Land off Crabtree Lane, Manchester

REMEDIATION STRATEGY & ENABLING WORKS

DRAFT

Version 1.0

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BSH
remediation

REMEDIATION STRATEGY & ENABLING WORKS REPORT

for a site known as

LAND OFF CRABTREE LANE, MANCHESTER

prepared for

KEEPMOAT

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APPENDIX A DRAWINGS

Drawing No.	Title	Scale
BSH2258 - 001	Site Location Plan	1:25,000
02292_JTP_MP_00_DR_A_1100 Rev P02	Proposed Site Plan	1:500 @ A1
BSH2258 - 002	Contamination Constraints Plan - e3P	NTS
BSH2258 - 003	Contamination Constraints Plan - Betts	NTS
BSH2258 - 004	Combined Exploratory Hole Location Plan	NTS
BSH2258 - 005	Additional Site Investigation	NTS

APPENDIX B GEO-ENVIRONMENTAL AND GEOTECHNICAL SITE INVESTIGATIONS

APPENDIX C SPECIFICATION FOR ENGINEERED FILLS

APPENDIX D CLEAN COVER SCREENING VALUES

1.0 INTRODUCTION

1.1 Background

BSH Remediation Limited were commissioned by Keepmoat (the "Client") to prepare an Enabling Works & Remediation Strategy required to facilitate their proposed residential development of land off Crabtree Lane, Manchester (the "site"). A Site Location Plan is presented as Drawing No. BSH2258 - 001 within Appendix A.

It is understood that the client is intending to develop the site with 195 No. low-rise residential properties with private gardens and associated infrastructure and parking as illustrated below. The site layout, Proposed Site Plan is presented as Drawing No. 02292_JTP_MP_00_DR_A_1100 Rev P02 within Appendix A.



1.2 Terms of Reference

The site has been subject to previous site investigations, as detailed below:

- Betts Geo Consulting Engineers Ground Investigation Report, Crabtree Lane, Openshaw, dated September 2021, Report No. 21CHE276/DSGI; and
- e3P Phase I and II Geoenvironmental Site Assessment, Crabtree Lane, Manchester, dated April 24, Report reference 17-548-R1.

The documents above are the principal sources of information used in the preparation of this Enabling Works and Remediation Strategy report and should be read in conjunction with this document.

This document summarises the investigative works undertaken to date and details the reclamation works required to provide a site considered suitable for the proposed residential development.

1.3 Objectives of the Remediation Strategy & Enabling Works

The main aims of this Strategy are summarised as follows:

- To complete further site investigations across the site in previously inaccessible areas;
- To characterise the ground conditions at the site and ensure that the ground to be prepared to a condition ready for development which is suitable for the proposed end use (residential properties with gardens and associated infrastructure) whilst ensuring construction workers and environmental receptors are not put at an unacceptable short-term risk during the remediation and redevelopment of the site;
- Construct a development platform suitable for the proposed foundation solutions; and
- To satisfy the Local Planning Authority (LPA) environmental health department and National House Building Council (NHBC), or other insurer, that the remedial works will provide a site ready and suitable for the proposed development.

1.4 Parties to the Works

The Principal Parties to the works include:

- **Client**: Keepmoat
- **Contractor for the Remediation Works**: BSH Remediation Limited
- **Consultant and Validation for the Works**: BSH Remediation Limited
- **Local Planning Authority**: Manchester City Council
- **National House Building Council (NHBC)**

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2.0 SITE CHARACTERISATION

2.1 Introduction

The Site is located approximately 4.7km east of Manchester City Council, within a mixed residential and commercial setting. The site is centred on National Grid Reference: 388767(E) 398056 (N).

It is now proposed to redevelop the site for a residential end use and therefore, a review of the existing information for the site is necessary in order to determine the remedial actions required to facilitate a residential end use.

The summary information in the following sections has been derived from the sources listed in Section 1.0 and describes the work undertaken to date at the site / adjacent to the site and the context under which it was undertaken.

2.2 Site Description

The site covers an area of approximately 2.97 hectares comprising an irregularly shaped piece of land. The site is currently derelict; the western portion is covered in trees and vegetation and features partially demolished buildings, while an open yard area makes up the eastern portion. The site is located within a mixed commercial / residential setting. A tow path forms the sites northern boundary beyond which is the Manchester Ship Canal, allotments are located to the east, Higher Openshaw community school/ residential properties to the south and Crabtree Lane forms the sites western boundary beyond which is Clayton Industrial Estate.

The site is generally flat at approximately 92.0m Above Ordnance Datum (AOD). The plan below shows the context of the site and adjacent land uses.



2.3 Site History

The earliest available map of site is the 1845 – 1948 mapping which shows the site to be largely undeveloped land with a culvert crossing the site.

1890 mapping indicates an Iron Foundry present in the eastern portion of the site. By 1906 the foundry had been extended further and by this time covered the majority of the eastern portion of the site with a chimney also detailed in the larger scaled mapping.

The 1908 mapping shows the construction of a number of buildings in the western portion of the site forming the northern boundary. The northern building is labelled as an iron works. The area to the south of the works is detailed as steep slopes indicating removal of materials. A smaller slope is also present in the southwest. Later mapping indicates the western area of the site is occupied by Crabtree Forge.

The 1949-1950 mapping shows significant extension to all the buildings in both the eastern and western portions of the site. In the north of the site with the introduction of travelling cranes and tanks. An electrical substation is also shown on the western boundary. Steep slopes are shown as a refuse heap along Clayton Brook. Steep slope is still shown around the stream in the southwest. The landfill markings remained until 1964, when it was no longer present.

By 2003 site structures in the eastern portion of the site were demolished and the site was vacant land. 2019 imagery shows the majority of buildings in the western portion of the site shows in its current state following demolition of several buildings.

2.4 Recorded Geology

The site is underlain by superficial deposits comprising glacial till overlying the Manchester Marl Formation (Mudstone).

2.5 Hydrology and Hydrogeology

The closest listed watercourse is the canal adjacent to the northern boundary. However it is not clear from historical mapping whether Clayton Brook is rerouted away from the site, as historical mapping does show it being culverted across the south of the site.

2.6 PFAS (Per - and Poly - Fluorinated Substances)

e3P identified no potential current or historical sources of PFAS on the site. However, recent correspondence from the Environment Agency (EA reference SO/2025/124953/01 dated 16 May 2025) requires further site investigation for Perfluorooctane sultonate (PFOS) and Perfluorooctanoic acid (PFOA). See Section 4.0 – Further Site Investigation.

2.7 PCB Contamination

Due to site constraints no PCB contamination testing has been undertaken on the western site boundary in the locality of a former substation. See Section 4.0 – Further Site Investigation.

2.8 Unexploded Ordnance

Brimstone undertook a detailed UXO risk assessment as reported in the e3P site investigation report. Brimstone concludes that UXO poses a MODERATE RISK to the proposed works.

2.9 Radon Risk

The site is not within an area recorded to require radon protection measures.

2.10 Sensitive Receptors

On-site potential sources of contamination identified within the Phase II site investigations by both Betts and e3P comprised of:

- Heavy metals, PAH, TPH hotspots and asbestos associated with the former use of the site;
- Localised made ground associated with the historical land use of the site;

- Ground gas potential from the historical landfill to the south of the site encroaching onto the southern site boundary; and
- Asbestos containing materials associated with the fabric of the current site structures.

Contamination constraints plans encountered during both phases of investigation are presented as Drawing No. BSH2258 – 002 and BSH2258 – 003.

The Site Investigation Reports (text only) completed by Betts and e3P are presented within Appendix B (full copies are available on request).

3.0 SITE INVESTIGATION WORKS

The site has been investigated in two phases by both Betts and e3P. Conditions at the site have not changed since either site investigation. A summary of the site investigation findings are presented in the following sections. A combined exploratory hole location plan is presented as Drawing No. BSH2223-004 within Appendix A.

3.1 Proven Ground Conditions

Ground conditions encountered during the Betts and e3P site investigations are summarised in Table 3.1.

Table 3.1 Summary of Ground Conditions

Strata	Maximum Thickness (Range)	Description
Made Ground	0.6m – 4.5 (Typically average 1.48m)	Deposits are variable but in general comprise blackish-brown gravelly fine to medium sand. The gravel fragments comprise concrete, brick, asphalt, ceramic, clinker and slate. Locally, pieces of glass, rebar and electrical wiring were also encountered along with inclusions of ash. Cobbles-sized fragments comprised brick and concrete.
Clay	Unproven	Firm to stiff CLAY overlying fine to medium loose to medium dense SAND

3.2 Groundwater

Groundwater strikes were recorded as slow ingress in the exploration holes at depths of between 1.3 m bgl and 6.0 m bgl in the eastern portion of the site (e3P report) . No shallow perched groundwater was encountered in the western portion of the site (Betts report).

3.3 Contamination Assessment

Assessment against a residential end-use with plant uptake has identified elevated arsenic, lead, zinc and asbestos as well as elevated PAH compounds. These are widespread throughout the Made Ground.

An annotated exploratory hole location plan with contaminant exceedances is presented as Drawing No's. BSH2258 – 002 & BSH2258 - 003 within Appendix A.

3.4 Hazardous Ground Gases / Vapours

Ground gas monitoring as per BS8485 indicates that the site has been characterised as CS1 in the eastern portion of the site and CS2 in the western portion of the site.

3.5 Remediation Recommendations

Both site investigation reports outline a brief remediation strategy based on the identified contamination recommending a 600mm thick clean soil capping layer in private gardens and soft landscaped areas to break the source – pathway – receptor linkage.

4.0 FURTHER SITE INVESTIGATION WORKS

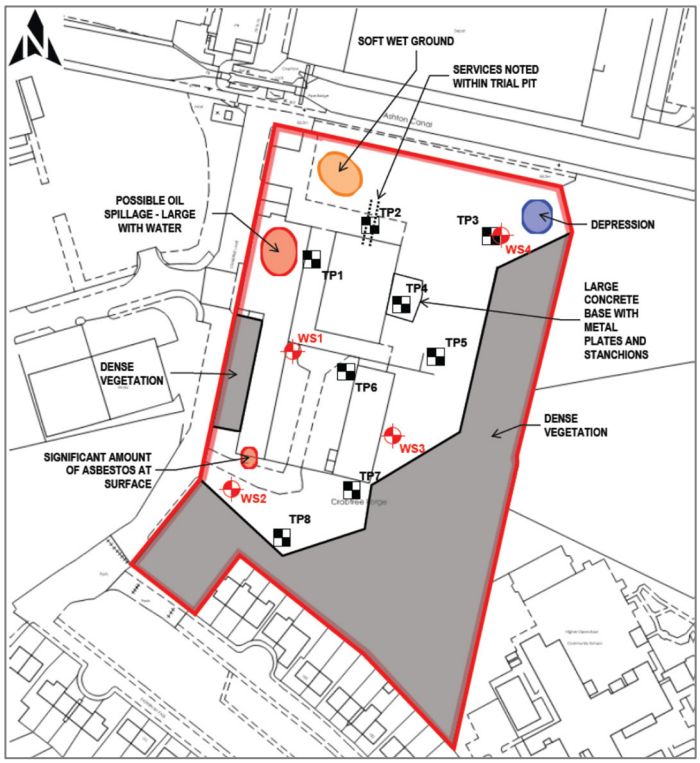
4.1 Site Investigation Objectives

The objectives of the intrusive ground investigation will be to:

- Clarify the shallow ground conditions encountered within the Third-Party Reports provided by the client in areas which were inaccessible during the first two phases of site investigations;
- Benchmark the contamination status of the site in the densely vegetated area in the south western portion of the site following extensive vegetation clearance;
- Benchmark the contamination status of the site previously occupied by site buildings;
- Confirm the initial findings of both site investigations and ensure that the proposed remediation solution is applicable; and
- Provide a geotechnical appraisal for the previously un-investigated areas.

4.2 Areas not accessed

As shown on the sketch below, some areas were not accessible due to dense vegetation. This area has now been cleared by BSH Remediation.



4.3 Scope of Further Site Investigation

Due to site accessibility issues during the two phases of previous site investigation further site investigation is required within former site buildings, the vegetated area to the south western portion of the site and additional requirements from the Environment Agency.

BSH will investigate by trial pits the areas not accessed previously by Betts, undertake trial pitting within building footprints following demolition works and complete trial pits in the eastern portion of the site to satisfy the concerns of the EA. The findings of the additional site investigation will be presented in the final BSH Remediation Validation Report in line with NHBC Technical Standards Chapter 4.1 and CL:AIRE guidance for verification reporting.

The areas subject to further investigation are presented on Drawing No.BSH2258 – 005 within Appendix A.

5.0 OUTLINE REMEDIATION STRATEGY AND OBJECTIVES

5.1 Remediation Objectives

The primary objective of the remediation works is to render the site suitable for the proposed residential development, whilst mitigating any potentially unacceptable transient and long-term risks to human health and the environment. The proposed remediation approach is summarised below:

- Undertake further site investigation in areas previously inaccessible; and
- Made ground soils exceeding current Soil Generic Assessment Criteria (GAC's) can be placed below plots, hardstanding, areas of POS and gardens (ie. below the proposed capping) as applicable.

BSH Remediation are proposing the following capping system to render the site suitable for use for futures site users. The capping system is to comprise:

- private rear garden areas: 600 mm (nominally 200 mm topsoil and 400 mm subsoil – imported).
- front garden and landscaped areas: 300 mm (typically topsoil (imported)).

Provision/ placement of the cover system is beyond the scope of works for BSH Remediation Limited. Due to the practicalities and logistics of construction, the placement of the cover system would most effectively be installed during the construction phase of the project and/or as part of the earthworks process as the project progresses.

BSH Remediation are therefore proposing a remediation strategy comprising provision of a cover system whilst adopting LQM 'S4UL' GAC's.

The remediation works will be undertaken under a CL:AIRE Development Industry Code of Practice Materials Management Plan (MMP); the MMP will need to be declared to CL:AIRE prior to commencement of earthworks.

5.2 Regulatory Consultation

All works will be undertaken following consultation and agreement with Manchester City Council and the NHBC.

6.0 GEO-ENVIRONMENTAL CONSULTANCY

Keepmoat has appointed BSH Remediation as the suitably experienced and qualified Geoenvironmental Consultant/ Engineer (GC/ GE) responsible for ensuring that the remediation and earthworks are completed in accordance with the remediation strategy and to provide advice on all relevant earthworks matters.

The GC/GE shall ensure that the earthworks elements of this Strategy, as defined above and in the specification, are complied with.

On satisfactory completion of all of the remediation earthworks, the GC/GE shall prepare a Remediation Verification Report, to include a description and interpretation of the remediation works undertaken against the defined requirements and the provision of all relevant data and supporting information, which may include but may not be limited to: relevant site information and records, analytical laboratory and geotechnical test data, materials management records, photographs and drawings.

The responsibilities of the GC/GE shall also include, but may not be limited to, the following:

- Undertake the additional site investigation proposed.
- Liaison with statutory bodies in relation to the remedial earthworks.
- Supervision and quality control of the remedial earthworks.
- Advice on the correct handling of materials and conditions encountered.
- The supervision of material sampling as required under the Strategy; and
- Review of site records and test results as they become available and make comment and act upon those results accordingly.

BSH Remediation have not currently been appointed to undertake the subsoil and topsoil validation / capping thickness as per Section 11. Once appointed by Keepmoat, BSH will ensure the regulators are aware of the chosen consultant and ensure that the requirements of the remediation strategy are passed on.

7.0 REMEDIAL WORKS

7.1 Site Clearance & Topsoil/ Made Ground Strip

Site vegetation shall be cleared and removed off-site as appropriate. Any general debris shall be cleared and placed in skips for off-site disposal.

7.2 Asbestos Removal & Demolition

Asbestos removal will be undertaken following the completion of a Refurbishment and Demolition Asbestos Survey. All notifiable asbestos will be removed by an appropriately licensed contractor, non notifiable asbestos will be removed by BSH. All asbestos waste will be removed off site to a suitably licensed landfill facility.

Following completion of asbestos removal works, the above ground structures will be removed under a Section 80 approval. Any materials suitable to be recycled ie. brick / concrete will be recycled into usable products ie. 6F2. Any general debris shall be cleared and placed in skips for off-site disposal.

7.3 Grubbing up of Slabs/Hardstands and Foundations

Any remnant hardstanding, foundations, drainage and other relic structures encountered during the proposed works shall be broken out and removed. Selected materials suitable for re-use or recycling shall be retained on site for potential re-use within the works.

Any deeper structures i.e. piles, encountered during the works shall be broken out to a depth of 2.5m below existing or finished ground levels, whichever is the deeper, surveyed and marked on a plan and then discussed with the client to determine if they cause a constraint to the proposed development.

All hard arisings/materials, where appropriate, shall be stockpiled and crushed in an agreed location. Appropriate materials shall be crushed (125mm down) to generate a 6F2-type material.

All unsuitable material, including, but not limited to, metal, steel reinforcement, rags, plastic, timber or degradable material shall be removed. The crushed product shall be inspected by a geo-environmental engineer (GE) to confirm such materials have been removed as far as practicable.

7.4 Site Wide Turnover & Re-Engineer Site Soils

As part of the remedial earthworks, it is proposed to excavate full depth of made ground where possible, in order that the materials can be classified for re-use within the engineering works and expose any previously unidentified contaminated materials and structures for appropriate treatment and/or removal, where required.

Previous investigation works have revealed chemically unsuitable (elevated concentrations of heavy metals, asbestos fibres, TPH and PAHs) soils below areas of the site.

The above soils, if retained on site, would need to be placed below a suitable cover system within areas of soft landscaping/private gardens or alternatively engineered below hardstanding areas i.e. plots, drives etc.

All above excavated materials shall be screened, where necessary, to remove oversized materials or any other unsuitable material. All arisings, if re-used in the works, should have a maximum particle size of 125mm. Oversized hard material shall be crushed to generate a 6F2 type material for re-use within the works.

Reference to Highways Agency Specification for Highway Works (Series 600 Earthworks) presented in Appendix C of this report should be made with respect to requirements for material type classification tests and/or the National Housebuilder Council (NHBC) Chapter 4.6 for Engineered Fills.

Typical material types expected to be produced on site are detailed below:

- Unsuitable Fill
- General Fill
  - Class 1A, B or C (general granular fill)
  - Class 2A, B, C or D (general cohesive fill)
- Special Fill
  - Class 6A, B or C, or Class 6F1, 2 or 3 (selected granular fill)
  - Class 9A or B (stabilised materials)
  - Type 1, A10, A14 or A20 (selected granular fill) if required

Materials unsuitable for incorporation into the works are to be divided into three categories:

- Materials which fail to comply with the requirements detailed in the “Specification for Highway Works and/ or Chapter 4.6”;
- Hydrocarbon impacted soils requiring bioremediation and/or Soil stabilisation treatment; and,

- Contaminated materials which vary significantly from those identified within the previous site investigation, and upon which the subsequent assessment and remediation has been agreed.

All made ground from within the areas of 'cut' will be carefully excavated and screened, where necessary, to remove oversize materials or any other unsuitable material.

During all excavations within the preparatory earthworks, the materials excavated should be inspected by a geo-environmental engineer (GE) to ensure there are no areas of previously undetected contamination. Any soils exhibiting visual and/ or olfactory evidence of gross contamination shall be placed in temporary stockpiles on hardstanding or heavy-duty plastic sheeting, suitably covered and bunded with appropriate signage and identification.

The GE shall advise the Earthworks Contractor of any testing requirements to adequately classify the materials for potential re-use or removal from site.

7.5 Adoptable Highways

With regard to adoptable roads, at this stage it is proposed to excavate and re-engineered with 'site won' soils to a finished remediated formation of 750mm below final design level, the client and / or BSH will cap adoptable roads with 300mm of site won/ imported 6f2 capping in accordance with Specification for Engineered Fills (series 600).

A minimum CBR value of 5% will be required on engineered fill within adoptable highway, estate roads or external hardstanding areas.

7.6 Re-profiling/ In-Filling

Any areas requiring infilling shall be made level with a nominal fall of 1v in 50h. The base of all excavations shall be surveyed, prior to the placement of any engineered fill.

The base of any excavation or surface prepared by BSH to accept fill material, shall be proof rolled using a vibratory roller and any soft (or hard) spots encountered investigated, removed as necessary and replaced with suitable fill materials.

Once a clean working surface has been exposed, inspected and approved by the GE, suitable fill materials shall be laid and compacted in accordance with the "Specification for Engineered Fills".

Areas of fill shall be benched into adjacent areas in accordance with BS6031:1981 "Code of Practice for Earthworks".

7.7 Compaction Requirements

Compaction works shall be undertaken in accordance with the BSH Specification for Engineered Fills and Chapter 4.6.

Method Compaction shall be used for granular material. Cohesive materials shall be compacted in accordance with an end product specification. Any deviation from this shall be subject to the approval of the GE.

Reference to the tables within Appendix C to the Specification for Engineered Fills for each material type should be made.

7.8 Control Testing

All control testing shall be carried out in accordance with the relevant British Standard or other relevant guidance, except where the specification adopts alternative methodologies.

If the results of control / validation tests indicate that the fill is being placed and compacted in such a way that the desired level of compaction is not being achieved, BSH shall further compact or, if necessary, shall excavate the affected work and replace with new fill, compacted to meet the specification requirements.

7.9 Control of Groundwater

Any perched / trapped groundwater encountered during the earthworks, or leachate arising from the site, shall be considered to be contaminated until proven otherwise. BSH shall ensure that potentially contaminated waters and leachate from excavations or stockpiling areas do not reach watercourses, surface water drains, etc. BSH shall ensure contaminated waters or leachate do not discharge onto ground external to the site or on the site.

All such waters will be treated on site using the pump and treatment tanks for subsequent disposal to foul sewer under a discharge consent, or alternatively removed from site by tanker to a suitable disposal facility.

BSH will be responsible for obtaining all necessary permits, licenses and consents for disposal to the foul sewer.

Contaminated waters pumped from excavations should be stored in a holding tank and chemically tested prior to disposal. Any discharges to foul sewer should be recorded in relation to date, time, quantity and quality. All records should be maintained at all times and be made available to the GE upon request.

7.10 ACM Impacted Soils

It is proposed to retain soils contaminated with asbestos (four localised hotspots) on site at a minimum depth of 600mm below the proposed final re-grade levels in a non sensitive area on site ie. under hardstanding / in an area of public open space. The deposition areas and depths shall be recorded by survey.

The asbestos hotspots identified previously, where soils are within the top 600mm of final development levels, these soils will be subject to controlled excavation. Validation samples shall be taken by the GC/GE from the exposed surfaces (i.e. base and sidewalls) on a nominal 5-10m grid (with at least one sample per sidewall/base) to confirm that all asbestos fibres have been removed within the top 600mm. Samples shall be tested for asbestos identification at a UKAS and MCERTS accredited laboratory, with “no asbestos fibres” (NAD) accepted as a suitable validation standard.

Any positive asbestos detections will be scheduled for quantification analysis. If the results of the quantification testing from the excavated soils returns results >0.001% but <0.1% by mass, then the soils will be re-used on site subject to certain criteria to negate any possible future risks to groundworkers and end users i.e. not within highways or areas where service/drainage runs will be excavated and will be at depths >1m below the proposed regrade levels. Should quantification analysis determine a hazardous waste classification then these materials will be disposed off-site to a suitably licensed landfill facility.

Where previously unknown ACM (or possible ACM) are encountered, works will be suspended in that area, the materials covered over, and the location cordoned off until the area can be assessed by a suitably qualified engineer.

Any works involving ACM will be undertaken in accordance with an addendum method statement/plan of works as appropriate.

7.11 Watching Brief for Contamination

During the earthworks operations, BSH will undertake a detailed watching brief for contamination during any significant ground disturbance which takes place at the site below surface level. This will ensure all reasonable steps are taken to identify any previously unidentified sources of contamination potentially present within the site.

