vii. Ramsey, W., *The Blitz Then and Now, Volume 1*, (Battle of Britain Prints International Limited. 1987).

viii. Ramsey, W., *The Blitz Then and Now, Volume 2*, (Battle of Britain Prints International Limited. 1988).

ix. Ramsey, W., *The Blitz Then and Now, Volume 3*, (Battle of Britain Prints International Limited. 1990).

x. Whiting, C., *Britain Under Fire: The Bombing of Britain's* Cities 1940-1945, (Pen & Sword Books Ltd. 1999).





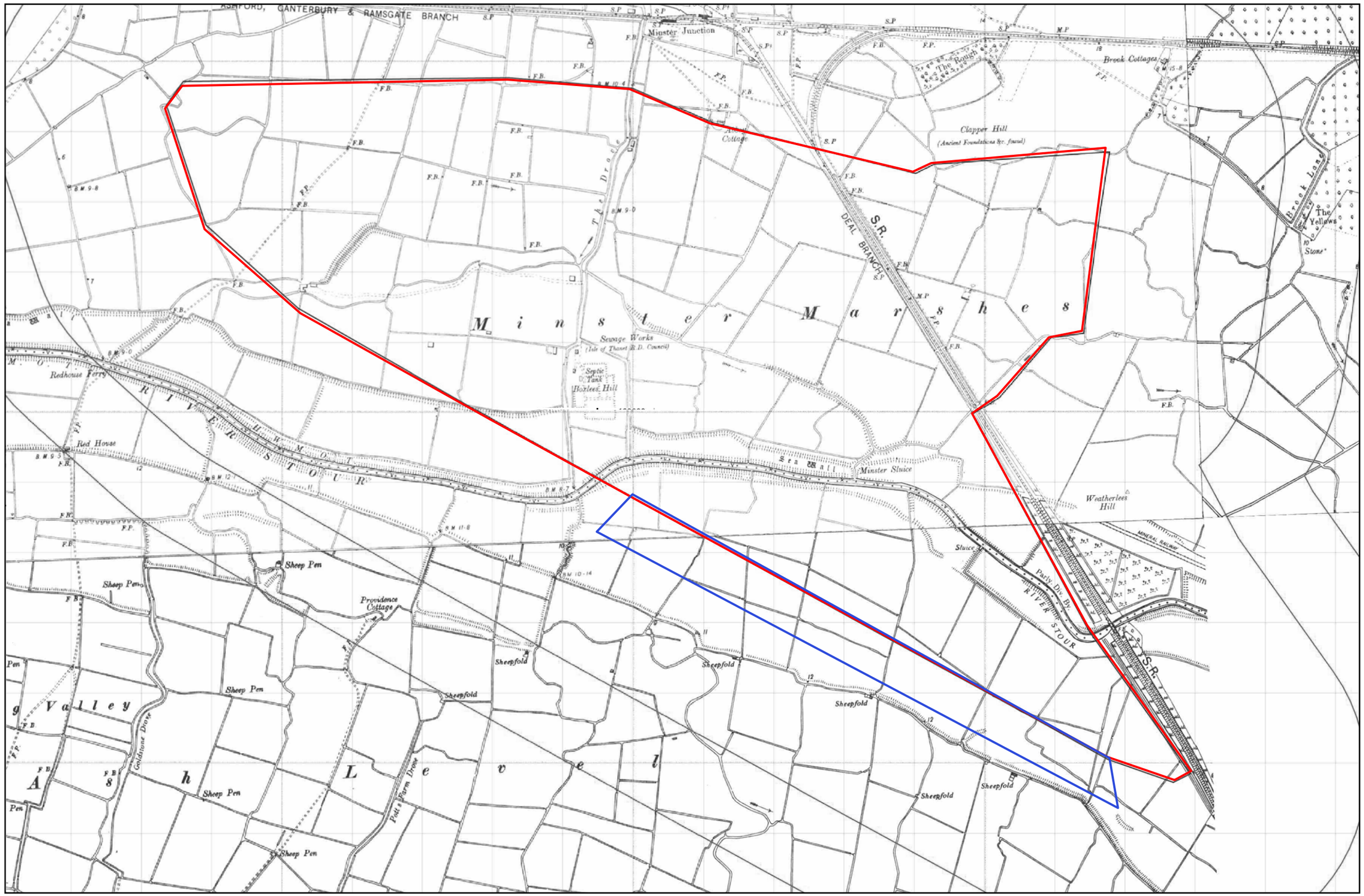
© OpenStreetMap contributors

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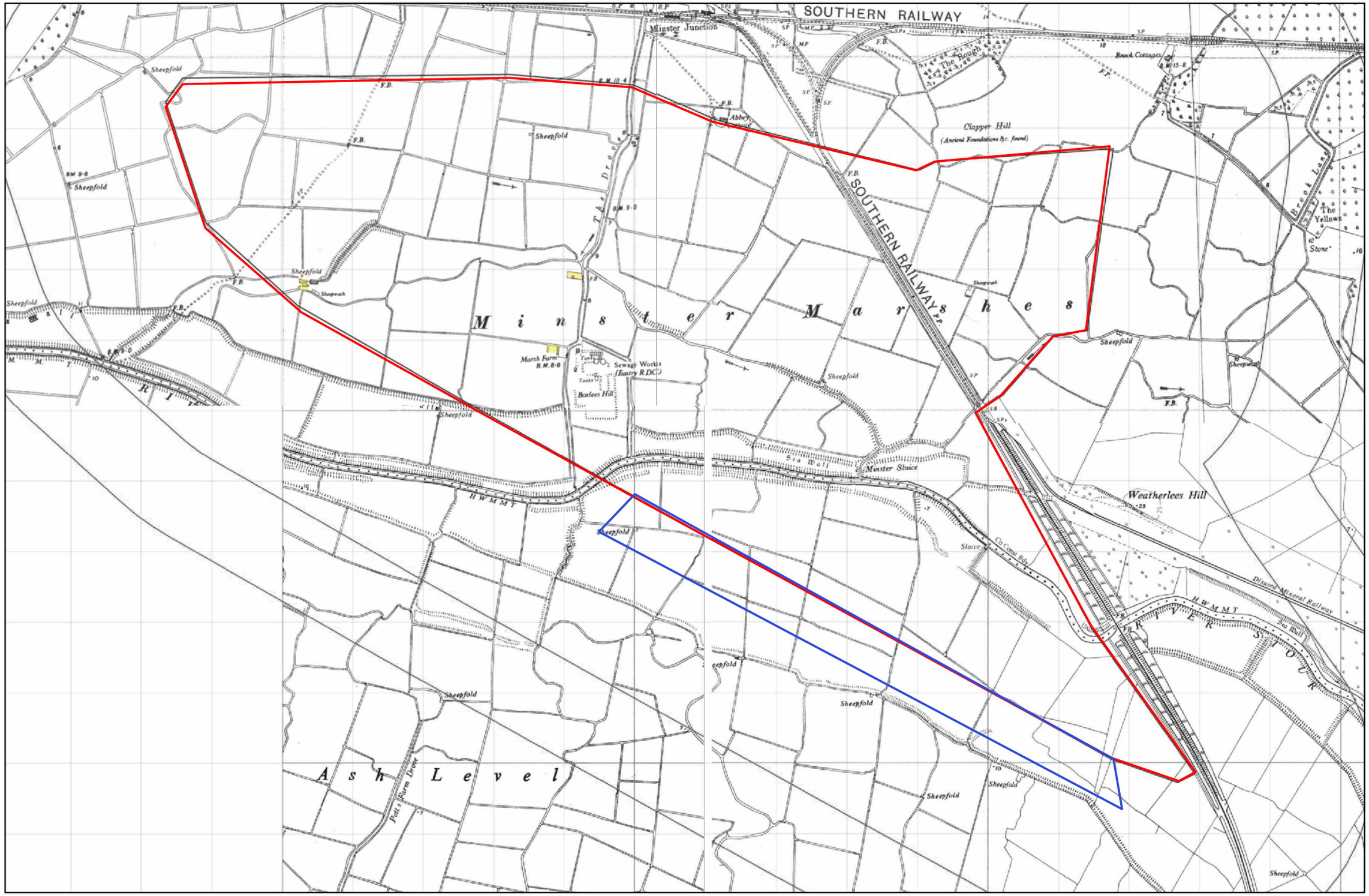


