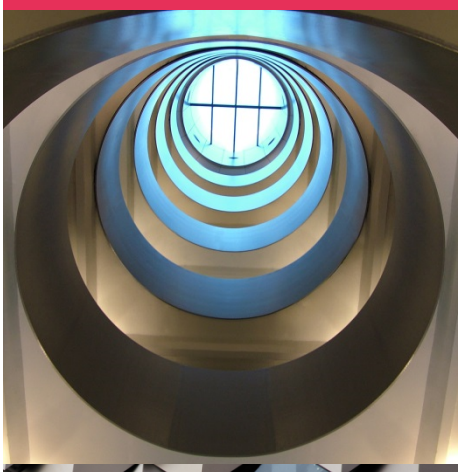

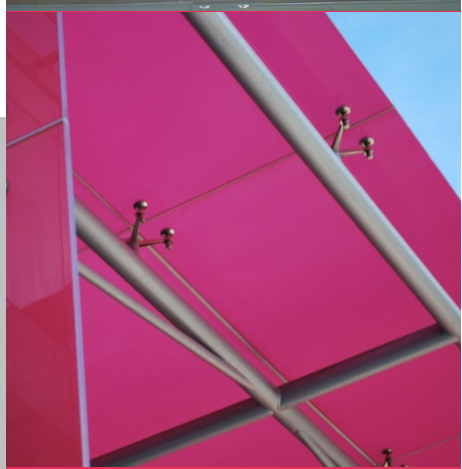

Former Shredded Wheat Factory - Phase 2

Phase 2 Ground Investigation Report

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Executive Summary

Appointment	In December 2018, Curtins were instructed by Metropolitan Thames Valley Housing (MTVH) to undertake a Supplementary Ground Investigation Report at Former Shredded Wheat Factory, Welwyn Garden City. The Supplementary Ground Investigation has been undertaken in support of the redevelopment of the site for six multi-storey residential accommodation blocks with areas of open space, roadways and parking spaces. The development layout plans, current at the time of writing, are presented in Appendix A. The following report detailing the findings of the Phase 2 area of ground investigation (Apartment Block 8,9,12 and 13).
Current Site Status	The subject site has recently undergone remediation and enabling works, resulting in remediation of previously identified NAPL within chalk (in a former tank farm area) and enabling works predominately comprising a 2.0m 'dig and turn' of site soils to remove above and below ground structures on-site. The undertaken remediation works has discharged the relevant planning conditions in regard to contaminative risk to environmental receptors. As such, the current reporting focuses on the design (structural, civil and landscape) of the development and is not suitable for the planning realm. The development site is located to the west of Broadwater Road, Welwyn Garden City and currently comprises unoccupied vacant land.
Fieldworks	The site investigation fieldworks were undertaken in March and April February 2019 by Harrison Group Ltd monitored by a Curtins Engineer. The investigation comprised the following: cable percussive boreholes, machine excavated trial pits, cone penetration testing, window sample boreholes, piling monitoring wells, in-situ geotechnical testing together with the logging and representative sampling of the site soils for environmental and geotechnical testing.
Ground Conditions	In general, the revealed ground model was consistent with the recorded geological succession and recent turnover of site soils. Made Ground comprising either Topsoil, demolition material or re-worked superficial deposits extended to 1.80m bgl to 4.80 m bgl. Thereafter either Lowestoft Formation or Kesgrave Catchment were encountered initially fine (soft and firm clays) and coarse grained soils (gravels), respectively to depths of circa 9.80m bgl to 14.40m bgl. Thereafter bedrock of the Lewes Nodular and Seaford Chalk was encountered initially comprising low density Dm grade chalk to depths of predominately between 17.0m to 24.0m bgl with medium density Dc grade chalk (inferred from SPT values) thereafter (base not encountered).
Laboratory Testing	Representative samples of the shallow and deep site soils were obtained and submitted to a suitably accredited laboratory for environmental chemistry analysis. The environmental chemistry results for soils have been compared with the Tier 1 criteria for soils with respect to human health for a Residential end uses (without homegrown produce and public open space) to determine site soils suitability for re-use at a design level and ensure no risk future site users, following change in shallow soil profile during the enabling works. In addition, representative samples of Made Ground and natural soils underwent geotechnical analysis to characterise site soils.
Generic Quantitative Risk Assessment	**Human Health –** Following the turnover of site soils, the current risk to future site users is considered Low, with the recommendation of 450mm of Topsoil (consisting of existing material - western boundary and importation of Topsoil material) is placed within soft landscaping areas. This is to protect future site users from localised Asbestos encountered within re-worked natural soils as part of the enabling works.
Geotechnical Considerations	**Block 8, 9, 12 and 13** It is considered that the likely carrying capacity of a 22.0 m long, 450 mm diameter bored pile (based on a factor of safety of 2.5) is estimated in the region of 1.2 to 1.3 MPa, based on medium density chalk at circa 20.0 to 24.0m bgl. Note – it is recommended that the localised dissolution features within Block 12 are grouted prior to piling, with a piling contractor unlikely to warranty piles within this area without such mitigation.

Recommendations	The production of a grouting specification to mitigate the localised dissolution features present within the north-western corner of Block 12 as identified as part of Delta Simons (BH407) and EAME investigation (Z5). Importation of 'clean' Topsoil to form 450mm of cover within soft landscaping covering the shortfall of existing material. It is recommended that a Materials Management Plan (MMP) combined with a Developer's Method Statement is undertaken for the site, detailing the requirements for importation of material (Topsoil and fill to the southern area) required to obtain necessary site levels and environmental measures for construction phase to ensure the current planning conditions (in regards to environmental) are suitability discharged. Given the results of the geotechnical testing undertaken on re-worked superficial soils, it is recommended that an earthworks strategy up to depths of 2.0m bgl is undertaken predominately comprising the re-compaction of shallow soils to form suitable platform levels and support required piling matt for each of the proposed blocks.

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Appendices

1.0 Introduction

1.1 Project Background

In December 2018, Curtins were instructed by Metropolitan Thames Valley Housing (MTVH) to undertake a Supplementary Ground Investigation at the Former Shredded Wheat Factory site, Welwyn Garden City.

The Supplementary Ground Investigation has been undertaken in support of the redevelopment of the site for six multi-storey residential accommodation blocks with areas of open space, roads, attenuation ponds and parking spaces. The development layout plans, current at the time of writing, are presented in Appendix A.

The following report detailing the findings of the ground investigation undertaken within the Phase 2 area of development (Blocks 8,9,12 and 13).

1.2 Previous Works and Reporting

The development site has undergone two phases of ground investigation undertaken by Delta Simons in 2015 and EAME in 2018. Two phases of remedial works were also undertaken on site overseen by Delta Simmons (2015) and EAME (2018) respectively. More recently, enabling works have been undertaken.

Historically, the development site has primarily consisted of industrial uses, with the most notable a former Polycell factory with a tank farm (in the western portion). These historical uses resulted in a varied contamination profile on site and led to the requirement for two sets of remedial works (2015 and 2018). A brief summary, of each element of these work packaged is presented below to provide context for this Supplementary Ground Investigation report.

1.2.1 Delta Simons (2015)

From 2003 to 2016, Delta Simons (1) (2) undertook environmental investigations, remedial works and a limited geotechnical investigation for a proposed commercial end use on the site. The investigation identified localised soil contamination and significant widespread groundwater contamination at depth within the Principal Chalk Aquifer. The source of the contamination was determined to be on-site tank farm area (proposed apartment Block 12 area), with key contaminants listed as ‘white spirit’ and kerosene at circa 22.0 m bgl within the chalk. Following this, the remediation works comprised the removal of source area (comprises tanks and impacted soils), bio-pile remediation, pump and treat, soil vapour extraction, oxygen injection and long-term groundwater monitoring/monitored natural attenuation.

The remedial works removed free product on groundwater, volatiles from soil within tank farm area and reduced the dissolved phase contamination across the site. The long term monitoring determined wells down hydraulic gradient of the tank farm, detailed an overall declining trend in hydrocarbon contamination.

During these works, seven preliminary geotechnical boreholes were advanced to 25.0m bgl across the site, as a general spread.

1.2.2 EAME (2018)

Following a change in site ownership and proposed development, Earth & Marine Environmental Consultants (EAME) undertook further environmental investigation across the development site for a proposed residential end use (current development).

The works comprised a combined Phase 1 and 2 Environmental Assessment (3). The results of the additional assessment determined '*the potential impacts associated with residual soil contamination are likely to be minimal'* and that '*given the recorded elevated concentrations of petroleum hydrocarbons in groundwater and the sensitivity of the Principal Chalk Aquifer it is considered likely that remedial actions will be required in the form of environmental betterment and taking into consideration current best practice guidance'*.

As such remedial measures (based on 'betterment' and reduction of contaminant concentrations in groundwater), outlined in a Remediation Strategy (4) comprised pre-trials, installation of borehole injection grid across tank farm area (source), injection of reagent, pump and treat system and recirculation. Following this long-term monitoring of on-site groundwater wells is to be undertaken (on-going at the time of writing). The remedial works determined a *'99.8% reduction in observed NAPL thickness (pre and post remediation)'* and it was therefore concluded that '*betterment'* had been achieved.

The results of these works undertaken by EAME has discharged the relevant environmental planning conditions (with approval from the Environment Agency) imposed for the proposed residential development of the site, discussed further in Section 1.3.

Historically, the two sets of ground investigation work undertaken primarily focused on the environmental conditions of the development site (understandably based on site history) rather than geotechnical, with exception of a preliminary geotechnical investigation undertaken by Delta Simons in 2014 as part of the wider environmental investigation.

1.2.3 Enabling Works (2018)

The enabling works package in response to ground conditions consisted of the removal and demolition of existing structures and basements along with their backfilling, a turnover of site

soils to a depth 2.00m below existing ground level across the site, with the resultant excavations backfilled in a 'controlled' manner. It is understood the backfilling was not undertaken to an engineering specification.

Further to this, the works comprised Asbestos hand-picking and removal of all bulk Asbestos material identified on-site. The material obtained from the demolition of former structures on-site, was crushed and has been used as backfill in certain area of the development site (north-eastern portion).

1.3 Outstanding Planning Requirements

It is understood that as a result of the above remediation work being completed to the satisfaction of the relevant regulatory authorities, all relevant planning conditions (under application 6/2018/0171/MAJ) with respect to contaminated land have been discharged.

The only outstanding planning conditions relating to contaminated land are; a) the requirement of a piling risk assessment, taking into account the requirements for piling into a known contamination source and a Principal Aquifer/groundwater source protection zone, as well as; b) the requirement for any unexpected contamination encountered to be dealt with in an agreed and acceptable method.

In addition, although strictly not a planning condition; the current long-term groundwater monitoring (and decommissioning of such boreholes) feeds into the approved environmental conditions (remediation strategy and validation report) and as such, there is a requirement to ensure the long-term monitoring wells on-site are protected as part of the construction phase. A drawing detailing the long-term monitoring wells is presented in Appendix A.

As such, the current reporting primarily focuses on the design (structural, civil and landscape) of the development with environmental risk assessments completed to verify the post-remediation condition of the site and confirm if the shallow soils are suitable for re-use.

1.4 Scope of Works

Curtins have previously undertaken a review of the existing ground investigation data and data presented by Wheat Quarter Limited (commissioned for both the enabling and remedial works) to determine potential data gaps/constraints to the proposed development works in terms of civil and structural design.

Based on this review, a requirement for a Supplementary Ground Investigation Report was identified to supplement data gaps and further understand the identified geotechnical constraints. A summary of these points are bulleted below.

- **Data Gap/Constraint 1** – To date, only seven geotechnical boreholes have been advanced on-site, of which six are located within proposed block footprints and further to this, the advanced boreholes are not considered to have reached sufficient depth (maximum depth of 25m bgl to date) to inform the structural and pile design of the proposed development.
- **Data Gap/Constraint 2 –** As part of the previous Delta Simons (2014) investigation, potential dissolution features were noted within the top of the chalk bedrock at 13.80m bgl within BH407, located in the footprint of Block 12. In addition, as part of the recent advancement of remediation monitoring wells within this Block 12 area, additional dissolution features were noted.
- **Data Gap/Constraint 3 –** To date, no testing of site soils has been undertaken to inform preliminary waste classifications for off-site disposal of soils as part of the development works. As such, the lack of waste classification data currently yields a cost uncertainty with respect to the disposal of soils off-site.
- **Data Gap/Constraint 4 –** Following the regrading of the site (which is understood to not be to an agreed engineering specification) and the site turnover using existing soils, there is currently no geotechnical data to determine the geotechnical suitability of shallow soils on-site for the re-use of shallow soils. There is potential for re-use, either as a sub-soil in landscaping areas or in proposed areas of roadways and hard standing.

This supplementary ground investigation report was therefore intended to determine,

a) If there is a risk of the proposed end user being adversely impacted upon by potential contamination in shallow site soils that may be present on the site following enabling works.

b) Identify the potential presence of dissolution features across the site within chalk bedrock.

c) Recommendations for the design of foundations and building ground floor slabs.

d) Recommendations for the specification of sub-structure concrete.

e) Recommendations for the potential re-use of site soils (environmentally and geotechnically) and preliminary waste classifications of site soils.

2.0 Current Site Setting

2.1 Site Setting

The development site is located to the west of Broadwater Road, Welwyn Garden City and currently comprises unoccupied vacant land having undergone the recent remedial and enabling works. A site plan is presented in Figure 2.1 below, with the Phase 2 site investigation boundary presented in red..

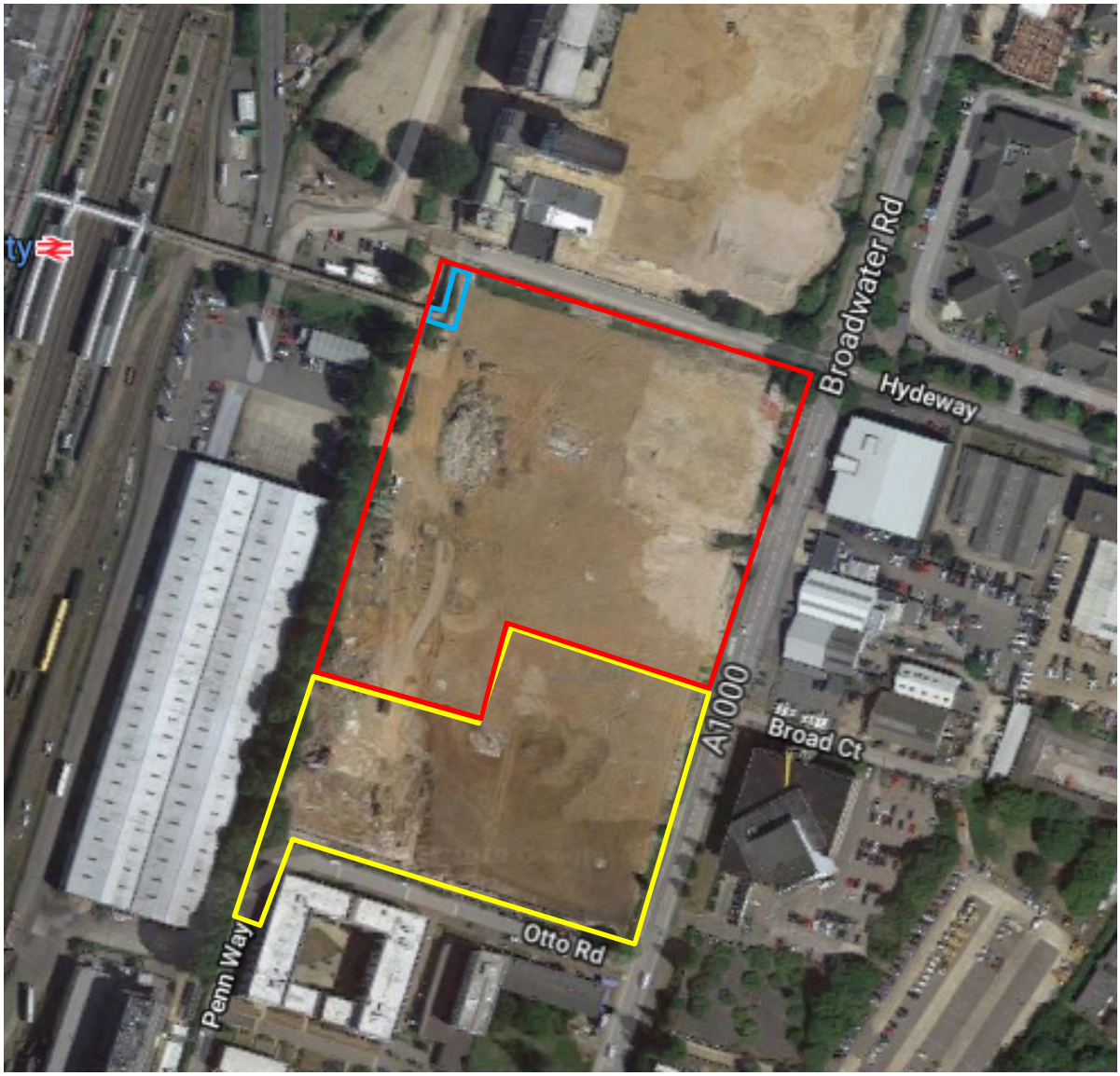

Figure 2.1 Site location plan. Approximate Phase 2 area boundary is identified in red. The approximate Phase 1 area is highlighted in yellow. Network rail asset outlined in blue. Extract from Google Map Data 2019

A site visit was undertaken in October 2018 following completion of the remediation and enabling works to ascertain the current site condition and inform the requirements of supplementary ground investigation.