The watching brief shall include:

- Detailed observation of all ground disturbing works by the remediation contractor.

- Site inspections during the hand picking of any asbestos contamination.
- Site inspections during the removal of the septic tank and any other in-ground infrastructure; and,
- Undertaking validation sampling where required or considered necessary.

In the event that unexpected contamination is identified during the course of the earthworks these shall be excavated and removed from site to an appropriately licensed waste disposal facility.

Following the removal of the impacted soils, and prior to any infilling works, validation samples for chemical analysis shall be taken by the GC from the exposed surfaces (i.e. base and sidewalls) on a nominal 5m grid to confirm that all potentially hazardous contamination has been removed. Samples shall be tested for a suite of analytes appropriate to the contamination observed at a UKAS and MCERTS-accredited laboratory, and the results compared to the criteria listed in Appendix D of this Strategy.

Where the results of laboratory testing are found to exceed the specified criteria, the GC shall advise the site foreman, and additional soils shall be excavated from the sidewalls or base of the excavation, following which, further validation samples shall be recovered and tested in accordance with the method described above. This shall be an iterative process until validation test results confirm concentrations of contaminants fall below the criteria across the entire face and base of the excavation.

Any contaminated materials designated for removal from site shall be placed in temporary stockpiles on hardstanding or heavy-duty Visqueen sheeting, suitably covered and bunded with appropriate signage and identification. The earthworks contractor shall undertake sampling and analysis of this material sufficient to classify it for disposal.

Unsuitable materials shall be exported from site to a suitably licensed landfill facility, in accordance with the requirements of the Landfill Directive and the Duty of Care Regulations, 1991 and where appropriate the Hazardous Waste Regulations, 2005, or any superseding legislation.

8.0 GENERAL SITE REQUIREMENTS

8.1 Introduction

BSH Remediation shall comply at all times with this Strategy, the Conditions of Contract and all relevant health and safety requirements.

BSH shall prepare and submit a programme for the works to Keepmoat prior to the commencement on site.

Site cabins, stores and welfare facilities shall be established at a convenient location to be agreed between BSH and the Client.

Prior to commencement of works, BSH shall establish the boundaries of the site and working areas and shall make adequate provision to secure the site boundary and prevent unauthorised access to the site during the course of the works.

If works are anticipated to extend beyond the hours of 07.30 to 18.00 Monday to Friday and 08.00 to 13.00 Saturday, then the site working hours shall be discussed and agreed with the Local Planning Authority prior to commencement. No works shall take place on Sunday or Bank Holiday.

8.2 Access / Egress

The principal access to the site will be off Nottingham Road. Appropriate care and attention should be paid to the proposed site access/egress by plant, and suitable cleaning measures shall be employed by BSH as necessary.

8.3 Services

Keepmoat shall be responsible for obtaining all relevant service records for the site and undertake any consultation with the statutory undertakers in relation to identifying the location of live services, including those to any adjacent properties. Keepmoat shall ensure the safe disconnection of all existing services entering the site, except for those which are to remain operational.

Prior to site works commencing, the position and depth of all services shall be determined and clearly identified on site by BSH. The locations should be confirmed on site by appropriate investigation and observations. The following should be undertaken:

- Copies of a consolidated services location drawing should be retained and displayed in BSH's office;
- Cable Avoidance Tool (CAT) scanning of areas where works are to be carried out;

- Hand dug holes to expose services location shall be undertaken (where possible);
- Physical marking out on the site of service routes on the ground and appropriate lay-offs/ easements using paint, pegging, bunting etc.;
- Retaining on the site drawings showing locations of all services;
- Where services are being re-routed during the works both the drawings and site markings must be kept up to date;
- When works commence on a new area of the site the site manager or relevant foreman must brief all operatives on the location of services in this area;
- Method statements / risk assessments must be read by all relevant personnel and their understanding of them confirmed in writing; and,
- If coloured sands, service ductwork or services are exposed during operations then work must cease until the site manager has confirmed it is safe to continue.

All manholes to remain should be located and clearly identified on site to prevent damage. The location, overall depth and diameter of each manhole, and the size and depth of all connections, shall be recorded.

Service providers shall be contacted by Keepmoat to determine any precautions, safe working distances etc. relating to services, both underground and overhead, if required.

8.4 Health and Safety

The earthworks shall be undertaken in accordance with all relevant legislation including, but not limited to:

- The Health and Safety at Work etc. Act, 1974;
- The Construction (Design and Management) Regulations, 2015;
- Construction (Health Safety and Welfare) Regulations, 1996;
- The Control of Substances Hazardous to Health Regulations, 2002, and,
- The Control of Asbestos at Work Regulations, 2012.

Contaminated materials are present on site. During the remediation and construction, it will be necessary to protect the health and safety of site personnel. General guidance on these matters is given in the Health and Safety Executive (HSE) document 'Protection of Workers and the General Public during the Redevelopment of Contaminated Land (HS(G)66)'. In summary, the following measures are suggested to provide a minimum level of protection.

- All ground workers should be issued with high visibility clothing, hard hats, protective footwear and impermeable heavy-duty gloves. Personnel should be instructed as to how they are to be used;
- Hand washing and boot cleaning facilities shall be provided;
- No smoking on site other than in designated areas if any are present on site; and,
- Good practices relating to personal hygiene shall be adopted.
- During the remediation / earthworks asbestos air monitoring will be undertaken on personal monitors and boundary monitoring to prevent the release of asbestos fibres to the atmosphere.

Before site operations are commenced the necessary COSHH Assessment, Method Statements and Health and Safety Plans should be completed and issued by BSH in accordance with the CDM Regulations 2015.

All site personnel shall undergo a site specific health and safety induction prior to commencement of work on site.

Gas monitoring of deep confined excavations, where man entry is required (including plant operators), shall be undertaken prior to commencement of work each day or after short-term suspension of works and shall be continuous throughout the working day.

Gas monitoring shall include:

- Methane;
- Carbon dioxide;
- Oxygen; and,
- Volatile organic compounds.

The results of the gas monitoring shall be recorded in the site diary. The gas monitor shall emit both audible and visual warnings. Alarm levels shall be set with due regard to the Occupational Exposure Limits provided in EH40/2005 (2011).

In the event of a gas alarm sounding, all personnel shall immediately evacuate the area. No personnel shall return to the area until advised by the site manager.

BSH shall provide details of emergency procedures. Emergency Services shall be informed of the site operations prior to commencement.

8.5 Mobile Plant

Mobile plant shall be operated by competent personnel for each item of plant. When not in use all plant shall be locked to prevent unauthorised access.

All traffic entering or working on site shall obey a maximum 10mph speed limit.

Fuelling of any plant shall be undertaken in a designated area and all above ground fuel storage tanks shall comply with the requirements of the Pollution Prevention Guidelines PPG2 (August 2011).

Specifically, any fuel storage tanks should:

- Be situated within an oil-tight secondary containment system such as an impermeable bund;
- The secondary containment must provide storage of at least 110% of the tanks maximum capacity;
- Be located within a secured area; and,
- All taps and valves should be fitted with a lock and be adequately secured when not in use.

Waste oil, hydraulic fluid etc. should not be tipped directly or otherwise discharged onto site. Such materials shall be stored separately, in a secure bunded area, for off site disposal. Waste oil is a Hazardous Waste, and disposal shall be undertaken by a registered carrier in accordance with the Duty of Care (DoC) Regulations (2006) and the Waste (England and Wales) Regulations (2011).

Contractors shall provide a fuel spill kit, to be kept on site in an accessible place near to the designated refuelling area.

8.6 Dust

Appropriate measures shall be implemented at all times during the remediation works, to minimise any dust emissions.

Any haul roads, shall where practical to do so, be constructed of crushed hardcore products. These haul roads shall be maintained for the duration of their use to minimise any build-up of mud, loose spoil etc. Mobile water bowsers and sprayers shall be made available to dampen unpaved haul roads and working areas. An adequate supply of clean water shall be maintained on site at all times to allow dust suppression activities to be carried out at short notice.

Traffic both entering and working on the site shall obey a maximum speed limit of 10 mph.

Regular inspections of the public highway adjacent to the site entrance shall be carried out by BSH. If deemed necessary, the highway shall be swept regularly to remove any mud, slurry or dust deposited by vehicles entering or departing the site, and a wheel wash provided for exiting vehicles if required.

If BSH considers that significant amounts of any detritus have been deposited on the public highway then operations shall be temporarily suspended until appropriate cleaning operations have been undertaken.

Any wagons that are to be used for the haulage of potentially contaminated material from the site shall be sheeted to prevent the release of fugitive dust.

8.7 Odour

If highly odorous materials are encountered which may give rise to nuisance to neighbouring properties, odour control measures can be considered at that time and an appropriate method statement supplied by BSH.

Any odorous materials shall be covered at the end of each working day and any stockpiles will be located away from any residential properties. This shall be continually assessed through the programmed works.

8.8 Noise

The requirements of BS 5228:2009 ‘Noise and vibration control on construction sites’ shall be adhered to at all times.

All machinery shall be fitted with effective silencers and shall be serviced at regular intervals. No items of plant shall be operated with engine covers raised.

The location of any crushing plant shall take into consideration the location of neighbouring properties and other noise sensitive receptors and shall be located away from these areas and located adjacent to proposed stockpile locations, where possible and practicable.

8.9 Off-site Disposal

Any materials encountered during the works designated for off-site disposal shall be safely stockpiled, sampled and analysed, by the Contractor, at rates sufficient to allow the material to be adequately categorised to the satisfaction of the receiving landfill operator in accordance with the Hazardous Waste Regulations (HWR) 2005.

All unsuitable materials shall be exported from site to a suitably licensed landfill facility, in accordance with the requirements of the Duty of Care (DoC) Regulations, April 2006 and where appropriate, the HWR, 2005 or any superseding legislation.

Material exported from site to landfill shall be hauled by a registered waste carrier in accordance with the HWR and DoC regulations. A waste transfer or consignment note shall be completed, signed and retained by all parties involved. The waste transfer or consignment note shall state the volume of waste, a physical description of the waste and statement of its chemical composition. These notes shall be kept by the Contractor for a period of at least two years.

9.0 CONTRACTOR'S RESPONSIBILITIES

9.1 Introduction

The following regulations, guidance and legislation relating to the works shall be complied with at all times:

- Health and Safety Executive "Protection of Workers and the General Public during Redevelopment of Contaminated Land", HS(G)66, HMSO 1991;
- The Construction, Design and Management Regulations 2015 and the Pre-tender and Construction Phase Health and safety Plans;
- The Control of Substances Hazardous to Health Regulations 2002; and,
- The Control of Asbestos at Work Regulations, 2012.

9.2 Surveying

BSH shall be responsible for the following survey work:

- Establishment of profile boards;
- Setting out of building footprints;
- Surveying the base and extent of all excavations following proof rolling and prior to placement of any fill to be engineered;
- Areas of localised overdig, i.e. any areas required to remove deep relic structures / areas of POS;
- Deposition of soils contaminated with asbestos;
- The finished surface (remediation level) prior to handover to Keepmoat;
- Interim surveys to be undertaken during the infilling works to provide information on issues such as progress, earthworks quantities, base/top of made ground etc.; and,
- The location and elevation of test and sample locations.

9.3 Testing

BSH shall be responsible for undertaking all geotechnical and chemical testing necessary to satisfy the GE that the works have been carried out in accordance with and comply with, the specification.

All soils and chemical testing shall be carried out by a UKAS and MCERTS accredited laboratory to the approval of the GE.

9.4 General

BSH shall also be responsible for the following:

- Provision of method statements and reports;
- Environmental Permits (waste and remediation) are in place prior to works commencing;
- Adhering to all recommendations relating to ecology issues;
- The provision of health and welfare facilities;
- Obtaining all relevant permits/ consents/ licenses i.e. treatment licenses, discharge consents etc.;
- Environmental monitoring; and,
- Mitigation measures.

10.0 VALIDATION AND REPORTING

The GE and / or site manager will maintain records of the works to include the following:

- Daily record sheets to include a summary of the day's activities;
- Weather conditions;
- Plant, personnel and visitors present;
- Aspects relating to Health and Safety, environmental control or non-compliance with the General Specification or BSH's Method Statement; and,
- Test results.

On satisfactory completion of all the remediation works, the GE will provide an initial validation report, comprising relevant site records and act as certification that the remedial and ground preparation works have been carried out in accordance with this Strategy.

The validation report shall include the following:

- A description of the works undertaken;
- Records of the works;
- Progress photographs;
- Waste transfer notes;
- Chemical and geotechnical validation test results;
- As built surveys, including base of excavation and final level survey, base and top of made ground; and,
- A statement that the works have been undertaken in accordance with the agreed specification.

Subsequent validation reports will be required following the final placement of any growing medium, in order to confirm its suitability both chemically and textually as well as its thickness. This needs to be carried out at the frequencies stated within Section 11.

11.0 CLEAN COVER SYSTEM VALIDATION

11.1 Clean Cover System Requirements

Elevated concentrations of metals (Lead), PAH's and a localised asbestos hotspot have been recorded within the made ground at a range of depths and pose a potential risk to residential end users.

These elevated concentrations will require remedial action via the construction of a clean cover layer in gardens and landscaped areas. On this basis, a 600mm clean cover system is considered appropriate at the site and 600mm in known areas of asbestos in soils. The clean cover system is proposed as follows in Table 11.1.

Table 11.1 Clean Cover Layer Thickness

Area	Subsoil (mm)	Topsoil (mm)	Total (mm)
Garden Areas (front and rear)	450	150	600
Soft Landscaping Areas	-	300	300
Asbestos deposition area	450	150	600

11.2 Chemical Suitability

All imported materials required to complete the cover soils shall be tested following importation in accordance with the guidance given in the Yorkshire and Humberside Pollution Advisory Council (YAHPAC) document 'Verification Requirements for Cover Systems', Version 3.2 dated October 2014. These are summarised in Table 11.2 below.

Table 11.2 Sampling and Testing for Imported Soils

Type	Number of Samples	Testing Schedule	Assessment Criteria
Virgin Quarried Material	1 or 2 depending on the type of stone used	Standard metals/metalloids (As, Cd, Cr, Cr(VI), Cu, Hg, Ni, Pb, Se, Zn)	As per BSH Ltd Clean Cover Criteria for Gardens (Appendix D)
Crushed Hardcore, Stone, Brick	Minimum 1 per 2500m³	Standard metals/metalloids (as above) PAH (16 USEPA speciation) Asbestos	
Greenfield/ Manufactured Soils	Minimum 3 or 1 per 250m³ (whichever is greater)	Standard metals / metalloids (As above) PAH (16 USEPA speciation) Asbestos	
Brownfield/ Screened Soils	Minimum 6 or 1 per 100m³ (whichever is greater)	Standard metals / metalloids (As above) PAH (16 USEPA speciation) TPH (CWG banded)	

Type	Number of Samples	Testing Schedule	Assessment Criteria
		Asbestos Any additional analysis dependant on the history of the donor site.	

The test results or other pertinent information regarding the source shall be made available to the GE prior to any material being delivered to site.

The analytical testing will be undertaken on a seven day turnaround and shall be forwarded to the GE as they become available.

The results shall be compared with the threshold guideline values given in Appendix D. Should any analyte exceed the concentrations, then the soil should be considered unsuitable for use within the clean cover.

The contractor shall ensure that any soils which are proposed for re-use as clean cover shall be subject to careful management in order to avoid potential cross contamination. All clean cover materials not immediately placed should be stockpiled at agreed locations away from working areas and lightly rolled or ‘sealed’.

11.3 Verification of Required Depth

Verification of depth of topsoil and subsoil shall be carried out by a suitably qualified geo-environmental engineer by excavation of a small trial pit. Trial pits shall be excavated within gardens and soft landscaping areas at a frequency agreed with the LPA Environmental Health Department.

12.0 POST RECLAMATION REQUIREMENTS

12.1 Validation Reporting

A validation report will be provided to Keepmoat on satisfactory completion of the remediation works.

Keepmoat and their sub-contractors shall be responsible for all construction works following handover of the works. Elements that need to be included in any subsequent method statements shall include:

- Compliance with on-going environmental issues;
- Construction of foundations;
- Placement of growing medium in soft landscaping areas;
- The provision of gas/vapour preventative measures as determined by post remediation monitoring;
- Health and Safety;
- Appropriate protection of underground services; and,
- Disposal of any contaminated arisings which cannot be accommodated onsite.

Keepmoat and their sub-contractors shall be responsible for the placement of the clean cover layer as required. The placement, final thickness, chemical suitability etc. of this capping layer will require validation.

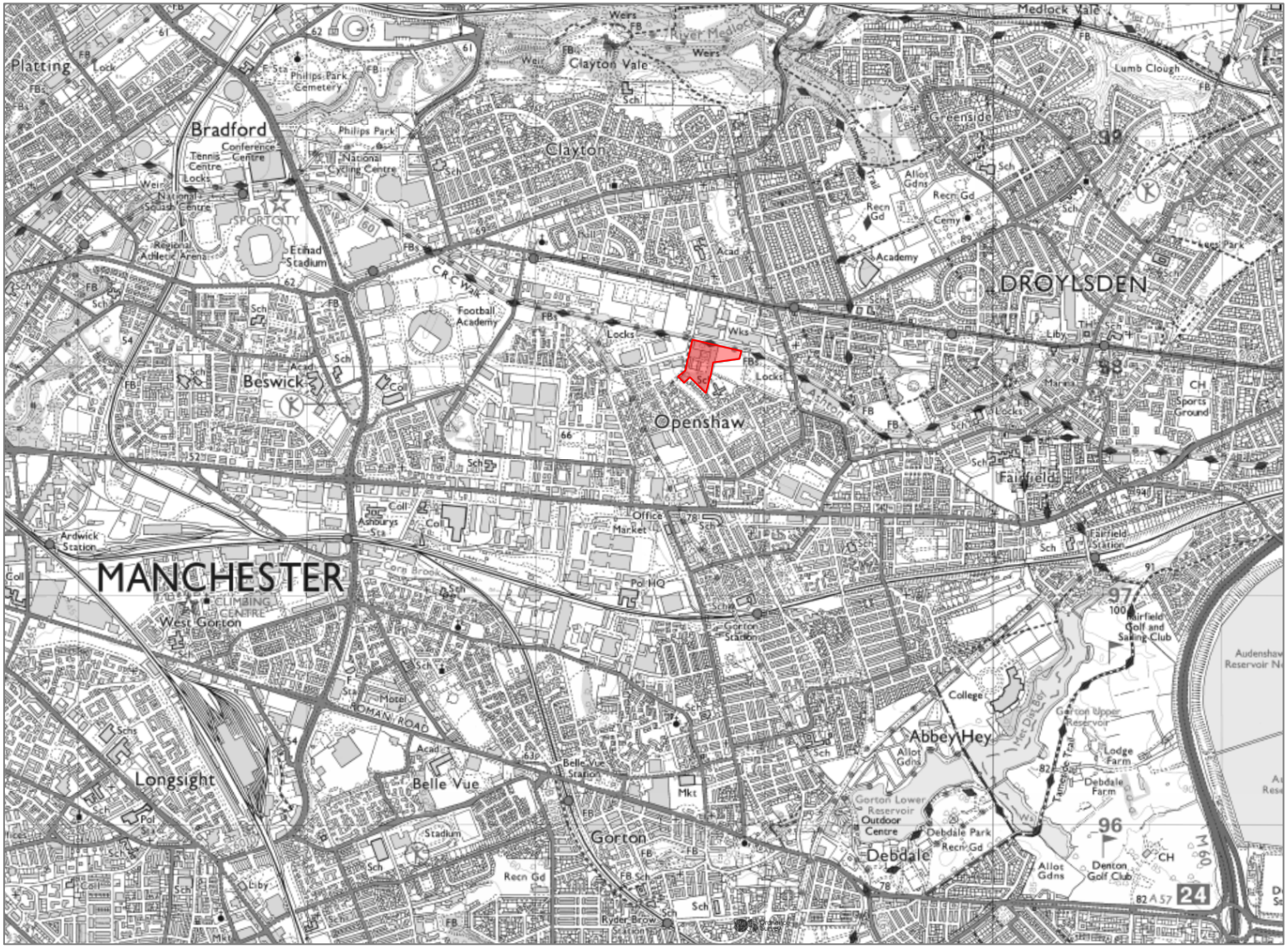
Should any excavation of foundations, drainage and services etc. extend below any placed “clean” capping layer, and therefore encounter underlying made ground materials, then there is a potential for cross-contamination. This should be avoided where possible. Detailed risk assessments and method statements outlining the soil management for the site shall be provided for this work by Keepmoat and their specialist sub-contractors.

13.0 REGULATORY APPROVAL

A copy of this Strategy shall be forwarded to the Local Planning Authority, and other regulators as appropriate for their approval, prior to the works.