Approximate site boundary

Approximate extension area



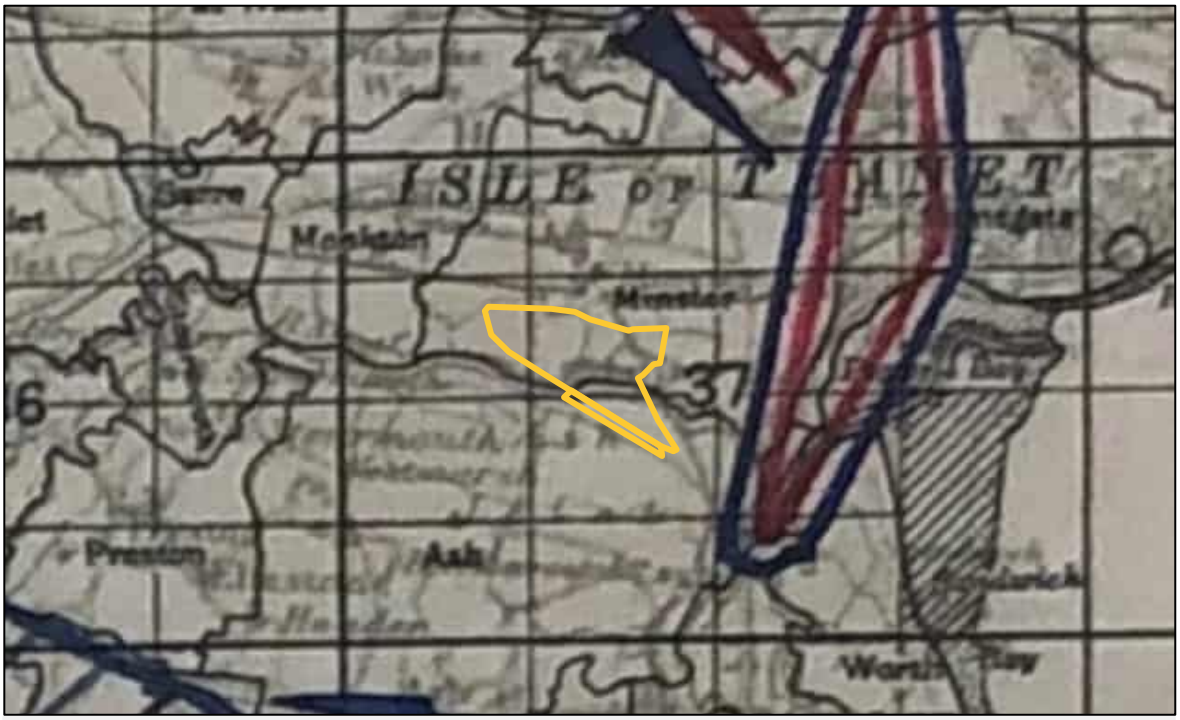
Approximate site boundary Approximate extension area



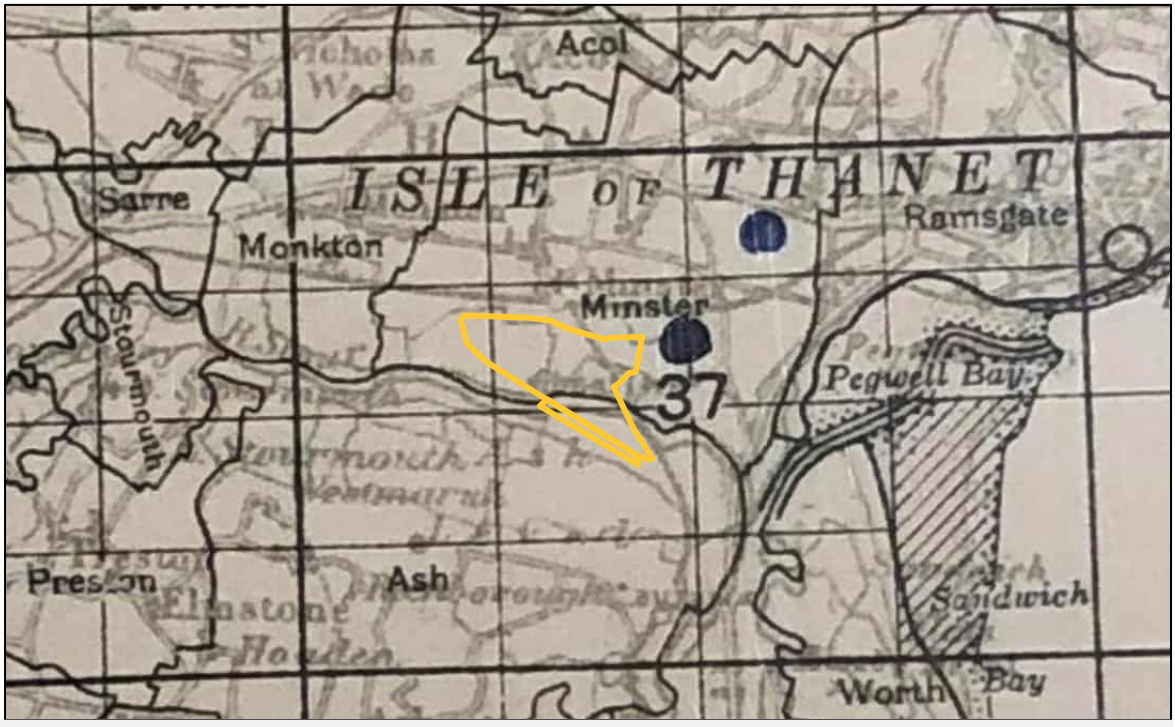
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Approximate site boundary Approximate extension area Redevelopment