As part of the enabling works and 2.0 m 'dig and turn', it was noted that re-worked natural soils were present at surface. However, it was evident the soils had not been compacted to an engineering specification, with some areas of the site soft under foot. A network rail asset (footbridge) is located on the far north-western area of the site, highlighted in Figure 2.1 above.

Within the northern portion of the site, remnants of an area of Asbestos hand-picking exercise to remove bulk Asbestos material was present.

An elevation difference of 2.0 m is noted between the south-western and southern boundary of the site, following the removal of former basement and a rifle range within this area. In addition, there are number of site level changes across the site ranging from 0.5 to 2.0 m difference.

2.2 Unexploded Ordnance Risk Assessment

Given the location of the former rifle range along the southern boundary of the site (detailed in Delta Simons and EAME reporting), it was recommended that a Detailed Unexploded Ordnance (UXO) risk assessment be undertaken for the development site to inform the current UXO risk and the require mitigation measures during development. A copy of the detailed UXO risk assessment is presented in Appendix B.

The detailed UXO risk assessment determined the following:

*'It was assessed that there is a **Low Risk** from items of unexploded German aerial delivered ordnance across the site and a **Low-Medium Risk** from historic Allied Land Service Ammunition/Small Arms Ammunition.*

The following risk mitigation measures are recommended to support the proposed works at the Former Shredded Wheat Factory (Southern Site), Welwyn Garden City:

All Works

- *Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.*

It is recommended that a copy of the detailed UXO risk assessment is held in the Health and Safety Plan for the site.

3.0 Fieldwork

3.1 General

The ground investigation fieldworks for the Phase 2 area were undertaken in March and April 2019. The fieldworks were completed by Harrison Group and monitored by a Curtins Engineer. A summary of the scope and rationale for the phases of investigation are summarised in Table 3.1 below.

The ground investigation was designed by Curtins with reference to the identified current data gaps, the proposed development and in general accordance with current UK guidance including CLR11 (5), British Standard (BS) 10175 (6), BS5930:2010 (7) and Eurocode 7 (8).

Table 3.1 *Ground Investigation Scope and Rationale*

Activity	Rationale
15 cable percussive boreholes (referenced CP101 to 107,109, 116 to 21) to depths of 33.45 m bgl.	To determine both shallow and deep ground conditions across the site to inform structural design.
31 cone penetration testing (reference CPT101 to CPT150 and TP112A, TP115, TP122, TP123*) to depths of 23.76 m bgl	To determine the potential presence of obstructions across the site and potential dissolution features within the chalk.
26 machine excavated trial pits (referenced TP101 to TP123 and TP127 to TP128) to depths of up of 4.20 m bgl	To determine shallow ground conditions, delineate potential subsurface contamination and obstructions across the site.
Two hand excavated trial pits (referenced PLT108 and TP129) to depths of 1.00m bgl.	To determine shallow ground conditions within densely vegetated area along western boundary.
One piling monitoring well (referenced PMW102) to depths of up to 25.00m bgl	To enable monitoring well installations to satisfy planning conditions relating to piling.
Description and logging of soil arisings from exploratory holes.	To provide a characterisation of ground conditions and inform sample selection for laboratory analysis.
Collection of representative soil samples from exploratory hole arisings.	To enable laboratory Environmental and Geotechnical analysis of recovered soil samples.
In-situ geotechnical testing.	To determine geotechnical properties of the strata revealed.

Notes - * Where trial pits were unable to reach target depth to pit instability, a CPT was advanced in the location to determine the potential presence of obstructions.

The exploratory hole location plan is detailed within Appendix C.

3.2 Soil Logging and Sampling (Soil and Groundwater)

Exploratory hole arisings were logged on site by a Harrison Group Engineer in accordance with the requirements of BS5930 (7), including recording observed visual and olfactory indications of contamination. Copies of the exploratory hole logs are provided in Appendix C.

Representative soil samples were selected for laboratory chemical analysis, based on field observations and to provide a characterisation of the Made Ground and natural strata encountered.

Selected soil samples were placed in laboratory provided containers and stored in cool boxes prior to being transported to the nominated laboratory under the laboratory's chain of custody documentation. The laboratory selected by Harrison Group for chemical analysis was i2 Analytical, a UKAS and MCerts accredited laboratory. The Harrison Group Laboratory, a UKAS and MCerts accredited laboratory undertook the geotechnical analysis.

3.3 In-Situ Tests

A programme of *in-situ* testing was undertaken to develop the preliminary ground model for the site and determine geotechnical properties of the strata revealed. In-situ testing was undertaken as detailed in Table 3.3 below.

Table 3.3 *Programme of In-Situ Testing*

Activity	Rationale
SPT tests within cable percussive and window sample boreholes.	Assess relatively density or consistency of various strata.
Plate load bearing tests within selected trial pits.	To determine CBR values of near surface soils for roadway design.
Dynamic Cone Penetrometer (DCP) Testing using a TRL probe.	To determine CBR values of near surface soils for roadway design.

3.4 Monitoring Well Installations

Groundwater monitoring installations (50mm OD) were installed within two boreholes, A bentonite seal was placed above the screened section of the borehole (and below where relevant) to minimise potential for downward migration of contaminants and the creation of a preferential migratory pathway. A gravel surround was installed in the annulus between the sides of the borehole and the slotted sections of pipe. A summary of the response zones is presented in Table 3.4 below.

Table 3.4 *Borehole Response Zones*

Borehole Reference	Response Zone(s) (m bgl)	**Strata Description(s)** (Principal strata in capitals)
PMW102	20.00-25.00	CHALK
CP121	1.00-3.00	MADE GROUND/ SUPERFICIAL DEPOSITS

Copies of borehole logs provided by Harrison Group can be referred to in Appendix C of this report

A monitoring installation was constructed in CP121, in response to the visual and olfactory indicator of contamination noted within shallow soils and the presence of shallow groundwater within TP119 as part of good practice. The installation was adopted to forensically determine the source of identified indicators were not unexpected contamination and consistent with current understanding of the site (expected contamination).

4.0 Laboratory Testing

4.1 Environmental Chemistry Testing

A programme of environmental chemistry testing was scheduled, with analytical suites developed reflecting the likely contaminants on-site reflecting the site scenario, to confirm the suitability of re-use of soils and confirm observations made during the ground investigation. Given the potential for site wide source of contamination the sampling positions (boreholes and trial pits) were generally located in a site wide non-targeted array to give adequate and representative coverage of the site.

4.1.1 Soil Analysis

Soil samples were taken from the shallow (<0.60 m) (Topsoil and Made Ground) and deep (>0.60 m) (Made Ground and natural) soils across the site and tested for either Suite A, or B The nature and type of soil contamination potentially present on the site was considered to include, amongst others; organic matter, ash and fill, hydrocarbons (e.g. fuel oils), heavy metals and asbestos the extent of which is captured by the broad environmental testing suite detailed in Table 4.1.1.

In addition, two samples (PLT108 and CP102) underwent Waste Acceptance Criteria (WAC) testing in support of a preliminary waste classification for off-site disposal.

Copies of the environmental chemistry testing certificates can be referred to in Appendix C of this report.

Table 4.1.1 *Environmental Chemistry Analysis Suite : Soils*

Suite Ref	Analysis	LOD
A	Asbestos Screen Asbestos Quantification pH Soil Organic Matter Arsenic Boron (water soluble) Cadmium Chromium Chromium VI Copper Lead Mercury Nickel Selenium Zinc Cyanide (total) Sulphate (total)	N/A 0.001% N/A 0.1% 1 mg/kg 0.2 mg/kg 0.2 mg/kg 1.2 mg/kg 1 mg/kg 1 mg/kg 1 mg/kg 0.3 mg/kg 1 mg/kg 1 mg/kg 1 mg/kg 1 mg/kg 1.25 mg/l

Suite Ref	Analysis	LOD
	PAH's (USEPA16)	0.05 mg/kg
B	TPH (Aro/Ali Split) BTEX SVOCs VOCs Total Phenols	0.01 to 10 mg/kg 0.01 to 1 ug/kg 0.05 to 0.3 mg/kg 1 ug/kg 1 mg/kg

4.2 Geotechnical Testing

A programme of geotechnical testing was scheduled by Curtins in order to develop the preliminary ground model for the site. Geotechnical samples representative of the main soil types encountered on site were tested for the suites detailed in Table 4.2 below and results presented in Appendix C.

Table 4.2 *Geotechnical Analysis Suite*

Geotechnical Analysis
Water soluble sulphate & pH (BS 1377-3: 1990 Clauses 3, 5.2, 5.5, 7.2 & 9)
Moisture Content (BS 1377: 1990: Part 2: Clause 3.2)
Plasticity testing (BS 1377-2: 1990 Clauses 4.3 and 5)
BRE Suite D (BS 1377:1990: Part 3 & BRE CP2/79)
Remoulded California Bearing Ratio Testing (BS 1377-4: 1990: Clause 7)
Particle Size Distribution and Sedimentation (BS 1377-2: 1990, Clause 9.2)
Moisture Condition Value (BS 1377-4: 1990, Clause 5)
Saturated Moisture Content/Intact Dry Density (BS 1377-2:1990, Clause 3.3)

5.0 Ground Conditions

The generalised ground model for the Phase 2 area is summarised below in Table 5.1.

5.1 Encountered Ground Conditions

Table 5.1 *Summary of Ground Conditions Encountered*

Stratum	Depth to top of strata (m bgl*/m AOD*		Thickness (m)		General Description
	Min	Max	Min	Max	
Made Ground	0.00	0.00	1.80 (CP117)	4.80 (PMW102)	**Topsoil** See description in 5.1.1 below. **Reworked Superficial Soils** See description in 5.1.1 below
Lowestoft Formation (Superficial Deposits)	2.10 /82.62 (TP123)	5.30 / *80.07* (CP102)	0.10 (CP106)	5.30 (CP102)	Firm dark brown to reddish brown gravelly CLAY with gravel of sub-angular to sub-rounded fine to coarse flint.
Kesgrave Catchment (Superficial Deposits)	1.80 /*82.96* (CP117)	9.50 / *75.87* (CP102)	1.80 (CP106)	9.00 (CP117)	Medium dense to dense brown sandy slightly clayey subangular to sub-rounded fine to coarse GRAVEL of flint.
Lewes Nodular and Seaford Chalk Formation (Bedrock	9.80/*75.40* (CP107)	14.40/*71.14* (CP106)	>16.05 (CP106)	>20.65 (CP107)	Dm – Recovered as structureless CHALK composed of cream to white gravelly SILT. Gravel is weak, low density, cream to white, angular to sub-rounded fine to coarse chalk with flint. Dc - Recovered as structureless CHALK composed of cream to white silty angular to sub-rounded fine to coarse GRAVEL. Clasts are weak, low to medium density, cream to white chalk with flint.

Notes - *Base not encountered

5.1.1 Made Ground

During the ground investigation, two types of Made Ground were encountered consisting of Topsoil, and reworked superficial deposits with the typical descriptions listed below.

Topsoil

Topsoil material was only encountered within locations advanced along the vegetated area of the western boundary to a depth of 0.20m (TP116). The unit comprised a dark brown to black slightly clayey very organic fine to coarse SAND with gravel of flint.

Re-worked Superficial Deposits

Reworked superficial deposits Made Ground was encountered within all intrusive locations to depth ranges of 2.10 m bgl (TP123) to 5.30 m bgl (CP102). The material predominately comprised a re-worked natural material either the Lowestoft Formation or Kesgrave Catchment (discussed below in Section 5.1.2) which is to be expected as a result of the site turnover consisting of either a soft to firm brown to reddish brown slightly sandy gravelly CLAY, with gravel of brick, ceramics, clinker and asphalt or an orangish brown slightly sandy silty angular to sub-rounded fine to coarse GRAVEL with flint, brick, clinker and concrete.

5.1.2 Superficial Deposits

The superficial deposits across the site predominately comprised interbedded fine and coarse-grained soils at shallow depths and thereafter predominately coarse-grained soils. The fine-grained soils are considered to represent the Lowestoft Formation are interbedded at shallow depths with the coarse-grained soils represented by the Kesgrave Catchment. The typical descriptions of superficial deposits are presented below.

Lowestoft Formation

The Lowestoft Formation predominately comprised a firm dark brown gravelly CLAY with gravel of sub-angular to sub-rounded fine to coarse flint. However, a brown to reddish brown gravelly clayey SILT with gravel of sub-rounded to fine to coarse flint was noted in select locations.

Typically, a less than metre to 5 metre thickness of soft to firm brown sandy Clay is encountered around c. 3.70 m bgl, between the Kesgrave Catchment soils.

Kesgrave Catchment

The Kesgrave Catchment was primarily encountered as a gravel, with a description of medium dense to dense brown sandy slightly clayey subangular to sub-rounded fine to coarse GRAVEL of flint. The unit was encountered to depths ranging from 1.80 m (CP117) to 9.50 m bgl (CP102).

5.1.3 Bedrock

Lewes Nodular and Seaford Chalk Formation

The depth to the top of the chalk ranges from 9.80 m/75.40 m AOD (CP107) to 14.40 m bgl / 71.14m AOD (CP106). The chalk strata were initially encountered as low density Dm chalk consisting of structureless CHALK composed of cream to white gravelly SILT. Gravel is weak, low density, cream to white, angular to sub-rounded fine to coarse chalk with flint. Thereafter Dc Chalk was encountered consisting of structureless CHALK composed of cream to white silty

angular to sub-rounded fine to coarse GRAVEL. Clasts are weak, low to medium density, cream to white chalk with flint.

Within the Phase 2 area of the site, there was limited evidence of a potential valley feature with start depths of the chalk typically consistent (typically ranging from 9.80m bgl to 11.60m bgl, with localised deepening to 14.40m bgl – CP106).

Potential Dissolution Features

As part of the previous Delta Simons (2014) investigation, potential dissolution features were noted within the top of the chalk bedrock at 13.80m bgl within BH407, located in the footprint of Block 12. In addition, as part of the recent advancement of remediation monitoring wells within this Block 12 area, additional dissolution features were noted in Z5.

It is anticipated that the dissolution features located beneath in Block 12 are due to the presence of a historical 'landfill soakaway' recorded to discharge wastewater effluent within this area which likely introduced acidic conditions (<7 pH) to groundwater and as result 'weakened' the weathered chalk through dissolution and thus creating 'soft spots'. This theory is also supported by the groundwater testing results undertaken by EAME recording a groundwater pH in the range of 6.2 to 7.0 within the Block 12 area.

Owing to the presence of dissolutions features, cone penetration testing was undertaken across each proposed Block to establish their nature and extent.

The results of testing (where target depth achieved) and along with cable percussive boreholes predominately did not indicate the presence of potential dissolution features within chalk strata across the Phase 2 area.

However, it is noted that the CPT149 located within Block 12 adjacent to two previously identified dissolution features (Z5 and BH407), identified potential 'soft spots' from circa 4.0m to 12.00m bgl and as such, it is likely that such dissolution features are primarily limited to this north-western region of Block 12. Consequently, it is recommended that this area is grouted prior to the adoption of pile foundations within this area.

Additionally, the refusals in certain areas of the site within the coarse grained soils overlying the chalk indicate that the presence of dissolution features within chalk are unlikely, with such features likely to cause a subsurface 'collapse' or swallow hole which would result in lower density values of coarse grained strata.

As such, based on current data, it is likely that dissolution features are limited to a localised north-western portion of Block 12. The CPT report provided by Harrison Group Environmental is presented in Appendix C.

5.2 Visual and Olfactory Indicators of Contamination

5.2.1 Mobile Indicators

During the ground investigation, faint and strong solvent/white spirit and fuel odours were encountered within the chalk bedrock just above the groundwater table (circa 22.0m bgl) and within the groundwater (circa 24.0m bgl).

The odours above the groundwater table (within the bedrock soils) are considered to be reflective of dissolved phase groundwater source from the tank farm, rising and falling with seasonal fluctuations in groundwater level. The identified odours are considered to represent the expected dissolved phase hydrocarbons in groundwater and not considered to represent unexpected contamination.

Additionally, shallow visual and olfactory indicators were present at circa 2.0m bgl within TP119. An environmental sample was obtained and submitted for environmental testing, whilst a shallow monitoring installation was constructed in CP121 adjacent to determine the presence of any potential perched groundwater. The results of the testing are presented in Section 6.0.

No further visual or olfactory indicators of contamination were noted within the Made Ground, superficial deposits, or chalk bedrock prior to the groundwater interface within the Block 8,9,12 and 13 area.

5.3 Obstructions

As part of the ground investigation, a relic foundation was encountered within TP108 at 0.80m bgl and possible foundation was encountered within TP109 at 1.10m, both located on the similar lateral extent within the eastern portion of the site (Block 8). As such, there is potential for further footings at circa 0.8m to 1.10m bgl, along this lateral extent within Block 8.

No further obstructions were encountered across Block 8, 9, 12 or 13 which have undergone enabling works and the 2.0 m soil turnover.

5.4 Site Wide Groundwater

Shallow groundwater was encountered within the Made Ground in a single location (TP119) at a depth of 2.00m bgl, with no further shallow groundwater encountered across the site. A monitoring well was installed adjacent to TP119 to determine the presence of perched groundwater, however during drilling and once the installation constructed, the borehole remained dry. As such, the perched groundwater is considered to be localised.

Deep groundwater was encountered within the chalk at depths ranging from 23.40m bgl/*61.78m AOD* (CP120 – south-western portion) to 25.70m bgl/*59.64m AOD* (PMW102 – north-eastern portion).

Based on the previous EAME works, deep groundwater within the chalk is considered to flow easterly to south-easterly across the site with above results likely reflecting as such.

6.0 Geochemical Ground Risk Assessment

As previously stated, all relevant planning conditions with respect to contaminated land have been discharged. However, given the enabling works and 2.0m turnover of site soils, a new shallow profile of soils exists on site. As such, an assessment of the suitability of such soils on-site for re-use in the areas of proposed soft landscaping and beneath the building footprints has been undertaken. This takes the form of a Generic Quantitative Risk Assessment (GQRA) to determine the suitability.