BSH Remediation Ltd

APPENDIX A – DRAWINGS



DO NOT SCALE

NOTES:

Site Location

BSH remediation

www.bshremediation.co.uk

CLIENT: Keepmoat Homes

PROJECT:

Land off Crabtree Lane, Manchester

TITLE:

Site Location Plan

SCALE@SIZE :	ISSUE:
1:25,000	Final
DESIGN/DRAWN :	DATE:
SPH	November 2025
PROJECT No:	DRAWING No:
BSH2258	BSH2258 - 001

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DO NOT SCALE

NOTES:

- Hydrocarbon Odours
- Asbestos Fibres WS104 @ 1.5m
- PAH Contamination
- Remediation Hotspots and Validation

BSH remediation

www.bshremediation.co.uk

CLIENT: Keepmoat Homes

PROJECT:

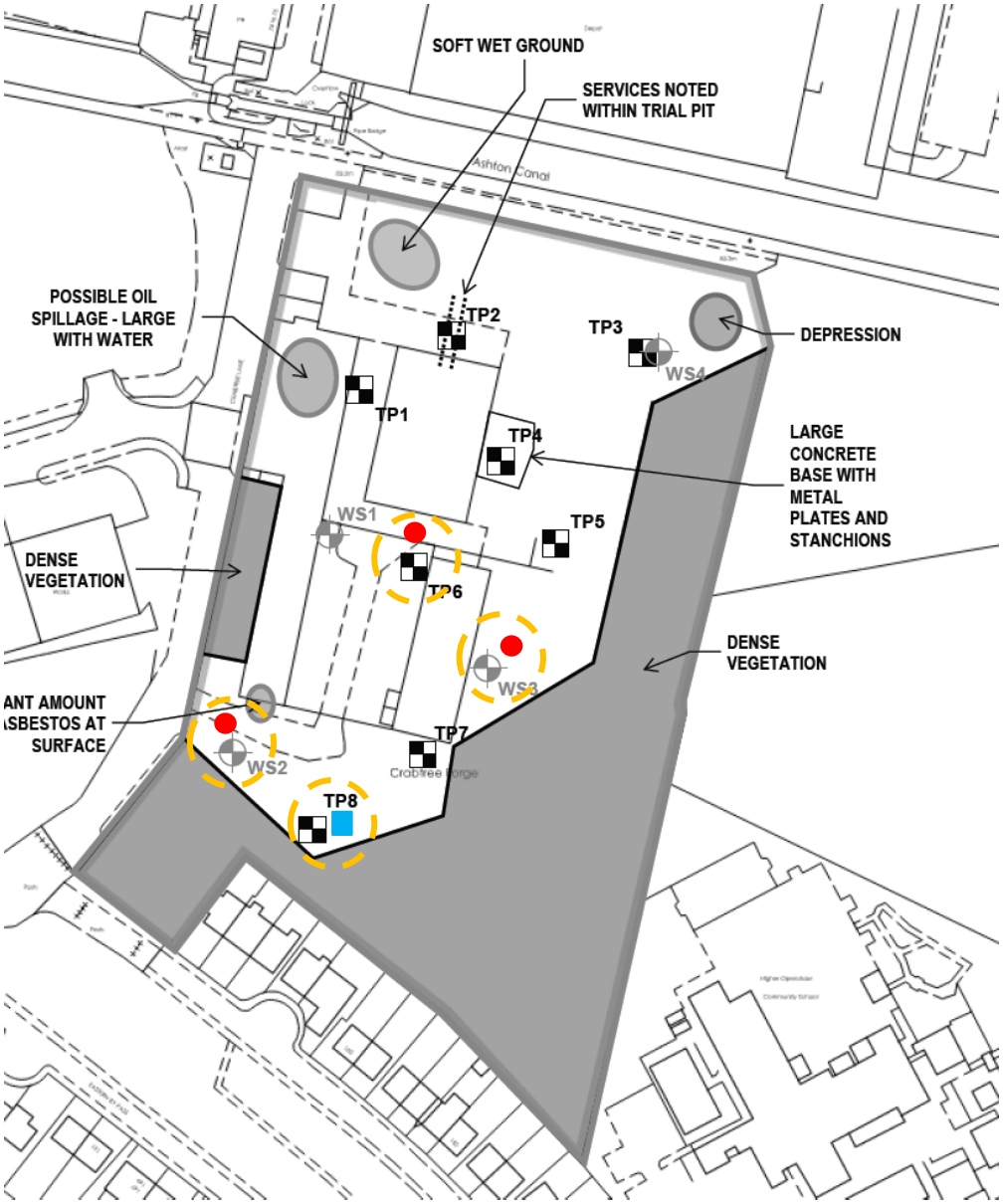
Crabtree Lane, Openshaw

TITLE:

Contamination Constraints Plan
e3P Site Investigation

SCALE@SIZE :	ISSUE:
NTS	Final
DESIGN/DRAWN :	DATE:
SPH	November 2025
PROJECT No:	DRAWING No:
BSH2258	BSH2258 - 002

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DO NOT SCALE

NOTES:

Asbestos Fibres
WS2 @ 3.8m
WS3 @ 2.0m
TP6 @ 1.0m

PAH Contamination

Remediation Hotspots and Validation

BSH remediation

www.bshremediation.co.uk

CLIENT: Keepmoat Homes

PROJECT:

Crabtree Lane, Openshaw

TITLE:

Contamination Constraints Plan
Betts Site investigation

SCALE@SIZE :	ISSUE:
NTS	Final
DESIGN/DRAWN :	DATE:
SPH	November 2025
PROJECT No:	DRAWING No:
BSH2258	BSH2258 - 003

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DO NOT SCALE

NOTES:

e3P Site Investigation – April 2024

Betts Geo Consulting Engineers Investigation September 2021

SI locations

BSH remediation

www.bshremediation.co.uk

CLIENT: Keepmoat Homes

PROJECT:

Land off Crabtree Lane, Manchester

TITLE:

Combined Site Investigation Exploratory Hole Location Plan

SCALE@SIZE :	ISSUE:
1:25,000	Final
DESIGN/DRAWN : SPH	DATE: November 2025
PROJECT No: BSH2258	DRAWING No: BSH2258 - 004

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DO NOT SCALE

NOTES:

- Proposed SI locations
- PFAS Testing
- PCB Testing
- General metal / PAH / TPH and asbestos suite

BSH remediation

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CLIENT: Keepmoat Homes

PROJECT:

Land off Crabtree Lane, Manchester

TITLE:

Proposed Site Investigation Plan

SCALE@SIZE :	ISSUE:
1:25,000	Final
DESIGN/DRAWN : SPH	DATE: November 2025
PROJECT No: BSH2258	DRAWING No: BSH2258 - 005

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APPENDIX B - SITE INVESTIGATION REPORTS

BSH
remediation

Phase I and II Geoenvironmental Site Assessment

Site: Crabtree Lane, Manchester
Reference: 17-548-R1
Date: April 24



e3p

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QUALITY ASSURANCE

Report reference	17-548-R1-2

REV REF:	DESCRIPTION	AUTHOR	CHECKED	AUTHORISED	DATE
R1-1	First issue-For Comment	JC	AE	DC	16/04/24
R1-2	Final	JC	AE	DC	29/04/24

This report has been prepared for the sole benefit, use, and information of the client. The liability of Environmental Engineering Partnership Limited T/A E3P with respect to the information contained in the report will not extend to any third party unless assigned has been agreed. This report has been prepared by the qualified persons as listed below.

WRITTEN BY	QUALIFICATIONS	POSITION
Jack Clayton	BSc (Hons)	Graduate Consultant

REVIEWED BY	QUALIFICATIONS	POSITION
Andrew Edgar	BSc, MSc, PIEMA, MIEnvSc, CENv	Director

AUTHORISED BY	QUALIFICATIONS	POSITION
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EXECUTIVE SUMMARY

Site Address	Crabtree Lane, Manchester, M11 4GU
Grid Reference	E388825, N398057
Site Area	0.69 Ha
Proposed Development	Connell Developments Ltd intends to divest the subject site with a view to the site being redeveloped for a mixed low-rise and high-rise residential development with associated gardens/landscaping, estate roads and infrastructure.
Current Site Use	The site is an irregularly shaped parcel of land located to the east of Crabtree Lane. The Ashton Canal is present to the north of the site boundary circa 0.50 m lower in elevation. The site is generally a level plateau however, there are mounds of material and stockpiled rubble present on-site and a small area of raised slab in the north. Upon entering the site through a gate off of Crabtree Lane, access is gained via a private road to the main site, there were several skips at the site that were being used for site clearance. Connell Developments Ltd has confirmed these will be removed ahead of divestment. The site is predominantly covered in concrete or asphalt hardstanding, although there are areas of broken gravel surfacing and the aforementioned stockpiles. All the former buildings on site have been demolished and no structures are on site except a temporary shipping container acting as a site office.
Site History	An examination of the relevant Ordnance Survey maps from 1848 to the present shows that the site originally is recorded as undeveloped land. However, there is a culvert present (no indication of the culvert location can be determined from the mapping). Circa 1890 an Iron Foundry is recorded on the site. By 1906 the foundry had been extended further and by this time covered the majority of the site with a chimney also detailed in the larger scaled mapping. Circa 1932 the site's layout remains the same but it has now been relabelled Acre Works (Packaging Materials). In 1949 a refuse heap was recorded to the south of the site which appears to encroach into the southern (leasehold) sector of the site. The landfill markings remained until 1964, when it was no longer present and the Acre Works had just been labelled as an unspecified works. By 2003 site structures were demolished and the site was vacant land, and by 2019 any rough scrub vegetation that had grown since the former works demolition had been removed. In 2024, satellite imagery depicts the site being occupied by a service yard, with the loading/unloading and storage of materials.

ENVIRONMENTAL SETTING

Geology	Drift Geology	Till, Devensian – Diamicton: SAND, CLAY and GRAVEL
	Bedrock Geology	Manchester Marls Formation: MUDSTONE
Geomorphology	The site has been subject to anthropogenic change which will likely have resulted in a greater thickness of Made Ground. Upfilling and levelling works are likely to have occurred during construction and demolition to form a level plateau.	
Hydrogeology	A Secondary (undifferentiated) Aquifer has been recorded on site in the drift geology with a Secondary B Aquifer in the bedrock geology. The site is not located within a defined Source Protection Zone.	
	A groundwater abstraction licence is recorded 687 m west of the site.	
Hydrology	The nearest surface water feature is the Ashton Canal approximately 5 m north of the site. Due to the local topography, it is likely that any shallow groundwater, will follow the general fall of the land to the southwest.	
	The site is located within Flood Zone 1 - low risk of fluvial flooding.	
Utility Locations	A formal utility survey has not been completed; however, a review of service records indicates that there are no current services on-site. A culvert is recorded on historical maps but its presence has not been confirmed.	
Landfill Sites and Waste Sites	A historic landfill is recorded to the south of the site operating between 31/12/1942–31/12/1992 and receiving inert, industrial permitting regulations (waste). Another landfill is recorded 113 m west but the details about this site are unknown. The landfill appears to have encroached into the southern (leasehold) sector of the site. The site has also undergone historical development and ground working, the Made Ground associated with the landmark development may produce hazardous ground gases such as methane and carbon dioxide.	
Radon	Radon Class 1 - less than 1% of homes are estimated to be at or above the Action Level. No radon protection measures are required.	
Unexploded Ordnance	A detailed UXO risk assessment has been completed by Brimstone and is presented in Appendix XI.	
PFAS	No potential current or historical sources of PFAS have been identified on-site. No further risk assessment is required.	
Hazardous Installations	No hazardous installations that could potentially prejudice the proposed construction of highly sensitive residential dwellings have been identified within influencing distance of the subject site.	

PREVIOUS REPORTS

E3P is aware that a previous ground investigation report has been completed for the site RSK ENSR in September 2006.

E3P GROUND INVESTIGATION

Ground Investigation Works	E3P has completed an intrusive ground investigation comprising: 14 x mechanically excavated trial pits, 6 x window sample boreholes, 3 x Cable percussion boreholes, and Construction of six environmental monitoring installations.

Ground Conditions	**Made Ground – 0.0m bgl to 4.5 m bgl** Made Ground deposits were encountered within all but one (WS106) location to depths ranging between 0.6 m bgl (TP104) and 4.5 m bgl (WS104). The shallowest Made Ground was encountered at the eastern (average 0.98 m) and western edges (average 0.85 m) of the site with thicker Made Ground through the centre (average 1.98 m). the deepest Made Ground appears to be in the southwest of the site where the thickness of 4.5 m (WS104) and 3.1 m (TP114) were recorded. TP104 and TP113 were not able to penetrate the Made Ground due to refusal on obstructions. Made Ground deposits are variable but in general comprise blackish-brown gravelly fine to medium sand. The gravel fragments comprise concrete, brick, asphalt, ceramic, clinker and slate. Locally, pieces of glass, rebar and electrical wiring were also encountered along with inclusions of ash. Cobbles-sized fragments comprised brick and concrete.
	Drift – 0.2m bgl to 10m bgl Drift deposits were encountered in all locations and typically comprise firm to stiff CLAY overlying fine to medium loose to medium dense SAND. Soft CLAY was encountered in TP110 below the Made Ground at 2.5 m bgl but this was recorded to become firm by 3.0 m bgl. In the deeper cable percussion boreholes CP101 and CP103 a deeper horizon of gravelly CLAY was recorded at depths of between 7.1-8.2 m bgl and 5.5-6.0 m bgl respectively. The deeper SAND horizons were recorded to become very dense from ca. 7.0 m bgl.
	Solid – Not encountered
	Groundwater Groundwater strikes were recorded as slow ingress in the exploration holes at depths of between 1.3 m bgl and 6.0 m bgl. Monitoring to date has not recorded significant recharge in the monitoring wells.

CONTAMINATED LAND ASSESSMENT

Initial Conceptual Site Model	The site was historically an iron foundry and packaging factory with an off-site landfill site appearing to encroach into the southern sector of the site. Based on these on-site uses, potential sources of heavy metals, polycyclic aromatic hydrocarbon (PAH), total petroleum hydrocarbon (TPH), asbestos and ground gas may be present. **Human Health** Metals, PAH, TPH and asbestos pose a risk to construction workers through dermal contact, ingestion and inhalation of soil particles and fibres when impacted soils are exposed. The risk to end users also includes the consumption of homegrown vegetables to which impacted soils may be present in garden and landscaped areas. **Controlled Waters** Mobile contaminants such as TPH and PAH could migrate laterally and vertically through permeable strata. The risk to controlled waters may be limited due to the lower sensitivity of the underlying aquifer and lining to the adjacent Ashton Canal channel and likely groundwater flow to the south following topographic gradient.

	Ground Gas Fill material and Made Ground may contain organic material that could generate ground gas such as methane and carbon dioxide. These gases could migrate through permeable strata and impact future structures and dwellings.
Human Health	Assessment against a residential end-use with plant uptake has identified elevated arsenic, lead, zinc and asbestos as well as elevated PAH compounds. These are widespread throughout the Made Ground. The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, landscaping and public open space to remove any potential for direct exposure to impacted soils. The specific design and installation process for the appropriate cover systems will be clearly defined within the site remediation and enabling works strategy.
Controlled Waters	Widespread arsenic, lead and PAH impact has been identified in the soil, with leachate testing indicating potentially mobile impact from arsenic, lead and zinc. The groundwater beneath the site is likely at depth and based on the site setting is not considered a highly sensitive receptor being a secondary B aquifer and with no groundwater abstraction within the drift. A groundwater abstraction is identified ca. 650 m to the west but this is for evaporative cooling and is likely abstracting from the Chester Formation Sandstone and not the Manchester Marl which underlies the subject site. A foundation design has not been determined but it is likely that for the majority of low-rise plots, these can be found in underlying clay or re-engineered Made Ground using vibro-replacement stone columns. Either option would not generate any new preferential vertical pathways. Further assessment of the risk associated with a piled foundation may be required. Ashton Canal is located at the northern boundary. However, this is not considered to be a sensitivity receptor as it is a lined artificial channel. The canal will be ca. 2.0 m deep and groundwater monitoring has confirmed that groundwater is greater than is at the south of the site; significantly below the base of the canal (3.68 m bgl – WS104). This would indicate a gradient away from the canal and provides evidence that the canal is not in continuity with groundwater. If subsequent monitoring of the wells does not provide an opportunity to sample shallow groundwater then testing of the canal may assist in demonstrating that there is no risk.
Ground Gas	Initial results have indicated that the site is classified as CS1-Low Risk. The full assessment will be completed in due course.
Potable Water Infrastructure	Barrier pipe will likely be required.

COAL MINING ASSESSMENT

Preliminary Assessment	The site is located within a Coal Mine Reporting Area but there are no crops, shallow seams or shafts within 1 km of the site. Furthermore, the site is not within a Development High-Risk Area with any coal deposits likely at significant depth beneath the Manchester Marl Formation.

GEOTECHNICAL ASSESSMENT

Underground Obstructions and Subterranean Hazards	Relict sub-structures have been identified across the site and as part of the process of creating a suitable platform for development, all relict sub-structures will need to be excavated and removed beneath new structures and infrastructure. This will facilitate the construction of the proposed plots as intended. A former refuse tip was identified in the south and with WS104 indicating up to 4.5 m of Made Ground compared with 0.8 m in TP109 there is an inference of a possible high-wall in this area. A culvert may be present beneath the site, however, its exact location and status have not been determined to date.
Allowable Bearing Capacity (ABC)	Across much of the site, the natural strata comprise CLAY overlying SAND. The CLAY has been determined to have an ABC ranging from 93–178 kN/m^2 at between 1.0 m and 2.0 m bgl and 112–268 kN/m^2 between 2.0 m and 3.0 m bgl. An area of soft CLAY was recorded in TP110 at 2.50 m where an ABC of 35 kN/m^2 has been recorded. The underlying SAND can be described as medium dense increasing to very dense from depths ca. 8.0 m bgl level with ABCs ranging from 139–238 kN/m^2 between 2.0 and 3.0 m bgl. At greater depths of between 4.0 and 5.0 m bgl two locations recorded loose SAND at ca. 5.0 m bgl. This may be due to perched groundwater. However, as noted above, in the deeper cable percussion boreholes the SAND becomes increasingly dense to refusal at ca 8.0 m bgl with SPTs greater than 50 for between 245 mm and 265 mm. This would indicate an ABC of greater than 400 kN/m^2.
Foundation Options	At this time it is not possible to accurately define the foundation types due to the absence of a detailed tree survey and final development levels and layout; however, based on our experience with similar sites, we would anticipate that the final foundation solution would be a combination of the following: • Shallow strip foundations bearing on firm to stiff gravelly CLAY from circa 1 m bgl, albeit limited areas and subject to proposed FFLs; • Trench fill to support reinforced strip foundations in areas of variable ground and/or potential tree influence. • Vibro Replacement Stone Columns (subject to re-engineering of the Made Ground) • Piled foundation set within the dense SAND for high-rise apartments or where sensitive infrastructure is present.

	Given the requirements for a large-scale phase of enabling works, it is highly likely that the most suitable foundation solutions for the proposed structures will be Vibro Replacement Stone Columns to support a suitably reinforced spread footing. Consideration must be given to the adjacent canal features and adjacent superstructures. Should an active culvert be present beneath the site piles may be required to transfer the load below the feature and prevent unacceptable structural loading.
Foundations Near Trees	Foundation depths within the conjectured influence of former, existing or proposed trees will need to be deepened to ensure that structural loading bears within the underlying target founding stratum, which cannot be subject to volumetric instability associated with fluctuation in moisture content.
Heave Precautions Near Trees	Given that the underlying clay is of low and medium volume change potential and for design purposes a medium volume change potential should be considered. As the site is underlain by medium volume change potential clay, appropriate heave precautions will be required for the sub-structure design as a part of the structural engineer's appraisal where in influencing distance of existing or proposed trees.
Building Floor Slabs	Ground-bearing floor slabs are not considered viable given the anticipated depths of Made Ground > 600 mm and shallow cohesive soils.
Soakaway Drainage	The Made Ground and underlying granular soils are cohesive in nature and impacted by low-level inorganic and hydrocarbon compounds which would preclude the use of infiltration drainage systems.
Sulphate Assessment	Concrete classification will be DS1 AC1s in the majority of cases. A single DS3/AC2s classification has been identified at the site.
Highway and Infrastructure Construction	Where a proposed highway or infrastructure is to be constructed in these areas, remediation works will be required to ensure the site is engineered to a suitable geotechnical design specification.
CBR Design %	Granular soils can be re-engineered to ensure 5% within the subgrade during favourable climatic conditions. Natural clay soils will provide a CBR in the order of 3–5% during drier climatic periods. However, if water is allowed to shed onto the formation, the CBR will reduce to < 2%, which will require specialist engineering of the subgrade.
Enabling Earthworks	Development levels are unknown at this time; however, engineering works to remove the relict sub-structures will be required. Any excavated material and resulting void will require backfilling the geotechnically suitable material. As part of the earthworks design, materials should be assessed and characterised prior to re-use in the construction of upfill to a geotechnical design. All future earthworks should be completed in accordance with a Geotechnical Design Report (GDR) that will consider the ground model within the context of the potential for settlement induced by surcharge from earthworks, dynamic and permanent loading of the development and all known hazards.
Civil Engineering Excavations	Due to the presence of granular strata, care will be required if undertaking any on-site dewatering to ensure that this does not cause a stability hazard to adjacent sites or structures.

Waste Characterisation	Any material that is to be disposed off site should undergo assessment using Technical Guidance WM3: *Waste Classification – Guidance on the classification and assessment of waste*. This can be done upon request and in line with the Environment Agency sampling frequencies.

RECOMMENDATIONS

Based on the findings of the Geoenvironmental site assessment and the various conclusions drawn, the following additional works are recommended to be completed in due course:

- Completion of the gas monitoring and ground gas assessment.
- Consideration of sampling the Ashton Canal,
- Plot-specific foundation schedule (upon receipt of the final development levels).
- Geotechnical Design Report.
- Geotechnical Earthworks Specification
- Remediation and enabling works strategy.
- Specification for Mitigation of Hazardous Ground Gases and Verification Plan.

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17-548-R1-010 – Conceptual Site Model
17-548-R1-011 – Groundwater Conceptual Site Model
17-548-R1-012 – Developed Conceptual Site Model

1. INTRODUCTION

1.1. BACKGROUND

Connell Developments Ltd (the client) commissioned E3P to undertake a Phase I and II Geoenvironmental Site Assessment at Crabtree Lane, Manchester, M11 4GU.

This report is required to determine potential contaminated land liabilities, remediation requirements and geotechnical engineering works that will be required as part of the proposed development for a mixed low-rise and high-rise residential development.

1.2. PROPOSED DEVELOPMENT

A detailed site layout has not been provided. However, the scheme is likely to comprise a mixed low-rise and high-rise residential development with associated gardens/landscaping, estate roads and infrastructure. A proposed development plan has not yet been submitted to E3P.

A snapshot of the proposed development area is indicated in Figure 1.

Figure 1 Snapshot of Proposed Development Area (Blue Area Denotes Leasehold Land)



1.3. OBJECTIVES AND SCOPE

The objectives of the geoenvironmental investigation are as follows:

- Review historical plans, geology, hydrogeology, site sensitivity, floodplain issues, mining records and any local authority information available to complete a desk study in line with Environment Agency (EA) document Land Contamination: Risk Management (LCRM) (updated June 2023).

- Undertake a phase of sampling and analysis to provide an overview of the environmental issues identified.
- Assess the implications of any potential environmental risks, liabilities and development constraints associated with the site concerning the site's future use and off-site receptors.
- Assess the geotechnical information and provide recommendations concerning foundations, pavement construction and floor slabs.
- Assess the coal mining-related information and provide recommendations regarding any future treatment; and,
- Provide recommendations regarding future works required.

1.4. SOURCES OF INFORMATION

Background information was sought from the following sources:

- Groundsure Enviro+Geo Insight Search Reference GS-M9N-NZ9-NQP-FQN;
- Historical mapping dated 1848 to 2024. A selection of historical maps is reproduced in APPENDIX VI;
- Online planning records held by Manchester City Council;
- Consultations with representatives of Manchester City Council;
- Magic Map Groundwater Vulnerability Map;
- Radon: Guidance on protective measures for new buildings (BRE Document BR 211, 2007);
- British Geological Survey Map;
- Groundsure IO database;
- https://zeticauxo.com/downloads-and-resources/risk-maps/;
- https://flood-map-for-planning.service.gov.uk
- *https://en-gb.topographic-map.com/*
- Search results | Catchment Data Explorer | Catchment Data Explorer

1.5. SCOPE OF WORKS

The scope of works includes the elements included in Table 1.

Table 1 Scope of Works

PRELIMINARY REPORTING
Phase 1 Geoenvironmental Assessment
GROUND INVESTIGATION
Design of suitable ground investigation
Window sample probeholes with the construction of environmental monitoring installations
Deep cable percussive boreholes
Mechanically excavated trial pits
Soil and groundwater sampling
TESTING AND MONITORING
In-situ geotechnical testing
Chemical and geotechnical analysis
Groundwater monitoring
Ground gas monitoring
ASSESSMENT AND REPORTING
Factual and interpretative reporting
Contamination risk assessment and conceptual site model
Geotechnical assessment and interpretation

1.6. LIMITATIONS

The limitations of this report are presented in APPENDIX I.

1.7. RISK CLASSIFICATION

The description of risk classification and the likely action required as set out in CIRIA C552 are included in APPENDIX III.

1.8. CONFIDENTIALITY

E3P has prepared this report solely for the use of the client and those parties with whom a warranty agreement has been executed or with whom an assignment has been agreed. Should any third party wish to use or rely upon the report's contents, written approval must be sought from E3P; a charge may be levied against such consent.

2. SITE SETTING

2.1. SITE DETAILS

Table 2 Site Details

Site Address	Crabtree Lane, Manchester, M11 4GU.
National Grid Reference	E 388825, N 398057.
Site Area	0.69 Ha.
Site Ownership	Freehold with a small area in the southern sector subject to leasehold.

The Glossary presented in APPENDIX II defines all acronyms used within this report.

A site location map is presented in APPENDIX IV as Drawing 17-548-001.

2.2. CURRENT SITE USE

A desk-based walkover was completed by an E3P representative, with the full details included in Table 3.

Table 3 Site Description

FEATURE	DESCRIPTION	PHOTOGRAPHIC EVIDENCE
Occupancy/Use	The subject site is an irregular-shaped parcel of land located east of Crabtree Lane and currently occupied by a service yard. The site is currently being cleared with stockpiled material being screened and crushed.	
Structures	There are no permanent structures on site though brick walls form the northern perimeter of the site.	
Retaining Structures	No retaining structures have been identified on-site.	
Access	Pedestrian and vehicular access can be gained from the east of Crabtree Lane through an access gate.	