N



9th July 1940



6th November 1940

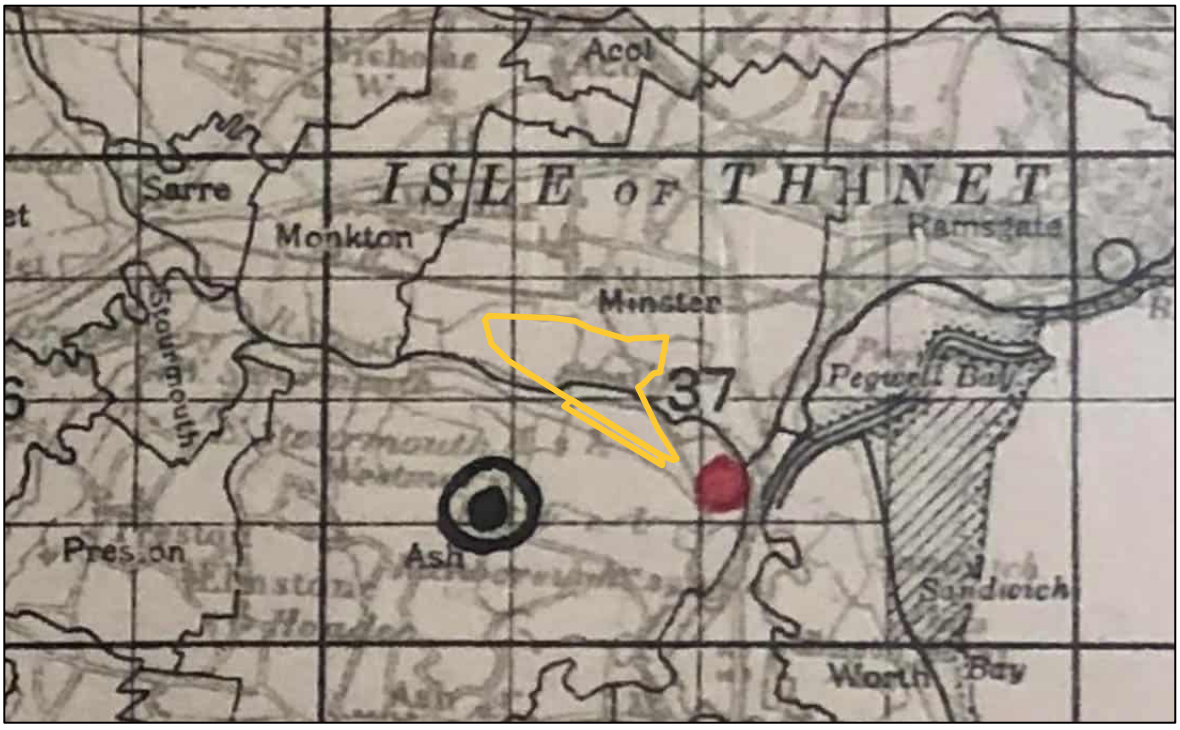
Approximate site boundary

HE bomb strike

Incendiary shower

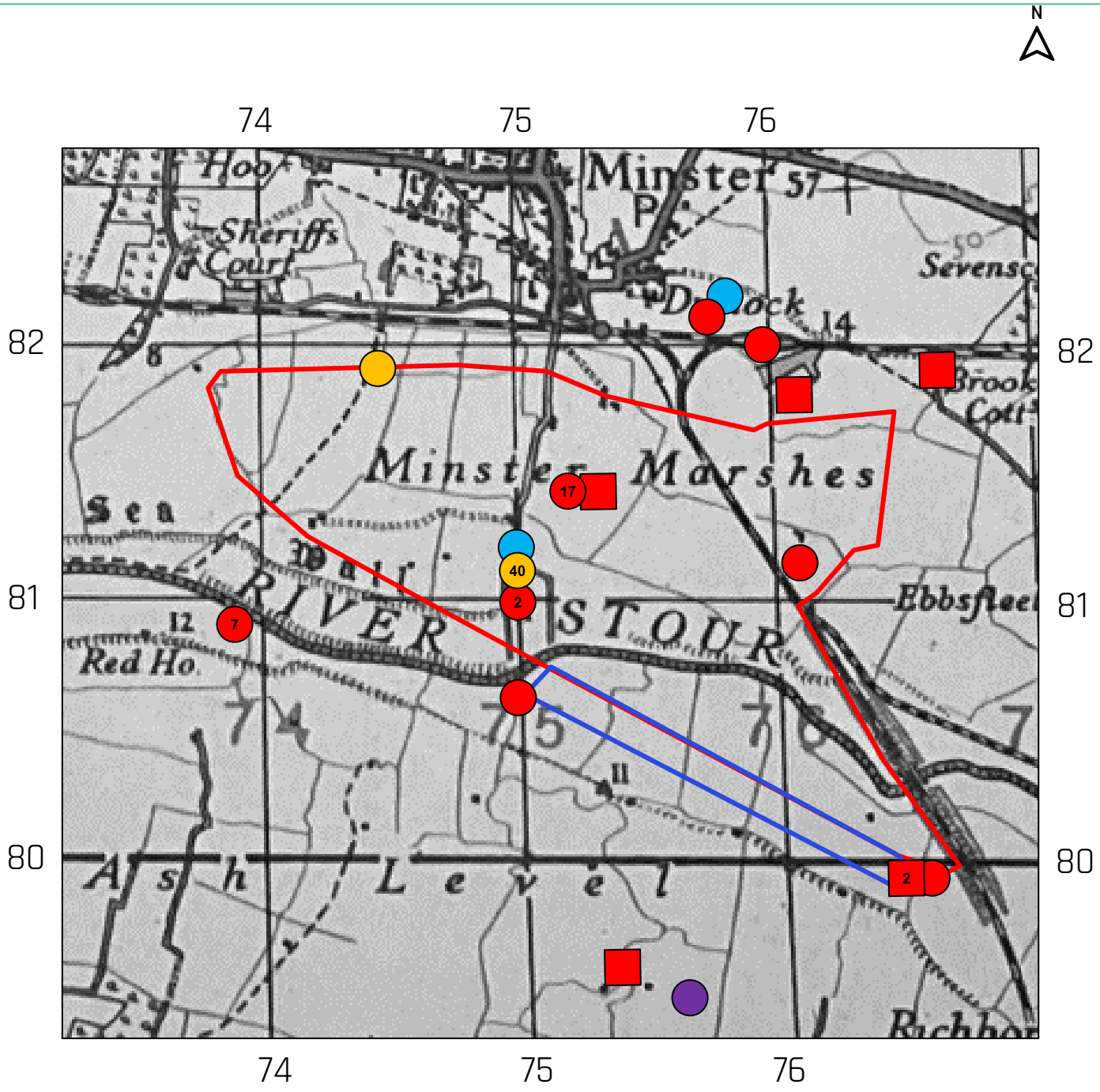
HE bomb area

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5th December 1940

Approximate site boundary Incendiary bomb Aerial mine



Approximate site boundary

HE bomb

Unexploded HE bomb

Incendiary bomb

Oil bomb

Firepot

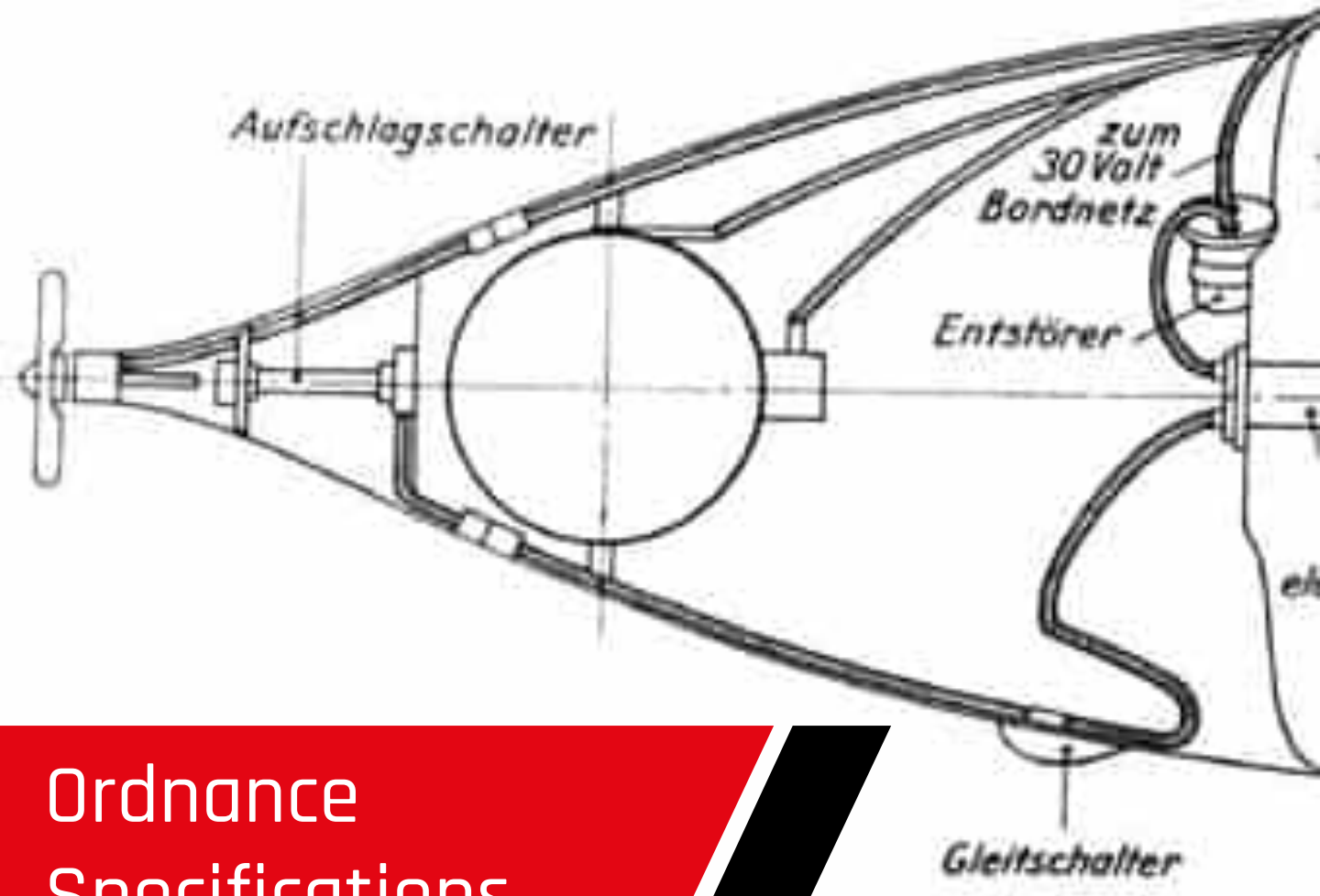
(Numbers in circles denote quantity of explosive ordnance recorded)