In guidance published by the Environment Agency, the risk to human health is determined through an assessment of contaminant linkages between a source of contamination (within the ground or groundwater either on or off site) and a sensitive receptor such as end users of the site, building materials, edible plants grown in gardens or groundwater abstracted for drinking. This is termed a source-pathway-receptor relationship.

The sub-sections hereafter therefore incorporate the first tier (Tier 1) of this approach otherwise referred to as the Generic Quantitative Risk Assessment (GQRA). The GQRA is based on with observations made during the ground investigation and is based solely on the results of the chemical and other testing data obtained as part of HGE ground investigation.

The following sections present more detail on the risk assessment methodology rationale for the main receptors.

6.1 Human Health GQRA

Detailed guidance on human health risk assessment is available within a number of documents, published by both the Environment Agency and Defra. Guidance includes Contaminated Land Exposure Assessment (CLEA) v1.07 model (9), Science Report 2 (10) and Science Report 3 (11).

A generic quantitative risk assessment (GQRA) has been carried out for the Potential Contaminant Linkages (PCLs) investigated by screening of soil contamination data against relevant Generic Assessment Criteria (GAC) where available, including:

i) **Soil Guideline Values (SGVs):** These have been published by the Environment Agency and are trigger values for screening out low risk areas of land contamination. SGV's give an indication of representative average concentrations of chemicals in soil, below which long-term health risks are likely to be minimal. SGVs have been published for a number of contaminants including arsenic, cadmium, mercury, nickel, selenium, BTEX, phenols and dioxins, furans and dioxin-like PCB substances for land uses including residential, allotments and commercial. The SGVs have been developed for a sandy loam soil with 6% soil organic matter (SOM) content;

ii) **Supplementary Screening Values:** In addition to the SGVs developed by the EA other third party organisations have derived GACs for a wider range of contaminants and land uses using

the CLEA Model. Curtins have adopted these numbers where applicable, including those developed by Atkins AtriskSoil™, the LQM/CIEH Suitable for Use Levels (S4UL) and EIC/AGS/CL:AIRE published thresholds.

iii) **Category 4 Screening Levels (C4SLs):** In March 2014 Defra published C4SLs for arsenic, benzene, benzo(a)pyrene, cadmium, hexavalent chromium and lead. These values were derived to support the revised Part 2A Statutory Guidance issued in 2012 (12) in which four categories of contaminated land are included, ranging from Category 1 (significant/high risk) to Category 4 (low risk). C4SLs are not representative of significant possibility of significant harm (SPoSH) and are values of low risk levels. As such, where the C4SLs are not exceeded, land can be demonstrated to be in Category 4 and therefore cannot be determined as contaminated land.

The proposed re-development of the site is to comprise the construction of six multi-storey (six to seven storey's) residential blocks (Block 8 to 13) with roadways, parking, open space and attenuation ponds. development is not anticipated to comprise private gardens. The current development layout plans are presented in Appendix A.

As such, this GQRA considers a combination of land use scenario:

- *'Residential without homegrown produce'* – within and adjacent to proposed building footprints; and,
- *'Public Open Space (Residential)'* in soils adjacent to or within existing areas of soft landscaping to be retained.

This has been undertaken to cover likely exposure scenarios for the development – i.e. inhalation of vapours, when no private gardens are scheduled and inhalation of dust, from 'tracked back' dust associated with Public Open Space adjacent to residential housing.

Details of the GAC's adopted for the GQRA are provided in Appendix D.

6.1.1 Soils

Representative samples of Topsoil, Made Ground and natural soils were taken from exploratory holes across the Phase 2 area and tested for suite presented in Table 4.1.1 with a total of 23 No. samples tested.

As discussed within the previous section, comparison of the soil analysis results has been undertaken against Generic Assessment Criteria (GAC) for combined land use scenarios *Residential without Homegrown Produce* for areas within and adjacent to proposed building footprints, whilst *Public Open Space (Residential)* is considered for areas of proposed open space.

Soil organic matter (SOM) has a strong bearing on the availability of potential contaminants and therefore influences the Tier 1 thresholds. The SOM typically ranged from 0.1 to 0.9%, with an average of 2.5%. As such, the comparison has been made against GACs developed for a sandy soil with a SOM of 1%.

The results of the environmental testing can be referred to in Appendix C. Copies of the adopted Tier 1 thresholds are contained within Appendix D.

The results of the screening did not identify any exceedances within the soils submitted for laboratory testing.

Additionally, were visual and olfactory indicators of contamination were noted in shallow soils of TP119, the results of the laboratory testing determined Total Petroleum Hydrocarbons and Volatile Organic Compounds concentrations below the conservative screening of Residential with Homegrown Produce 1%SOM.

6.1.2 Asbestos

A total of 23 No. samples (Topsoil and Made Ground) obtained as part of the investigation were submitted for Asbestos presence and screening, (detailed in Table 6.1.2 below). The results of the testing determined the presence of Asbestos in one sample (TP116), further details of the sample presented in Appendix A.

Following the positive identification of Asbestos, the positive identification sample underwent further testing to determine the percentage weight of Asbestos within the sample (Asbestos Quantification), presented in Table 6.1.2.

Table 6.1.2 *Summary of Asbestos Identification and Quantification*

Location	Depth (m bgl)	Strata	Determinant	Mass Quantification (%)
TP116	0.20	Topsoil	Chrysotile - Loose Fibres	<0.001

The positive identifications were noted within existing vegetation area (TP116) along the western boundary within Topsoil material. As such, this is indicative of potential localised Asbestos present within Topsoil in this area, with soil noted to contain hardcore, brick and concrete which is likely the source of the identified Asbestos. TP106 and TP107 advanced within the area of former Asbestos hand-picking exercise did not identify the presence of Asbestos in soil samples submitted for laboratory testing.

Although present within a proposed soft landscaping area adjacent to Block 12, where a potential risk to future site users is present through inhalation of fibres risk, it is envisaged the risk would be considered to be **Low** following the formation a 450mm clean capping layer in areas of soft landscaping, consisting of the importation of Topsoil/sub-soil material (to cover the likely shortfall of material). Where building footprints are present, the potential risk to future site users is negate due to presence of hardstanding breaking the contaminant pathway.

The results of the quantification testing recorded Asbestos per unit weight of <0.001% and as such these soils would be considered non-hazardous (<0.1%) in terms of Asbestos content (discussed further in Section 7.2).

7.0 Preliminary Waste Characterisation and Re-Use of Soils

7.1 Re-use of Site Soils

Following the human health GQRA undertaken within Section 6.0, it is considered that re-use of soils across the Phase 2 site area is suitable without posing a potential risk to future site users, providing a 450mm of clean capping (above existing Made Ground soils) is incorporated in proposed public open space areas. Based on existing preliminary data, the Topsoil along the western boundary is not considered suitable re-use within the Phase 2 area (in terms of environmental quality) due to presence of Asbestos within TP116. However, it is considered existing Topsoil volumes are unlikely to be sufficient for the site and it is likely that the importation of further Topsoil and sub-soil will be required.

On this basis, with respect to their quality, all site-won soils are considered suitable for re-use.

In addition to quality, the re-use of site-won soils is governed by the following principles:

i) the geotechnical suitability of the material needs to be confirmed;
ii) ii) the re-use of the material needs to be covered as part of the planning approval, e.g. site levels maintained within agreed limits;
iii) iii) the volume of the material being re-used needs to be confirmed and traceable and iv) regulatory approval from the relevant authorities should be sought.

These principles are outlined within the CL:AIRE Code of Practice (v2) and if and where the re-use of site-won soils is proposed as part of the development works it is recommended that a Materials Management Plan is produced in line with the Code of Practice to detail and document the process.

7.2 Waste Classification of Soils

It is the responsibility of the contractor and/or their appointed groundworks contractor to confirm waste classifications of soils requiring disposal off site.

Where any site soils are to be disposed of off-site guidance on the disposal of contaminated soils is provided within the following documents published by the Environment Agency.

a) Guidance on the classification and Assessment of Waste Technical Guidance WM3 (1st Edition 2015) (13)

Guidance states that the principal contractor (or any other sub-contractor undertaking excavations) should, in conjunction with the proposed disposal facility, use where possible the relevant environmental chemistry analyses results to classify any surplus material identified for

off-site disposal. However, it should be noted that this information is for guidance only and material identified for disposal should be tested and assessed in accordance with WM3 to enable classification during the works.

An initial assessment for the waste classification of the Topsoil, Made Ground and natural soils on-site encountered on site has been carried out through a comparison of the soil testing results, using the Waste Soils Characterisation Assessment Tool, Cat-Waste^{Soil}, developed by M^{c}Ardle and Atkins. This online tool gives a rapid assessment of contaminated soils and their classification as either hazardous or non-hazardous waste. In addition, two samples of shallow soils underwent Waste Acceptance Criteria (WAC) testing to determine indicative disposal requirements.

The initial CAT Waste assessment has revealed that Made Ground and natural soils on-site may be considered non-hazardous for off-site disposal as a preliminary classification.

The results of WAC testing on the Made Ground and natural soils indicate these soils could be considered an Inert waste classification. However, given the localised presence of Asbestos (loose fibres) within Topsoil in vegetated western area of the Phase 2 site, these such soils are likely to be considered non-hazardous (quantifications recorded <0.001%).

It is recommended that prior to disposal any potential bulk Asbestos/ACM and general Made Ground are separated to prevent cross-contamination and the unnecessary creation of larger streams of potentially hazardous waste based on Asbestos content. Further to this, it is recommended that prior to removal and disposal of any soils off-site, that the stockpiled material undergo Asbestos presence and screen along with quantification to determine their non-hazardous/hazardous Asbestos waste threshold.

As discussed, preliminary waste classification is undertaken to offer indicative advice with respect to disposal requirements and Waste Acceptance Criteria (WAC) testing has been scheduled to support these classifications. Given the potential variance of soils, it is recommended that additional WAC testing of each material to be disposed is undertaken to verify the waste classification, however this is to be confirmed by the contractor. Furthermore, landfill operators are not obliged to accept waste and, if they were to do so, may have specific requirements beyond those outlined above prior to acceptance.

8.0 Geotechnical Assessment

8.1 Structural Design Details

At the point of issue, the current development plans for the subject site, include for the construction of six multi-storey (six to seven storey's) residential blocks (Block 8 to 13) with roadways, parking, open space and attenuation ponds. The following sections outlines general geotechnical advice for the Block 8, 9, 12 and 13 apartment developments only.

General design considerations are therefore, identified as follows;

- Potential high imposed loads by multi-storey (6 to 7) structures;
- Areas of deep reworked uncompacted natural soils across the site (>2.0 m bgl);
- Ground floor slab options;
- Presence of localised dissolution features within the north-western region of Block 12;
- Areas of dense mature vegetation along western boundary of the site;
- Earthworks appraisals – materials classification and practicalities of material on-site; and,
- Materials management, e.g. suitability of existing soils for re-use on site and waste classification of existing soils.

8.2 Ground Conditions

The generalised geological succession is outlined in Section 6.0 and copies of the borehole logs presented within Appendix B.

In general, the revealed ground model was consistent with the recorded geological succession and recent turnover of site soils. Made Ground comprising re-worked superficial deposits extended to 1.80 to 5.0 m bgl. Thereafter either Lowestoft Formation or Kesgrave Catchment were encountered initially fine (soft and firm clays) becoming coarse grained (gravels), to depths of between 9.80 to 14.40 m bgl. Thereafter bedrock of the Lewes Nodular and Seaford Chalk was encountered initially comprising low density Dm grade chalk to depths of 20.0m to 24.00m bgl with medium density Dc grade chalk thereafter (base not encountered).

The typical values for each of the different strata revealed on site are tabled below.

8.2.1 Made Ground

The Made Ground deposits are characterised by either a Topsoil or a reworked superficial deposits material with the following properties, highlighted in Table 8.2.1a and 8.2.1b below.

Table 8.2.1a *Typical values of Made Ground: Topsoil*

Made Ground: Topsoil	Minimum	Maximum	Mean
Layer Thickness (m)	0.20	0.40	-
pH Value	7.2	7.4	7.3
Water Soluble Sulphate Content (mg/l)	10.5	387	198.8

Table 8.2.1b *Typical values of Made Ground: Reworked Superficial*

Made Ground: Reworked Superficial	Minimum	Maximum	Mean
Layer Thickness (m)	1.20	4.80	-
pH Value	5.0	9.3	7.2
Water Soluble Sulphate Content (mg/l)	10.5	387	198.8
Moisture Content (%)	2.9	24	13.5
Liquid Limit (%)	33	41	37
Plasticity Index (%)	17	32	20
Shear strength cu – (derived by N value x 4.5) (kN/m^2)	22.5	225	123.8
N Values (Relative Density)	5 (Loose)	50 (Very Dense)	27.5 (Dense)
Remoulded CBRs (%)	0.26	22	11.1
In-Situ CBRs (%)			
1st Load Cycle	0.26	6.4	3.3
2nd Load Cycle	1.5	22	11.8
Moisture Condition Values	2.2	13.9	16.1

The fine grained re-worked superficial soils are recorded to comprise low to high plasticity clays and consequently have a low to moderate volume change potential.

The MCVs (minimum of 2.2) and remoulded/in-situ CBRs (minimum of 0.26) are reflective of a material that has been deposited as part of the turnover without compaction and not in line with an engineering specification. It is considered that shallow soils in some areas of the site within their current state are unsuitable for development without appropriate treatment (under an engineering specification) to form suitable development levels and support the proposed temporary platform for piling operations.

Particle Size Distribution testing was undertaken on re-worked superficial soils to confirm on-site observations and provide material class in line with Specification for Highway Works (SHW) 600 Series. The testing confirmed the presence of both fine and coarse-grained material within re-worked superficial soils, with testing presented in Appendix C.

8.2.2 Superficial Deposits

The superficial deposits are predominately characterised by either fine grained soils (Lowestoft Formation) or coarse-grained soils (Kesgrave) with the following properties, highlighted in Table 8.2.2.1 below and 8.2.2.2.

Table 8.2.2.1 *Typical values of Lowestoft Formation – fine grained soils*

Lowestoft Formation	Minimum	Maximum	Mean
Layer Thickness (m)	0.1	5.3	-
pH Value	5.9	8.4	7.2
Water Soluble Sulphate Content (mg/l)	63.6	109	86.3
Moisture Content (%)	3.1	25	14.1
Liquid Limit (%)	34	-	-
Plasticity Index (%)	17	-	-
Shear strength cu – (derived by N value x 4.5) (kN/m^2)	18	225	121.5

On-site observations supported by in-situ testing confirm the fine-grained soils to consist of soft gravelly clays with a high plasticity and consequently a moderate volume change potential.

Table 8.2.2.2 *Typical values of Kesgrave – coarse grained soils*

Kesgrave Catchment	Minimum	Maximum	Mean
Layer Thickness (m)	1.8	9.0	-
pH Value	7.3	8.5	7.9
Water Soluble Sulphate Content (Soils) (mg/l)	12	-	-
N Values (Relative Density)	10 (Very Loose)	50 (Very Dense)	30 (Dense)

On site observations, supported by in-situ testing, indicate the coarse grained Kesgrave soils are predominately medium dense to very dense at the interface with the chalk strata, resulting in refusal of CPTs in very dense material. The refusals in certain areas of the site indicate that the presence of dissolution features within chalk are unlikely, with such features likely to cause a subsurface 'collapse' or swallow hole which would result in lower density values of coarse grained strata (further discussion provided in Section 5).

8.2.3 Bedrock – Lewes Nodular and Seaford Chalk Formation

The bedrock deposits of the Chalk are characterised by initially Dm grade Chalk with Dc grade Chalk thereafter with the following properties, highlighted in Table 8.2.3. below.

Table 8.2.3 *Typical values of Bedrock*

Bedrock: Chalk	Minimum	Maximum	Mean
Depth to Bedrock (m bgl)	9.5	14.40	-
Moisture Content (%)	29.3	36.2	32.8
pH Value	8.1	9.3	8.7
Water Soluble Sulphate Content (mg/l)	13	85	48
N Values	6 (Low density)*	50 (Medium/High Density)*	28 (Medium Density)*

Bedrock: Chalk	Minimum	Maximum	Mean
Saturated Moisture Content (%)	29.8	42.0	34.9
Bulk Density (Mg/m^3)	1.74	1.93	1.84
Dry Density (Mg/m^3)	1.26	1.50	1.38

Notes - *Inferred based on CIRIA C574 Engineering in Chalk Guidance

The saturated moisture contents and intact dry density testing of the chalk material indicate low density chalk. With reference to CIRIA C574 the N values detail the chalk ranges from low to medium/high density.

8.3 Foundation Design

At the point of issue, the current development plans for the subject site, include for the construction of six multi-storey (six to seven stories) residential blocks (Block 8 to 13) with roadways, parking, open space and attenuation ponds.

The following preliminary foundation design pertains to Block 8, Block 9, Block 12 and Block 13 only, with reporting to be updated following completion of the second phase of ground investigation.

The high imposed loads together with the revealed ground model on site direct the adoption of a deep foundation solution for the developments commentary on which is presented below in Section 8.3.1.

8.3.1 Piled Foundations

Considering the geotechnical parameters outlined above in Section 8.2.3, and observations made on site it is recommended that piled foundations be formed within the Lewes Nodular and Seaford Chalk Formation. Due to the similar depths to the top of chalk bedrock between Block 8 to Block 13, a general preliminary pile foundations information has been given.