FEATURE	DESCRIPTION	PHOTOGRAPHIC EVIDENCE
Slope	The site is topographically level though a small area of raised slab is present in the northeast of the site. There are mounds of materials on the site which are currently being processed for removal.	
Vegetation/Ecology	Mature trees are present along the western/southern/eastern boundary of the site. There are no features which are considered to be ecologically sensitive within the subject site.	
Hazardous Material Storage	No above-ground storage tanks (ASTs) or underground storage tanks (USTs) were observed during the preliminary desk-based walkover. Temporary diesel storage and skips containing waste materials are currently present associated with the site clearance works.	
Asbestos-Containing Material (ACM)	No evidence of ACM was noted across the site during the initial site inspection but its presence in the material stockpiles cannot be entirely discounted. E3P understands that the current stockpiles will be removed from site ahead of the proposed divestment.	

FEATURE	DESCRIPTION	PHOTOGRAPHIC EVIDENCE
Polychlorinated Biphenyls (PCBs)	No equipment that may contain PCBs, such as transformers or electric substations, is identified on the Site.	
PFAS/PFOA	No evidence of PFAS/PFOA has been identified on site.	
Waste Storage	There are currently skips stored on the site that relate to the site clearance operations being completed.	
Drainage	A formal drainage survey has not been completed; however, a review of service records held by United Utilities indicates that there are no sewers on-site and no relict storm drainage features were noted. A culvert is recorded on historical maps but no evidence for this was determined during this phase of works.	

2.3. SURROUNDING AREA

The immediate surrounding area land uses are summarised in Table 4.

Table 4 Surrounding Land Uses

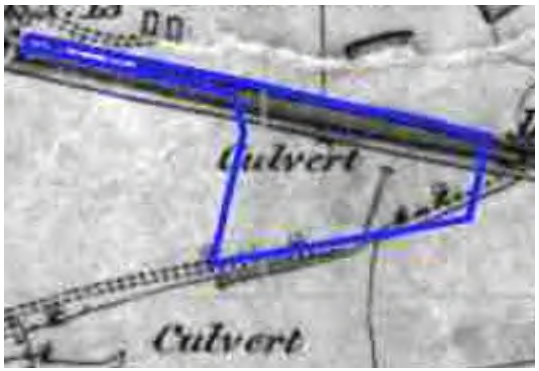
DIRECTION	LAND USE
North	Ashton Canal and Commercial Units
East	Allotment Gardens
South	Higher Openshaw Community School and Residential Properties
West	Commercial Units

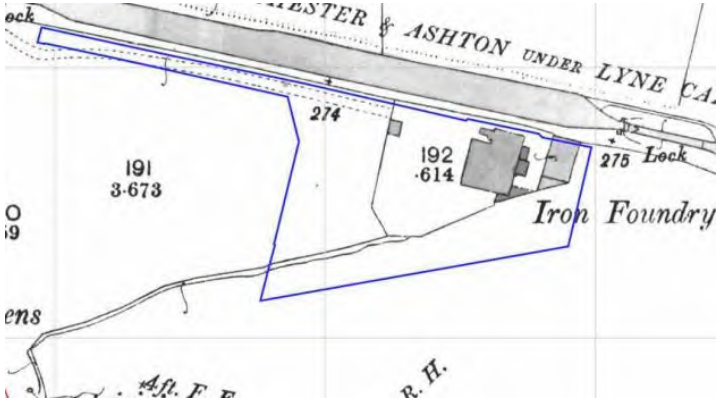
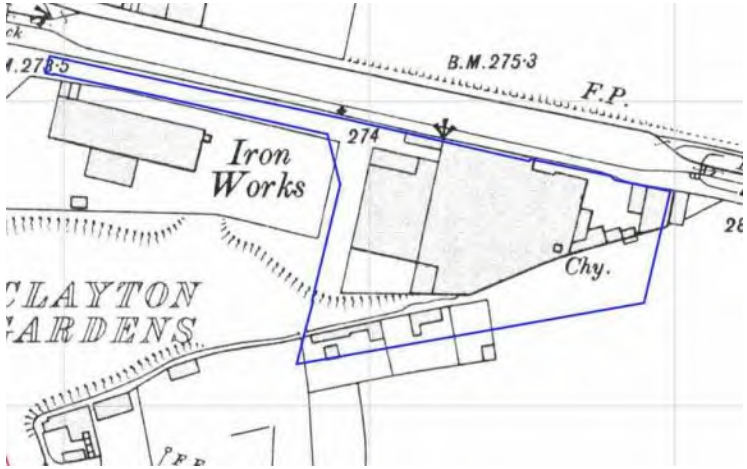
3. SITE HISTORY

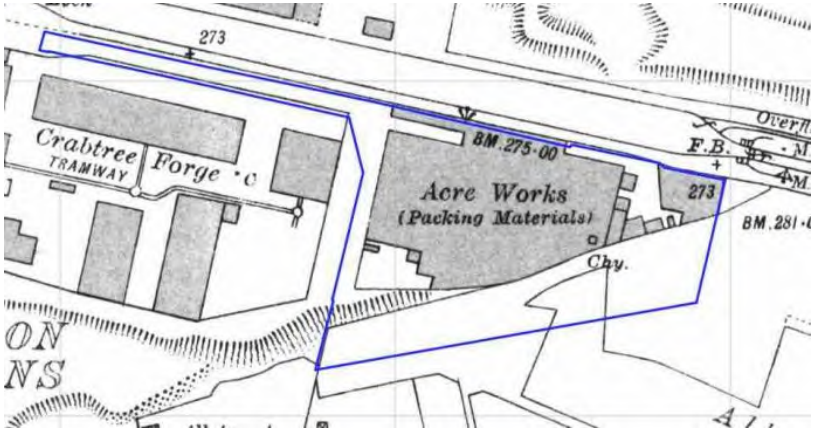
3.1. ON-SITE HISTORICAL DEVELOPMENT

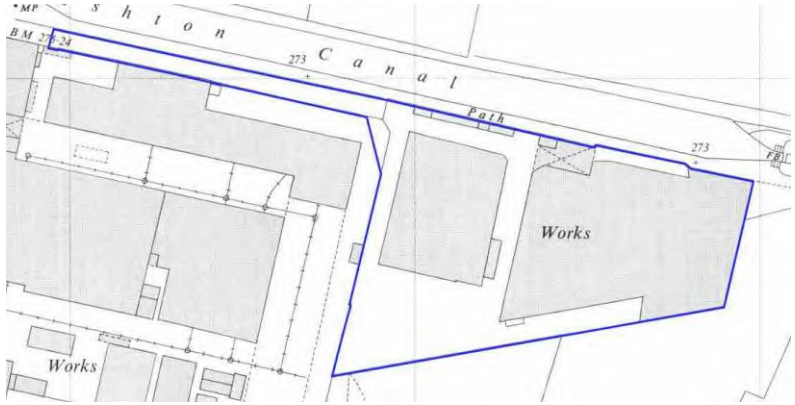
A review of historical mapping and historical aerial imagery pertinent to the site is summarised in Table 5. In addition, historical site features are presented in Drawing No 17-548-003 in APPENDIX IV.

Table 5 Historical Development

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
1848 1:10,560	The site is recorded as undeveloped land. However, there is a culvert present.	
1890-1892 1:10,560	An Iron Foundry is recorded on the site comprising two buildings in the west.	

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
1893 **1:2,500**	The earliest large-scale mapping provides a greater detailed insight into the Iron Foundry. The map also suggests that an open watercourse may have been present in the southwest though the culvert is no longer marked.	
1908 **1:2,500**	The iron works have expanded and there is now a chimney detailed in the central eastern sector of the site. Markings also suggest that the site levels have been raised with a slope marked in the southwest.	

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
1932-1933 1:2,500	The site's layout remains the same but is has now been relabelled Acre Works (Packing Materials). The watercourse is no longer recorded with markings suggesting it has been covered or infilled.	
1949-1950 1:1,250	The site remains the same. However, the more detailed mapping demonstrates that the site has multiple buildings as opposed to one large building which is detailed in the smaller scale mapping. A refuse heap is also present in the south of the site but is considered to be predominantly located to the south.	

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
1964-1968 1:1,250	The site remains unchanged but has been detailed as an unspecified works. There is no longer a refuse heap present in the south of the site.	
1992-1994 1:1,250	There are no significant changes recorded when compared with the previous map.	

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
2003 **1:1,250**	The unspecified works has been demolished and the site is vacant land with no structures recorded on it.	
2009 **Satellite** **Imagery**	There are no significant changes when compared with the previous map.	

MAP EDITION	HISTORICAL LAND USE	HISTORICAL MAP EXCERPT
2019 Satellite Imagery	The rough scrub vegetation has been cleared from site.	
2024 Satellite Imagery	The site is occupied by a service yard. Site activities at the service yard include the loading and unloading of materials and the storage of these materials.	

3.2. SUMMARY OF ON-SITE HISTORICAL DEVELOPMENT

The following summary points have been highlighted after a detailed review of the historical mapping series.

3.2.1. POTENTIAL HISTORICAL CONTAMINATION ISSUES

Historical buildings – Historical developments on-site may have been constructed with ACM which may be present within Made Ground from the demolition of these structures.

The industrial use as an iron works/packing materials/unspecified works suggests the potential for heavy metals (copper, zinc, lead and chromium), waste oils (PAHs) to be present. In addition, with a chimney being recorded on this, combustion processes are likely to have taken place. While likely coal, there is the potential for diesel or heating oil-fired systems, suggesting the potential for petroleum hydrocarbons.

3.2.2. POTENTIAL HISTORICAL GEOTECHNICAL ISSUES

Obstructions associated with the former iron works/foundry foundations, sub-strucutres and floor slabs may be present. Additionally, a culvert may be present across the site and an easement may be needed.

3.3. OFF-SITE HISTORICAL DEVELOPMENT

A review of potentially contaminative uses identified on historical Ordnance Survey maps within a 100 m radius of the Site is summarised in Table 6.

Table 6 Surrounding Historical Development

SURROUNDING FEATURE	DISTANCE	DATES	DIRECTION
Unspecified Tank **Then: no longer marked**	0 m	Pre 1979–Pre2009 Pre2009–Present	South
Refuse Heap **Then: no longer recorded**	4 m	Pre 1949–Pre 1964 Pre 1964–Present	South
Railway Sidings **Then: no longer recorded**	5 m	Pre 1938–Pre 1994 Pre 1994–Present	West
Forge **Then: marked as disused**	5 m	Pre1922-Pre2009 Pre2009-Present	West
Chemical Works **Then: marked as Works** **Then: no longer recorded**	10 m	Pre 1922–Pre 1964 Pre 1964–Pre 1979 Pre 1979–Present	West
Brick Kilns **Then: recorded as Chemical works** **Then: no longer recorded**	12 m	Pre1848-Pre1894 Pre1894-Pre1949 Pre1949-Present	Northwest
Limepit **Then: no longer recorded**	18 m	Pre1932-Pre1952 Pre1952-Present	Northeast
Works **Then: no longer recorded**	57 m	Pre1981-Pre2003 Pre2003-Present	Northeast

3.4. PLANNING HISTORY

E3P has reviewed online planning records held by Manchester City Council, and a list of the relevant documents are summarised in Table 7 below.

Table 7 Planning History

PLANNING REFERENCE	PLANNING APPLICATION	PERTINENT DOCUMENTS
13891/FO/2023	Erection of 9 no. units	Intrusive geoenvironmental and geotechnical site assessment Topographical survey and existing elevations Arboricultural impact assessment
138523/DEM/2023	Prior approval for the demolition of the existing industrial buildings	Topographical survey Ecological appraisal
134463/FO/2022	Erection of 3 x 3 storey apartments	Flood risk assessment Tree survey
085106/TEL/2007/N2	Erection of 11.7m high monopole	Supporting information

3.5. PREVIOUS REPORTS

E3P has been provided with an RSK ENSR Report dated September 2006. The report was entitled Site Investigation, Acre Works, Louisa Street, Manchester and comprised a desk study and intrusive ground investigation. The main environmental findings of this report are summarised below:

- RSK ENSR reported that Made Ground was present in all their exploration locations to a maximum depth of 4.5 m bgl. The Made Ground was described as consistent and generally comprising of black, ashy gravelly sand containing varying concentrations of clinker, slag and brick.
- In all but one location, natural strata were reported to comprise an upper horizon of soft to firm CLAY. RSK ENSR then reported this stratum to be underlain by SAND with bands of soft to firm CLAY.
- Groundwater was reported to have been encountered as a slow seepage in a deeper borehole at a depth of 5.00 m bgl.
- Laboratory testing was completed on selected soil samples and the results were then compared with Soil Guideline Values that were appropriate for the time.
- This assessment identified widespread elevated concentrations of arsenic (max 70 mg/kg) and copper (max 1420 mg/kg); locally elevated lead (max 2240 mg/kg); and a single isolated cadmium (8 mg/kg), nickel (64 mg/kg) and zinc (2220 mg/kg).
- TPH analysis was completed by RSK ENSR reportedly identified elevated C12-C16 aromatic compounds. However, it should be noted that the screening values used at this time were extremely conservative.
- PAH analysis and assessment identified elevated naphthalene in two locations (max 7.05 mg/kg); fluoranthene in one location (max 165 mg/kg); benzo(a)anthracene in three locations (max 64.50 mg/kg); chrysene in three locations (max 73.5 mg/kg); and benzo(b) fluoranthene in two locations (max 63.20 mg/kg).
- Gas monitoring recorded a maximum methane concentration of 0.2 % and a maximum carbon dioxide concentration of 8.5%. The lowest oxygen concentration was 10.5%. Significant flow was not recorded during the RSK ENSR monitoring visits.

4. ENVIRONMENTAL SETTING

4.1. GEOLOGY

The British Geological Survey (BGS) map (Sheet 085) for the Site (1:50,000, Solid and Drift editions) and online records indicate the area is underlain by the geological sequence presented in Table 8.

Table 8 Summary of Underlying Geology

GEOLOGICAL UNIT	CLASSIFICATION	DESCRIPTION	AQUIFER CLASSIFICATION
Drift	Till, Devensian - Diamicton	SAND, CLAY and GRAVEL	Secondary undifferentiated
Solid	Manchester Marls Formation	MUDSTONE	Secondary B aquifer

E3P has reviewed the BGS database, which has not identified any boreholes in close proximity, from which to compare the published geology above.

4.2. HYDROGEOLOGY

The Groundsure report indicates that the site is not located within a groundwater source protection zone. Furthermore, there are no potable abstractions within 1 km of the Site. The closest active groundwater abstraction point is located 687 m west of the site.

Based on the local topography and the location of surface watercourses within the proximity to the site boundary, it is likely that shallow groundwater, if present, will flow in a southwesterly direction.

4.3. HYDROLOGY

Surface water features within 50 m of the subject site are summarised in Table **9**.

Table 9 Surface Water Features

SURFACE WATER FEATURE	EA CLASSIFICATION	QUALITY	DISTANCE (m)	DIRECTION
Ashton Canal	Canal	Moderate	Adjacent	North
River Medlock	Main River	Moderate	1.3 km	North (at the closest point)

Historical maps indicate the presence of a culvert on-site ca. 1848 and that this may have flowed into a watercourse called Clayton Brook ca 50 m to the south. The culvert is not recorded on any subsequent maps and by 1968 Clayon Brook is no longer recorded. United Utilities sewer plans record a 600 mm piped watercourse to the south of Crabtree Forge which may be the historical Clayton Brook.

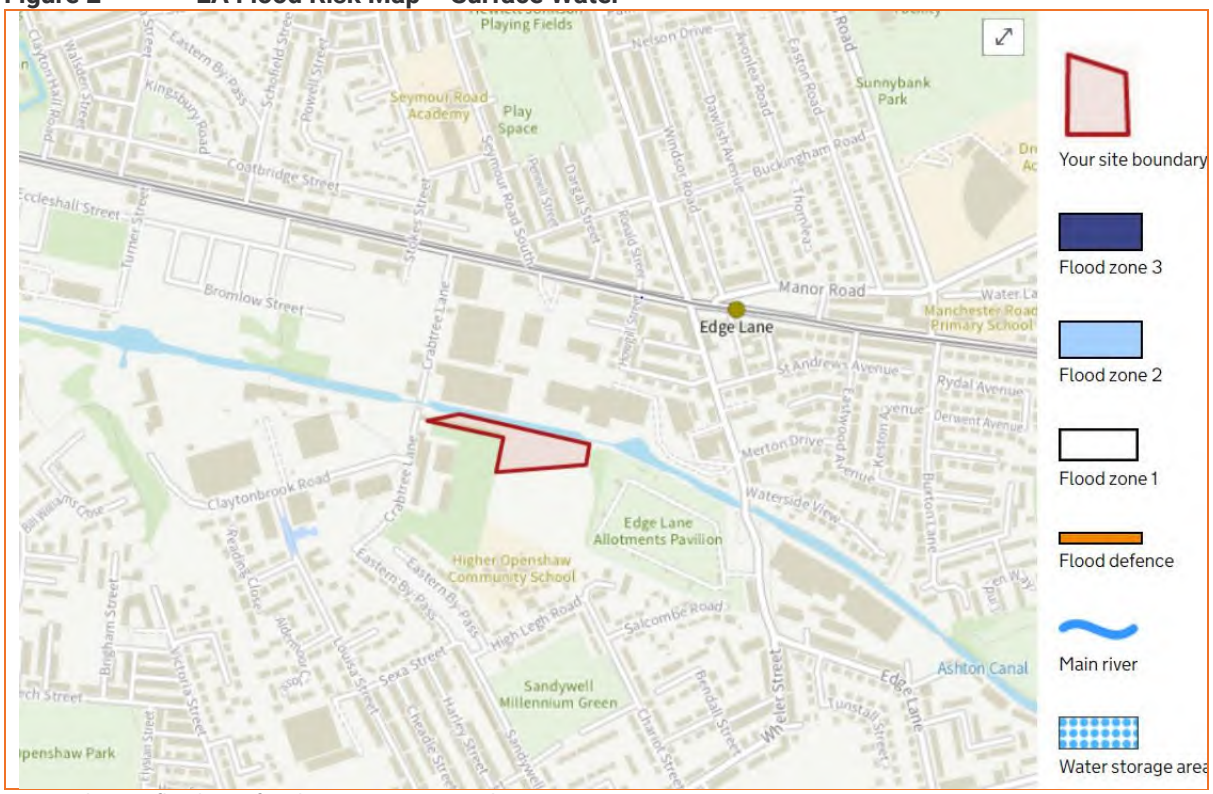
The site is predominantly located within a currently defined “Flood Risk Zone 1”, defined as land assessed as having less than 1 in 1,000 annual probability of river or sea flooding (< 0.1%) and, as such, is considered to be unaffected by river flooding.

In addition, the Groundsure report states there is a limited potential for groundwater flooding at the Site.

The Environment Agency (EA) Flood Risk Maps for the Site is presented in

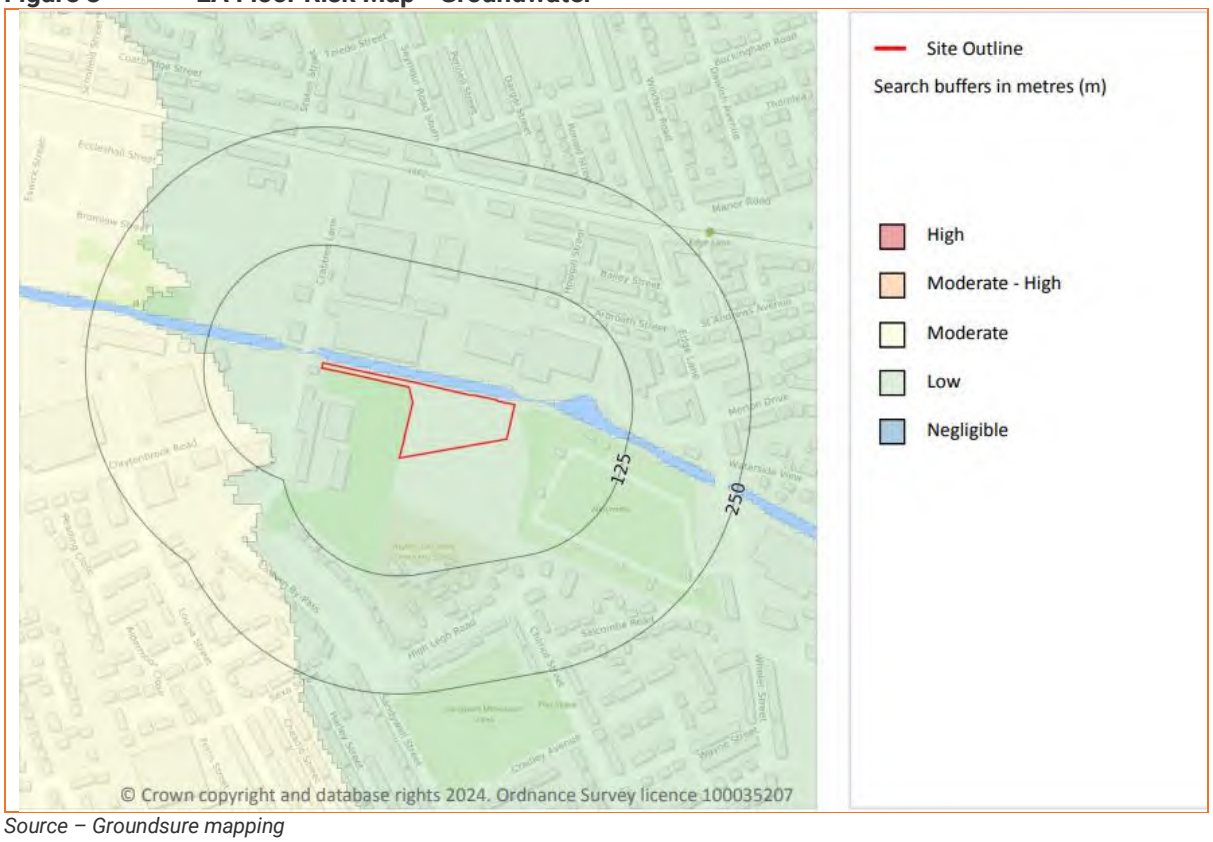
Figure 2 and Figure 3.

Figure 2 EA Flood Risk Map – Surface Water



Source - https://flood-map-for-planning.service.gov.uk/

Figure 3 EA Floor Risk Map - Groundwater



Source – Groundsure mapping

4.4. RADON RISK POTENTIAL

The Groundsure report indicates the site is situated in an area where less than 1% of homes are above the "Action Level" and that the BGS reports that full radon protective measures are not necessary for the construction of new dwellings or extensions.