WWII-era RAF Aerial Photography – Circa 1946

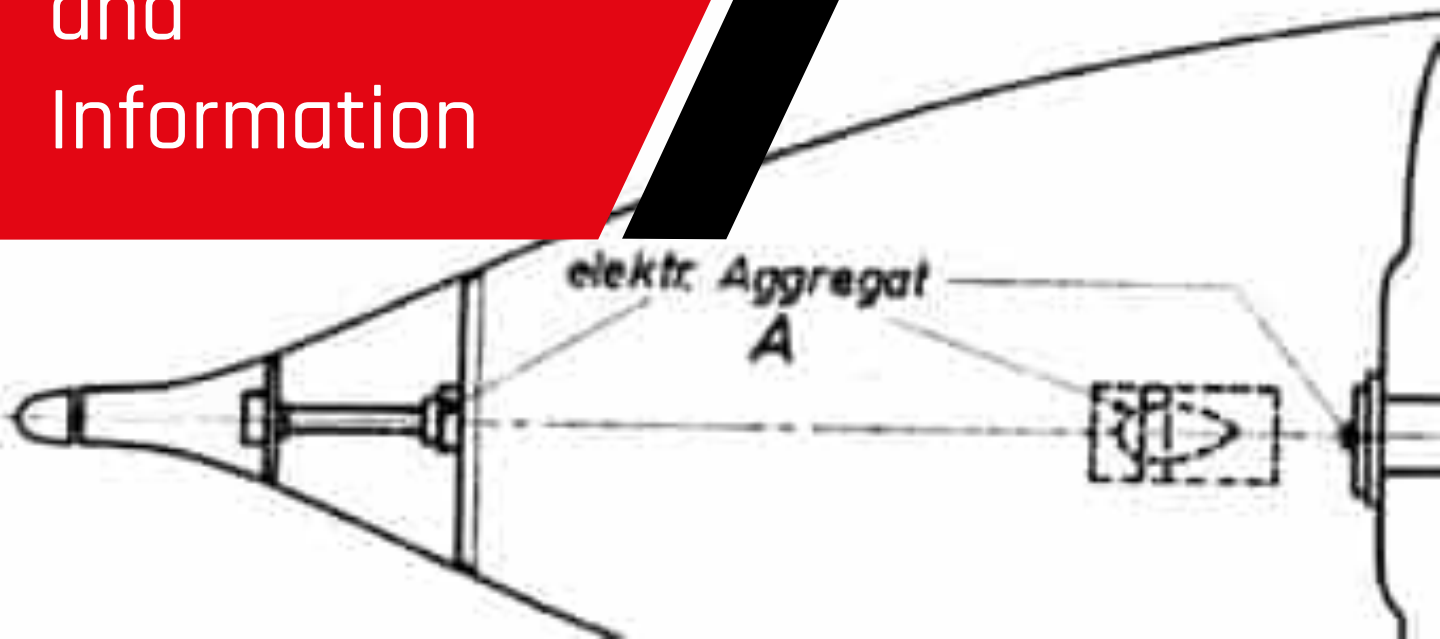


Kent County Council

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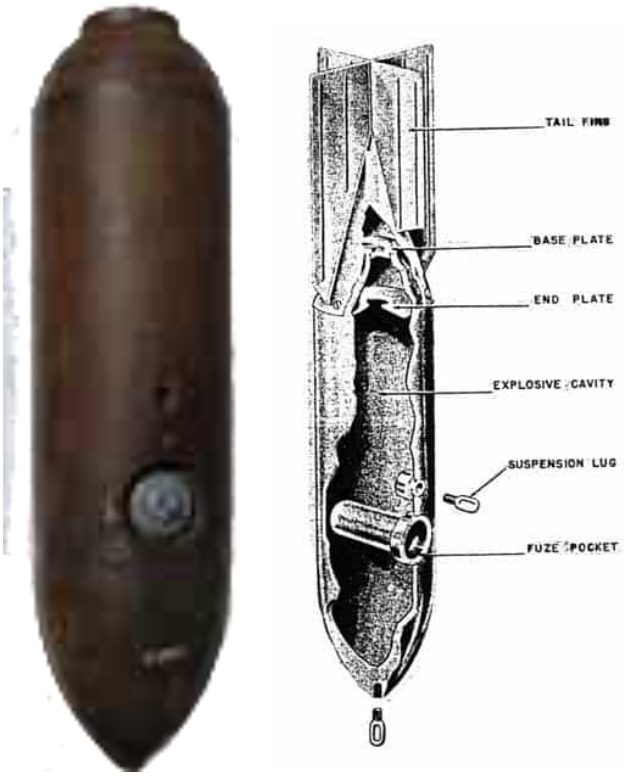


Ordnance Specifications and Information





German Ordnance





Sprengbombe Cylindrisch 50

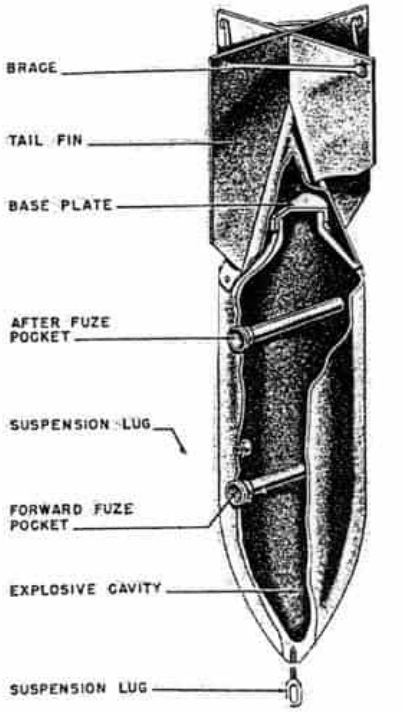
Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)







Sprengbombe Cylindrisch 250

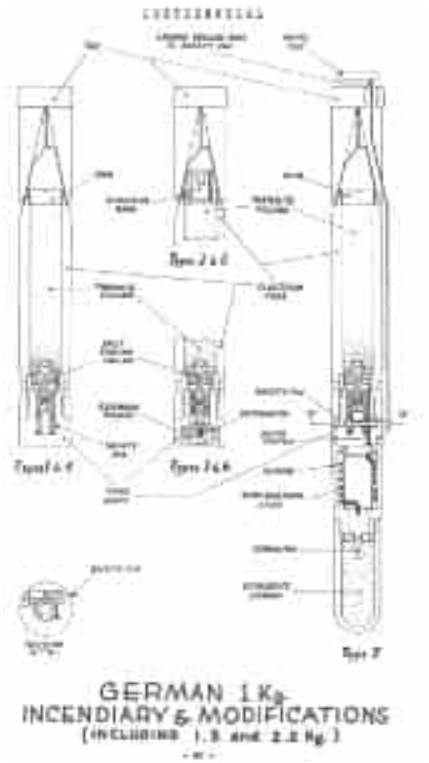
Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.









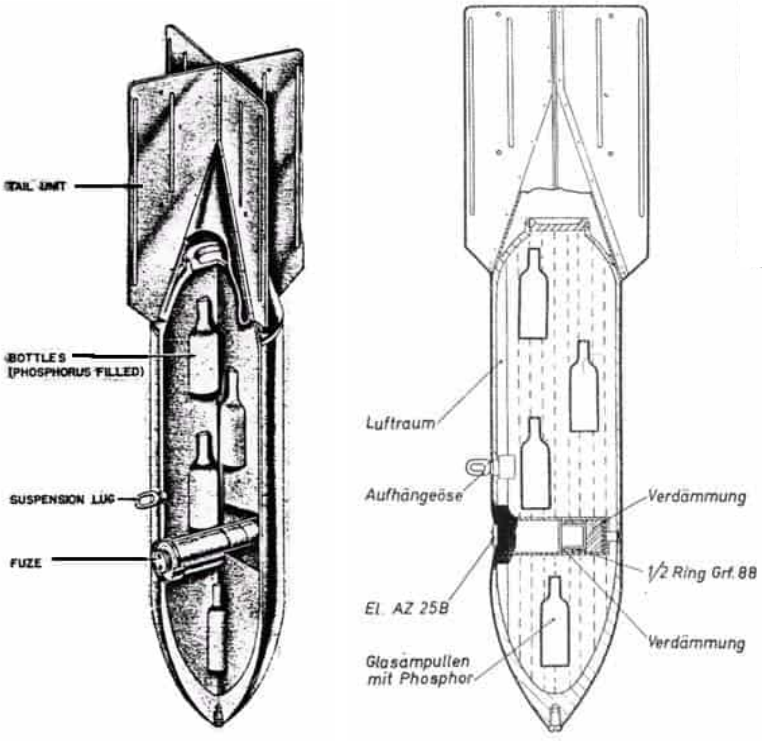
Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.