It is recommended that piled foundations are advanced into sufficient (<2m thick) uniform bedrock strata that, in general, corresponds with the medium density (inferred from SPT values) chalk deposits underlying the site encountered at depths of between 20.00m to 24.00 m bgl

Given the evolving nature of pile design and pile technology it is recommended that a specialist contractor is commissioned to undertaken detailed design of the piles. The following commentary is therefore offered as preliminary guidance with respect to their design, with the final design to be undertaken by specialist contractor.

Pile Type: In light of the ground conditions revealed a bored, e.g. Continuous Flight Auger (CFA), piled solution is considered technically feasible within any proposed development and given the dissolved phase contamination noted within groundwater the only method likely to be approved by the Environment Agency (piling into a Principal Aquifer and groundwater source protection zone).

It is considered that the likely carrying capacity of a 22.0 m long, 450 mm diameter bored pile (based on a factor of safety of 2.5) is estimated in the region of 1.2 to 1.3 MPa, based on medium density chalk at circa 20.0 to 24.0m bgl.

Note – it is recommended that the localised dissolution features within Block 12 are grouted prior to piling, with a piling contractor unlikely to warrant piles within this area without such mitigation.

Potential Constraints: It is recommended that due consideration be given to the practicalities of installing piles and the proximity to pre-existing structures. Retaining structures, if and where required, could be designed as either temporary or permanent elements. Advice of the appointed structural engineer and suitably experienced piling contractor should be sought in both instances.

Temporary Casing: The presence of Made Ground deposits will likely necessitate temporary casing within some pile locations to ensure pile consistency and avoid excessive loss of concrete within voids.

Piling Platforms: In its current condition, it is unlikely that the shallow Made Ground soils will be suitable (in their current state based on geotechnical testing) to support the load of a piling rig, with recommendation for a piling matt to be imported onto site. In addition, prior to the importation the shallow soils will either require proof rolling or else regulation and proof testing to confirm suitability underlying the matt. The presence of soft natural soils at the base of the Made Ground should be considered when designing piling platforms.

8.4 Ground Floor Slabs

In general, based on the current condition of the shallow site soils (uncompacted reworked superficial soils), Made Ground predominately greater than 1 m across the site and the required piled foundation solution, a suspended floor slab is recommended for the majority of the development.

Regulation of the Made Ground (reworked superficial soils) through ground improvement is considered technically feasible and should be considered if and where the adoption of ground bearing floor slabs is considered.

8.4.1 Ground Gas Protection Measures

Ground gas protection measures are not recommended for the development site in line with previous reporting undertaken by EAME (as discussed in Section 2.0)

8.5 Settlement and Heave Considerations

In addition, due to the presence of medium to high volume change potential soils (clays) and the presence of mature trees (primarily western portion of the site), reference to NHBC Standards 'Building near trees' (14) should be made prior to the removal and planting of such trees with foundations designed accordingly.

With reference to the proposed piled foundation solution settlement levels should be limited to tolerable levels as agreed with the Structural Engineer.

8.6 Excavations

General advice on excavation support is given in CIRIA Report No 97: Trenching Practice (15).

Based on observations on site, together with the results of in-situ and laboratory tests, it is considered likely that most shallow excavations will stand unsupported in the short term within areas of reworked superficial Made Ground. However, excavations are likely be prone to instability if there is the presence of boulders and cobbles (concrete and brick) within the excavation. Further to this, pit instability was noted in a number of trial pit excavations across the site beyond depths of 1.80m bgl, as presented on the logs in Appendix C. The instability noted within the trial pits is likely due to the enabling works excavations being completed in a 'controlled manner' rather than to an engineering specification.

Side support for safety purposes should be provided to all excavations which appear unstable and those more than 1.20 m deep, in accordance with Health and Safety Regulations. Excavations below 1.20 m requiring personnel access will require closed side support.

Site wide groundwater has predominately not been encountered in shallow soils (with exception of TP119 at 2.0m bgl – localized perched groundwater) and, if present, would likely comprise seepages and as such pumping from a sump is considered to be a suitable control measure. Pumping rates within the granular demolition fill should be monitored closely so as to not result in excessive loss of fines and thus loss of support. General advice on de-watering is given in CIRIA Report No C750: Groundwater Control (16).

8.7 Concrete Design

In accordance with BRE Special Digest 1 (17) the site has been classified as 'brownfield land unlikely to contain pyrite' and laboratory testing undertaken accordingly within the Made Ground and natural deposits.

The results of chemical tests in the Made Ground, superficial deposits and bedrock deposits indicate sulphate concentration in the soil of <0.5 g/l l as a 2:1 water/soil extract. pH values were found to be in the range of 5.0 to 9.3. It is recommended that the groundwater should be regarded as mobile for ground conditions due to presence of deep groundwater on-site.

Based on the above and a worst-case scenario, the Made Ground and natural deposits tested, fall within DS-1, AC-3z classification category and as such it is recommended that the concrete should be designed to the above.

In addition, it is recommended that the designing of concrete takes into account the presence of dissolved phase hydrocarbons in groundwater across the site.

8.8 Roads and Hard-standing Design

In-situ and laboratory (on re-moulded specimens) CBR testing was undertaken as part of the ground investigation.

On the basis, that in-situ testing and laboratory testing derived the following worst case CBRs value of 0.26%, it is recommended that: a CBR value of no more than 1% is adopted for preliminary design purposes.

As the Made Ground is variable it is suggested that the formation be proof rolled prior to the installation of the required sub-base layers. It is recommended that with proof rolling higher CBR values may be achievable (evident of 22% CBR value in area compacted as part of the remedial works), where required this should be confirmed through additional testing. In addition, it is recommended that any potential boulders or cobbles be removed from the formation.

In general, any areas of soft or deleterious material in the site shallow soils should be excavated and replaced with a properly compacted granular fill to suit both road and hard-standing design as well as other ground bearing structures.

8.9 Soakaways

Infiltration testing of shallow soils in accordance with BRE365 was not undertaken as part of the ground investigation. With reference to BRE365 soakaways are not recommended to be adopted within Made

Ground soils and as a result of the site turnover, Made Ground is present across the Block 8 to 13 areas at depths ranging from 1.20m to 4.80m bgl, predominately 2.00m bgl.

9.0 Conclusion and Recommendations

9.1 Conclusion

The findings on the Generic Quantitative Risk Assessment and suitability for re-use of site soils is presented in Section 6.0.

9.1.1 Ground Model

In general, the revealed ground model was consistent with the recorded geological succession and recent turnover of site soils. Made Ground comprising re-worked superficial deposits extended to depths of between 1.20 and 4.80 m bgl. Thereafter either Lowestoft Formation or Kesgrave Catchment were encountered initially fine (soft and firm clays) becoming coarse grained (gravels) to depths of 9.80m bgl to 14.40m bgl. Thereafter bedrock of the Lewes Nodular and Seaford Chalk was encountered initially comprising low density Dm grade chalk to depths of circa 20.0m to 24.0m bgl with medium density Dc grade chalk thereafter (base not encountered).

9.1.2 Risk Assessments

Following the turnover of site soils, the current risk to future site users is considered Low, with the recommendation of 450 mm of clean capping (consisting of existing material - western boundary and importation of Topsoil/sub-soil material) is placed within soft landscaping areas. This is to protect future site users from localised Asbestos encountered within Topsoil as part of the enabling works and serve as a suitable growing medium for soft landscaping area (subject to the landscape architect's design).

9.2 Recommendations

With reference to the generic quantitative risk assessments the requirement for risk mitigation measures has been identified for both the Development Works and Proposed End Use of the site as outlined below under the respective headings.

Geotechnical recommendations are presented within Section 8.0.

9.2.1 Risk Mitigation Measures - Development Works

The Principal Contractor shall be responsible for ensuring that method statements and risk assessments are in place for the safe handling of excavated soils on-site during construction, in line with their requirements under the CDM Regulation (2015).

Appropriate measures should be in place to mitigate the risk posed by the Made Ground identified on site with particular attention paid to the presence of asbestos fibres and potential for Asbestos Containing Materials to be identified.

With respect to unexploded ordnance, the risk is considered predominately **Low to Medium** with the recommendation for the following;

All Works

- *Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.'*

9.2.2 Risk Mitigation Measures - Proposed Residential End Use

One risk mitigation action is recommended for the proposed end use of the development:

1) 450mm of clean cover (consisting of importation of Topsoil/sub-soil) within all proposed soft landscaping areas to break potential contaminant pathway.

9.2.3 Follow-on Works and Reporting

It is recommended that the following additional works are undertaken prior to the development on-site:

- The production of a grouting specification to mitigate the localised dissolution features present within the north-western corner of Block 12 as identified as part of Delta Simons (BH407) and EAME investigation (Z5).
- Importation of Topsoil to form the required 450mm of clean cover within soft landscaping covering the shortfall of existing Topsoil material on-site.
- It is recommended that a Developer's Method Statement is prepared for the site, detailing the requirements for importation of material (Topsoil, sub-soil and fill to the southern area) required to obtain necessary site levels, the suitability (environmental) thereof and environmental measures for construction phase to ensure the current planning conditions (in regard to environmental) are suitability discharged.

Given the results of the geotechnical testing undertaken on re-worked superficial soils, it is recommended that an earthworks strategy is undertaken comprising the re-compaction of shallow soils to form suitable platform levels, capable of supporting the anticipated works of the construction phase and the required piling matt to be imported for each of the proposed blocks.

10.0 References

1**Delta Simons***Phase I Environmental Assessment - Former Shredded Wheat Factory, Broadwater Road, Welwun Garden City*January 2015

2*Factual and Interpretative Geotechnical Report - Former Shredded Wheat Factory, Broadwater Road, Welwyn Garden City*January 2015

3**EAME***Environmental Assessment (Southern Area), Broadwater Road Site, Welwyn Garden City*March 2018

4*Remediation Strategy (Southern Area), Broadwater Road Site, Welwyn Garden City*June 2018

5**Environment Agency (EA)***Model Procedures for the Management of Land Contamination, Contaminated Land Report (CLR) 11*September 2004

6**British Standard Institution (BSI)** *Investigation of Potentially Contaminated Sites (report no. BS10175).*2011

7**British Standards (BS)***BS 5930, Code of practice for site investigations*2010

8**British Standards Institution***Eurocode 7: Geotechnical Design (report no. BS EN 1997*2006

9**Environment Agency***Contamined Land Exposure Assessment (CLEA) v.1.06 Model*September 2009

10*Human health toxicological assessment of contaminants in soil. Science report 2.*January 2009

11*Updated technical background to the CLEA model. Science Report 3*January 2009

12**Department of Environment, Food and Rural Affairs (DEFRA)***Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance (report no.PB13735).*2014

13**Environment Agency***Guidance on the classification and assessment of waste (1st edition 2015). Technical Guidance WM3*May 2015

14**National House Building Council (NHBC)***NHBC Standards, 'Building Near Trees' Chapter 4.2*2016

15**CIRIA***CIRIA Report 97 - Trenching Practice - Second Edition*November 1992

16*CIRIA Report No C750 Groundwater Control*2016

17**BRE***BRE Special Digest 1 (SD1:2005), Concrete in aggresive ground, 3rd Edition*2005

Appendices

Appendix A **Drawings**

Appendix B **Detailed Unexploded Ordnance Risk Assessment**

Appendix C **Factual Ground Investigation Report**

Appendix D **Curtins Tier 1 Thresholds**

Appendix A Drawings

- Proposed Development Plans; and,
- Plan of Long-Term Monitoring Boreholes.

NOTE:
STRUCTURE AND M&E NOT SHOWN FOR CLARITY.
MINOR COORDINATION TWEAKS MAY BE REQUIRED FOLLOWING DESIGN FREEZE ISSUE.

PLEASE REFER TO:

00 SERIES:
SITE WIDE DRAWINGS

20 SERIES:
GENERAL ARRANGEMENT DRAWINGS

22 SERIES:
EXTERNAL WALL SETTING OUT
INTERNAL WALL SETTING OUT
SLAB EDGE SETTING OUT

24 SERIES:
STAIRCASE DRAWINGS
BALUSTRADE DRAWINGS

25 SERIES:
CORE / LIFT DRAWINGS

27 SERIES:
ROOF DRAWINGS

30 SERIES:
APARTMENT TYPE DRAWINGS

31 SERIES:
WINDOW TYPE / DETAILS / SCHEDULE DRAWINGS

32 SERIES:
DOOR TYPE / DETAILS / SCHEDULE DRAWINGS

70 SERIES:
KITCHEN / BATHROOM DRAWINGS

FOR LANDSCAPE:
PLEASE REFER TO LANDSCAPE ARCHITECTS INFORMATION

NOTES
CONSULTANTS
- Refer to highways consultant's drawings for details
- Refer to landscape consultant's drawings for details
- Landscaping layout is indicative only

AREAS
- Refer to area schedule

Rev	Notes	Date	By	Auth
D1	Design Freeze	31.07.2018		MR

0m 10m 20m 30m 40m 50m

VISUAL SCALE 1:500 @ A1

ColladoCollins Architects
17-19 Foley Street
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www.colladocollins.com

Date: 31/07/2018
Drawn By: RB / BM
Checked by: MR
Scale @ A1: As indicated
Scale @ A3:
CAD File No:

Plutus Estates (WGC) Limited and Metropolitan Housing Trust
Former Shredded Wheat Factory

Overall Ground Floor GA plan

STAGE 4

18009-CCA-00-00-DR-A-20-000 D1 Revision

SURFACE WATER TO BE RESTRICTED TO 5 l/s/Ha

DISTRIBUTION OF ATTENUATION VOLUME ACROSS SITE TO BE CONFIRMED BY DETAILED HYDRAULIC MODELLING AND CONFIRMATION OF SUDS PROPOSALS FROM PLANNERS.

PERMEABLE PAVING AREAS DESIGNED TO SELF ATTENUATE DUE TO UNDERLYING CHALK. YARD GULLIES IN PATIO AREAS MY BE ABLE TO DISCHARGE TO GROUND INFILTRATION TO BE CONFIRMED BY GEO-TECHNICAL REVIEW.

GENERAL NOTES:

1. This drawing is to be read in conjunction with all relevant Architects and Engineers drawings and specifications.
2. Do not scale from this drawing. All details and dimensions and levels are to be checked by the contractor prior to commencement of construction. Any discrepancies are to be reported to the Engineer.
3. All levels are in meters & dimensions in millimeters unless noted otherwise.
4. Design based on topographical survey and CCTV survey information available at the time of design. All existing sewers, connections, pipe sizes and invert levels to be confirmed by contractor prior to commencement of works to ensure connectivity. Any variance from the information shown should be reported to the engineer for review.
5. Where existing drainage is being used, allowances should be made to remediate this drainage in line with available CCTV survey information.
6. Where there is no requirement to keep existing drainage, allowances should be made to abandon this in line with Curtins drainage specification.
7. Any new gully and external surface water inlet positions and associated falls to them are shown indicatively and to be designed set out by the Landscape Architect.
8. Cover levels should be confirmed against Landscape Architects level design. Any discrepancy should be raised and coordinated to the engineer ASAP.
9. All internal drainage points are shown indicatively and are to be designed and set out by the M&E engineer.
10. Any drainage runs and their connections damaged through construction works should be replaced to sufficient standard.
11. Diversion and abandonment of services associated with these designs by others.
12. Lateral connections from internal drain points should be sized to match above ground designs, with minimum size of 100Ø.
13. Infiltration to ground from permeable paving areas to be confirmed by further geo-technical review.
14. Surface water restricted to Greenfield runoff rates. 5 l/s/Ha for total site area of 3.79 Ha equates to 19.86 l/s for the entire site.
15. S106 Application required for new connection to public sewer.
16. Pipe diameter indicative only. Capacity check to be carried out to confirm proposals.
17. Further co-ordination required with Structural Engineers.
18. Current drawing taken from Proposed Drainage Layout including pile caps.

KEY

RW/BH – Potential Long Term Monitoring Borehole (Delta Simons, 2015)

BH01-17 – Potential Long Term Monitoring Borehole (EAME, 2017)

A,B,C,D,Z – Potential Long Term Monitoring Borehole (JFH, 2018)

● To be retained until September 2019

● To be retained until April 2021

Rev:	Description:	Date:	By:	Chkd:
P01	STAGE 4 ISSUE	28.08.18	FD	AS
T02	FOUL NETWORK REVISED TO GRAVITY	01.08.18	NMH	AS
T01	STAGE 3 ISSUE	20.04.18	DSR	AS

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Civils & Structures • Transport Planning • Environmental • Infrastructure • Geotechnical • Conservation & Heritage • Principal Designer
Birmingham • Bristol • Cambridge • Cardiff • Douglas • Dublin • Edinburgh • Glasgow • Kendal • Leeds • Liverpool • London • Manchester • Nottingham

Status: STAGE 4

Project: SHREDDED WHEAT, METROPOLITAN

Drg Title: LONG TERM MONITORING BOREHOLE PLAN

Size:	Date:	Drawn By:	Designed By:	Checked By:
A0	02.11.2018	W.SPRAGGS	W.SPRAGGS	D.HAMMOND
Scale: 1:250				

Project No:	Originator:	Zone:	Level:	Type:	Discipline:	Category / Number:	Rev:
067358	CUR	00	00	DR	GE	00003	P01

\\LOFS03\Projects\067000.000 - 067999.000\067358 - Shredded Wheat\Data for August Progress Report WS\Drawings for Meetings\

Appendix B Detailed Unexploded Ordnance Risk Assessment

Detailed Unexploded Ordnance (UXO) Risk Assessment

Project Name	Former Shredded Wheat Factory, Welwyn Garden City
Client	Curtins
Site Address	Former Shredded Wheat Factory (Southern Section), Broadwater Road, Welwyn Garden City, AL73BQ
Report Reference	DA7853-00
Date	8th January 2019
Originator	HS

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1st Line Defence Limited

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Tel: +44 (0)1992 245 020 info@1stlinedefence.co.uk

Executive Summary

Site Location and Description

The site is located in the town of Welwyn Garden City, within the county of Hertfordshire. It is bound by Hydeway to the north, Broadwater Road to the east and Otto Road to the south, whilst railway and associated structures bind the site to the west.
The site is comprised of a large plot of cleared former industrial land alongside the railway. A line of trees and vegetation lines the western border of the site, with much of the site being typified by rough recently cleared ground; aside from an area of the site in the west, which extends onto the roadway in the south. The remainder of the area of the site is typified by cleared ground interspaced with rubble, brick and concrete debris.