4.5. LANDFILL SITES

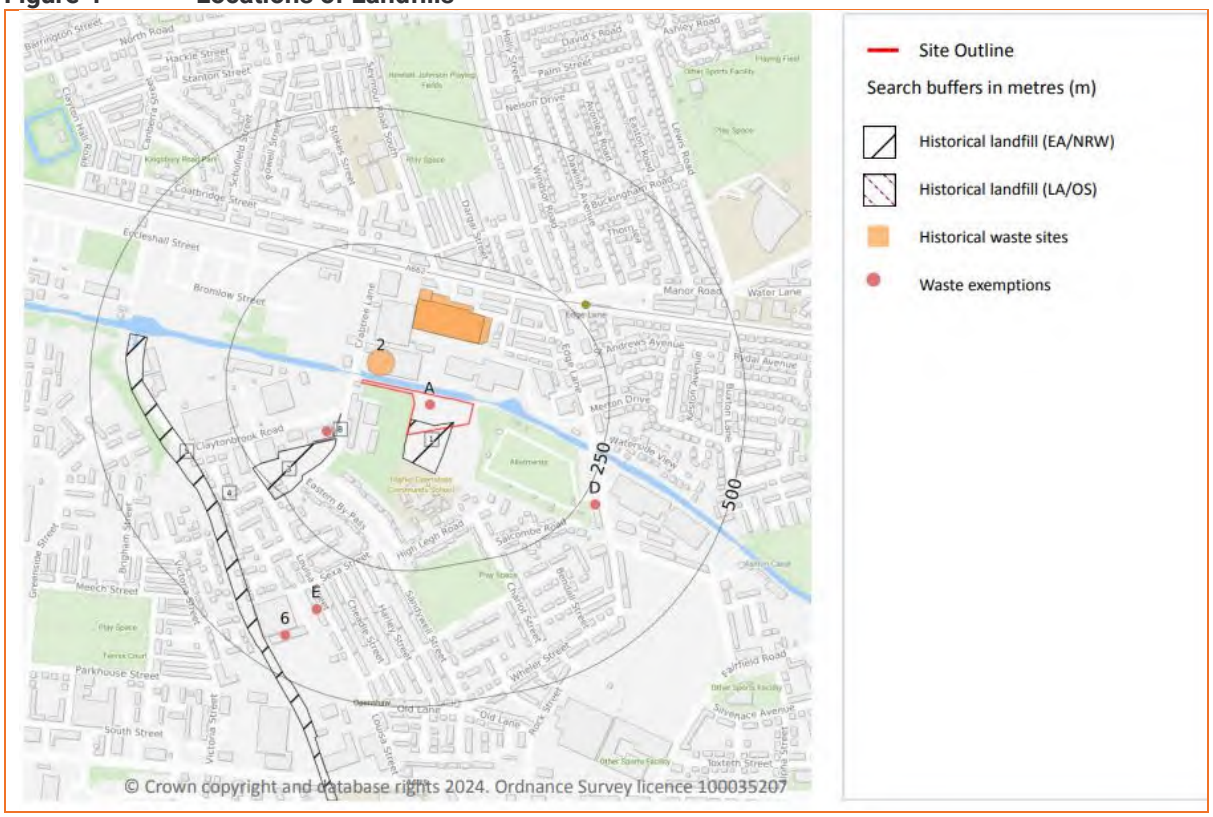
Two landfills are within a 250 m radius of the site. The details of these are presented in Table 10 below.

Table 10 Licensed Landfills

LANDFILL NAME	OPERATING DATE	ACCEPTED WASTE	DIRECTION
Crabtree Forge – Site Reference: RD/LIC/216/81 GDO F049	31/12/1942 - 31/12/1992	Inert, Industrial	South
Site Reference:F048	Unknown	Unknown	113 m West

A screenshot of the mapping showing landfill locations within 250 m radius of the site is included in Figure 4.

Figure 4 Locations of Landfills



The Crabtree Forge and Clayton Industrial Estate landfill sites are recorded as a historical landfill and pre-date the Control or Pollution Act (COPA) and current environmental permitting requirements.

4.6. WASTE MANAGEMENT LICENSES AND ENVIRONMENTAL PERMITS

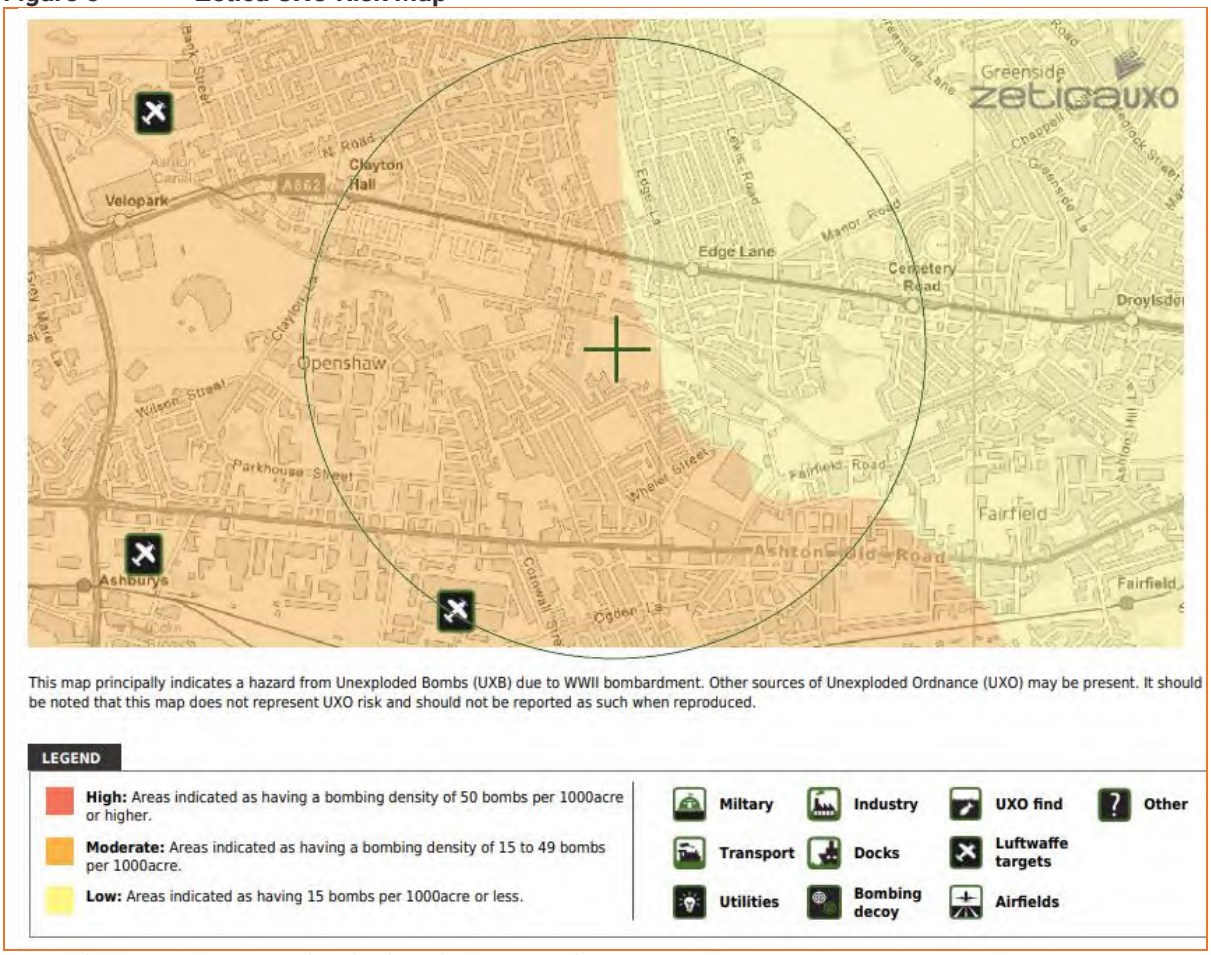
Two waste exemptions have been recorded on-site; for the use of waste in construction and for the screening and blending of waste. Supplementary to this, there are two further exemptions 112 m west of the site, for the storage of waste in a secure place and the use of waste in construction.

4.7. UNEXPLODED ORDNANCE

The regional unexploded bomb risk map from Zetica (2014) indicates that the Site is in an area at moderate risk from possible unexploded ordnance (UXO) resulting from the Second World War. The Zetica UXO Risk Map is presented in
Figure **5**.

A Detailed UXO Risk Assessment is included in APPENDIX XI.

Figure 5 Zetica UXO Risk Map



Source - https://zeticauxo.com/downloads-and-resources/risk-maps/

4.8. INDUSTRIAL LAND USES

The site is located within a predominantly industrial area, therefore several industrial land uses have been identified within a 100 m radius of the site, summarised in Table 11.

Table 11 Industrial Land Uses

INDUSTRIAL LAND USE	DISTANCE	DIRECTION	STATUS
Tank	3m	West	Inactive
Tank	6m	Northwest	Active
Travelling Crane	12m	Southwest	Active
Travelling Crane	35m	Southwest	Active
Mast	44m	West	Active
Works	76m	Northeast	Active

4.9. SITE SENSITIVITY ASSESSMENT

The site is assessed to be located within a "Moderate" sensitivity setting, as discussed in Table 12.

Table 12 Site Sensitivity Assessment

SENSITIVITY PROFILE	DISCUSSION	RATING
Groundwater Source Protection Zone or Drinking Water Safeguard Zone	The Groundsure report indicates that the Site is not located within a groundwater source protection zone.	Low
Distance to the Closest Groundwater Abstraction Point	687 m west.	Moderate
Aquifer Classification in Superficial Drift Deposits	Secondary undifferentiated.	Low
Aquifer Classification in Bedrock	Secondary B aquifer.	Low/Moderate
Is the Site Underlain by Low-Permeability Drift to Depths in Excess of 10 m?	The underlying superficial deposits are likely to comprise gravelly sands interbedded with low-permeability clay soils to depths in excess of 5 m, which may reduce the potential for mobile phase contaminants to migrate towards the bedrock aquifer or adjacent watercourses.	Low/Moderate
Is the Site Located Within 50 m of a Surface Watercourse?	The Ashton Canal is located to the north of the site. A culvert is recorded at the site but only on historical maps. Its current presence has not been established.	Moderate
Sensitive Land Uses	Higher Openshaw Community School is located 70 m to the south and allotment gardens are situated adjacent to the site.	Moderate
Sensitive Ecological Receptors	No environmental designations are recorded within a 500 m radius of the site.	Low
OVERALL SITE ENVIRONMENTAL SENSITIVITY		**Low/Moderate**

4.10. REGULATORY DATABASE

The information summarised in Table 13 has been obtained from a commercially available environmental database. The summary table only includes records from within 250 m of the subject site and is not otherwise detailed in the report.

Table 13 Summary of Environmental Data

RECORD	ENTRIES WITHIN 250 m	DETAILS
Contaminated Land Register Entries and Notices	6	All six sites identified as contaminated land was identified in either 2004 or 2005 and are all described as "contaminated land owing to the presence of arsenic, heavy metals, and polyaromatic hydrocarbons". The closest of these sites is located 116 m southwest of the site.
Authorised Industrial Processes (IPC/IPPC/LAPPC)	1	105 m north – Petrol vapour recovery Status: Historical Permit Type: B
Fuel Stations Entries	1	22 m northeast of the site.
Licensed Radioactive Substances	0	None Identified
Enforcements, Prohibitions or Prosecutions	0	None Identified
Discharge Consents	0	None Identified
Pollution Incidents	0	None Identified
Consents Issued Under the Planning (Hazardous Substances) Act 1990	0	None Identified
Control of Major Accident Hazard (COMAH) Sites	0	None Identified

4.11. REGULATORY CONSULTATIONS

E3P has contacted Manchester City Council (26/03/2024) and are currently awaiting a response from their representatives.

5. PRELIMINARY MINING ASSESSMENT

5.1. COAL MINING

The subject site is located within a Coal Authority Mining Reporting Area but is not located within a Development High Risk Zone. Furthermore, no coal seams or shafts are identified within a 1 km radius.

Based on the information reviewed and recorded underlying geology, no further coal mining risk assessment is considered necessary.

5.2. PRELIMINARY BRINE WORKINGS ASSESSMENT

The Site is not situated within the Cheshire Salt Field and no further assessment is considered necessary.

6. PRELIMINARY GEOTECHNICAL ASSESSMENT

6.1. GEOTECHNICAL DATA

Geotechnical data presented within a commercially available environmental database is summarised in Table 14.

Table 14 Summary of Geotechnical Data

HAZARD	DESIGNATION
Shrink-Swell Clay	Very low risk
Landslides	Very low risk
Ground Dissolution	Negligible Risk
Compressible Ground	Moderate Risk
Collapsible Deposits	Very low Risk
Running Sand	Very low risk

6.2. ARTIFICIAL LANDFORM AND GEOMORPHOLOGY

Based on the initial geological assessment, a review of available topographic data and pertinent mapping, E3P has undertaken a preliminary geomorphological evaluation of the landform and its possible mechanism for formation.

The site is likely to have been subject to anthropogenic change which will likely have resulted in a greater thickness of Made Ground. Upfilling and levelling works are likely to have occurred during construction and demolition to form a level plateau.

The LIDAR imagery shown in Figure 6 shows topography within the local area context.

Figure 6 Surface Lidar Data

(https://en-gb.topographic-map.com/)



6.3. GROUND CAVITIES AND SINK HOLES

Information within the Groundsure Report states the site is within an area of negligible hazard from rock solubility. When undertaking an online search for sinkholes in the area, multiple news reports identify sinkholes opening within eastern Manchester. However, every report relates the sinkhole to failed water infrastructure such as a sewer collapse and are not attributed to natural causes.

6.4. PRELIMINARY GEOTECHNICAL ASSESSMENT

Based on the desk-study information, the following geotechnical assessment has been made:

- Obstructions in previously developed areas of the site may remain in situ, particularly in the east of the site. Where below-ground obstruction and unsuitable fill require removal, the resulting voids will need to be backfilled with suitably engineered fill.
- A culvert and watercourse were historically mapped at the site.

7. INITIAL CONCEPTUAL SITE MODEL

Under EA LCRM (updated June 2023) and BSI 10175 (Code of Practice for Investigation of Potentially Contaminated Land), and BS EN ISO 21365:2021 (Soil Quality – Conceptual models for potentially contaminated sites), E3P has developed a Tier 1 risk assessment comprising an initial conceptual site model (CSM) to identify potential contamination sources, migration pathways and receptors within the study area. An initial screening of the on and potential off-site sources of contamination has been undertaken in Table 15, with the more detailed initial CSM included overleaf as Table 16.

Table 15 Initial Contaminant Source Screening

SOURCE	SOIL	GROUNDWATER	GROUND GAS
ON-SITE			
Iron Works / Unspecified Works	Heavy Metals, PAH, TPHs, Asbestos, Sulphates	Heavy Metals, TPHs,	Carbon Dioxide and Methane
Refuse Tip	Heavy Metals, PAH, TPHs, Asbestos, Sulphates	Heavy Metals, TPHs,	Carbon Dioxide and Methane
OFF-SITE			
Railway Sidings	Heavy Metals, Asbestos, TPHs, PAHs	Heavy Metals, TPHs	Carbon Dioxide and Methane
Unspecified Tanks	Heavy Metals, TPH, PAH	Heavy Metals, TPH, PAH	Carbon Dioxide, Methane and VOCs
Brick Kilns	Heavy Metals, PAH Sulphates	Heavy Metals, TPHs	-
Forge	Heavy Metals, PAH TPHs, Sulphates	Heavy Metals, TPHs	-
Chemical Works	Heavy Metals, TPH, PAH, BTEX, S/VOC, asbestos	Heavy Metals, TPH, PAH	Carbon Dioxide, Methane and VOC
Lime Pit	Heavy metal	Heavy metals	-

After reviewing all environmentally pertinent information and the potential contaminant sources, the following initial conceptual site model has been developed for the site.

Table 16 Initial Conceptual Model

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	LEVEL OF RISK	JUSTIFICATION
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
HUMAN HEALTH						
MADE GROUND, Railway Sidings, Tanks, Chemical Works, Iron Forge and Unspecified Works Heavy Metals, PAH, TPH	Accidental ingestion and/or dermal contact with contaminated soil and/or leachate. **PL1/PL2**	Human Health – construction workers	Likely	Medium	Moderate	Site personnel have a greater chance of coming into contact with potentially contaminated soils. Particularly during excavation and soil recovery works. **Recommendation:** Construction works are to be completed with appropriate PPE and welfare facilities.
		Human Health – end users	Unlikely	Medium	Moderate	The proposed development will be a residential end-use and there is potential exposure in garden and landscaped areas.
Tanks, Railway Sidings, Chemical Works, Iron Forge and Unspecified Works TPH, PAHs	Migration through permeable strata and preferential pathways.	Human Health – end users Human Health – Off-site receptors	Likely	Medium	Moderate	The desk study has identified the presence of off-site storage tanks which may be a source of TPH. Intrusive investigation and assessment will be required to determine the level of mitigation measures and/or remediation.
Made Ground, Tanks, Railway Sidings, Chemical Works, Iron Forge and Unspecified Works Asbestos (Asbestos containing materials (ACM) and loose fibres)	Inhalation (of fibres). Construction works disturbing bound material and releasing fibres. **PL3**	Human Health – construction workers, end land users, and users of adjacent sites	Likely	Medium	Moderate	Risk of inhalation of fibres during construction works. Disturbance of ACMs and dust derivatives from construction would increase risk to adjacent sites. Fibres present in garden and landscaped areas may pose a risk to end users. Intrusive investigation will be required to determine presence of ACMs and develop appropriate mitigation measures.

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	LEVEL OF RISK	JUSTIFICATION
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
Made Ground Sulphate from potential ash within the Made Ground.	Sulphate attack on concrete. **PL6**	Building concrete	Likely	Medium	Moderate	Due to the presence of Made Ground on the site, there is the potential for sulphate associated with ash deposits on-site. This may pose a risk to building concrete. Intrusive investigation will be required to assess the concrete classification.
Made Ground Organic contaminants such as hydrocarbons, solvents	Ingestion of tainted water supply. **PL7**	Human Health – End Users Water pipeline	Likely	Medium	Moderate	Impacted soil may be present at pipeline depth across the west of the site (0.75–1.35 m). Intrusive investigation is required.
Made Ground Phytotoxic contaminants	Direct contact (plant uptake). **PL8**	Flora	Likely	Medium	Moderate	Likely probability as contamination is considered possible, which may be taken up by flora in soft landscaping/gardens. Intrusive investigation is required to determine if a cover system is required.
CONTROLLED WATERS						
Groundwater	Contact with contaminated groundwater. **PL2**	Human Health – site personnel	Low likelihood	Medium	Moderate	Impacted groundwater may be encountered by construction workers during earthworks. Construction control measures can mitigate this risk.
	Contaminants leached from the Made Ground through infiltration and percolation of rainwater. **PL5**	Underlying Secondary B aquifer (solid) Ashton Canal Culvert	Likely	Medium	Moderate	The site is thought to be underlain by SAND/CLAY/GRAVEL. Therefore, the granular layers may provide a pathway to the underlying aquifer if they are penetrated by deeper foundations to the underlying secondary B aquifer. The canal is not considered to be a plausible receptor as this is likely lined with clay and not in continuity with site groundwater.

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	LEVEL OF RISK	JUSTIFICATION
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
						A culvert is recorded on historical maps. It is not known if it is still present. If it is it will likely be wihtin an brick or concrete structure and unlikely to be in continuity with groundwater.
GROUND GAS						
Ground gases (methane and carbon dioxide)	Inhalation of ground gas. **PL4** Accumulation of ground gas in confined spaces (asphyxiation or explosion)	Human Health – site personnel	Likely	Medium	Moderate	Ground gases may migrate through permeable strata to enter proposed buildings. A period of ground gas monitoring will be required to determine the gas regime for the site.
		Human Health – end users	Likely	Medium	Moderate	
		Infrastructure and services	Likely	Medium	Moderate	
Radon	Inhalation of ground gas. **PL4** Accumulation of ground gas in confined spaces (carcinogenic)	Human Health – site personnel	Unlikely	Medium	Low	Radon mapping has identified the site is within an area not at risk from radon. Radon mitigation measures will not be required.
		Human Health – end users	Unlikely	Medium	Low	

Main exposure pathways:
PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation; PL5 = Vertical / Lateral Migration; PL6 = Corrosion of concrete; PL7=Tainting of water supply; PL8 = Uptake by plants.

Level of Risk
Very Low
Low
Low/Moderate
Moderate
Moderate/High
High

8. E3P GROUND INVESTIGATION

8.1. GENERAL OVERVIEW

A ground investigation has been designed based on the findings of the desk study, with exploratory holes advanced to target specific potential contaminant sources summarised in Section 7.0. The investigation has also been used to collect geotechnical information to assist in the design and construction of the proposed development.

The majority of the fieldwork was completed 12 March 2024 with the deeper Cable Percussion boreholes completed between 12 March 2024 and 14 March 2024. The works are summarised in Table 8.1.

8.2. LIMITATIONS OF THE INVESTIGATION

There were stockpiles and skips at the site which prevented localised access toward the northern boundary.

8.3. SCOPE OF INVESTIGATION

A summary of the fieldwork completed are included in Table 17.

Table 17 Summary of Fieldwork

POTENTIAL SOURCE/RATIONALE	LOCATION HOLE	TYPE	MAXIMUM DEPTH (m BGL)	MONITORING WELLS RESPONSE ZONE (m BGL)
Ground conditions including the presence/nature of obstructions	TP101-TP114	Trial Pit	3.4	n/a
Ground conditions – groundwater quality and presence of ground gas	WS101	Window Sample Probehole	5.45	0.5-3.5
	WS102		5.45	0.5-2.0
	WS103		5.45	2.0-4.0
	WS104		5.45	1.0-4.5
	WS105		5.45	1.0-2.5
	WS106		5.45	2.0-4.0
Deep ground conditions in the area of proposed high-rise residential apartment blocks	CP101	Cable Percussion	9.74	n/a
	CP102		9.74	n/a
	CP103		9.76	n/a

The sampling locations are illustrated in Drawing 17-548-005 (APPENDIX IV). The ground conditions encountered are indicated on the logs, which are provided in APPENDIX VII.

The locations were recorded using hand-held GPS and what3words to an accuracy of 3 metres.

Return visits were made to monitor installations for groundwater level and gas concentrations. In addition, selected wells were purged and samples of groundwater recovered for chemical analysis.

8.4. IN-SITU STANDARD PENETRATION TESTING (SPT)

In-situ geotechnical testing was conducted using the standard penetration test (SPT) and, where the ground is granular, a 60° cone (SPT(C)) was used instead of the sampling tube. The results are shown in the probehole logs in APPENDIX VI, presented in Table 38 and discussed in Section 12.0.

8.5. LABORATORY ANALYSIS

Selected soil samples were submitted for a range of chemical and geotechnical analysis, summarised in Table 18.

Table 18 Summary of Laboratory Analysis

CHEMICAL ANALYSIS
Metals
pH, total sulphate, water-soluble sulphate (2:1 extract)
Sulphide
Cyanide
Phenols
Total and speciated polycyclic aromatic hydrocarbons (PAHs)
Asbestos identification and quantification
Speciated and banded total petroleum hydrocarbons (TPHs)
Total Organic Carbon (TOC)
GEOTECHNICAL ANALYSIS
Atterberg limits determinations
Moisture content
Particle Size Distribution
Undrained Shear Strength in Triaxial Compression

8.6. STORAGE, PRESERVATION AND TRANSPORT OF SAMPLES

Measures taken to ensure the quality and integrity of the collected samples, from collection to receipt of the samples by the laboratory, are summarised in Table 19.

Table 19 Sample Integrity Information

SUBJECT	CHEMICAL SAMPLING	
Storage	**Soil**	**Groundwater**
	Glass jars supplied by the laboratory were used for the collection of soil samples to be analysed for VOCs.	Glass vials supplied by the laboratory were used for the collection of samples to be analysed for VOCs. Samples to be analysed for lower volatility compounds were stored in laboratory-prepared glass jars.
Preservation	Soil and groundwater sample containers were filled to minimise headspace prior to sealing and stored at a low temperature within cool boxes with cooling aids to minimise the loss of volatile contaminants and reduce microbial activity during the collection of samples.	
Sample Integrity	**Soil**	**Groundwater**
	Dedicated disposable nitrile gloves were worn and changed between sample collections to prevent cross-contamination.	Groundwater samples were collected using dedicated plastic tubing, which was changed between monitoring well locations to prevent cross-contamination.
Transport	Samples were stored and shipped in dedicated sample boxes provided by the laboratory. Sample details were recorded on the laboratory chain of custody form enclosed with the samples prior to dispatch. Scheduling information for the samples was confirmed with the laboratory via email.	