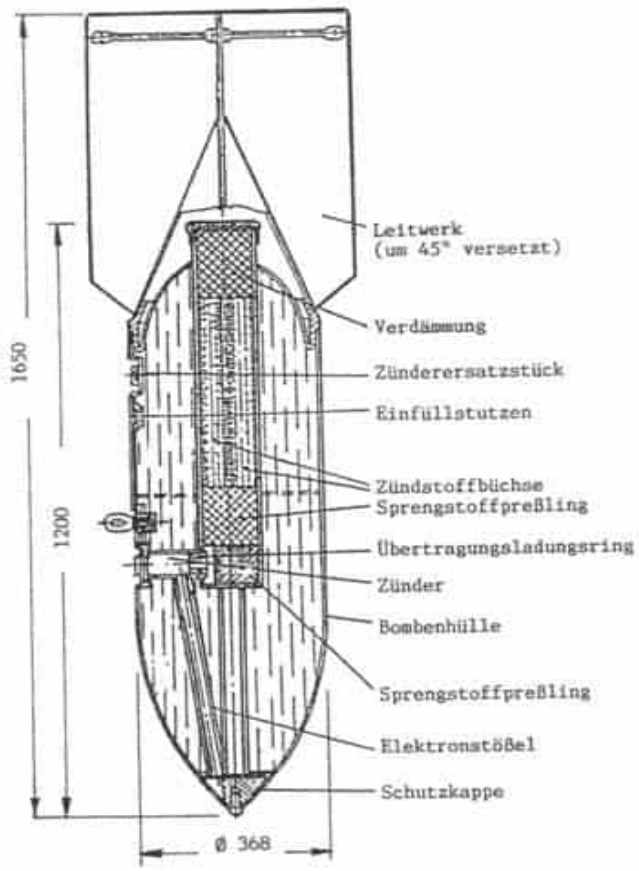






C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture

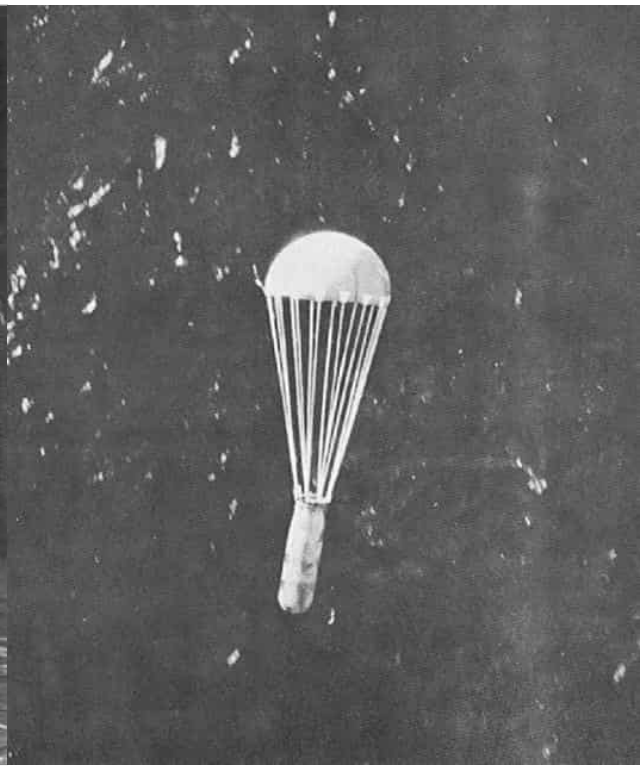




Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration





Luftmine A/B 'Parachute Mine'

Bomb Weight: A- 500kg, B – 1000kg

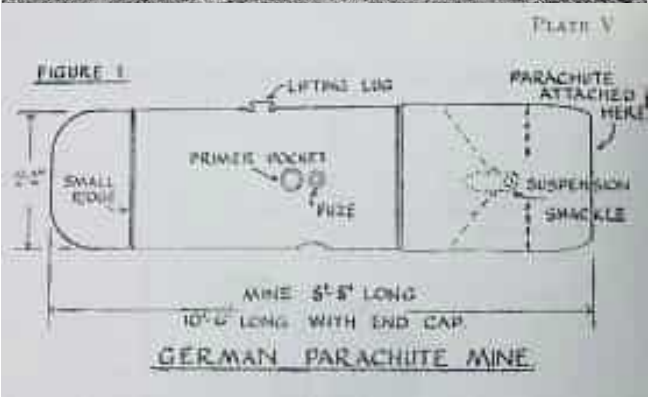
Fuze Type: Mechanical clockwork fuze

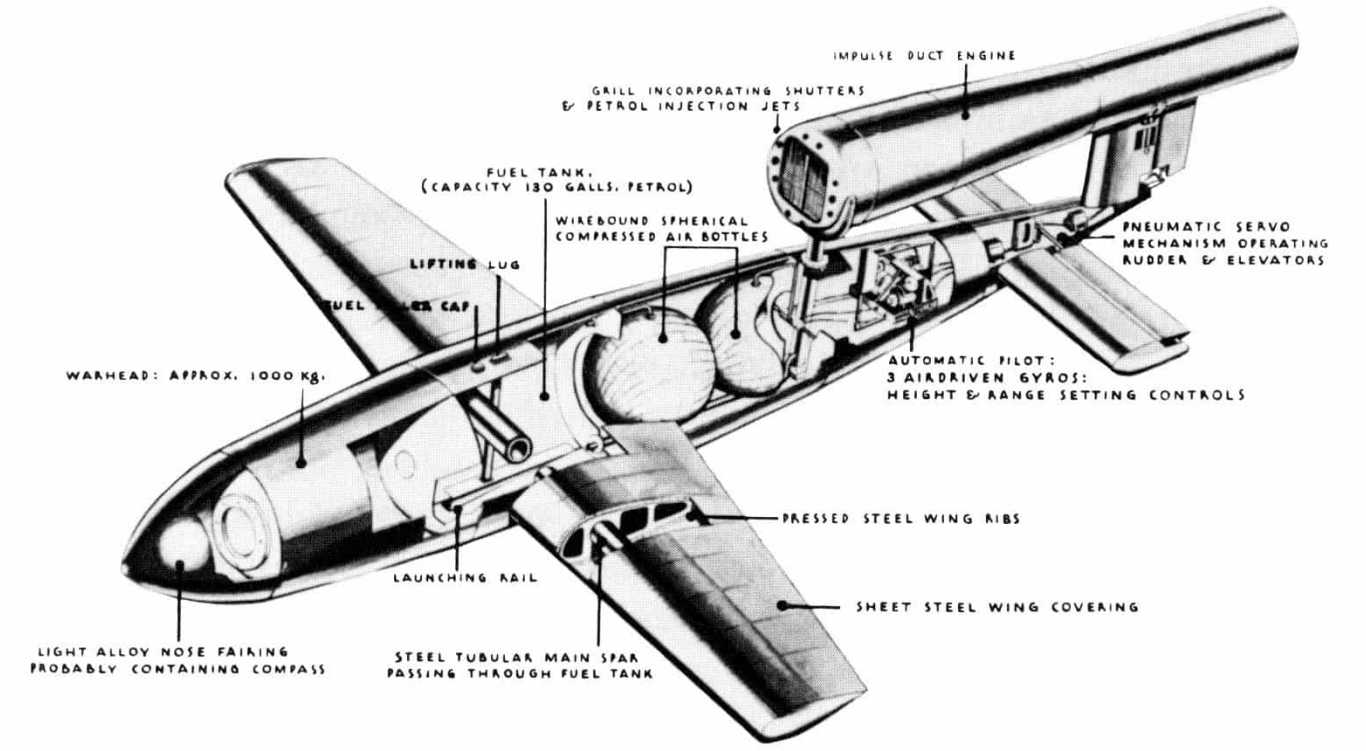
Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.