The site is approximately centred on the OS grid reference: **TL 2413412724**

Proposed Works

The scope of works on site are understood to comprise a variety of ground investigational works including cable percussion boreholes, cone penetration testing, the excavation of trial pits and trenches as well as plate load testing works, in preparation for the construction of several blocks of residential dwellings.

Geology and Bomb Penetration Depth

The British Geological Survey (BGS) map shows the bedrock geology of the site to be underlain by the White Chalk Subgroup Formation– chalk, of the Cretaceous Period. The superficial deposits are comprised of glacial and gravel of the Quaternary Period.
Taking into account the site specific geology provided by Curtins (see section 9.2) and the factors discussed in this section, it has been assessed that a 500kg bomb could have had a maximum bomb penetration depth of **8.7m** below WWII ground level.

It should be noted that the maximum depth that a bomb could reach may vary across a site and will be largely dependent on the specific underlying geological strata and its density.

UXO Risk Assessment

1st Line Defence has assessed that there is a **Low Risk** from items of unexploded German aerial delivered ordnance across the site and a **Low-Medium Risk** from historic Allied Land Service Ammunition/Small Arms Ammunition. This assessment is based on the following factors:

The Likelihood of German Aerial Delivered Ordnance Contamination

- During WWII, the Urban District of Welwyn Garden City sustained an overall low density bombing campaign, with an average of 12 items falling per 1,000 acres according to Home Office statistics. The district sustained only 29 recorded HE bomb strikes - this can likely be attributed to the lack of strategic targets in the area.
- Hertfordshire Air Raid Damage files do not refer to any incidents or damage being sustained on the site or the immediate surrounding area, with the closest incident being the explosion of an anti-aircraft projectile approximately 200m from the site, below Welwyn railway station.
- OS mapping does not present any significant changes to the structural composition of the site, with post-war changes restricted to the construction of several small outbuildings, whilst the footprint of larger structures remains consistent. No elements indicative of bomb damage such as missing or ruined structures are present, either on or within the environs of the site area.
- Immediate post-war aerial photography parallels OS mapping, illustrating the same structures to be on site. Whilst certain areas of the site feature disturbed ground, these are all areas that would have been used as access ways, with no visible damage or repair work observable.
- Access on site is anticipated to have been regular throughout the start of the war, due to the presence of the British Instructional Film Studios and an electrical heater works on site. The wartime of the operation of the former is very

UXO Risk Assessment

well documented in historical source material, including the production of several propaganda and public information films. It is therefore considered highly likely that any bomb strikes falling on or near this structure would have been documented and dealt with.

- Whilst the northernmost section of the site remained as unoccupied ground, it appears well maintained in aerial photography, and the presence of the tennis courts, as well as the road to the north would have provided a good deal of access to this area, increasing the likelihood that evidence of UXO would have been observed and subsequently reported.

The Risk from Allied Ordnance Contamination

- During WWII the site area is recorded to have been positioned within close proximity to several Home Guard installations and defensive locations. Both a road block and pillbox, as well as a mobile reserve company are recorded to have been situated to the north, whilst Home Guard Location statements for Welwyn highlight that the original location of the Shredded Wheat Factory, to the north of the site, was designated as a 'battle' Headquarters.
- Additionally, a rifle range is recorded to have been located within the site area. This range officially opened as the 4th Battalion Herts Home Guard Rifle Club in 1945, and was used for the shooting of small arms including rifles and submachine guns. The exact date when the range was disused could not be identified, however records indicate that the club continued as the Welwyn Garden Rifle Club until the mid-1980s.
- Whilst OS mapping does not indicate any features consistent with military use on site, 1946 aerial photography highlights several 'Zig Zag' trenches approximately 200m to the south-east of the site area. It is considered likely that these are connected to the Home Guard activity in the area, and were potentially used for training purposes. Despite their proximity, this feature is not considered to directly impact the risk on site, although they do highlight the build-up of Home Guard activity in the wider area.
- The exact nature of activities conducted with ordnance, both on the rifle range and on by the Home Guard could not be discerned with available records, however their presence in the general vicinity and well as the shooting of small arms ammunition on the range presents a potential risk of contamination. This level of contamination is considered to be limited by the presence of the film studios on site and is not anticipated to have comprised any major military training exercises or the storage of significant volumes of live ordnance. However, due to the lack of clarity surrounding this usage, it has not been possible to entirely mitigate the risk posed by Allied ordnance on site.
- The conditions in which HAA or LAA projectiles may have fallen unnoticed within the site boundary are however analogous to those regarding aerial delivered ordnance.
- There has been some substantial redevelopment work undertaken on site in post-war years, including the demolition of the former film studios and associated structures and the construction of new industrial structures of the Shredded Wheat Factory.
- Items of LSA and SAA if present, are likely encountered at a depth between just below ground level, accordingly there is also a possibility that UXBs could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level.
- There is not considered to be any significant risk of encountering UXO during works planned within the footprint and down to the depth of any post-war buildings/excavations. Beyond these depths and away from these areas, a risk of encounter could remain.

Recommended Risk Mitigation Measures

The following risk mitigation measures are recommended to support the proposed works at the Former Shredded Wheat Factory (Southern Site), Welwyn Garden City:

All Works

- Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.

Glossary

Abbreviation	Definition
AA	Anti-Aircraft
AFS	Auxiliary Fire Service
AP	Anti-Personnel
ARP	Air Raid Precautions
AWAS	Air Warfare Analysis Section
DA	Delay-action
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
FP	Fire Pot
GM	G Mine (Parachute mine)
HAA	Heavy Anti-Aircraft
HE	High Explosive
IB	Incendiary Bomb
LAA	Light Anti-Aircraft
LCC	London County Council
LRRB	Long Range Rocket Bomb (V-2)
LSA	Land Service Ammunition
MOL	Molotov (Incendiary Bomb)
OB	Oil Bomb
PAC	Pilotless Aircraft (V-1)
PB	Phosphorous Bomb
PM	Parachute Mine
POW	Prisoner Of War
RAF	Royal Air Force
RCAF	Royal Canadian Air Force
RFC	Royal Flying Corps
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SA	Small Arms
SAA	Small Arms Ammunition
SD1000	1,000kg high explosive bomb
SD2	Anti-personnel “Butterfly Bomb”
SIP	Self-Igniting Phosphorous
U/C	Unclassified bomb
UP	Unrotated Projectile (rocket)
USAAF	United States Army Air Force
UX	Unexploded
UXAA	Unexploded Anti-Aircraft
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	Flying Bomb (Doodlebug)
V-2	Long Range Rocket
WAAF	Women’s Auxiliary Air Force
X	Exploded

Contents

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1st Line Defence Limited
Detailed Unexploded Ordnance (UXO) Risk Assessment

Site: Former Shredded Wheat factory, Welwyn Garden City
Client: Curtins

1. Introduction

1.1. Background

1st Line Defence has been commissioned by Curtins to conduct a Detailed Unexploded Ordnance (UXO) Risk Assessment for the proposed works at the Former Shredded Wheat Factory (Southern Site).

Buried UXO can present a significant risk to construction works and development projects. The discovery of a suspect device during works can cause considerable disruption to operations as well as cause unwanted delays and expense.

UXO in the UK can originate from three principal sources:

1. Munitions resulting from wartime activities including German bombing in WWI and WWII, long range shelling, and defensive activities.
2. Munitions deposited as a result of military training and exercises.
3. Munitions lost, burnt, buried or otherwise discarded either deliberately, accidentally, or ineffectively.

This report will assess the potential factors that may contribute to the risk of UXO contamination. If an elevated risk is identified at the site, this report will recommend appropriate mitigation measures, in order to reduce the risk to as low as is reasonably practicable. Detailed analysis and evidence will be provided to ensure an understanding of the basis for the assessed risk level and any recommendations.

This report complies with the guidelines outlined in *CIRIA C681*, 'Unexploded Ordnance (UXO) A Guide for the Construction Industry'.

2. Method Statement

2.1. Report Objectives

The aim of this report is to conduct a comprehensive assessment of the potential risk from UXO at the Former Shredded Wheat Factory (Southern Site). The report will also recommend appropriate site and work-specific risk mitigation measures to reduce the risk from explosive ordnance during the envisaged works to a level that is as low as reasonably practicable.

2.2. Risk Assessment Process

1st Line Defence has undertaken a five-step process for assessing the risk of UXO contamination:

1. The risk that the site was contaminated with UXO.
2. The risk that UXO remains on the site.
3. The risk that UXO may be encountered during the proposed works.
4. The risk that UXO may be initiated.
5. The consequences of initiating or encountering UXO.

In order to address the above, 1st Line Defence has taken into consideration the following factors:

- Evidence of WWI and WWII German aerial delivered bombing as well as the legacy of Allied occupation.
- The nature and conditions of the site during WWII.
- The extent of post-war development and UXO clearance operations on site.
- The scope and nature of the proposed works and the maximum assessed bomb penetration depth.
- The nature of ordnance that may have contaminated the proposed site area.

2.3. Sources of Information

Every reasonable effort has been made to ensure that relevant evidence has been consulted and presented in order to produce a thorough and comprehensible report for the client. To achieve this the following, which includes military records and archive material held in the public domain, have been accessed:

- The National Archives, Kew, and Hertfordshire Archives.
- Historical mapping datasets.
- Historic England National Monuments Record.
- Relevant information supplied by Curtins.
- Available material from 33 Engineer Regiment (EOD) Archive.
- 1st Line Defence's extensive historical archives, library and UXO geo-datasets.
- Open sources such as published books and internet resources.

Research involved a visit to Hertfordshire Archives and The National Archives.

2.4. General Considerations of Historical Research

This desktop assessment is based largely upon analysis of historical evidence. Every reasonable effort has been made to locate and present significant and pertinent information. 1st Line Defence cannot be held accountable for any changes to the assessed risk level or risk mitigation measures, based on documentation or other data that may come to light at a later date, or which was not available to 1st Line Defence during the production of this report.

It is often problematic and sometimes impossible to verify the completeness and accuracy of WWII-era records. As a consequence, conclusions as to the exact location and nature of a UXO risk can rarely be quantified and are to a degree subjective. To counter this, a range of sources have been consulted and analysed. The same methodology is applied to each report during the risk assessment process. 1st Line Defence cannot be held responsible for any inaccuracies or the incompleteness in available historical information.

3. Background to Bombing Records

During WWII bombing records were gathered by the police, Air Raid Precaution (ARP) wardens and military personnel. Records were maintained in the form of local and regional written records, maps depicting the locations of individual strikes, and maps indicating the levels of damage sustained by structures. Records typically documented when, where and what types of bombs had fallen during an air raid. Records of bomb strikes were made either through direct observation or by post-raid surveys. The immediate priority was focused on assisting casualties and minimising damage. As a result some records were incomplete and contradictory.

The quality, detail and nature of record keeping could vary considerably between boroughs and towns. No two areas identically collated or recorded data. While some local authorities maintained records with a methodical approach, sources in certain areas can be considerably more vague, dispersed, and narrower in scope. Many records were even damaged or destroyed in subsequent bombing raids. Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are therefore not always reliable. Furthermore, records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

4. Background to Allied Records

During WWII considerable areas of land were requisitioned by the army for the purpose of defence, training, and the construction of airfields and facilities for munitions production. Records relating to military features vary and some may remain censored. Within urban environments datasets will be consulted detailing the location of munition production as well as air and land defences. In rural locations it may be possible to obtain plans of airfields and military establishments, as well as operational training logs, plans and personal memoirs.

5. UK Regulatory Environment

5.1. General

There is no formal obligation requiring a UXO risk assessment to be undertaken for construction projects in the UK, nor is there any specific legislation stipulating the management or mitigation of UXO risk. However, it is implicit in the legislation outlined below that those responsible for intrusive works (archaeology, site investigation, drilling, piling, excavation etc.) should undertake a comprehensive and robust assessment of the potential risks to employees and that mitigation measures are implemented to address any identified hazards.

5.2. CDM Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) define the responsibilities of parties involved in the construction of temporary or permanent structures.

The CDM 2015 establishes a duty of care extending from clients, principle co-ordinators, designers, and contractors to those working on, or affected by, a project. Those responsible for construction projects may therefore be accountable for the personal or proprietary loss of third parties, if correct health and safety procedure has not been applied.

Although the CDM does not specifically reference UXO, the risk presented by such items is both within the scope and purpose of the legislation. It is therefore implied that there is an obligation on parties to:

- Provide an appropriate assessment of potential UXO risks at the site (or ensure such an assessment is completed by others).
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks presented by the project.
- Ensure the preparation of a suitably robust emergency response plan.

5.3. The 1974 Health and Safety at Work etc. Act

All employers have a responsibility under the Health and Safety at Work etc. Act 1974 and the Management of Health and Safety at Work Regulations 1999, to ensure the health and safety of their employees and third parties, so far as is reasonably practicable and conduct suitable and sufficient risk assessments.

5.4. Additional Legislation

In the event of a casualty resulting from the failure of an employer/client to address the risks relating to UXO, the organisation may be criminally liable under the Corporate Manslaughter and Corporate Homicide Act 2007.

6. Role of Commercial UXO Contractors and The Authorities

6.1. Commercial UXO Contractors

In the event that a risk of UXO contamination is detected at the proposed site, the support of a UXO specialist may be recommended. A UXO specialist may be able to avoid unnecessary call-outs to the authorities through the disposal or removal of low risk items. In addition a specialist will assist in the swift recognition of high risk items, and will thereafter co-ordinate with the local authority with the objective of causing minimal levels of disruption to site operations, whilst putting in place safe and appropriate measures.

For more information on the role of commercial UXO specialists, see *CIRIA C681*.

6.2. The Authorities

The police have a responsibility to co-ordinate the emergency services in the event of an ordnance-related incident at a construction site. Upon inspection they may impose a safety cordon, order an evacuation, and call the military authorities Joint Services Explosive Ordnance Disposal (JSEOD) to arrange for investigation and/or disposal. In the absence of a UXO specialist, police officers will usually employ such precautionary safety measures, thereby causing works to cease, and possibly requiring the evacuation of neighbouring businesses and properties.

The priority given to the police request will depend on JSEOD's judgement of the nature of the UXO risk, the location, people and assets at risk, as well as the availability of resources. The speed of response varies; authorities may respond immediately or in some cases it may take several days for the item of ordnance to be dealt with.

Depending on the on-site risk assessment the item of ordnance may be removed from the site and/or destroyed by a controlled explosion. The latter process is lengthy and may necessitate the establishment of addition cordons and evacuations.

Following the removal of an item of UXO, the military authorities will only undertake further investigations or clearances in high risk situations. If there are regular UXO finds on a site the JSEOD may not treat each occurrence as an emergency and will recommend the construction company puts in place alternative procedures, such as the appointment of a commercial contractor to manage the situation.

7. The Site

7.1. Site Location

The site is located in the town of Welwyn Garden City, within the county of Hertfordshire. It is bound by Hydeway to the north, Broadwater Road to the east and Otto Road to the south, whilst railway and associated structures bind the site to the west.

The site is approximately centred on the OS grid reference: **TL 2413412724**

Site location maps are presented in **Annex A**.

7.2. Site Description

The site is comprised of a large plot of cleared former industrial land alongside the railway. A line of trees and vegetation lines the western border of the site, with much of the site being typified by rough recently cleared ground; aside from an area of the site in the west, which extends onto the roadway in the south. The remainder of the area of the site is typified by cleared ground interspaced with rubble, brick and concrete debris.

A recent aerial photograph and site plan are presented in **Annex B** and **Annex C** respectively.

8. Scope of the Proposed Works

8.1. General

The scope of works on site are understood to comprise a variety of ground investigational works including cable percussion boreholes, cone penetration testing, the excavation of trial pits and trenches as well as plate load testing works, in preparation for the construction of several blocks of residential dwellings.

9. Ground Conditions

9.1. General Geology

The British Geological Survey (BGS) map shows the bedrock geology of the site to be underlain by the White Chalk Subgroup Formation– chalk, of the Cretaceous Period. The superficial deposits are comprised of glacial and gravel of the Quaternary Period.

9.2. Site Specific Geology

Borehole data has been provided by Curtins for seven locations within the site boundary. See below for an example and brief description of the typical encountered geology.