Chemical analysis has been undertaken by an accredited laboratory with the testing results summarised and discussed in Section 10 and the testing certificates included in APPENDIX VIII.

Geotechnical samples were collected as required per location immediately after excavation, labelled and sealed to minimise moisture loss. The geotechnical samples were collected and couriered by a dedicated courier to an accredited geotechnical testing laboratory. The testing results are summarised and discussed in Section 9 and the testing certificates are included in APPENDIX IX.

9. GROUND AND GROUNDWATER CONDITIONS

9.1. SUMMARY OF GROUND CONDITIONS

The ground investigation identifies the strata set out in Table 20.

Table 20 Summary of Strata

HOLE	DEPTH TO STRATUM (m BGL)			
	HARDSTANDING	MADE GROUND	CLAY	SAND
TP101	-	0.0-1.4	1.4-2.0	-
TP102	0.0-0.2	0.2-2.1	2.1-2.6	-
TP103	0.1-0.3	0.0-0.1 0.3-2.0	2.0-2.70	-
TP104	-	0.0-0.6	-	-
TP105	-	0.0-1.3	1.3-2.7	-
TP106	0.0-0.2	0.2-0.7	0.7-2.1	-
TP107	0.0-0.6	0.6-2.2	2.2-2.9	-
TP108	0.0-0.2	0.2-2.5	2.5-3.0	-
TP109	0.2-0.3	0.0-0.2 0.3-0.8	0.8-1.2	1.2-1.7
TP110	-	0.0-2.3	2.3-3.2	-
TP111	0.0-0.2	0.2-1.7	1.7-2.2	-
TP112	0.0-0.2	02-0.4	0.4-2.2	-
TP113	0.0-0.1	01-2.2	-	-
TP114	-	0.0-3.1	3.1-3.4	-
WS101	-	0.0-0.8	0.8-1.8	1.8-5.45
WS102	0.0-0.2	0.2-2.3	2.3-4.0	4.0-5.45
WS103	-	0.0-1.0	1.0-3.8	3.8-5.45
WS104	-	0.0-4.5	-	4.5-5.45
WS105	0.0-0.2	0.2-2.5	2.5-4.6	4.6-5.45
WS106	0.0-0.2	-	0.2-2.5	2.5-5.45
CP101	0.0-0.1	0.1-1.2	1.2-2.1 7.1-8.2	2.1-7.1 8.2-9.74
CP102	0.0-1.2	1.2-2.5	2.5-3.7	3.7-9.74
CP103	-	0.0-1.8	1.8-2.7 5.5-6.0	2.7-5.5 6.0-9.76

9.2. MADE GROUND

Made Ground deposits were encountered within all but one (WS106) location to depths ranging between 0.6 m bgl (TP104) and 4.5 m bgl (WS104). The thinnest Made Ground was encountered at the eastern (average 0.98 m) and western edges (average 0.85 m) of the site with thicker Made Ground through the centre (average 1.98 m). The deepest Made Ground appears to be in the southwest of the site where a thickness of 4.5 m (WS104) and 3.1 m (TP114) were recorded. TP104 and TP113 were not able to penetrate the Made Ground due to refusal on obstructions.

Made Ground deposits are variable but in general comprise blackish-brown gravelly fine to medium sand. The gravel fragments comprise concrete, brick, asphalt, ceramic, clinker and slate. Locally, pieces of glass, rebar and electrical wiring were also encountered along with inclusions of ash. Cobbles-sized fragments comprised brick and concrete.

A Depth of Made Ground Plan is presented as Drawing 17-548-006 in APPENDIX IV.

9.3. DRIFT DEPOSITS

Drift deposits were encountered in all locations and typically comprise firm to stiff CLAY overlying fine to medium loose to medium dense SAND. Soft CLAY was encountered in TP110 below the Made Ground at 2.5 m bgl but this was recorded to become firm by 3.0 m bgl.

In the deeper cable percussion boreholes CP101 and CP103 a deeper horizon of gravelly CLAY was recorded at depths of between 7.1–8.2 m bgl and 5.5–6.0 m bgl respectively. The deeper SAND horizons were recorded to become very dense from ca. 7.0 m bgl.

9.4. SOLID GEOLOGY

Solid strata were not recorded during this phase of ground investigation and there are no BGS records within proximity of the site to determine a likely depth.

9.5. GROUNDWATER

Groundwater strikes were encountered as seepages. The depth of the seepages are shown on the exploratory hole records in APPENDIX VII and are summarised in Table 21.

Table 21 Summary of Groundwater Strikes

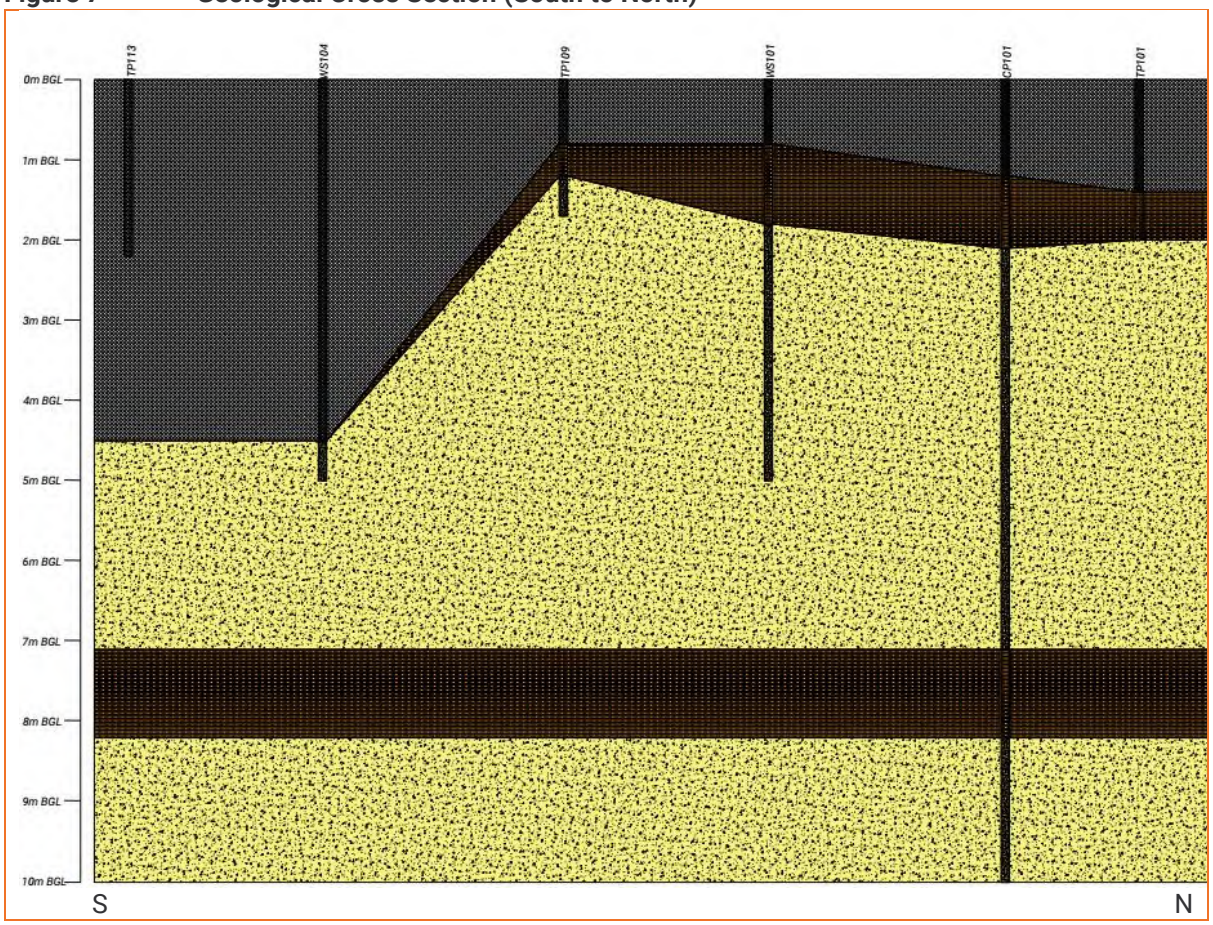
LOCATION	DEPTH TO STRIKE (m)	NOTES
WS101	3.8	Slow ingress
WS102	3.0	Slow ingress
WS104	4.0	Slow ingress
WS106	3.7	Slow ingress
CP101	6.0	Slow ingress
CP102	5.0	Slow ingress
CP103	2.7	Slow ingress
TP105	1.3	Slow ingress

Monitoring was undertaken using an electronic dip meter and interface probe to record the depth to groundwater and the thickness of any free-phase hydrocarbon product, if present. These results are summarised in Table 31.

9.6. GEOLOGICAL CROSS SECTION

A geological cross-section is included shown below in Figure 7.

Figure 7 Geological Cross Section (South to North)



9.7. VISUAL AND OLFACTORY EVIDENCE OF CONTAMINATION

Visual and olfactory evidence of potential contamination has been identified during the site investigation and these are summarised in Table 22. No free-phase hydrocarbons were observed during drilling.

Table 22 Summary of Visual and Olfactory Evidence of Contamination

LOCATION	DEPTH (m)	STRATUM	NOTES
TP101	0.0-1.4	Made Ground	Slight hydrocarbon odours
TP102	2.1	Made Ground	Slight hydrocarbon odours
TP109	0.3-0.8	Made Ground	Slight hydrocarbon odours
TP114	0.2-3.1	Made Ground	Slight hydrocarbon odours
WS104	4.0-4.5	Made Ground	Slight hydrocarbon odours

9.8. OBSTRUCTIONS

Obstructions and relict substructures were identified in several locations across the site, with their positions summarised in Table 23.

Table 23 Summary of Obstructions

LOCATION	DEPTH (m)	STRATUM	NOTES
TP103	0.4-1.8	Made Ground	Relict brick wall
TP104	0.6	Made Ground	Concrete slab
TP105	0.7-1.2	Made Ground	Relict brick wall
TP108	0.3-2.2	Made Ground	Relict brick wall
TP110	0.5-1.7 0.6	Made Ground Made Ground	Relict brick wall Concrete pipe
TP111	0.8	Made Ground	Boulder of concrete
TP114	3.1	Made Ground	Concrete

10. TIER 2 QUALITATIVE CONTAMINATED LAND RISK ASSESSMENT

E3P has undertaken a Tier 2 qualitative land risk assessment with respect to human health, controlled waters and ground gas to determine if any potential contaminants within the underlying soils and groundwater pose an unacceptable level of risk to the identified receptors.

10.1. DEVIATING SAMPLES

Best practice sampling procedures including the use of appropriate sampling containers and adhering to the laboratory holding times for each contaminant analysis, were undertaken in order to avoid samples being deviating.

10.2. SAMPLE ANALYSIS POPULATION

Table 24 summarises the chemical analysis testing scheduled.

Table 24 Summary of Testing Schedule

TYPE OF SAMPLE	NO. OF SAMPLES	DETERMINANDS
Made Ground	9	Metals, Asbestos, General inorganics, Total phenol, PAH, Ali/Aro TPH, VOC
Natural	3	Metals, Asbestos, General inorganics, Total phenol, PAH, Ali/Aro TPH, VOC
Leachate – Made Ground	3	Metals, PAH, phenol, Ali/Aro TPH, BTEX, pH, Cyanide
Groundwater	1	Metals, PAH, phenol, Ali/Aro TPH, BTEX, pH, Cyanide

10.3. HUMAN HEALTH RISK ASSESSMENT

At the Tier 2 stage, the long-term (chronic) human health toxicity of the soil has been assessed by comparing the on-site concentrations of organic and inorganic compounds with reference values published in LQM/CIEH S4UL (S4UL3267).

Where Tier 2 screening values are not provided by LQM, other screening values have been used and these are referenced in Table 25.

The Tier 2 screening values for residential with plant uptake have been utilised for this assessment due to the proposed development being a residential end-use. To remain conservative at an early stage, the screening values based on a 1% SOM have been utilised for this assessment.

The results of the comparison have been summarised in Table 25.

Table 25 Summary of Inorganic and Hydrocarbon Toxicity Assessment for a Residential End Use (with plant uptake)

DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PL	ASSESSMENT
Arsenic	mg/kg	37	12	130 190 65 49 55 62 46 52	WS102-1.5 WS103-0.3 WS104-1.5 TP102-1.5 TP103-1.0 TP108-2.2 TP111-0.8 TP114-1.5	1	Further Action
Cadmium	mg/kg	11	12	5.5	-	1	No Further Action
Chromium (VI)	mg/kg	6.0	12	<1.8	-	1	No Further Action
Lead	mg/kg	200**	12	560 660 960 220 390 370 2100 1200	WS102-1.5 WS103-0.3 WS104-1.5 TP102-1.5 TP103-1.0 TP108-2.2 TP111-0.8 TP114-1.5	1	Further Action
Mercury	mg/kg	1.2	12	0.9	-	4	No Further Action
Nickel	mg/kg	130	12	100	-	1	No Further Action
Selenium	mg/kg	250	12	<1.0	-	1	No Further Action
Copper	mg/kg	2400	12	1300	-	1	No Further Action
Zinc	mg/kg	3700	12	4800	TP114-1.5	1	Further Action
Cyanide – Total	mg/kg	791	12	16	-	1	No Further Action
Phenols – Total	mg/kg	120	12	<1.0	-	1	No Further Action
Asbestos	Fibres	NFD	12	0.033%	WS104-1.5	3	Further Action
Naphthalene	mg/kg	2.3	12	0.47	-	4	No Further Action
Acenaphthylene	mg/kg	170	12	0.41	-	2	No Further Action
Acenaphthene	mg/kg	210	12	1.6	-	1	No Further Action
Fluorene	mg/kg	170	12	1.3	-	1	No Further Action
Phenanthrene	mg/kg	95	12	14	-	2	No Further Action
Anthracene	mg/kg	2400	12	3.3	-	2	No Further Action
Fluoranthene	mg/kg	280	12	16	-	2	No Further Action
Pyrene	mg/kg	620	12	16	-	2	No Further Action
Benzo(a)Anthracene	mg/kg	7.2	12	6.6	-	2	No Further Action
Chrysene	mg/kg	15	12	7	-	2	No Further Action
Benzo(b)Fluoranthene	mg/kg	2.6	12	7	TP102-1.5	2	Further Action
Benzo(k)Fluoranthene	mg/kg	77	12	2.7	-	2	No Further Action
Benzo(a)Pyrene	mg/kg	2.2	12	2.9 6.6 5	WS104-1.5 TP102-1.5 TP111-0.8	2	Further Action
Indeno(123-cd)Pyrene	mg/kg	27	12	3.1	-	2	No Further Action
Dibenzo(a,h)Anthracene	mg/kg	0.24	12	0.42 0.86 0.69	WS104-1.5 TP102-1.5 TP111-0.8	2	Further Action
Benzo(ghi)Perylene	mg/kg	320	12	3.8	-	2	No Further Action
TPH C5-C6 (aliphatic)*	mg/kg	42	2	<1.0	-	4	No Further Action
TPH C6-C8 (aliphatic)*	mg/kg	100	2	<0.1	-	4	No Further Action
TPH C8-C10 (aliphatic)*	mg/kg	27	2	<1.0	-	4	No Further Action
TPH C10-C12 (aromatic)*	mg/kg	74	2	<2.0	-	4	No Further Action
TPH C12-C16 (aromatic)*	mg/kg	140	2	<4.0	-	4	No Further Action
TPH C16-C21 (aromatic)*	mg/kg	260	2	42	-	1	No Further Action
TPH C21-C35 (aromatic)*	mg/kg	1100	2	140	-	1	No Further Action
TPH C5-C6 (aliphatic)	mg/kg	42	10	<0.02	-	1	No Further Action

DETERMINANT	UNIT	GAC	N	MC	LOC. OF EX	PL	ASSESSMENT
TPH C6-C8 (aliphatic)	mg/kg	100	10	<0.02	-	4	No Further Action
TPH C8-C10 (aliphatic)	mg/kg	27	10	<0.05	-	4	No Further Action
TPH C10-C12 (aliphatic)	mg/kg	74	10	<1.0	-	4	No Further Action
TPH C12-C16 (aliphatic)	mg/kg	140	10	<2.0	-	4	No Further Action
TPH C16-21 (aliphatic)	mg/kg	260	10	3.3	-	1	No Further Action
TPH C21-C35 (aliphatic)	mg/kg	1100	10	200	-	1	No Further Action
TPH C5-C7 (aromatic)	mg/kg	70	10	<0.01	-	4	No Further Action
TPH C7-C8 (aromatic)	mg/kg	130	10	<0.01	-	4	No Further Action
TPH C8-C10 (aromatic)	mg/kg	34	10	<0.05	-	4	No Further Action
TPH C10-C12 (aromatic)	mg/kg	74	10	2.0	-	4	No Further Action
TPH C12-C16 (aromatic)	mg/kg	140	10	8.5	-	4	No Further Action
TPH C16-C21 (aromatic)	mg/kg	260	10	38	-	1	No Further Action
TPH C21-C35 (aromatic)	mg/kg	1100	10	270	-	1	No Further Action

Notes
PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = Vapour/Gas Inhalation

Abbreviations: GAC = general assessment criteria, N = number of samples, MC = maximum concentration; Loc of Ex = location of exceedance; PL = Contaminant Pathway; NFD = no fibres detected.

The pathway noted in the table is the primary pathway, however it may not be the only pathway of that contaminant
* The Tier 2 GAC for the hydrocarbon fraction is derived from the CIEH assessment for petroleum hydrocarbons Criteria Working Group (CWG) for both aliphatic and aromatic compounds. E3P has utilised the Tier 2 values for aliphatic compounds for the volatile and semi volatile fractions (C5-C12) and the Tier 2 values for aromatic compound for the non-volatile fractions (C12-C35). The comparison of a total (aliphatic/aromatic) compounds to an individual fraction is considered to be a conservative approach and satisfactory for the protection of human health.
**The Tier 2 GAC for lead has been taken from CL:AIRE C4SL.

Referring to Table 25, the results of this direct comparison indicate that the data exceeds the screening criteria for residential end-use for the following contaminants:

Inorganics

- Aresenic-PL1
- Lead-PL1
- Zinc-PL1
- Asbestos-PL3

Organics

- Benzo(b)Fluoranthene-PL2
- Benzo(a)Pyrene-PL2
- Dibenzo(a,h)Anthracene -PL2

10.3.1. EXPOSURE PATHWAYS

The main exposure pathways based on the Tier 2 exceedances are:

- Soil ingestion (PL1);
- Dermal contact and ingestion (PL2);
- Consumption of homegrown vegetables (PL1); and
- Fibre/dust inhalation (PL3).

10.3.2. HUMAN HEALTH RISK ASSESSMENT AND MITIGATION

Inorganic Heavy Metals

All of the identified elevated concentrations have primary exposure pathways related to dermal contact and ingestion of soils (PL2), inhalation of particulate (PL3) and consumption of homegrown vegetables (PL1). The risk to chronic human health associated with the elevated concentrations of inorganic heavy metals and non-volatile PAH compounds can be mitigated through the installation of a suitable cover system in all proposed private gardens, landscaping and public open space to remove any potential for direct exposure to impacted soils.

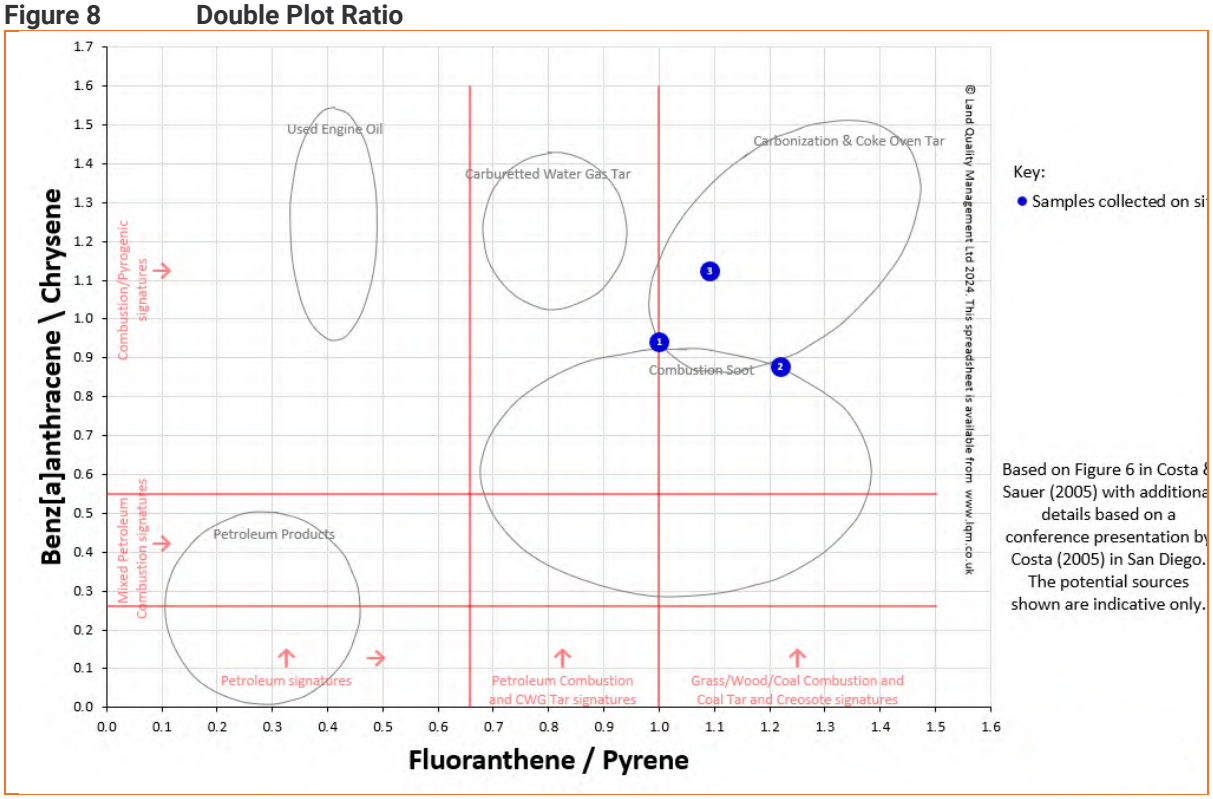
The specific design and installation process for the appropriate cover systems will be clearly defined within the site remediation and enabling works strategy.

PAH Double Plot Ratio

Based on the elevated PAHs identified within the soils, the PAH double ratio tool (based on work by Costa & Sauer 2005) has been utilised for the samples where exceedances have been recorded to enable a quick assessment of the potential source of PAH within the soil samples.

Figure 8 includes a snapshot of the double plot ratio for the PAH impacted soils in question.

Figure 8 Double Plot Ratio



The double plot ratio indicates that the recorded PAH in samples from TP102 and WS104 are a result of combustion soot with ash noted in the soil descriptions. The sample from TP111 may be a result of carbonization with the soil description noting the presence of asphalt which may be the source. It should therefore be considered that other exceedances of these PAH compounds may be recorded in locations where ash and asphalt are noted.

Asbestos

Asbestos in the form of loose chrysotile fibres has been identified in the granular Made Ground in WS104. The concentration recorded was 0.033%.

No visual signs of ACM were encountered during the ground investigation; it is, therefore, likely that only trace fibres are present. Impacted soils should be managed according to the asbestos risk mitigation conceptual site model shown in Figure 9.