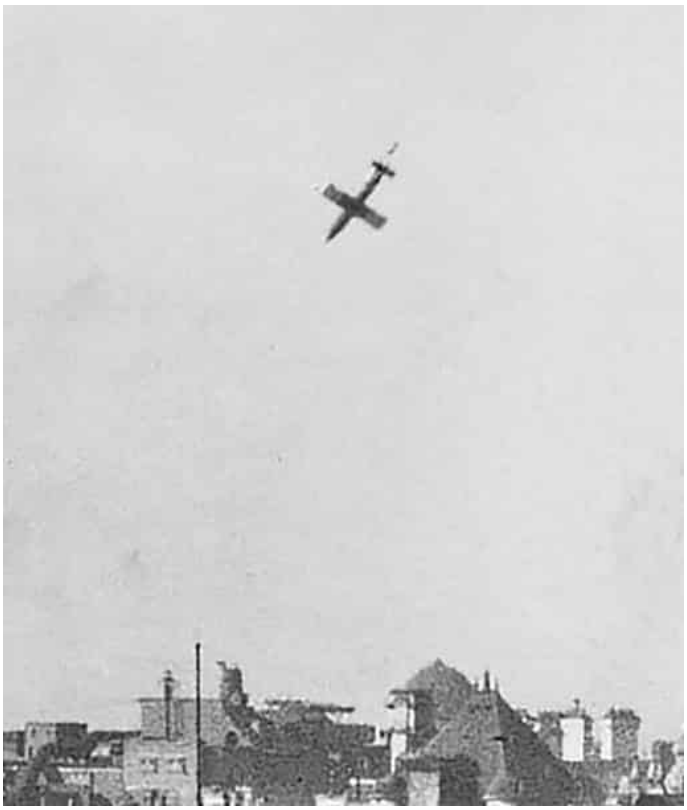




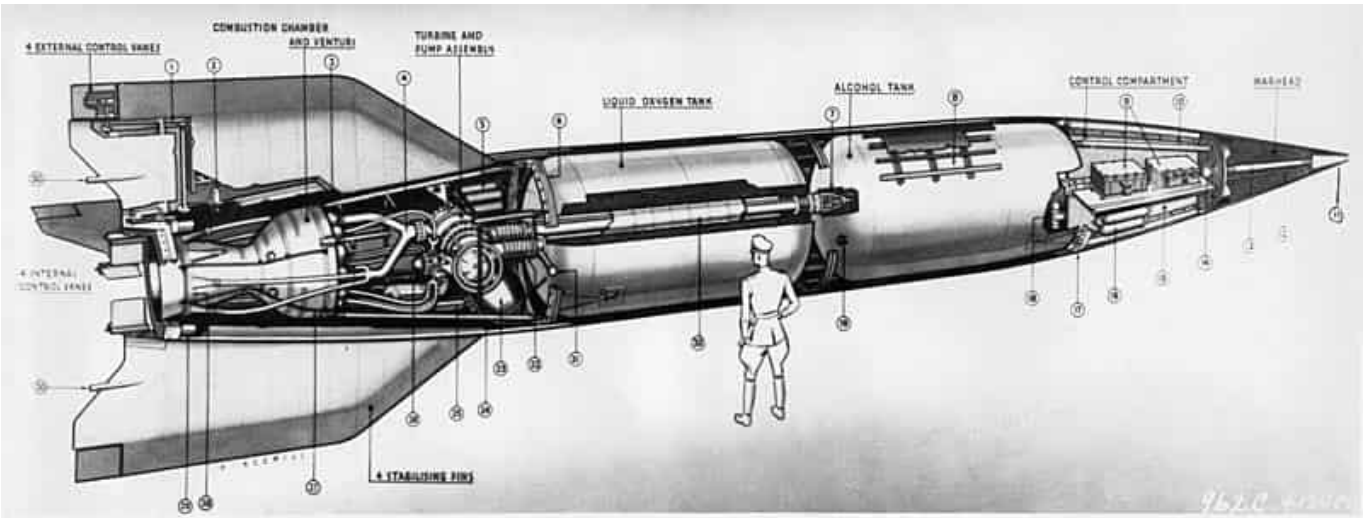


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTACL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCOHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALCOHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

Vergeltungswaffe 2 (V-2) Rocket

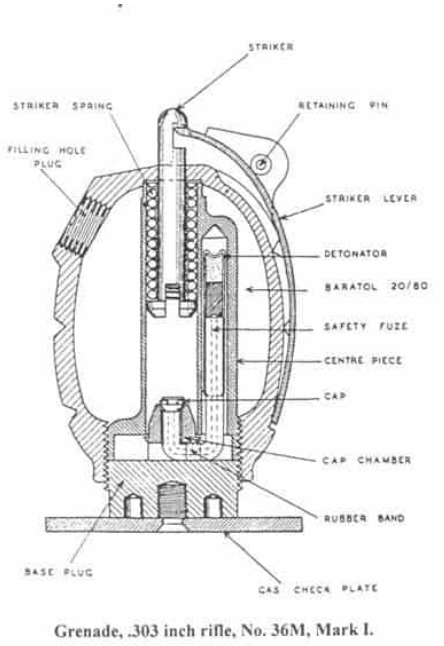
Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.





British & Allied Ordnance



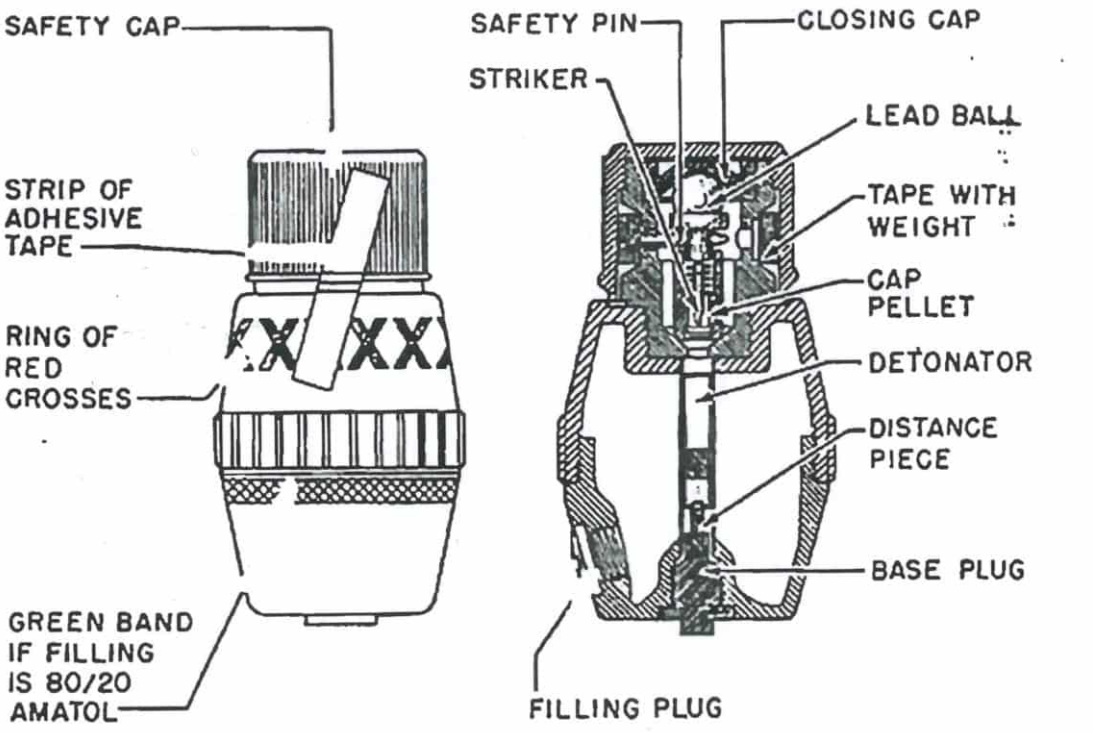


Grenade, .303 inch rifle, No. 36M, Mark I.