Example Borehole	
Depth (m)	**Description**
0.5	Made Ground: Brown sandy clayey gravel. Gravel is angular fine to course concrete and brick. Sand is fine to coarse.
1.0	Stiff orangey brown slightly sandy gravelly clay. Gravel is angular to subrounded fine to coarse flint. Sand is fine to course. (Lowestoft Formation.)
5.0	Very Stiff orangey brown slightly sandy gravelly clay. Gravel is angular to rounded fine to coarse flint. Sand is fine to coarse Fine to medium gravel and medium to coarse flint. Sand is fine to coarse. Fine to medium gravel and medium to coarse sand sized organic particles throughout. (Lowestoft Formation)
6.0	Medium to very dense orange brown sandy subangular to rounded fine to coarse flint Gravel. Sand is fine to coarse. (Kesgrave catchment subgroup)
10.5	Medium to very dense orange brown sandy subangular to rounded fine to coarse flint gravel. Sand is fine to coarse. (Kesgrave catchment Subgroup)
12.0	Recovered as structureless chalk composed of cream with rare orange veins slightly gravelly silt. Gravel is angular to subangular fine to medium extremely weak low density chalk. Rare subrounded coarse rinded flint gravel. Grade Dm. (Lewes Nodular/Seaford Chalk Formation)
21.0	Recovered as structureless chalk composed of cream with rare orange veins slightly gravelly silt. Gravel is angular to subangular fine to medium extremely weak low density chalk. Rare subrounded coarse rinded flint gravel. Grade Dm. (Lewes Nodular/Seaford Chalk Formation)
25.0	Borehole completed

10. Site History

10.1. Introduction

The purpose of this section is to identify the composition of the site pre and post-WWII. It is important to establish the historical use of the site, as this may indicate the site's relation to potential sources of UXO as well as help with determining factors such as the land use, groundcover, likely frequency of access and signs of bomb damage.

10.2. Ordnance Survey Historical Maps

Relevant historical maps were obtained for this report and are presented in **Annex D.** See below for a summary of the site history shown on acquired mapping.

Pre-WWII		
Date	**Scale**	**Description**
1923	1:2,500	This map shows the site area to be encompassed within an area of vacant agricultural land alongside railway lines. No defining structures are present on site, with the only landmark being the structures of *Peartree Farm* located approximately 250m to the east of the site.
1938-1939	1:2,500	This map edition highlights some extensive development to have taken place on site and in the immediate surrounding area. The site itself is now occupied by a large structure and additional surrounding structures labelled as a *Film Studios* as well as a *Manufactory (Electric Heaters)* in the northern half of the site. Surrounding the *Manufactory* in the north a small gauge railway line extends to the west, joining several smaller lines, which extend to the main railway in the west and alongside the large *Cereal Manufactory* located beyond Hydeway in the north. A tennis court is situated in the north-eastern corner of the site. Beyond Broadwater, eight commercial structures have been constructed, although they remain unlabelled. Beyond the road to the south, is a large industrial structure marked as a *Manufactory (Chemical Products)*.

Post-WWII		
Date	**Scale**	**Description**
1960 – 1961	1:1,250	This map indicates some significant structural changes to have taken place on site and in the surrounding vicinity. Whilst the previous structure of the *Film Studios* is present in this mapping, it is now labelled as a *Factory* whilst having also been extended to the south, with a connecting walkway having been constructed to connect the two structures. In the centre of the site, some of the surrounding outbuildings have been cleared with new structures having constructed in their place. In the north, the structures of the *Manufactory (Electrical Heaters)* and its small gauge railway, as well as the tennis court have also been cleared, with four larger *Factory* and *Works* buildings having been constructed in their place. Across Broadway the eight commercial structures are now labelled, as *Depots, Factories, Warehouses* and *Works* respectively. To the south, the former *Manufactory (Chemical Products)* has been expanded with multiple additional structures having been constructed.

10.3. Historical Aerial Photographs of the Site

Historical aerial photographs have been consulted from the Aerofilms collection available from Britain From Above. These photographs provide a view of the site in 1928 and 1935 (see **Annex E**). See below for a description of each photograph.

Historical Aerial Imagery of the Site	
Title	**Comments**
British Instructional Films Studio, Welwyn Garden City, 1928	This photo illustrates the site area in 1928 during the construction of the Welwyn Film Studios in the southern half of the site area. The large curved roof structure of the studio is under construction, with building materials and temporary structures visible to the north of the studio. The northern section of the site remains vacant land alongside the railway, whilst a temporary film set is visible in the south.
The British Instructional Films Studio under construction, Welwyn Garden City, 1928	This photo illustrates the construction work of the British Instructional Films Studio, Welwyn in more detail. The roof is clearly under construction whilst scaffolding can be seen to the north. Temporary structures comprising film sets can be seen to the south.
Howardsgate and the railway station, Welwyn Garden City, 1935	This photo highlights the film studios on site and environs in 1935. The film studio has been completed and has been expanded, with a variety of outbuildings situated to the north, and a much more substantial film set situated to the south. A large flat-roofed structure is situated beyond the boundary of the film studio, whilst the northernmost half of the site beyond it is vacant ground and grassland, aside from a tennis court observable in the north-eastern corner. Significant development can also be observed in the wider surrounding area.

11. Aerial Bombing Introduction

11.1. General

During WWI and WWII, many towns and cities across the UK were subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. The poor accuracy of WWII targeting technology and the nature of bombing techniques often resulted in neighbouring areas to targets sustaining collateral damage.

In addition to raids which concentrated on specific targets, indiscriminate bombing of large areas also took place, this occurred most prominently in the London 'Blitz', though affected many other towns and cities. As discussed in the following sections, a proportion of the bombs dropped on the UK did not detonate as designed. Although extensive efforts were made to locate and deal with these UXBs at the time, many still remain buried and can present a potential risk to construction projects.

The main focus of research for this report will concern German aerial delivered weapons dropped during WWII, although WWI bombing will also be considered.

11.2. Generic Types of WWII German Aerial-delivered Ordnance

An understanding of the type and characteristics of the ordnance used by the Luftwaffe during WWII allows an informed assessment of the hazards posed by any unexploded items that may remain in situ on a site. Images and brief summaries of the characteristics of the above listed German aerial delivered ordnance are presented in **Annex F**.

Generic Types of WWII German Aerial Delivered Ordnance		
Type	**Frequency**	**Likelihood of detection**
High Explosive (HE) bombs	In terms of weight of ordnance dropped, HE bombs were the most frequently deployed by the Luftwaffe during WWII.	Although efforts were made to identify the presence of unexploded ordnance following an air raid, often the damage and destruction caused by detonated bombs made observation of UXB entry holes impossible. The entry hole of an unexploded bomb can be as little as 20cm in diameter and was easily overlooked in certain ground conditions (see **Annex G**). Furthermore, ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. UXBs therefore present the greatest risk to present–day intrusive works.
Aerial or Parachute mines (PM)	There were deployed less frequently than HE and IBs due to size, cost and the difficulty of deployment.	If functioning correctly, PMs generally would have had a slow rate of descent and were very unlikely to have penetrated the ground. Where the parachute failed, mines would have simply shattered on impact if the main charge failed to explode. There have been extreme cases when these items have been found unexploded. However, in these scenarios, the ground was either extremely soft or the munition fell into water.
1kg Incendiary bombs (IB)	In terms of the number of weapons dropped, small IBs were the most numerous. Millions of these were dropped throughout WWII.	IBs had very limited penetration capability and in urban areas would often have been located in post-raid surveys. If they failed to initiate and fell in water, on soft vegetated ground, or bombed rubble, they could have gone unnoticed.
Large Incendiary bombs (IB)	These were not as common as the 1kg IBs, although they were more frequently deployed than PMs and AP bomblets.	If large IBs did penetrate the ground, complete combustion did not always occur and in such cases they could remain a risk to intrusive works.
Anti-personnel (AP) bomblets	These were not commonly used and are generally considered to pose a low risk to most works in the UK.	SD2 bomblets were packed into containers holding between 6 and 108 submunitions. They 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.

11.3. Failure Rate of German Aerial-delivered Ordnance

It has been estimated that 10% of WWII German aerial delivered HE bombs failed to explode as designed. Reasons for why such weapons might have failed to function as designed include:

- Malfunction of the fuze or gain mechanism (manufacturing fault, sabotage by forced labour or faulty installation).
- Many were fitted with a clockwork mechanism that could become immobilised on impact.
- Failure of the bomber aircraft to arm the bombs due to human error or an equipment defect.
- Jettisoning the bomb before it was armed or from a very low altitude. This most likely occurred if the bomber aircraft was under attack or crashing.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg, over, 7,000 anti-aircraft projectiles and 300,000 beach mines. Unexploded ordnance is still regularly encountered across the UK, see press articles in **Annex H**.

11.4. V-Weapons

Hitler's 'V-weapon' campaign began from mid-1944. It used newly developed unmanned cruise missiles and rockets. The V-1 known as the *flying bomb* or *pilotless aircraft* and the V-2, a long range rocket, were launched from bases in Germany and occupied Europe. A total of 9,251 V-1s and 1,115 V-2s were recorded in the United Kingdom.

Although these weapons caused considerable damage their relatively low numbers allowed accurate records of strikes to be maintained. These records have mostly survived. There is a negligible risk from unexploded V-weapons on land today since even if the 1000kg warhead failed to explode, the weapons are so large that they would have been observed and the risk dealt with at the time. Therefore, V-weapons are referenced in this report not as a viable risk factor, but primarily in order to help account for evidence of damage and clearance reported.

12. UXB Ground Penetration

12.1. General

An important consideration when assessing the risk from a UXB is the likely maximum depth of burial. There are several factors which determine the depth that an unexploded bomb will penetrate:

- Mass and shape of bomb.
- Height of release.
- Velocity and angle of bomb.
- Nature of the ground cover.
- Underlying geology.

Geology is perhaps the most important variable. If the ground is soft, there is a greater potential of deeper penetration. For example, peat and alluvium are easier to penetrate than gravel and sand, whereas layers of hard strata will significantly retard and may stop the trajectory of a UXB.

12.2. The J-Curve Effect

J-curve is the term used to describe the characteristic curve commonly followed by an aerial delivered bomb dropped from height after it penetrates the ground. Typically, as the bomb is slowed by its passage through underlying soils, its trajectory curves towards the surface. Many UXBs are found with their nose cone pointing upwards as a result of this effect. More importantly however is the resulting horizontal offset from the point of entry. This is typically a distance of about one third of the bomb's penetration depth, but can be up to 15m.

12.3. WWII UXB 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 (BD) teams. Conclusions were made as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

For example, the largest common German bomb (500kg) had a likely concluded penetration depth of 6m in sand or gravel but 11m in clay. The maximum observed depth for a 500kg bomb was 11.4m and for a 1,000kg bomb 12.8m. Theoretical calculations suggested that significantly greater penetration depths were probable.

12.4. Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site of proposed works the following parameters have been used:

- WWII geology –White Chalk Formation.
- Impact angle and velocity – 10-15° from vertical and 270 metres per second.
- Bomb mass and configuration – The 500kg SC HE bomb, without retarder units or armour piercing nose (this was the largest of the common bombs used against Britain).

Taking into account the site specific geology provided by Curtins (see section 9.2) and the above-mentioned factors, it has been assessed that a 500kg bomb could have had a maximum bomb penetration depth of **8.7m** 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.

13. Initiation of Unexploded Ordnance

13.1. General

Unexploded ordnance does not spontaneously explode. All high explosive filling requires significant energy to create the conditions for detonation to occur. In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms.

13.2. UXB Initiation Mechanisms

UXB Initiation	
Direct Impact	Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g. from piling or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Such violent action can cause the bomb to detonate.
Re- starting the Clockwork Fuze	A small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion would have taken place within the fuze mechanism over the last 70+ years that would prevent clockwork mechanisms from functioning. Nevertheless, it was reported that the clockwork fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did re-start.
Friction Impact	The most likely scenario resulting in the detonation of a UXB is friction impact initiating the shock-sensitive fuze explosive. The combined effects of seasonal changes in temperature and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive which could detonate the main charge.

Annex H2 details incidents where intrusive works have caused items of UXO to detonate, resulting in death or injury and damage to plant.

13.3. Effects of Detonation

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

- People – site workers, local residents and general public.
- Plant and equipment – construction plant on site.
- Services – subsurface gas, electricity, telecommunications.
- Structures – not only visible damage to above ground buildings, but potentially damage to foundations and the weakening of support structures.
- Environment – introduction of potentially contaminating materials.

14. The Risk from German Aerial Delivered UXBs

14.1. World War I

During WWI Britain was targeted and bombed by Zeppelin Airships as well as Gotha and Giant fixed-wing aircraft. The objective of these raids was to unnerve the British public, to destroy strategic targets and to ultimately attempt to coerce Britain's capitulation from the war. A WWI map of air raids and naval bombardments across England is presented in **Annex I**. Whilst consulted, this source does not record any WWI bombing incidents to have affected the site.

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude. This resulted 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 in the urban environment. 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.

14.2. World War II Bombing of Welwyn Garden City

The Luftwaffe's main objective for the attacks on Britain was to inhibit the country's economic and military capability. To achieve this they targeted airfields, depots, docks, warehouses, wharves, railway lines, factories, and power stations. As the war progressed the Luftwaffe bombing campaign expanded to include the indiscriminate bombing of civilian areas in an attempt to subvert public morale.

During WWII the site was located within the Urban District of Welwyn Garden City, which sustained an overall low density of bombing according to Home Office statistics. This low density can be attributed to the relative lack of strategic targets in the vicinity, with the closest significant target, the De Havilland (DH) Aircraft Company works in Hatfield, situated some 4km to the south-west of the site area. The associated DH factory (presented in Luftwaffe target photography in **Annex J**) represented a major target for Luftwaffe bombing, and was responsible for designing and manufacturing some of the most important aircraft of the war, such as the DH.98 Mosquito, the 'wooden wonder' fighter bomber flown in numerous bombing and special operations raids throughout the war.

Throughout the war Welwyn would be subjected to 13 separate air raids resulting in only four fatalities and three injuries for the entire district. It is likely therefore that any bombing within Welwyn Garden City would have been largely restricted to 'tip-and-run' raids by bombers en-route or returning from main targets such as London or any airfields in the vicinity, as opposed to targeted attacks. Such tip-and-run raids offered crews the opportunity to bomb areas whilst also avoiding the additional weight when returning to base with unspent ordnance.

Records of bombing incidents in the civilian areas of Welwyn Garden City were collected by the Air Raid Precautions wardens and collated by the Civil Defence Office. Some other organisations, such as port and railway authorities, maintained separate records. Records would be in the form of typed or hand written incident notes, maps and statistics. Bombing data was carefully analysed, not only due to the requirement to identify those parts of the country most needing assistance, but also in an attempt to find patterns in the German bombing strategy in order to predict where future raids might take place.

Records of bombing incidents for Welwyn Garden City are presented in the following sections.

14.3. WWII Home Office Bombing Statistics

The following table summarises the quantity of German aerial delivered bombs (excluding 1kg incendiaries and anti-personnel bombs) dropped on the Urban District of Welwyn Garden City between 1940 and 1945.

Record of German Ordnance Dropped on the Urban District of Welwyn Garden City		
Area Acreage		**2,598**
Weapons	High Explosive bombs (all types)	**29**
	Parachute mines	**2**
	Oil bombs	**1**
	Phosphorus bombs	**0**
	Fire pots	**0**
	Pilotless aircraft (V-1)	**0**
	Long range rocket bombs (V-2)	**0**
Total		**32**
Number of Items per 1,000 acres		**12.3**

Source: Home Office Statistics
This table does not include UXO found during or after WWII.

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 risk relating to IBs is lesser than that relating to larger HE bombs, they were similarly designed to inflict damage and injury. Anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. Although Home Office statistics were not recorded, both types of item should not be overlooked when assessing the general risk to personnel and equipment.

14.4. Hertfordshire Air Raid Damage Reports

Air raid damage reports compiled by the Hertfordshire County Council's Air Raid Precaution (ARP) Department during WWII, were consulted at Hertfordshire Archives. These reports recorded information such as the date, time, type and damage caused by major bomb incidents in Welwyn Garden City.

A transcript of the only associated written record of a bomb incident on or in close proximity to the site is presented below. Imagery of this record is presented in **Annex K**.

Hertfordshire Air Raid Damage Reports		
Date	**Size of bomb**	**Comments**
30th October 1940	AA Shell	1 Anti-Aircraft Shell exploded on railway line 200 yards south of Station, slight damage, traffic not interrupted.

14.5. WWII-Era Aerial Photography

A high-resolution scan of WWII-era aerial photography for the site area was obtained from the National Monuments Record Office (Historic England). This photograph provides a record of the potential composition of the site during the war, as well as its condition immediately following the war (**see Annex L**).

WWII-Era Aerial Photography	
Date	**Description**
10th October 1946	This photograph illustrates the site in the immediate post-war period. In terms of the general composition of the site, the structures constructed prior to the war are still present on site, although some additional structures have clearly been constructed. In the north-west of the site, a large square structure has been constructed to the north of the light gauge rail lines, whilst several small out-buildings have also been constructed to the north of the Film Studios in the site's centre. The northernmost section of the site is still occupied by vegetated ground, with the tennis courts occupying the north-eastern corner of the site. In the south a structure is visibly under construction adjoining the *Manufactory (Chemical Products)*. No evidence could be found to suggest the presence of bomb damage at the site location or its immediate surroundings.

14.6. 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 of an entry hole 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 or 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.

1st Line Defence holds no records of officially registered abandoned bombs at or near the site of the proposed works.

14.7. Bomb Disposal Tasks

The information service from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD) is currently facing considerable delay. It has therefore not been possible to include any updated official information regarding bomb disposal/clearance tasks with regards to this site. A database of known disposal/clearance tasks has been referred to which does not make reference to such instances occurring within the site of proposed works. If any relevant information is received at a later date Curtins will be advised.