Figure 9 Asbestos Risk Mitigation Conceptual Site Model



Notes
ND None Detect
0.001% Soils may contain ≤ 0.001% asbestos using composite testing to ensure there is no potential risk to human health. This value is present within areas where there may be a short term low level exposure of soils containing trace asbestos fibres by construction workers where an appropriate level of asbestos management is employed (dust suppression)
0.1% Soils at a depth of >1.00m bgl may contain <0.1% asbestos using composite testing where they will not be likely to be disturbed in the future and will therefore be in an area of low sensitivity. Risk assessment completed in accordance with Asbestos JIWG risk assessment tools.
Undefined- this will be dependent upon soils encountered during earthworks, which may be placed at these depths to ensure no potential risk to human health.

Chemical analysis of the natural clay drift deposits has identified these soils to be acceptable for use as subsoil within the proposed garden areas; however, further chemical validation samples may be required to meet regulatory sampling frequency. There are no suitable sources of topsoil available on the site.

10.4. CONTROLLED WATERS RISK ASSESSMENT

E3P has undertaken a controlled waters risk assessment for the site based on the consideration of the conceptual site model and the sensitive receptors which are summarised in Table 26.

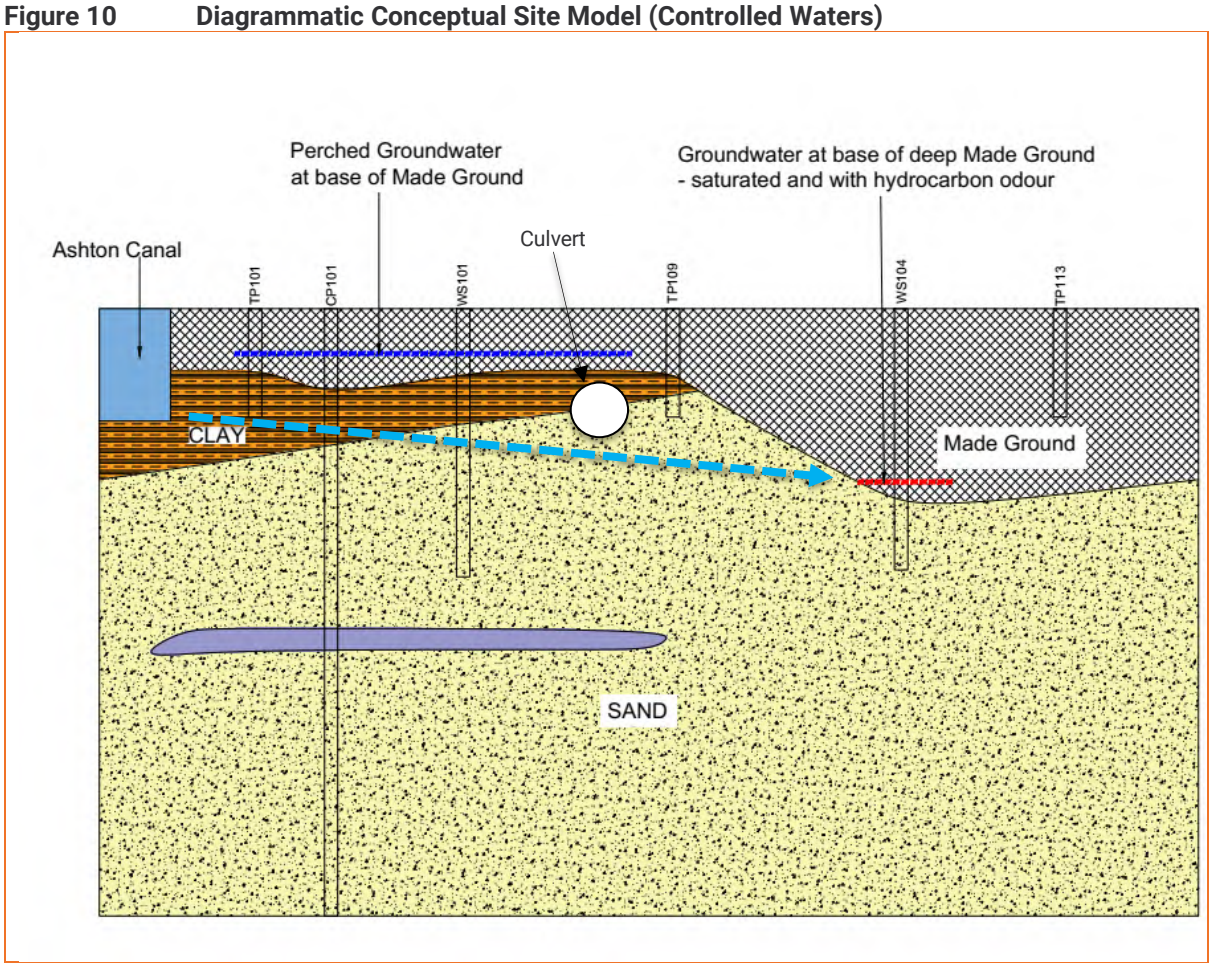
Table 26 Controlled Waters Conceptual Model and Sensitivity Profile

DISCUSSION		SENSITIVITY RATING
Contaminant Source		
The site has historically been an iron foundry and packaging works with an area of suspected landfilling encroaching onto the southern sector of the site. Made Grund deposits at the site have been recorded in all but one location with the thickest deposits being recorded in the southwest which may correspond with the area of the historical landfill. Within the Made Ground, fragments of clinker, metal and asphalt have been recorded and soil analysis has recorded elevated concentrations of arsenic, lead and PAH compounds when compared with human health screening criteria. These determinands would not typically be considered as significantly mobile. Slight hydrocarbon odours were noted within the Made Ground but no elevated concentrations of TPH or VOC were identified in the subsequent analysis.		**Medium**
Pathway		
Vertical Migration The exploration has identified that there is an upper clay horizon to the drift across the majority of the site which will afford some protection to the underlying granular drift deposits. This is however absent in the area where the Made Ground is deepest (WS104). Further deeper clay horizons have been identified in the cable percussion boreholes CP101 and CP103 but not in CP102.		**Medium**
Lateral migration Lateral migration of contaminants is considered possible due to the presence of granular drift deposits across the site.		**Medium**
Receptor		
Aquifer Classification in Superficial Drift Deposits	Undifferentiated – Glacial Till - Clay Secondary B aquifer – Fluvoglacial - Sand	**Medium**
Aquifer Classification in Bedrock	Secondary B aquifer – Manchester Marl	**Medium**
Groundwater Source Protection Zone or Drinking Water Safeguard Zone	The site is not affected.	**Low**
Distance to the Closest Groundwater Abstraction Point	687 m west – Evaporative Cooling. Aquifer is the Chester Formation	**Low**
Is the Site Located Within 50 m of a Surface Watercourse?	Ashton Canal is located at the northern boundary. However, this is not considered to be a sensitivity receptor as it is a lined artificial channel. The canal will be ca. 2.0 m deep and groundwater monitoring has confirmed that groundwater is at a greater depth in the south; below the base of the canal (3.68 m bgl – WS104). This would indicate a gradient away from the canal and provides evidence that the canal is not in continuity with groundwater.	**Medium**

DISCUSSION		SENSITIVITY RATING
	Historical maps identify a culvert on site on the earliest maps but its presence was not confirmed on-site. If present, this will likely flow through a brick or concrete duct which will afford some protection from shallow groundwater infiltration and the culvert will also be of low ecological value.	
The ICSM developed within the context of the site setting has identified viable pollutant pathways, which would be the downward migration of potentially mobile phase-soluble contaminants towards the underlying secondary B aquifer and lateral migration to the adjacent canal.		

In addition to above, E3P has developed a diagrammatic conceptual model which considers the factors in Table 26. This is included in Figure 10.

Figure 10 Diagrammatic Conceptual Site Model (Controlled Waters)



The Tier 2 assessment in line with LCRM (2023) has included a comparison of leachate analysis from samples of the Made Ground and groundwater samples to drinking water standards (DWS) and environmental quality standards (EQS).

DWS will be viewed as a priority given the pollutant linkage is considered to be vertical migration to the secondary B aquifer, however where there are no regulatory guidance values for EQS, the DWS will be utilised in their absence.

Limited groundwater was recorded during subsequent monitoring, with only one sample collected for subsequent analysis. The result is still awaited and will be reported in due course.

Leachate samples were selected on the basis that they represented typical Made Ground at the site and included potentially contaminating material such as clinker, ash and hydrocarbon odours, thereby representing a likely worst-case.

A single water sample was obtained utilising a bailer but this result is not yet available.

These are presented in Table 27.

Table 27 Comparison of Groundwater and Leachate Analysis with Tier 2 Screening Levels

DETERMINAND	UNIT	EQS [1, 2] AA	DWS [3,4]	NO. OF GW SAMPLES	MAX CONC. IN GROUNDWATER	LOCATION OF EXCEEDANCE	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
Arsenic	µg/l	50	10	1	1.1	-	3	15	DWS	Further Action
Cadmium	µg/l	0.08-0.25	5	1	<0.11	-	3	<0.08	-	No Further Action
Chromium (VI)	µg/l	3.4	–	1	<20	-	3	57	EQS	Further Action
Chromium (III)	µg/l	4.7	50	1	<0.50	-	3	60	DWS/EQS	Further Action
Copper	µg/l	1	2000	1	3.8	-	3	22	-	No Further Action
Total Cyanide	µg/l	1	50	1	<0.005	-	3	6.6	EQS	Further Action
Lead	µg/l	1.2	10	1	0.63	-	3	18	DWS/EQS	Further Action
Mercury	µg/l	–	1.0	1	<0.001	-	3	<0.5	-	No Further Action
Nickel	µg/l	4	20	1	2.9	-	3	2.6	-	No Further Action
Selenium	µg/l	–	10	1	<0.5	-	3	<4.0	-	No Further Action
Zinc	µg/l	10.9	–	1	4.5	-	3	18	EQS	Further Action
pH	6–9			1	7.3	-	3	7.8-7.9	-	No Further Action
Polycyclic Aromatic Hydrocarbon										
Naphthalene	µg/l	2	10*	1	<0.5	-	3	<0.01	-	No Further Action
Anthracene	µg/l	0.1	10*	1	<0.5	-	3	<0.01	-	No Further Action
Benzo[b]fluoranthene	µg/l	0.00017*	10*	1	<0.5	-	3	<0.01	-	No Further Action
Benzo[k]fluoranthene	µg/l	0.00017*	10*	1	<0.5	-	3	<0.01	-	No Further Action
Benzo(a)pyrene	µg/l	0.00017*	10*	1	<0.5	-	3	<0.01	-	No Further Action
Indeno(123-cd)pyrene	µg/l	0.00017*	10*	1	<0.5	-	3	<0.01	-	No Further Action
Fluoranthene	µg/l	0.0063	10*	1	<0.5	-	3	<0.01	-	No Further Action
Benzo(ghi)perylene	µg/l	1.7–4	10*	1	<0.5	-	3	<0.01	-	No Further Action
Aromatic Hydrocarbon										
TPH C5-C7 (benzene)	µg/l	10	1	1	<0.1	-	3	<1.0	-	No Further Action
TPH C7-C8 (toluene)	µg/l	74	700	1	<0.1	-	3	<1.0	-	No Further Action
TPH C8-C10 (xylene)	µg/l	30	300	1	<0.1	-	3	<1.0	-	No Further Action
TPH C10-C12 (naphthalene)	µg/l	2	90	1	<0.1	-	3	<10	-	No Further Action

DETERMINAND	UNIT	EQS [1, 2] AA	DWS [3,4]	NO. OF GW SAMPLES	MAX CONC. IN GROUNDWATER	LOCATION OF EXCEEDANCE	NO. OF LEACHATE SAMPLES	MAX CONC. IN LEACHATE	LOCATION OF EXCEEDANCE	ASSESSMENT
TPH C12-C16	µg/l	–	90	1	<0.1	-	3	<10	-	No Further Action
TPH C16-C35	µg/l	–	90	1	<0.1	-	3	<10	-	No Further Action
Aliphatic Hydrocarbon										
TPH C5-C6	µg/l	–	1000[5]	1	<0.1	-	3	<1.0	-	No Further Action
TPH C6-C8	µg/l	–	1000[5]	1	<0.1	-	3	<1.0	-	No Further Action
TPH C8-C10	µg/l	–	300	1	<0.1	-	3	<1.0	-	No Further Action
TPH C10-C12	µg/l	–	300	1	<0.1	-	3	<10	-	No Further Action
TPH C12-C16	µg/l	–	300	1	<0.1	-	3	<10	-	No Further Action
TPH C16-C21	µg/l	–	300**	1	<0.1	-	3	<10	-	No Further Action
TPH C21-C35	µg/l	–	300**	1	<0.1	-	3	<10	-	No Further Action
Volatile Organic Compounds										
Benzene	µg/l	10	1	1	<0.1	-	3	<3	-	No Further Action
Toluene	µg/l	74	700	1	<0.1	-	3	<3	-	No Further Action
Xylene	µg/l	30	300	1	<0.1	-	3	<3	-	No Further Action

Notes
 # Solubility <0.01µg/l
AA – Annual Average
** Polyaromatic hydrocarbons (PAH) - Benzo(a)pyrene (BaP), Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)-perylene and Indeno(1,2,3-cd)-pyrene. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water*
*** There are no WHO Guideline Values for aliphatic fractions C16-C21 and C21-C35, therefore the guideline value for aliphatic fractions inclusive of C8-C16 (300µg/l) has been applied.*

1. The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (legislation.gov.uk)
2. The Water Supply (Water Quality) Regulations 2018 (legislation.gov.uk)
3. Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum (who.int)
4. CL:AIRE publishes Petroleum Hydrocarbons in Groundwater guidance (claire.co.uk)
5. *A total TPH criteria of 1000 mg/kg will act as a surrogate criterion for remaining aliphatic and aromatic TPH fractions.*

10.4.1. CONTROLLED WATER RISK ASSESSMENT AND MITIGATION

This comparison indicates that the data exceeds the EQS and DWS values for the following inorganic compounds:

Table 28 Summary of Controlled Waters Risk Assessment

EXCEEDANCE OF EQS	EXCEEDANCE OF DWS
Chromium VI	Arsenic
Total Chromium (as Cr III)	Total Chromium
Total Cyanide	Lead
Lead	
Zinc	

Although widespread observations of hydrocarbon odours were noted throughout the site, both soil analysis and leachate testing have not identified significantly elevated concentrations of PAH and TPH.

In line with soil analysis, the leachate testing has also recorded elevated arsenic and lead when compared to the DWS. Elevated chromium and hexavalent chromium have also been recorded in the leachate tests.

The leachate test is aggressive (de-ionised water) and is not in aqueous equilibrium (steady state) within the solid sample. This may cause rapid dissolution and overestimation of the aqueous phase concentrations compared to groundwater in contact with contaminated soils. Although dissolution may be reduced for highly hydrophobic contaminants, such as B(a)P the initial leaching will likely remove the most readily available hydrocarbons and subsequent flushing would reduce the leachable concentrations.

10.4.2. M-BAT ASSESSMENT

Although the Ashton Canal is not considered a main receptor in view that the channel will be lined, due to exceedances in leachate samples for zinc in all three samples, an m-BAT assessment has been completed to assess the bioavailability of the metals with respect to surface water receptors (Ashton Canal). The chemical values from the groundwater analysis have been input into the assessment.

Where the Risk Characterisation Ratio (RCR) is greater than 1, this indicates the bioavailable concentration is above the EQS and the receptor is therefore at risk.

1. WS102
    - Zinc - 0.21
2. WS103
    - Zinc - 0.16
3. WS104
    - Zinc - 0.20

The m-BAT assessment has confirmed that the RCR for zinc is below 1, indicating that is it not bioaccessible and therefore unlikely to be a risk.

10.4.3. FINAL PB SCREENING TOOL

Lead was recorded in two of the leachate samples in excess of the EQS value. To further assess the potential risk, an assessment using the Pb screening tool has been completed.

The assessment confirms that the following

- WS102 – 0.75
- WS104 – 0.08

As the RCR is below 1, E3P does not consider lead to pose an unacceptable level of risk to surface waters for lead.

10.4.4. DISCUSSION OF CONTROLLED WATERS RISK ASSESSMENT

Historically, the site comprised an iron foundry, packaging works with evidence of possible landfilling the south of the site.

The site is underlain by Made Ground which in turn is underlain by a clay horizon across much of the site except for the southwest of the site (WS104). The clay and Made Ground at WS104 are underlain by sand, the full thickness of which was not proven during this phase of investigation.

Groundwater strikes were recorded as slow ingress in the window sample probeholes but monitoring wells installed to their full depth (ca. 5 m bgl) did not generate significant groundwater for subsequent sampling except for WS103 in the northeast.

Widespread arsenic, lead and PAH impact has been identified in the soil, with leachate testing indicating potentially mobile impact from arsenic, lead and zinc.

The groundwater beneath the site is likely at depth and based on the site setting is not considered a highly sensitive receptor being a secondary B aquifer and with no groundwater abstraction within the drift. A groundwater abstraction is identified ca. 650 m to the west but this is for evaporative cooling and is likely abstracting from the Chester Formation Sandstone and not the Manchester Marl which underlies the subject site.

A foundation design has not been determined but it is likely that for the majority of low-rise plots, these can found in underlying clay or re-engineered Made Ground using vibro-replacement stone columns. Either option would not generate any new preferential vertical pathways.

For the high-rise plots, it is likely that a piled foundation would be required and a pile design contamination risk assessment will be required once the type of pile has been determined. However, it is considered that penetrative piling techniques would not create significant vertical pathways is located in the north of the site where extensive Made Ground has not been identified.

Surface Water Receptor

As the m-BAT and Pb screening tools have confirmed, the surface water receptor, the Ashton Canal, is not at risk from lead and zinc. It is also considered that due to the depth of groundwater recorded in the on-site monitoring wells, the canal is not in hydraulic continuity groundwater. Sampling of the canal may assist in determining if the canal is at risk.

The historical culvert has not been identified on-site and if present is likely to be set within a brick or concrete culvert and and low ecological value. Further survey work is recommended to try and determine if this feature is still present and if so its current condition.

E3P consider the underlying granular drift aquifer as the critical receptor.

10.5. GROUND GAS RISK ASSESSMENT

10.5.1. RATIONALE

Hazardous ground gas qualitative risk assessment is based on a conceptual site model (CSM) similar to that used for soil and groundwater contamination sources (i.e., source pathway receptor pollutant linkages).

The risk can be assessed based on knowledge of the ground conditions and CSM and a measure of hazardous gas concentrations and gas flow at the site within monitoring standpipes.

10.5.2. SOURCES AND PATHWAYS OF GROUND GAS

Table 29 summarises the potential sources and pathways of ground gas within the context of the recorded site setting and proposed development.

Table 29 Identified Potential Sources of Ground Gas

SOURCE
Made Ground Made Ground deposits were encountered within all but one (WS106) location to depths ranging between 0.6 m bgl (TP104) and 4.5 m bgl (WS104). The thinnest Made Ground was encountered at the eastern (average 0.98 m) and western edges (average 0.85 m) of the site with thicker Made Ground through the centre (average 1.98 m). the deepest Made Ground appears to be in the southwest of the site where thicknesses of 4.5 m (WS104) and 3.1 m (TP114) were recorded. Made Ground deposits are variable but in general comprise blackish-brown gravelly fine to medium sand. The gravel fragments comprise concrete, brick, asphalt, ceramic, clinker and slate. Locally, pieces of glass, rebar and electrical wiring were also encountered along with inclusions of ash. Cobbles-sized fragments comprised brick and concrete.
Drift Strata Drift deposits were encountered in all locations and typically comprise firm to stiff CLAY overlying fine to medium loose to medium dense SAND. Soft CLAY was encountered in TP110 below the Made Ground at 2.5 m bgl but this was recorded to become firm by 3.0 m bgl. In the deeper cable percussion boreholes CP101 and CP103 a deeper horizon of gravelly CLAY was recorded at depths of between 7.1-8.2 m bgl and 5.5-6.0 m bgl respectively. The deeper SAND horizons were recorded to become very dense from ca. 7.0 m bgl.
Solid Strata The site is underlain by Manchester Marl and although located within a Coal Mining Reporting Area no seams or shafts have been identified within 1 km of the site and associated coal will be at a significant depth.
Landfill Sites Groundsure data indicates that there is one historical landfill that is located principally on land to the south of the subject site but which may extend into the southern sector. Exploration has identified Made Ground in this sector to 4.5 m bgl. The landfill site has no historical or current environmental permits. Records suggest that this site accepted inert industrial wastes between ca. 1942 and 1992 and pre-dated licencing requirements.
Other Gases The BGS reports that full radon protective measures are not necessary in the construction of new dwellings or extensions. Volatile organic compounds and volatile PAH and TPH compounds have not be recorded at the site..

The CIRIA C665 guidance on gas risk assessment includes recommendations for periods and frequencies for monitoring visits. These recommendations take into account the nature of the proposed development and the likely generation potential of the source.

The proposed development comprises private residential properties, which would be classified as a Type A development (high sensitivity) in accordance with BS8485:2015+A1:2019. However, it is considered that the likely generation potential of the identified gas sources (taking into account the likelihood of future increases in gas generation) would be best classified as low.

Therefore within the context of the proposed residential end-use and ground gas generation potential, the gas assessment requires six visits over three months, with at least two sets of readings at low or falling atmospheric pressure.

10.5.3. GROUND GAS RISK ASSESSMENT METHODOLOGY

The potential impact on the development from ground gases has been assessed with reference to standards and guidelines published in:

- CIRIA Report 665 – Assessing risks posed by hazardous ground gases to buildings (2007)
- BS8485:2015+A1:2019 – Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings

BS8485 provides guidance on the level of gas protection requirements based upon the characteristic situation (CS) and the proposed development based on building type.

Therefore, in accordance with BS8485, based on the measured flow rates and hazardous gas concentrations, individual hazardous gas flow rates (Q_{hg}) shall be derived for each monitoring point, from which the site characteristic hazardous gas flow rate (Q_{hgs}), and then the Characteristic Situation (CS) can be determined.

The following equation should be utilised:

$$Q_{hg} = q\left(\frac{C_{hg}}{100}\right)$$

Where:
q is the measured flow rate (in litres per hour) of combined gases from the monitoring standpipe
C_{hg} is the measured hazardous gas concentration (in percentage volume/volume).

The subsequent derived gas screening value (GSV) should be the maximum Q_{hg} (flow rate x concentration as a percentage volume) for all the monitoring events.

A 'worst case check' may be carried out using the maximum recorded flow in any hole with the maximum concentration in any hole to present the plausible worst case conditions. Adoption of the worst case Q_{hg} requires thorough justification and reference to the CSM.

The final derived GSV can then be used to characterise the site as summarised in Table 30.

Table 30 Site Characterisation by GSV (BS8485:2015)

CS	HAZARD POTENTIAL	GSV (L/HR) FOR METHANE AND CARBON DIOXIDE	ADDITIONAL FACTORS
CS1	Very Low	< 0.07	Typically <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2)
CS2	Low	< 0.70	Typical measured flow rate <70 l/h (otherwise consider an increase to CS3)
CS3	Moderate	< 3.5	N/A
CS4	Moderate to High	< 15	N/A
CS5	High	< 70	N/A
CS6	Very High	> 70	N/A

Notes

1) *The CS is equivalent to the characteristic GSV in CIRIA C665.*
2) *The worst-case ground gas regime identified on the site, either methane or carbon dioxide, at the worst-case temporal conditions that the site may be expected to encounter should be considered.*
3) *Gas Screening Value is the Borehole Gas Volume Flow Rate, in litres per hour, multiplied by the concentration in the air stream of the particular gas being considered.*
4) *The Gas Screening Value thresholds should not generally be exceeded without the completion of a detailed ground gas risk assessment taking into account site-specific conditions.*

It should be noted that in the first instance, this assessment has been carried out in accordance with BS8485:2015+A1(2019) and the thresholds given in Table 30.