No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



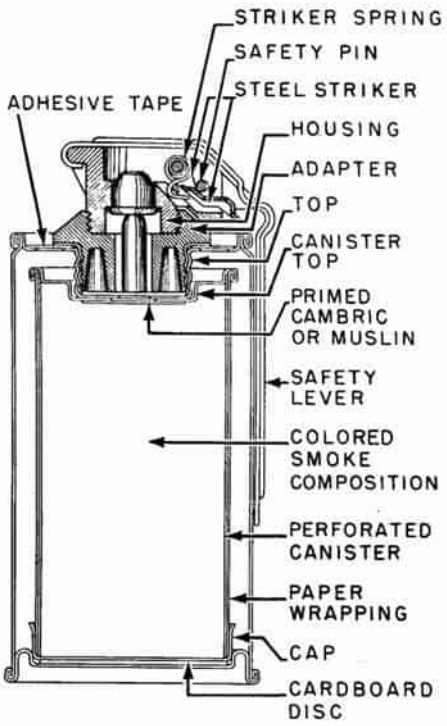


No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.







Typical Smoke Grenade

Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.





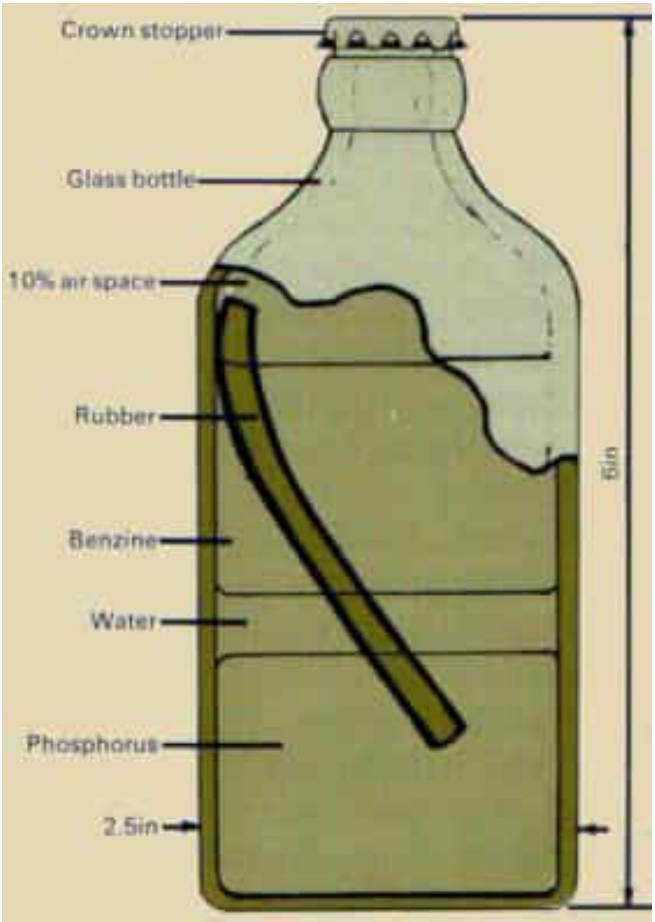


Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.

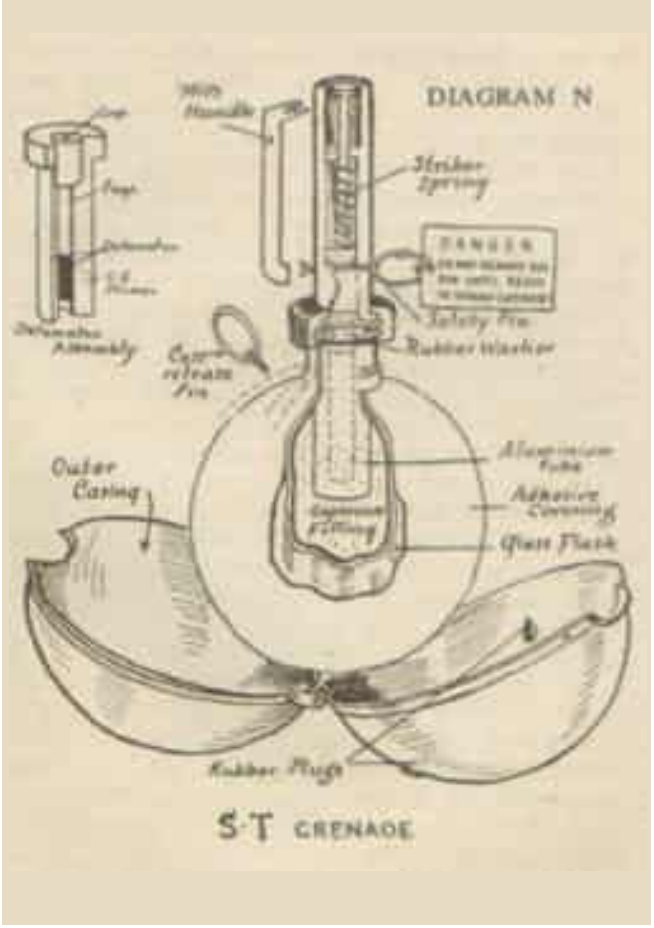






No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.

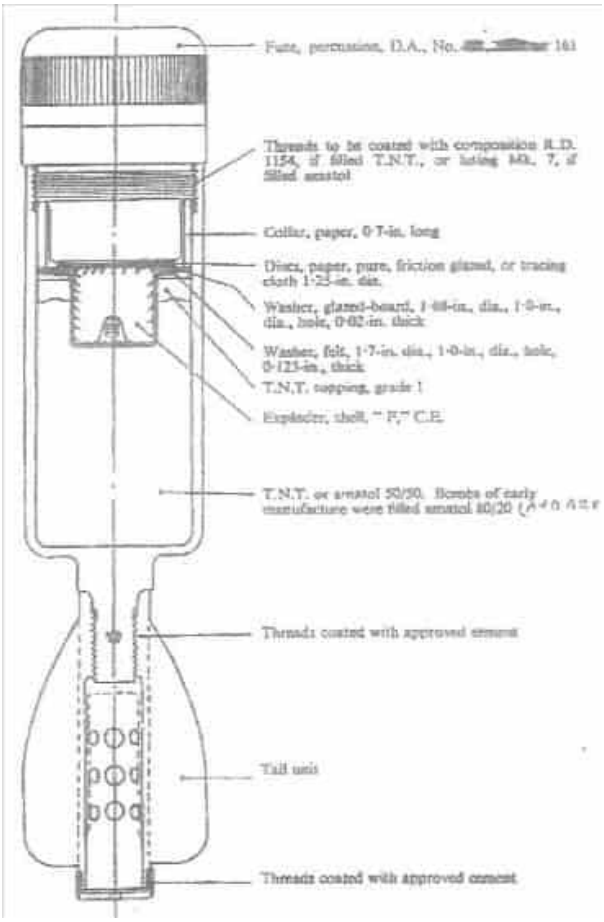






Typical 2" High Explosive Mortar

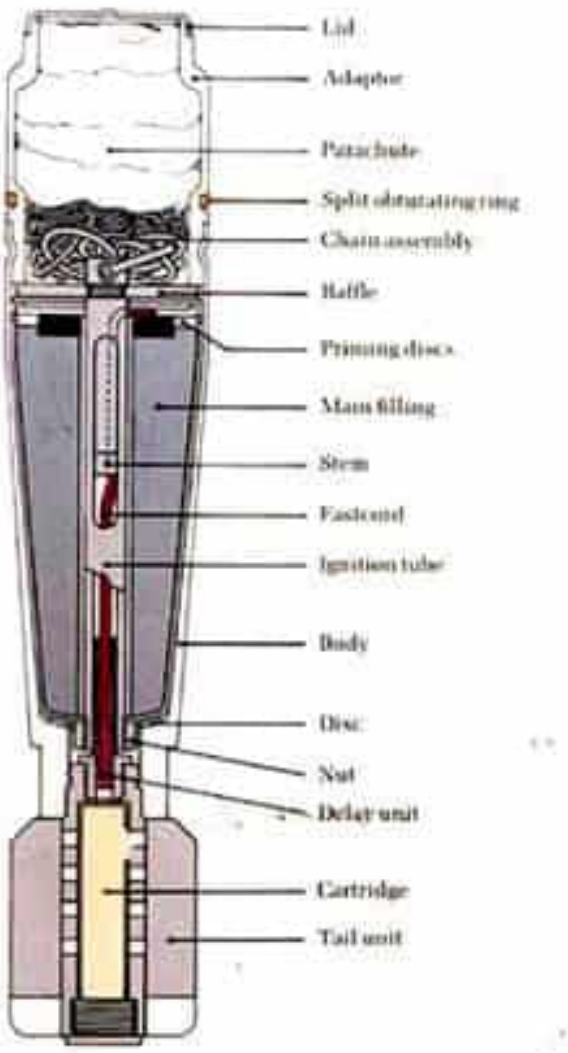
Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.





Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.







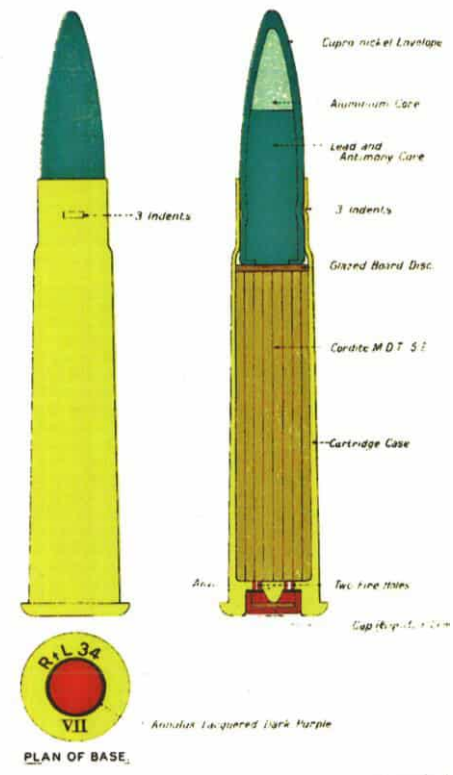


Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



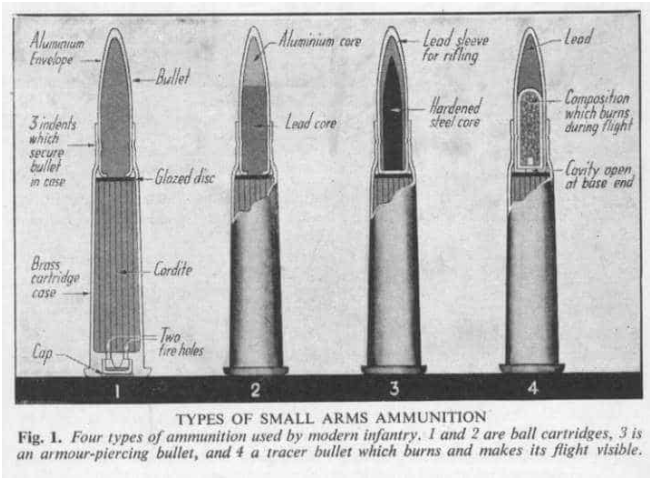




.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



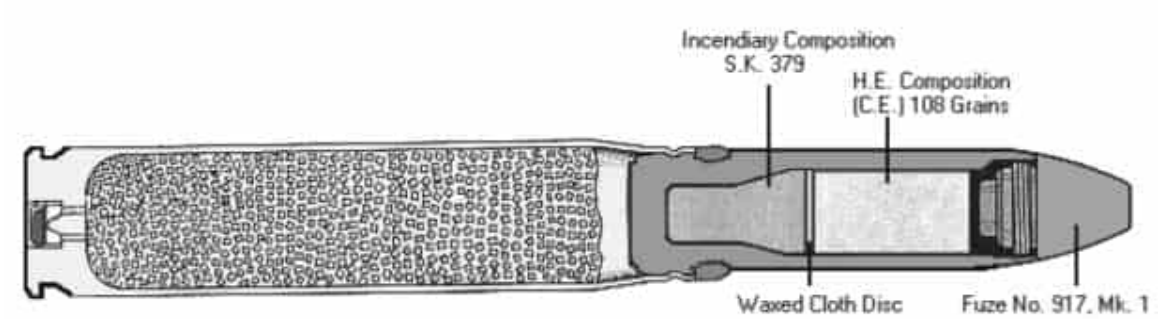


TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*

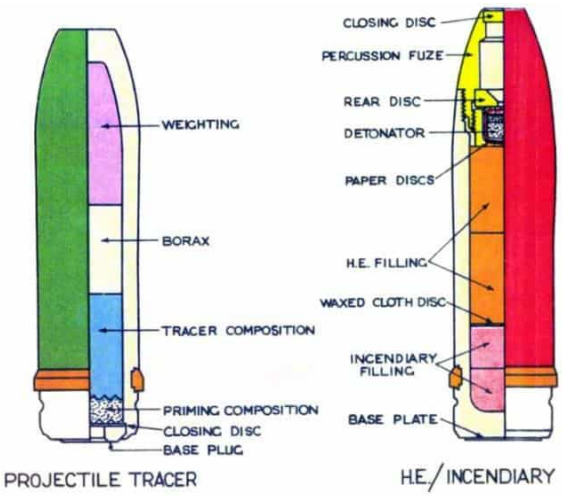






20mm Hispano HEI Ammunition

Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



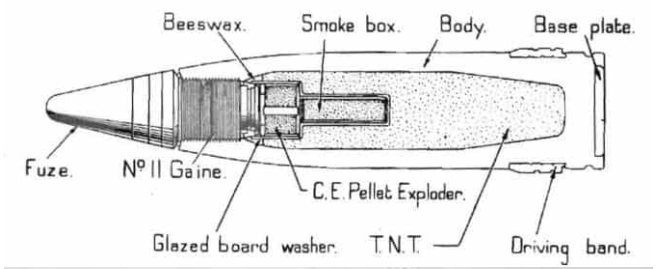
COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	



3.7" Anti-Aircraft Projectile

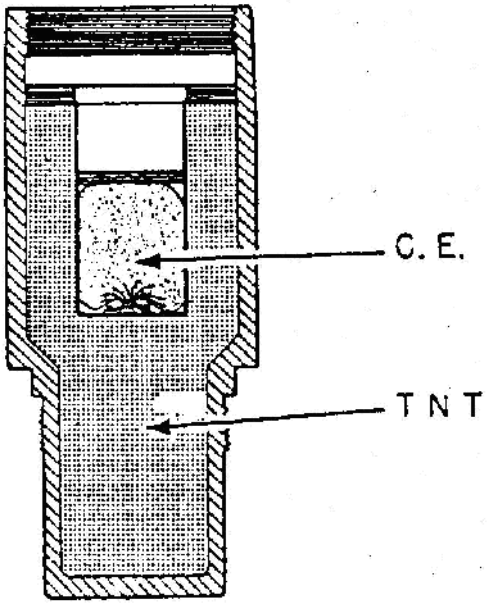
Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.





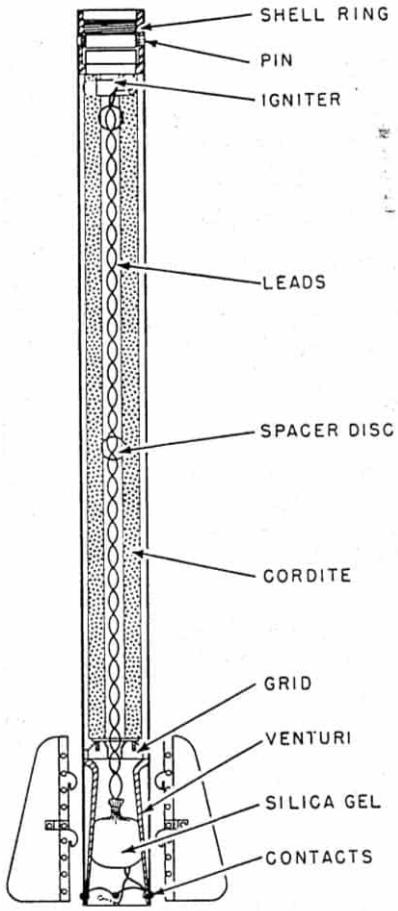






Rockets / Un-rotating Projectiles

Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery



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