14.8. Evaluation of German Aerial Delivered UXB Risk

Factors	Conclusion
Density of Bombing *It is important to consider the bombing density when assessing the possibility that UXBs remain in an area. High levels of bombing density could allow for error in record keeping due to extreme damage caused to the area.*	The Urban District of Welwyn Garden City was subject to an overall low density of bombing, with an average of 12 bombs recorded per 1,000 acres according to Home Office statistics. This can likely be attributed to the lack of strategic targets in the immediate area of the site, the closest significant target being the De Havilland Aircraft Company factory located 4km away in Hatfield. Local ARP damage records and Home Office Statistics indicate that although Welwyn Garden City was targeted on 13 separate occasions, but only 32 bombs fell within the urban district. Whilst ARP records were consulted for Welwyn Garden City, no reference to the site area could be found, with the closest incident being the explosion of an anti-aircraft shell below the railway station, approximately 300m from the westernmost edge of the site.
Damage *If buildings or structures on a site sustained bomb or fire damage any resulting rubble and debris could have obscured the entry holes of unexploded bombs dropped during the same, or later, raids. Similarly, a High Explosive bomb strike in an area of open agricultural land will have caused soil disturbance, increasing the risk that a UXB entry hole would be overlooked.*	ARP damage records for Welwyn Garden City do not indicate that the site area sustained any damage as the result of bombing, with no incidents recorded as being on site or within the immediate surrounding vicinity. Additionally, post-war historical OS mapping does not indicate any changes typical of bomb damage such as missing or ruined structures. Instead the structures on site maintain much the same structural footprint that they had prior to the war. Immediate post-war aerial photography dating from 1946 shows no immediately obvious signs of bomb related damage such as craters, debris, or structural damage on site or to neighbouring buildings.
Access Frequency *UXO in locations where access was irregular would have a greater chance of passing unnoticed than at those that were regularly occupied. The importance of a site to the war effort is also an important consideration as such sites are likely to have been both frequently visited and subject to post-raid checks for evidence of UXO.*	Being occupied by both the British Instructional Film studios and an Electrical Heater Factory, as well a tennis court, the whole site is anticipated to have been subject to a generally good degree of frequent access during wartime. The B.I.F. Studios was frequently in use throughout the war producing morale and public information films, including two films directed by Alfred Hitchcock for the French Resistance. Additionally, the Shredded Wheat Factory employing some 1,200 workers was located beyond Hydeway to the north. Thus it is anticipated that a good degree of post raid checks would have been maintained to ensure the area remained serviceable. Consequently, evidence of items of UXO on site should have been observed and subsequently reported.
Ground Cover *The nature of the ground cover present during WWII would have a substantial influence on any visual indication that may indicate UXO being present.*	Being largely occupied by both a Film Studios and an Electrical Heater Factory, the site area was largely comprised of favourable ground conditions, including both structures and hardstanding ground. The northernmost section of the site however is recorded to have remained as vacant ground, and can be seen as vegetated ground in 1946 aerial photography. This area is considered to be less conducive to the observation of items of UXO, despite being close to areas of frequent access.

Bomb Failure Rate	There is no evidence to suggest that the bomb failure rate in the locality of the site would have been dissimilar to the 10% normally used.
Abandoned Bombs	1st Line Defence holds no records of abandoned bombs at or within the site vicinity.
Bombing Decoy sites	1st Line Defence could find no evidence of bombing decoy sites within the site vicinity.
Bomb Disposal Tasks	1st Line Defence could find no evidence of bomb disposal tasks within the site boundary and immediate area.

15. The Risk from Allied Ordnance

15.1. General

The potential risk of encountering Allied ordnance on construction sites is particularly elevated in areas previously associated with military activity. This includes munitions deposited by military training exercises, dumped as a result of poor working practices, or deliberately placed to prevent adversary occupation and from other home defence activities. For example, contamination from items of Land Service (LSA) and Small Arms Ammunition (SAA) may result from historical occupation of an area or its use for military training.

According to available records the site area was situated within close proximity to several features used by the Welwyn branch of the Hertfordshire Home Guard during WWII. These included a HQ and Mobile Reserve Company located in the Shredded Wheat Factory immediately to the north, as well as roadblocks and pillboxes situated in the surrounding vicinity.

The following sections will examine the history of the Home Guard installations in the area of the site, and assess to what degree, if any, the site could have become contaminated as a result of the historic military use of the surrounding area.

15.2. Welwyn Garden City Home Guard

Established in 1940 as the Local Defence Volunteers, the Home Guard was tasked with the defence of Britain in the event that the country was invaded. In light of this remit, the Home Guard established a network of defensive positions across the country and were tasked with defending strategic positions and destroying or disabling bridges and other key points the enemy would want captured intact.

Welwyn Garden City's Home Guard was organised as part of the 4th Battalion Hertfordshire Home Guard, comprising of A, B and C companies respectively. These three companies comprising the Battalion were stationed at separate HQ buildings around the town; with A Co. positioned at Midland Bank Chambers, B Co. at the Broadwater Tennis Club at Moatwood Green, and C Co. at the Kiosk at the Entrance to the Railway Station. These units were active in training and preparation in the Welwyn area throughout the war until 1945 when the Hertfordshire Home Guard was disbanded.

A complete overlay of Allied features on 1946 Aerial photography is presented in **Annex P**

15.3. 4th Battalion Herts Home Guard Rifle Club

Available records indicate that a rifle range was located on site. This range was originally established as the 4th Battalion Herts Home Guard Rifle Club, with club files indicating that the club was established in February 1945, although there is the possibility that the site was used for firing practice even earlier.

A club communique obtained from the Hertfordshire Archives suggest that the membership in 1945 was some 75 members, and that 200 members were expected to join thereafter, with a certificate from the Society of Miniature Rifle Clubs showing that the club was approved as a full-range club in August 1945. The weapons listed as being needed for shooting at the club are listed as 25 .303 Rifles, 25 9mm Sten Submachine guns, and 10 .22 target rifles. (See **Annex M**) Renamed the Welwyn Garden Rifle Club, the club was still active until the 1980s, when full –bore rifle shooting became more strictly regulated.

While these records were consulted, no reference to the exact location of the range within the site could be found. Despite this, information provided by Curtins indicates that this feature was situated in the southernmost section of the site location.

15.4. Welwyn Garden City Home Guard Installations Map

A map illustrating the positions of Home Guard installations was obtained from J.D. Sainsbury's *The Home Guard in Hertfordshire 1940-1945*, illustrating the locations of Home Guard defensive positions across Welwyn Garden City including roadblocks, pillboxes, and platoon positions.

The area featuring the site is discussed in the table below and in **Annex N.**

Map of Home Guard Installations in Welwyn Garden City	
Date	**Description**
January 1944	This map indicates several Home Guard positons in the immediate vicinity of the site. Both a Mobile Reserve Company and a 'Road Block with Pill Box' are located in the vicinity of the Shredded Wheat Factory to the north of the site, whilst a second 'Road Block and Pill Box' are situated approximately 500m beyond the southernmost boundary of the site.

15.5. Hertfordshire Home Guard Location Statement

Documents listing the locations of Home Guard Headquarters across the county were obtained from the Hertfordshire Archives. These documents provide the exact locations of Home Guard HQs both for normal use, under 'battle' conditions and an alternative in case of emergency.

The following table presents the locations of HQs in Welwyn Garden City, whilst the original document is presented in **Annex O.** Although no features are referenced on-site, a 'battle' Home Guard HQ is recorded at the Shredded What Factory to the north of the site location.

Hertfordshire Home Guard Location Statement	
HQ Type	**Description**
Normal	4th Battalion, A Co.- Midland Bank Chambers, Howardsgate, W.G.C.
Battle	4th Battalion, A Co.-Cherry Tree, W.G.C.
Alternative	4th Battalion, A Co. - Nissen Hut, 20 Miles Bridge.
Normal	4th Battalion, B Co.- Broadwater Tennis Club, Moatwood Green, W.G.C.
Battle	4th Battalion, B Co.-Attimore Hall, W.G.C.
Alternative	4th Battalion, B Co.-Same as Normal
Normal	4th Battalion, C Co.-The Kiosk, Station Entrance , W.G.C.
Battle	4th Battalion, C Co.-Shredded Wheat Co., Broadwater Road, W.G.C.
Alternative	4th Battalion, C. Co.- Roche Products

15.6. Land Service Ammunition

Home Guard Units were equipped with a variety of land service weapons, including No. 36 Mills Bombs, Spigot Mortars as well as other more exotic weapons unique to the Home Guard. Live ordnance was often used during training, and accordingly may be found on areas formerly used for training or as defensive positions.

The term LSA covers items of ordnance that are propelled, placed, or thrown during land warfare. These items may be filled or charged with explosives, smoke, incendiary, or pyrotechnics and can be divided into five main groups:

Land Service Ammunition	
Item	**Description**
Mortar Rounds	A mortar round is normally nosed-fused and fitted with its own propelling charge. Its flight is stabilised by the use of a fin. They are usually tear-drop shaped (though older variants are parallel sided), with a finned 'spigot tube' screwed or welded to the rear end of the body which houses the propellant charge. Mortars are either High Explosive or Carrier (i.e. smoke, incendiary, or pyrotechnic).
Grenades	A grenade is a short range weapon designed to kill or injure people. It can be hand thrown or fired from a rifle or a grenade launcher. Grenades either contain high explosive or smoke producing pyrotechnic compounds. The common variants have a classic 'pineapple' shape.
Projectiles	A projectile (or shell) is propelled by force, normally from a gun, and continues in motion using its kinetic energy. The gun a projectile is fired from usually determines its size. A projectile contains a fuzing mechanism and a filling. Projectiles can be high explosive, carrier or Shot (a solid projectile).
Rockets	Rockets were commonly designed to destroy heavily armoured military vehicles (anti-tank weapon). The device contains an explosive head (warhead) that can be accelerated using internal propellants to an intended target. Anti-aircraft rocket batteries were also utilised as part of air defence measures.
Landmines	A landmine is designed to be laid on or just below the ground to be exploded by the proximity, or contact of a person or vehicle. Landmines were often placed in defensive areas of the UK to obstruct potential invading adversaries.

In the UK unexploded or partially exploded mortars and grenades are the most common items of LSA encountered, as they could be transported and utilised anywhere. They are mostly encountered in areas used for military training and are often found discarded on or near historical military bases.

As with UXBs, items of LSA do not become inert or lose their effectiveness with age. Time can 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.

Images of the most commonly found items of LSA are presented in **Annex Q,** whilst items of Home Guard ordnance are presented in **Annex R.**

15.7. Small Arms Ammunition

The most common type of ordnance encountered on land used by the military are items of Small Arms Ammunition (SAA). SAA refers to the complete round or cartridge designed to be discharged from varying sized hand-held weapons such as rifles, machine guns and pistols. SAA can include bullets, cartridge cases and primers/caps. Items of SAA can be accidentally initiated by striking the casing or coming into contact with fire. However even if an item 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 Images of SAA are presented in **Annex S.**

15.8. Defending the UK From Aerial Attack

During WWII the Ministry of Defence employed a number of defence tactics against the Luftwaffe from bombing major towns, cities, manufacturing areas, ports and airfields. These can be divided into passive and active defences (examples are provided in the table below).

Active Defences	Passive Defences
• Anti-aircraft gun emplacements to engage enemy aircraft. • Fighter aircraft to act as interceptors. • Rockets and missiles were used later during WWII.	• Blackouts and camouflaging to hinder the identification of Luftwaffe targets. • Decoy sites were located away from targets and used dummy buildings and lighting to replicate urban, military, or industrial areas. • Barrage balloons forced enemy aircraft to greater altitudes. • Searchlights were often used to track and divert adversary bomber crews during night raids.

Active defences such as anti-aircraft artillery present a greater risk of UXO contamination than passive defences. Unexploded ordnance resulting from dogfights and fighter interceptors is rarely encountered and difficult to accurately qualify.

15.9. Anti-Aircraft Artillery (AAA)

During WWII three main types of gun sites existed: heavy anti-aircraft (HAA), light anti-aircraft (LAA) and 'Z' batteries (ZAA). If the projectiles and rockets fired from these guns failed to explode or strike an aircraft they would descend back to land. The table below provides further information on the operation and ordnance associated with these type of weapons.

Anti-Aircraft Artillery				
Item	**Description**			
HAA	These large calibre guns such as the 3.7" QF (Quick Firing) were used to engage high flying enemy bombers. They often fired large HE projectiles, which were usually initiated by integral fuzes triggered by impact, area, time delay or a combination of aforementioned mechanisms. The closest HAA was located approximately 3km to the south-west of the site, however the range of a projectile can be up to 15km.			
LAA	These mobile guns were intended to engage fast, low flying aircraft. They were typically rotated between locations on the perimeters of towns and strategically important industrial works. As they could be moved to new positions with relative ease when required, records of their locations are limited. The most numerous of these were the 40mm Bofors gun which could fire up to 120 x 40mm HE projectiles per minute to over 1,800m.			
Variations in HAA and LSA Ammunition	**Gun type**	**Calibre**	**Shell Weight**	**Shell Dimensions**
	3.0 Inch	76mm	7.3kg	76mm x 356mm
	3.7 Inch	94mm	12.7kg	94mm x 438mm
	4.5 Inch	114mm	24.7kg	114mm x 578mm
	40mm	40mm	0.9kg	40mm x 311mm
Z-AA	The three inch unrotated rocket/projectile known as the UP-3 had initially been developed for the Royal Navy. The UP-3 was also used in ground-based single and 128-round launchers known as ''Z'' batteries. The rocket, containing a high explosive warhead was often propelled by cordite.			
29mm Spigot Mortars (Blacker Bombards)	This was an infantry anti-tank weapon. A heavy steel rod (spigot) would be driven into the hollow tail of a projectile to ignite the explosive charge located in the rear of the projectile, and lead to it being propelled toward a target. It was not an effective method of air defence and was mainly used in defensive positons at key locations. If encountered, a spigot mortar projectile will resemble a mortar round, but with an elongated metal tail rod.			
Quick Firing (QF) 1 and 2 Pounder	QF 1 and 2 Pounders, or 'pom poms' were a light battery most often used by the navy. During the beginning of WWII they were used to defend targets in the absence of more effective LAA or HAA.			
Machine Gun Posts	These were established at some significant military and industrial positions. Machine guns were a largely ineffective form of AAA. Machine guns usually fired the .303 Round.			

The conditions in which an HAA or LAA projectiles may have fallen unnoticed within a site area are analogous to those regarding aerial delivered ordnance. For detailed analysis on the ground conditions and access frequency within the proposed site, see the evaluation of German Bombing Records in, **Section 14.8**.

Illustrations of Anti-Aircraft artillery, projectiles and rockets are presented at **Annex T**.

15.10. Evaluation of Allied Ordnance Risk

1st Line Defence has considered the following potential sources of Allied ordnance contamination:

Sources of Contamination	Conclusion
Military Camps *Military camps present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training.*	1st Line Defence could find no evidence of a military camp within the site.
Anti-Aircraft Defences *Anti-Aircraft defences were employed across the country. Proximity to anti-aircraft defences increases the chance of encountering AA projectiles.*	1st Line Defence could find no evidence of Anti-Aircraft defences such as a HAA or LAA gun emplacement occupying or bordering the site. The closest HAA was located approximately 3km south-west of the site, however the range of a projectile can be up to 15km. The conditions in which HAA or LAA projectiles may have fallen unnoticed within a site footprint are analogous to those regarding German aerial delivered ordnance.
Home Guard Activity *The Home Guard regularly undertook training and ordnance practice in open areas, as well as burying ordnance as part of anti-invasion defences.*	Records indicate that several Home Guard installations, including a roadblock with pillbox and a mobile reserve company, were located within close proximity to the site. Additionally, records obtained from the Hertfordshire Archives highlight that the Shredded Wheat Factory to the north was used as a Home Guard 'Battle' HQ. Aerial photography further highlights potential home guard activity in the wider area, with several 'Zig-Zag' trenches visible approximately 200m to the south-east of the site dug into an area of vacant land near *Peartree Farm.* See **Annex P** for a complete overlay of Allied features on 1946 Aerial photography.
Defensive Positions *Defensive positions suggest the presence of military activity, which is often indicative of ordnance storage, usage or disposal.*	A pillbox and roadblock are recorded to have been positioned to the north of the site, close to the bridge over the railway. 'Zig-Zag' trenches can be seen in 1946 aerial photography to the south-east, whilst the Shredded Wheat Factory is listed as a Headquarters to be used in 'Battle' conditions. Whilst the exact nature of these positions cannot be discerned, they were manned by members of the 4th Battalion Herts Home Guard, and as such are not anticipated to have been manned on a permanent basis.
Training or firing ranges *Areas of ordnance training saw historical ordnance usage in large numbers, often with inadequate disposal of expended and live items. The presence of these ranges significantly impact on the risk of encountering items of ordnance in their vicinity.*	Records indicate that a rifle range, constituting the 4th Battalion Herts Home Guard Rifle Club was located on site. This club was established in the latter stages of the war, and was active until the 1980s as civilian marksmanship club. The exact date that the range was sued until is not known. Sources suggest that the club was predominately utilised for the shooting of rifles and other small arms, including submachine guns, however the exact nature of firing conducted on site is not known. According to information provided by Curtins this feature was located within the southern section of the site location.

Defensive Minefields *Minefields were placed in strategic areas to defend the country in the event of a German invasion. Minefields were not always cleared with an appropriate level of vigilance.*	There is no evidence of defensive minefields affecting the site.
Ordnance Manufacture *Ordnance manufacture indicates an increased chance that items of ordnance were stored, or disposed of, within a location.*	No information of ordnance being stored, produced, or disposed of within the proposed site could be found.
Military Related Airfields *Military airfields present an elevated risk from ordnance simply due to the large military presence and likelihood of associated live ordnance training or bombing practice.*	The site was not situated within the perimeters or vicinity of a military airfield.

16. Ordnance Clearance and Post-WWII Ground Works

16.1. General

It is important to consider the extent to which any explosive ordnance clearance (EOC) activities or extensive ground works have occurred on site. This may indicate previous ordnance contamination or reduce the risk that ordnance remains undiscovered.

16.2. UXO Clearance

1st Line Defence has no evidence that any official ordnance clearance operations have taken place on site. Note however that we have not received confirmation of this fact from 33 EOD Regiment.

16.3. Post-war Redevelopment

Some significant re-development work is recorded to have taken place on site, including the construction of the large industrial structures of the Shredded Wheat Factory upon its acquisition of the former B.I.F. Studios.

17. 1st Line Defence Risk Assessment

17.1. Risk Assessment Stages

Taking into account the quality of the historical evidence, the assessment of the overall risk from unexploded ordnance is based on the following five considerations:

1. That the site was contaminated with unexploded ordnance.
2. That unexploded ordnance remains on site.
3. That such items will be encountered during the proposed works.
4. That ordnance may be initiated by the works operations.
5. The consequences of encountering or initiating ordnance.

UXO Risk Assessment	
Quality of the Historical Record	The research has evaluated pre- and post-WWII Ordnance Survey maps, Luftwaffe reconnaissance imagery, pre-war oblique imagery, RAF aerial photography, Hertfordshire Air Raid Damage reports, 4th Battalion Herts Home Guard Rifle Club files, Welwyn Garden City Home Guard Installations mapping and Hertfordshire Home Guard Location Statements. The record set is of generally good quality, although certain aspects are not as comprehensive as others. Whilst Hertfordshire air raid damage files are believed to be relatively comprehensive, the exact nature of home guard activities conducted on site an in the surrounding vicinity cannot be entirely discerned from the available records.
The Risk that the Site was Contaminated with UXO	After considering the following facts, 1st Line Defence has assessed that there is a **Low Risk** that items of unexploded German aerial delivered and anti-aircraft ordnance could have fallen unrecorded within the site boundary, whilst a **Low-Medium Risk** from Allied Land Service Ammunition/Small Arms Ammunition has been identified across the site. **The Likelihood of German Aerial Delivered Ordnance Contamination** • During WWII, the Urban District of Welwyn Garden City sustained an overall low density bombing campaign, with an average of 12 items falling per 1,000 acres according to Home Office statistics. The district sustained only 29 recorded HE bomb strikes - this can likely be attributed to the lack of strategic targets in the area. • Hertfordshire Air Raid Damage files do not refer to any incidents or damage being sustained on the site or the immediate surrounding area, with the closest incident being the explosion of an anti-aircraft projectile approximately 200m from the site, below Welwyn railway station. • OS mapping does not present any significant changes to the structural composition of the site, with post-war changes restricted to the construction of several small outbuildings, whilst the footprint of larger structures remains consistent. No elements indicative of bomb damage such as missing or ruined structures are present, either on or within the environs of the site area. • Immediate post-war aerial photography parallels OS mapping, illustrating the same structures to be on site. Whilst certain areas of the site feature disturbed ground, these are all areas that would have been used as access ways, with no visible damage or repair work observable. • Access on site is anticipated to have been regular throughout the start of the war, due to the presence of the British Instructional Film Studios and an electrical heater works on site. The wartime of the operation of the former is very well documented in historical source material, including the production of several propaganda and public information films. It is therefore considered highly likely that any bomb

	strikes falling on or near this structure would have been documented and dealt with. • Whilst the northernmost section of the site remained as unoccupied ground, it appears well maintained in aerial photography, and the presence of the tennis courts, as well as the road to the north would have provided a good deal of access to this area, increasing the likelihood that evidence of UXO would have been observed and subsequently reported. **<u>The Risk from Allied Ordnance Contamination</u>** • During WWII the site area is recorded to have been positioned within close proximity to several Home Guard installations and defensive locations. Both a road block and pillbox, as well as a mobile reserve company are recorded to have been situated to the north, whilst Home Guard Location statements for Welwyn highlight that the original location of the Shredded Wheat Factory, to the north of the site, was designated as a 'battle' Headquarters. • Additionally, a rifle range is recorded to have been located within the site area. This range officially opened as the 4th Battalion Herts Home Guard Rifle Club in 1945, and was used for the shooting of small arms including rifles and submachine guns. The exact date when the range was disused could not be identified, however records indicate that the club continued as the Welwyn Garden Rifle Club until the mid-1980s. • Whilst OS mapping does not indicate any features consistent with military use on site, 1946 aerial photography highlights several 'Zig Zag' trenches approximately 200m to the south-east of the site area. It is considered likely that these are connected to the Home Guard activity in the area, and were potentially used for training purposes. Despite their proximity, this feature is not considered to directly impact the risk on site, although they do highlight the build-up of Home Guard activity in the wider area. • The exact nature of activities conducted with ordnance, both on the rifle range and on by the Home Guard could not be discerned with available records, however their presence in the general vicinity and well as the shooting of small arms ammunition on the range presents a potential risk of contamination. This level of contamination is considered to be limited by the presence of the film studios on site and is not anticipated to have comprised any major military training exercises or the storage of significant volumes of live ordnance. However, due to the lack of clarity surrounding this usage, it has not been possible to entirely mitigate the risk posed by Allied ordnance on site. • The conditions in which HAA or LAA projectiles may have fallen unnoticed within the site boundary are however analogous to those regarding aerial delivered ordnance.
The Risk that UXO Remains on Site	There has been some substantial redevelopment work undertaken on site in post-war years, including the demolition of the former film studios and associated structures and the construction of new industrial structures of the Shredded Wheat Factory. Items of LSA and SAA, if present, would likely only be encountered at relatively shallow depths. The risk of such items remaining is considered to have been mitigated at the location of and down to the depth of post-war foundations and excavations.
The Risk that UXO may be Encountered during the Works	The most likely scenarios under which items of UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The risk of encountering will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Items of LSA and SAA if present, are likely encountered at a depth between just below ground level, accordingly there is also a possibility that UXBs could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level.

	There is not considered to be any significant risk of encountering UXO during works planned within the footprint and down to the depth of any post-war buildings/excavations. Beyond these depths and away from these areas, a risk of encounter could remain.
The Risk that UXO may be Initiated	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. Certain construction activities such as piling and percussive drilling pose a greater risk of initiating UXO in comparison to machine excavation, where the force of impact is generally lower and the item is more likely to be observed. If piling works are planned at the Former Shredded Wheat Factory (Southern Site), there is a potential risk that items of UXO, if present, could be initiated. The risk of initiation is assessed to be lower for any shallow intrusive works planned.
The Consequences of Encountering or Initiating Ordnance	The repercussions of the inadvertent detonation of items of UXO during intrusive ground works are potentially severe, both in terms of human and financial cost. A serious risk to life and limb, damage to plant and total site shutdown during follow-up investigations are potential outcomes. If appropriate risk mitigation measures are undertaken, the chances of initiating an item of UXO during ground works is comparatively low. The primary consequence of encounter of UXO will therefore be economic. This would be particularly notable in the case of sites with a high-profile or where it is necessary to evacuate the public from the surrounding area. A site may be closed from a few hours to a week with potentially significant cost in lost time. It should be noted that even the discovery of suspected or possible items of UXO during intrusive works (if handled solely through the authorities), may also involve loss of production. Generally, the first action of the police in most cases will be to isolate the locale whilst awaiting military assistance, even if this becomes unnecessary.

17.2. Assessed Risk Level

Taking into consideration the findings of this study, 1st Line Defence has assessed that there is a **Low Risk** from German and anti-aircraft unexploded ordnance, whilst a **Low-Medium Risk** from historic Allied LSA/SAA has been identified at the site of proposed works.

Ordnance Type	Risk Level			
	Negligible	Low	Medium	High
German Unexploded HE Bombs		✓		
German 1kg Incendiary Bombs		✓		
Anti-Aircraft Artillery Projectiles		✓		
Allied Military Land Service Ammunition / Small Arms Ammunition		✓		

18. Proposed Risk Mitigation Methodology

18.1. General

The following risk mitigation measures are recommended to support the proposed works at Former Shredded Wheat Factory (Southern Site):

Type of Work	Recommended Mitigation Measure
All Works	• **Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.** As a minimum precaution, all personnel working on the site should be briefed on the basic identification of UXO and what to do in the event of encountering a suspect item. This should in the first instance be undertaken by a UXO Specialist. Posters and information on the risk of UXO can be held in the site office for reference.

In making this assessment and recommending these risk mitigation measures, if known, the 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, 1st Line Defence should be consulted to see if a re-assessment of the risk or mitigation recommendations is necessary.

1st Line Defence Limited **8th January 2018**

This Report has been produced in compliance with the Construction Industry Research and Information Association (CIRIA) C681 guidelines for the writing of Detailed UXO Risk Assessments.

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This report has been prepared by 1st Line Defence Limited with all reasonable care and skill. The report contains historical data and information from third party sources. 1st Line Defence Limited has sought to verify the accuracy and comprehensiveness of this information where possible but cannot be held accountable for any inherent errors. Furthermore, whilst every reasonable effort has been made to locate and access all relevant historical information, 1st Line Defence cannot be held responsible for any changes to risk level or mitigation recommendations resulting from documentation or other information which may come to light at a later date.

Site Location Maps

Annex: **A**

1ST LINE DEFENCE

Unit 3, Maple Park
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Hertfordshire. EN11 0EX
Email: info@1stlinedefence.co.uk
Tel: +44 (0)1992 245 020

Client: **Curtins**

Approximate site boundary

N

Project: **Former Shredded Wheat Factory, Welwyn Garden City**

Ref: **DA7853-00**

Source: Google Maps

Recent Aerial Photography

Annex: **B**

1ST LINE DEFENCE

Unit 3, Maple Park
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Tel: +44 (0)1992 245 020

Client: **Curtins**

Approximate site boundary

Project: **Former Shredded Wheat Factory, Welwyn Garden City**

N

Ref: **DA7853-00**

Source: Google Earth ™ Mapping Services

Client Provided Site Plan

Annex: **C**

1ST LINE DEFENCE

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Client: **Curtins**

Approximate site boundary

N

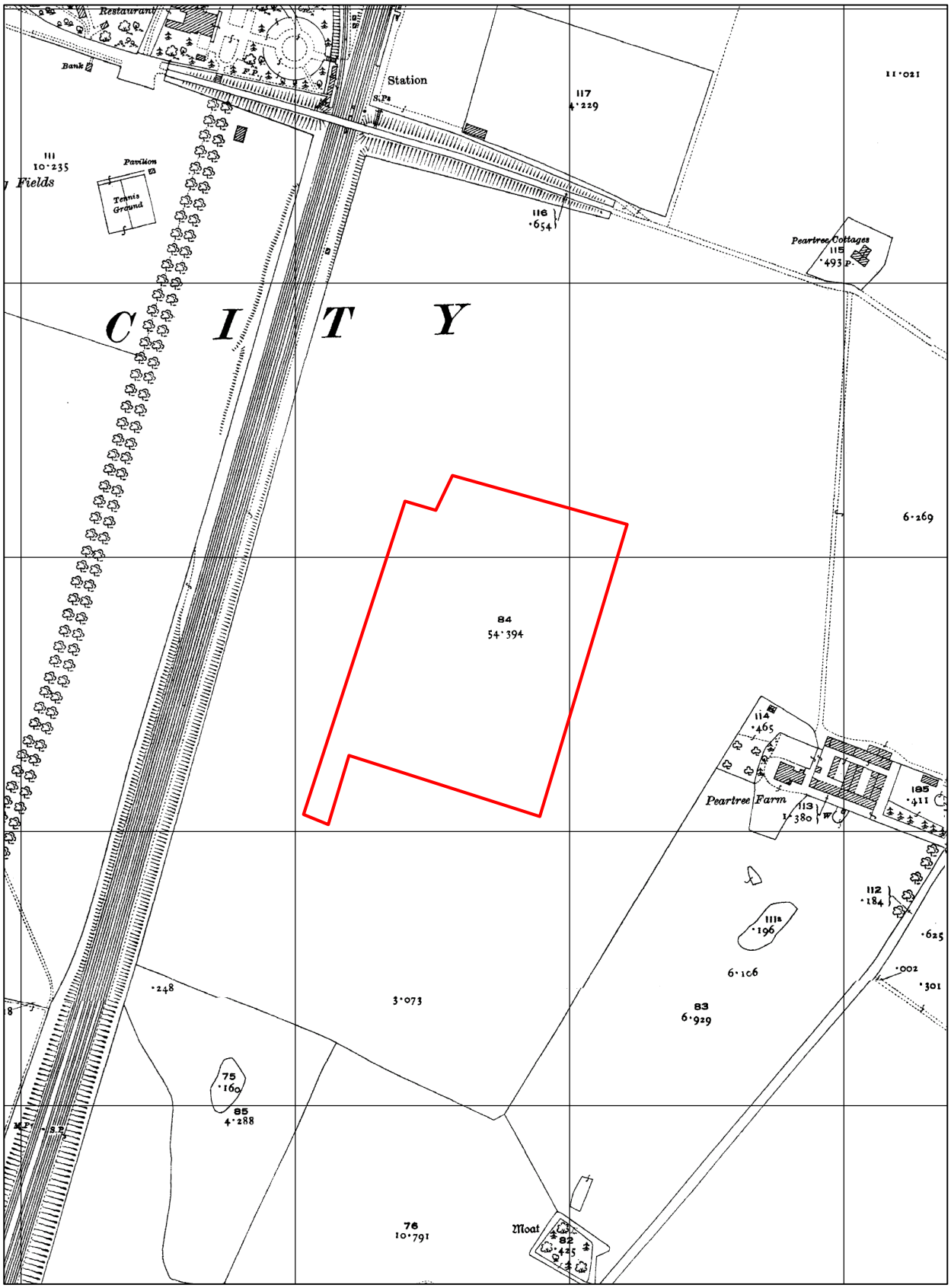
Project: **Former Shredded Wheat Factory, Welwyn Garden City**

Ref: **DA7853-00**

Source: Curtins

1923 Historical Map

Annex: **D1**



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Tel: +44 (0)1992 245 020

Client: **Curtins**

Project: **Former Shredded Wheat Factory, Welwyn Garden City**

Ref: **DA7853-00**

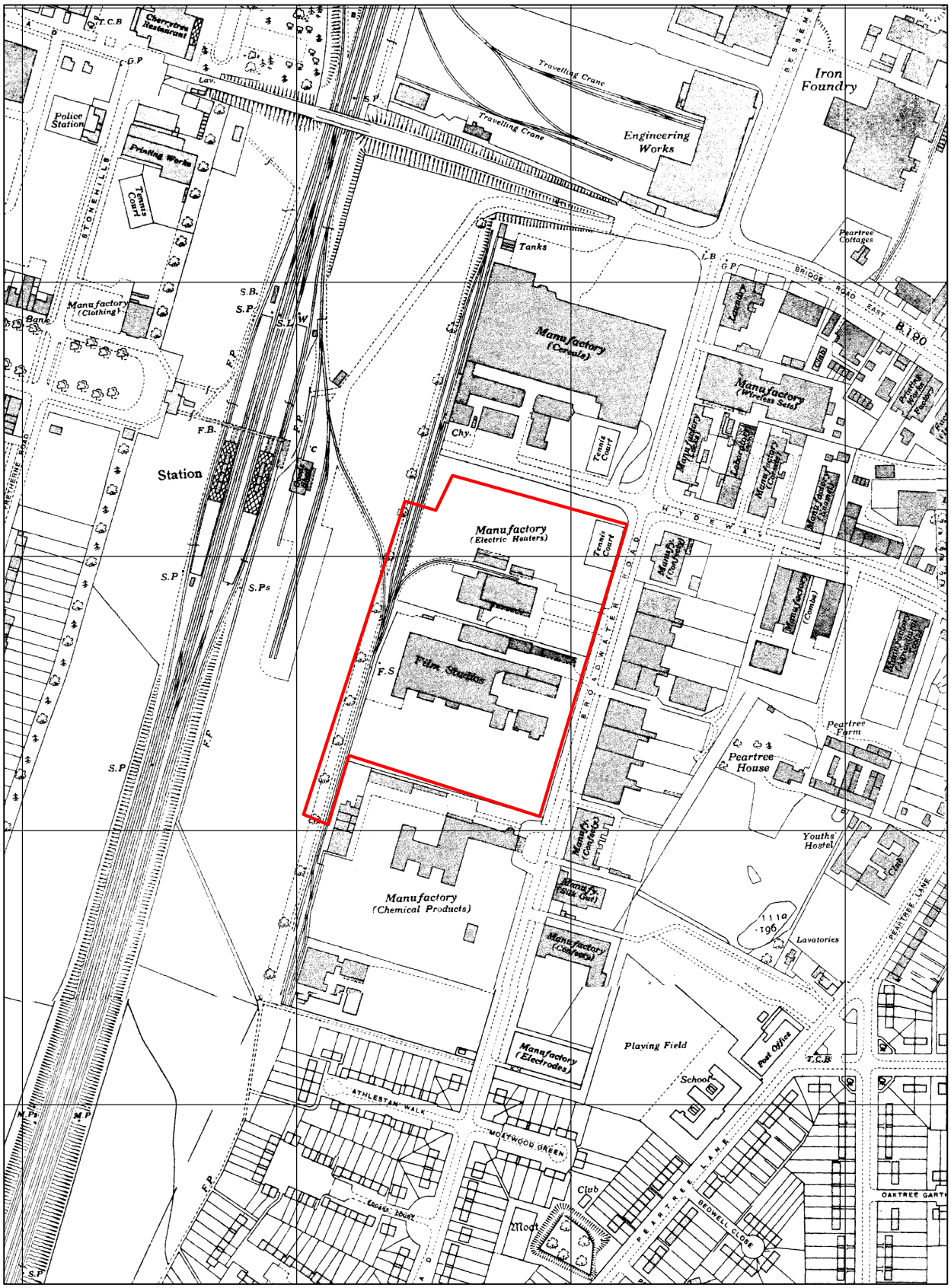
Source: Landmark Maps

Approximate site boundary

N

1938 – 1939 Historical Map

Annex: D2



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Approximate site boundary

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N

Ref: **DA7853-00**

Source: Landmark Maps