10.5.4. MONITORING METHODOLOGY

Concentrations of methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) were measured using a calibrated infrared gas analyser (GFM435) with gas flow rates measured using an integrated flow meter.

Gas measurements were recorded for a minimum of 300 seconds (5 minutes) at each location, increasing to 600 seconds if elevated concentrations identified, at which point the maximum concentration of CH_4 and CO_2, together with the lowest concentration of O_2 were recorded.

The results of the ground gas monitoring are presented in Table 31.

In addition to the raw data, the results for each individual standpipe have been assessed with reference to guidance provided in BS8485:2015. Based on the initial peak measured flow rates and hazardous gas concentrations, individual hazardous gas flow rates (Q_{hg}) have been derived for each monitoring point, from which an individual Characteristic Situation (CS) can ultimately be determined.

10.5.5. SUMMARY OF MONITORING RESULTS

Table 31 presents of the ground gas and groundwater monitoring results to date.

Table 31 Summary of Ground Gas Monitoring Results

WELL	STRATA	DATE	CH_4 PEAK (%V/V)	CH_4 STEADY (%V/V)	CH_4 Q_{hg} (l/hr)	CO_2 PEAK (%V/V)	CO_2 STEADY (%V/V)	CO_2 Q_{hg} (l/hr)	O_2 (%V/V)	ATMOS (mb)	ATMOS. DYNAMIC	PEAK FLOW (l/hr)	STEADY FLOW (l/hr)	RESPONSE ZONE (m bgl)	DEPTH TO BASE (m bgl)	DEPTH TO WATER (m bgl)
WS101	Natural	26/03/2024	0.2	0.1	0.0002	4.6	4.6	0.0046	9.9	977	Falling	0.1	0.1	0.5-3.5	3.56	3.55
WS102	Made Ground	26/03/2024	0.1	0.1	0.0001	2.6	2.6	0.0026	15.4	977	Falling	0.1	0.1	0.5-2.0	2.57	2.22
WS103	Natural	26/03/2024	0.1	0.1	0.0001	0.1	0.1	0.0001	20.3	976	Falling	0.1	0.1	2.0–4.0	3.25	1.35
WS104	Made Ground	26/03/2024	0.1	0.1	0.0001	0.1	0.1	0.0001	20.3	976	Falling	0.1	0.1	1.0-4.5	4.25	3.68
WS105	Made Ground	26/03/2024	0.1	0.1	0.0001	0.9	0.9	0.0009	19.3	978	Falling	0.1	0.1	1.0-2.5	2.43	Dry
WS106	Natural	26/03/2024	0.1	0.1	0.0001	1.4	1.4	0.0014	16.2	978	Falling	0.1	0.1	2.0-4.0	3.88	3.76

Notes

CIRIA Characteristic Situation Q_{hg}

	CS1	*<0.07*	*Typical Max CO2 <5 % Typical Max CH4 <1 %*
	CS2	*<0.7*	*Flow rate not to exceed 70 l/hr otherwise consider increase to CS3*
	CS3	*<3.5*	
	CS4	*<15*	*Quantitative Risk Assessment required to evaluate scope of protective measures*

Values in BOLD exceed CS1 Thresholds

Values in BLUE denote water above level of response zone (flooded)

10.5.6. GROUNDWATER

The water level within WS103 was recorded to be above the top of the response zone (flooded) on a number of occasions, as summarised in Table 32, thus rendering some the monitoring data unreliable.

Table 32 Flooded Monitoring Well Data

WELL	VISIT 1 26/3/2024	VISIT 2	VISIT 3	VISIT 4	VISIT 5	VISIT 6
WS101	-					
WS102	-					
WS103	Y					
WS104	-					
WS105	-					
WS106	-					

10.5.7. BAROMETRIC PRESSURE

Only one visit has been completed to date and this was completed during a period of low and falling pressure.

10.5.8. GAS FLOW

Gas flow rates were recorded to be 0.1 l/hr (limit of detection of the analyser) in each of the monitoring locations.

10.5.9. GAS CONCENTRATIONS

The maximum methane value recorded within the monitoring wells was 0.1% v/v (limit of detection of the analyser).

Carbon dioxide concentrations were recorded at a concentration of 4.6 % v/v (WS101).

10.5.10. RADON RISK

The subject site is not located within an area at risk of radon gas.

10.5.11. CONCLUSION

The determined Characteristic Situation for each standpipe for is presented in Table 33. This indicates that based on the peak flow rates the monitoring visits classify as Characteristic Situation (CS)1 – Very Low Gas Risk.

Table 33 Gas Risk Profile and Location

WELL	DEPTH TO WATER (m bgl)	MAX FLOW (l/hr)	MAX CH_4 (%V/V)	MAX CH_4 Q_{hg} (l/hr)	MAX CO_2 (%V/V)	MAX CO_2 Q_{hg} (l/hr)	CHARACTERISTIC SITUATION
WS101	3.56	0.1	0.1	0.0002	4.6	0.0046	CS1
WS102	2.22	0.1	0.1	0.0001	2.6	0.0026	CS1
WS103	1.35	0.1	0.1	0.0004	0.1	0.0001	CS1
WS104	3.68	0.1	0.1	0.0001	0.1	0.0001	CS1
WS105	DRY	0.1	0.1	0.0001	0.9	0.0009	CS1
WS016	3.76	0.1	0.1	0.0001	1.4	0.0014	CS1

The full gas assessment will be reported in due course.

10.6. POTABLE WATER SUPPLY

This section provides a summary of the site investigation data with reference to the selection of potable water supply pipework. The assessment is made with reference to the UK Water Industry Research (UKWIR) publication "Guidance on the selection of Water Supply Pipes to be used in Brownfield Sites"

Table 34 Pipeline Selection PE Threshold Concentrations

CONTAMINANT GROUP	PE-THRESHOLD (mg/kg)	CONCENTRATIONS AT CURRENT PIPELINE DEPTH (mg/kg)
Total VOC	0.5	<1.0
Total BTEX And MTBE	0.1	N/A
Total SVOCs (Excluding PAH and those substances marked with an *)	2	N/A
EC5-EC10 Aliphatic and Aromatic Hydrocarbons	2	<1.0
EC10-EC16- Aliphatic and Aromatic Hydrocarbons	10	3.3
EC16-EC40 Aliphatic and Aromatic Hydrocarbons	500	510-WS104
Phenols (From SVOC Analysis)*	2	N/A
Cresols and Chlorinated Phenols (From SVOC Analysis)	2	NA
Ethers*	0.5	NA
Nitrobenzene*	0.5	NA
Ketones*	0.5	NA
Aldehydes*	0.5	NA
Amines	Fail	NA
Other Consideration		
Are there any exceedances of the PE threshold outside of the pipeline depth?	None have been recorded.	
Is free product present in soil and groundwater?	None	
Could hydrocarbon impact at greater depth than current pipeline depth be mobilised by rising groundwater levels?	Unlikely.	
Will soils impacted with above determinands likely be utilised elsewhere on site?	Unknown at this stage	

CONTAMINANT GROUP	PE-THRESHOLD (mg/kg)	CONCENTRATIONS AT CURRENT PIPELINE DEPTH (mg/kg)
Will soils be imported to site as part of any future earth works	Currently unknown.	

Notes - Pipe line depth normally between 0.75m–1.35m

Based on the assessment of current site conditions it is likely that barrier pipe will be required at the proposed development.

10.7. DEVELOPED CONCEPTUAL SITE MODEL

Following the completion of the intrusive site investigation, chemical analysis and risk assessment, the conceptual model shown in Table 35 has been prepared for the site.

Table 35 Developed Conceptual Model

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	MITIGATION DISCUSSION	RESIDUAL RISK
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
SOIL						
		HUMAN HEALTH				
Made Ground Metals (arseni, lead, PAH) –	Accidental ingestion and/or dermal contact with contaminated soil and/or leachate. **PL1/PL2** Inhalation of contaminated dust. **PL3**	Human Health – construction workers Human Health – end users	Likely	High	The CSM has identified contaminants of concern as above assessment criteria. Site personnel have a greater chance of coming into contact with contaminated soils. Particularly during excavation and soil recovery works. **Recommendation:** Construction works are to be completed with appropriate PPE and welfare facilities.	Low
		Human Health – end users	Likely	High	Impacted soils may pose a risk where present in garden and landscaped areas. **Recommendation:** Cover system to garden and landscaped areas will prevent exposure to future site users.	Low

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	MITIGATION DISCUSSION	RESIDUAL RISK
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
Made Ground Hydrocarbon	Inhalation of vapours. **PL4**	Human Health – end users Human Health – Off-site receptors	Low likelihood	Low	Hydrocarbon odours throughout the Made Ground. However, no elevated concentrations were recorded in the laboratory analysis. **Recommendation:** No further action is required	Very low
Made Ground Asbestos (Asbestos containing materials (ACM) and loose fibres)	Inhalation (of fibres). Construction works disturbing bound material and releasing fibres. **PL3**	Human Health - Site personnel, end land users, and users of adjacent sites	Likely	Medium	One soil sample has identified loose chrysotile fibres at 0.03% v/v. While this would indicate a low risk, further occurrences cannot be entirely discounted **Recommendation:** Cover system to garden and landscaped areas will prevent exposure to future site users. Construction works completed with PPE and provision of welfare.	Low
Made Ground Sulphate from potential ash within the Made Ground.	Sulphate attack on concrete. **PL6**	Building concrete	Low likelihood	Medium	Due to the presence of Made Ground on the Site, elevated sulphate cannot be discounted with a single result indicating a concrete classification of DS3/AC2. The majority of the site is DS1/AC1. **Recommendation:** Construction works to be completed with appropriate PPE and welfare facilities.	Low

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	MITIGATION DISCUSSION	RESIDUAL RISK
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
Made Ground Petrolum hydrocarbons	Ingestion of tainted water supply. **PL7**	Human Health – End Users Water pipeline	Likely	Medium	Likely probability as significant contamination identified at pipeline depth across the west of the Site (0.75–1.35 m). **Recommendation:** Barrier pipe is likely to be required following a pipeline risk assessment.	Low
Made Ground Phytotoxic contaminants	Direct contact (plant uptake). **PL8**	Flora	Likely	Medium	Likely probability as contamination considered possible, which may be taken up by flora in soft landscaping/gardens. **Recommendation:** A cover system is recommended for garden and landscaped areas.	Low
CONTROLLED WATERS						
Made Ground Metals	Leaching of metals from Made Ground and infiltration and percolation of rainwater. **PL5**	Controlled waters: Secondary B aquifer Ashton Canal	Low likelihood	Low	Elevated metals have been identified in the Made Ground and leachate analysis has indicated that concentrations in excess of DWS are possible. However, the overall sensitivity of controlled water receptors is reduced due to the absence of any groundwater abstractions and the likelihood that the canal is not in hydraulic continuity with the site.	Low

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	MITIGATION DISCUSSION	RESIDUAL RISK
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
					Recommendation: No further works are considered necessary but additional groundwater and surface water monitoring may help to confirm the current assessment.	
Groundwater	Contact with contaminated groundwater. **PL2**	Human Health – site personnel	Unlikely	Low	Groundwater is known to be below construction level and as such, is expected to not rise above ground level or the final level of the road.	Low
	Contaminants leached from the off-site sources. **PL5**	Human Health – end users	Low likelihood	Low	An off-site landfill has been identified to the south. The northern sector of the landfill may have encroached on the southern boundary of the subject site. The landfill may contain elevated concentrations of metals, hydrocarbons and ammonia etc. However, given the topographic gradient, the main body of the landfill is considered to be down-gradient and therefore unlikely to be a risk to on-site controlled waters.	Low
GROUND GAS						
Ground gases (methane and carbon dioxide)	Inhalation of ground gas. **PL4**	Human Health – site personnel	Unlikely	Low	Ground gas assessment is ongoing but initial results indicate that there is no on-site source.	Low

CONTAMINANT RISK			LIKELIHOOD	SEVERITY	MITIGATION DISCUSSION	RESIDUAL RISK
SOURCES	**MIGRATION PATHWAYS**	**RECEPTORS**				
	Accumulation of ground gas in confined spaces (asphyxiation or explosion)	Human Health – end users	Unlikely	Low	Ground gas assessment is ongoing but initial results indicate that there is no on-site source.	Low
		Infrastructure and services	Unlikely	Low	Ground gas assessment is ongoing but initial results indicate that there is no on-site source.	Low
Radon	Inhalation of ground gas. **PL4**	Human Health – site personnel/ensures	Unlikely	Low	The site is not in a radon affected area.	Very low

Main Exposure Pathways:
PL1 = soil ingestion, PL2 = dermal contact and ingestion, PL3 = dust inhalation; PL4 = vapour/gas inhalation; PL5 = vertical / lateral migration; PL6 = corrosion of concrete; PL7=tainting of water supply; PL8 = uptake by plants.

LEVEL OF RISK	
Very Low	
Low	
Low/Moderate	
Moderate	
Moderate/High	
High	

11. GEOTECHNICAL ASSESSMENT

11.1. SOIL CONSISTENCY

Undrained shear strength values were measured using both field hand shear vane tests and laboratory undrained triaxial tests. Results of the tests are presented in Table 36 and Table 37, respectively, which indicate the clay soils vary between stiff and very stiff. Strength test data is generally consistent with the field descriptions of the aforementioned soils.

Table 36 Summary of Hand Shear Vane Tests

LOCATION	DEPTH (m)	SHEAR STRENGTH (KPA)	CALCULATED ALLOWABLE BEARING CAPACITY (KN/M^2)
TP101	1.5	78	Firm to stiff
TP101	2.0	81	Firm to stiff
TP102	2.1	57	Firm
TP102	2.6	59	Firm
TP103	2.5	110	Stiff
TP105	1.5	51	Firm
TP105	2.0	122	Stiff
TP105	2.5	90	Firm to stiff
TP106	1.0	124	Stiff
TP106	1.5	149	Stiff
TP107	2.2	49	Firm
TP107	2.7	46	Firm
TP108	2.7	106	Stiff
TP109	0.9	117	Stiff
TP109	1.1	84	Firm to stiff
TP110	2.5	36	Soft to firm
TP110	3.0	72	Firm
TP111	1.2	144	Stiff
TP111	1.8	142	Stiff
TP112	0.5	171	Very stiff
TP112	1.0	139	Stiff
TP112	2.0	124	Stiff
TP114	3.2	65	Firm

Notes: ABC Calculated using Stroud and Butler et al 1974.
** granular content within soil tests may underestimate true shear strength.*

Results of the standard penetration tests, including undrained shear strengths derived from SPTs are included in Table 38.

Table 37 Summary of Undrained Shear Strength in Triaxial Compression – Laboratory Test

LOCATION	SAMPLE DEPTH (m)	LAB DESCRIPTION	UNDRAINED SHEAR STRENGTH (kN/m^2)	CONSISTENCY
WS106	0.5–1.0	Firm brown, slightly gravelly, very sandy CLAY	52	Firm

11.2. SIDE STABILITY AND EASE OF EXCAVATION

The sides of the exploratory trial pit excavations appeared to be generally stable during excavation. Locally, the Made Ground was observed to collapse during excavation at TP108 (0.8 m) and TP113 (0.8 m)

The presence of brick and concrete cobbles in addition to relict structures within the Made Ground deposits meant that in certain places, excavation was slow through the Made Ground. The natural strata were excavated with relative ease.

Table 38 Standard/Cone Penetration Test Results

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m²)	ALLOWABLE BEARING CAPACITY (kN/m²)*
WS101	1	Brown slightly gravelly CLAY.	10	10.08	N/A	Medium strength	Stiff	50.41	103.64
WS101	2	Brown slightly gravelly fine to medium SAND.	31	28.32	Medium Dense	N/A	N/A	N/A	283.20
WS101	3	Brown slightly gravelly fine to medium SAND.	16	13.91	Medium Dense	N/A	N/A	N/A	139.14
WS101	4	Brown fine to medium SAND.	30	25.35	Medium Dense	N/A	N/A	N/A	253.46
WS101	5	Brown fine to medium SAND.	11	9.13	Loose	N/A	N/A	N/A	91.26
WS102	1	MADE GROUND:	8	8.07	Loose	N/A	N/A	N/A	80.65
WS102	2	MADE GROUND:	22	20.10	Medium Dense	N/A	N/A	N/A	200.98
WS102	3	Grey slightly sandy CLAY.	20	17.39	N/A	High strength	Very Stiff	86.97	178.80
WS102	4	Brown slightly gravelly fine to medium SAND.	35	29.57	Medium Dense	N/A	N/A	N/A	295.70
WS102	5	Brown slightly gravelly fine to medium SAND.	34	28.21	Medium Dense	N/A	N/A	N/A	282.07
WS103	1	Grey slightly sandy CLAY.	9	9.07	N/A	Medium strength	Stiff	45.37	93.27

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m²)	ALLOWABLE BEARING CAPACITY (kN/m²)*
WS103	2	Brown slightly sandy slightly gravelly CLAY.	12	10.96	N/A	Medium strength	Stiff	54.81	112.69
WS103	3	Brown slightly sandy slightly gravelly CLAY.	30	26.09	N/A	High strength	Very Stiff	130.45	268.20
WS103	4	Brown fine to medium SAND.	16	13.52	Medium Dense	N/A	N/A	N/A	135.18
WS103	5	Brown fine to medium SAND.	16	13.27	Medium Dense	N/A	N/A	N/A	132.74
WS104	1	MADE GROUND:	6	6.05	Loose	N/A	N/A	N/A	60.49
WS104	2	MADE GROUND:	4	3.65	Very Loose	N/A	N/A	N/A	36.54
WS104	3	MADE GROUND:	8	6.96	Loose	N/A	N/A	N/A	69.57
WS104	4	MADE GROUND: Black fine to medium sand. (Saturated).	4	3.38	Very Loose	N/A	N/A	N/A	33.79
WS104	5	Brown fine to medium SAND.	10	8.30	Loose	N/A	N/A	N/A	82.96
WS105	1	MADE GROUND:	6	6.05	Loose	N/A	N/A	N/A	60.49
WS105	2	MADE GROUND:	5	4.57	Loose	N/A	N/A	N/A	45.68
WS105	3	Grey slightly gravelly slightly sandy CLAY.	12	10.44	N/A	Medium strength	Stiff	52.18	107.28
WS105	4	Grey slightly gravelly slightly sandy CLAY.	16	13.52	N/A	Medium strength	Stiff	67.59	138.96

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING CAPACITY (kN/m^2)*
WS105	5	Greyish brown slightly clayey fine to medium SAND.	19	15.76	Medium Dense	N/A	N/A	N/A	157.63
WS106	1	Grey slightly gravelly slightly sandy CLAY.	13	13.11	N/A	Medium strength	Stiff	65.53	134.73
WS106	2	Grey slightly gravelly slightly sandy CLAY.	35	31.97	N/A	Very high strength	Very Stiff	159.87	328.69
WS106	3	Brown fine to medium SAND.	26	22.61	Medium Dense	N/A	N/A	N/A	226.11
WS106	4	Brown fine to medium SAND.	23	19.43	Medium Dense	N/A	N/A	N/A	194.32
WS106	5	Brown clayey fine SAND.	18	14.93	Medium Dense	N/A	N/A	N/A	149.33
CP101	1	MADE GROUND:	5	5.04	Loose	N/A	N/A	N/A	50.41
CP101	2	Soft brown slightly sandy CLAY.	11	10.05	N/A	Medium strength	Stiff	50.24	103.30
CP101	3	Medium dense brown fine to medium SAND.	17	14.78	Medium Dense	N/A	N/A	N/A	147.84
CP101	4	Medium dense brown fine to medium SAND.	21	17.74	Medium Dense	N/A	N/A	N/A	177.42
CP101	5	Medium dense brown fine to medium SAND.	22	18.25	Medium Dense	N/A	N/A	N/A	182.52

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING CAPACITY (kN/m^2)*
CP101	6.5	Medium dense brown fine to medium SAND.	21	17.14	Medium Dense	N/A	N/A	N/A	171.44
CP101	8	Brown slightly gravelly CLAY.	50	40.47	N/A	Very high strength	Very Stiff	202.37	416.07
CP101	9.5	Dense brown gravelly fine to medium SAND.	50	40.30	Dense	N/A	N/A	N/A	402.97
CP102	1	MADE GROUND: Concrete.	50	50.41	Very Dense	N/A	N/A	N/A	504.07
CP102	2	MADE GROUND:	6	5.48	Loose	N/A	N/A	N/A	54.81
CP102	3	Stiff grey slightly sandy CLAY.	13	11.31	N/A	Medium strength	Stiff	56.53	116.22
CP102	4	Dense brown gravelly fine to medium SAND.	30	25.35	Medium Dense	N/A	N/A	N/A	253.46
CP102	5	Medium dense brown fine to medium SAND.	26	21.57	Medium Dense	N/A	N/A	N/A	215.70
CP102	6.5	Medium dense brown fine to medium SAND.	30	24.49	Medium Dense	N/A	N/A	N/A	244.92
CP102	8	Dense brown fine to medium SAND.	50	40.47	Dense	N/A	N/A	N/A	404.73
CP102	9.5	Dense brown fine to medium SAND.	50	40.30	Dense	N/A	N/A	N/A	402.97
CP103	1	MADE GROUND:	50	50.41	Very Dense	N/A	N/A	N/A	504.07

BOREHOLES	DEPTH (m bgl)	MATERIAL FIELD DESCRIPTION	CPT/SPT "N" VALUE	CORRECTED "N" VALUE $(N_1)_{60}$	TERZAGHI & PECK RELATIVE DENSITY (SANDS)	EUROCODE SOIL STRENGTH	CONSISTENCY (BS 5930)	TERZAGHI & PECK APPROXIMATE UNDRAINED SHEAR STRENGTH (kN/m^2)	ALLOWABLE BEARING CAPACITY (kN/m^2)*
CP103	2	Brown slightly sandy CLAY.	14	12.79	N/A	Medium strength	Stiff	63.95	131.48
CP103	3	Medium dense brown fine to medium SAND with interbedded gravel.	25	21.74	Medium Dense	N/A	N/A	N/A	217.41
CP103	4	Medium dense brown gravelly fine to medium SAND.	25	21.12	Medium Dense	N/A	N/A	N/A	211.21
CP103	5	Medium dense brown gravelly fine to medium SAND.	27	22.40	Medium Dense	N/A	N/A	N/A	224.00
CP103	6.5	Dense brown fine to medium SAND.	50	40.82	Dense	N/A	N/A	N/A	408.19
CP103	8	Dense brown fine to medium SAND.	50	40.47	Dense	N/A	N/A	N/A	404.73
CP103	9.5	Dense brown fine to medium SAND.	50	40.30	Dense	N/A	N/A	N/A	402.97

NOTES
* The Allowable Bearing Capacity (ABC) should be considered indicative.
The interpretation of in situ mass undrained shear strength (cu) data from SPT Blow Count (N) results and the influence of the Plasticity Index (PI) was reported in Standard Penetration Test in Insensitive Clays and Soft Rocks. Stroud (1974). The standard penetration test and the engineering properties of glacial materials subsequently. Stroud and Butler (1975) and (1989).
Allowable bearing capacity on sands. Soil Mechanics in Engineering Practice Terzaghi, K. & Peck, R.B. 1996.

11.3. PARTICLE SIZE DISTRIBUTION

Particle Size Distribution Tests have been undertaken on selected samples of granular material via wet sieve to obtain information on the soil fractions. The results are included in Table 39. The full results can be found in APPENDIX IX.

Table 39 Summary of Particle Size Distribution Test Results

LOCATION	DEPTH (m)	SOIL FRACTION (%)			
		COBBLES	GRAVEL	SAND	SILT/CLAY
CP101	2.00 (Natural)	0	15	71	14

11.4. SOIL PLASTICITY

The Atterberg limits determinations, summarised in Table 40, show the clay to be of predominantly low plasticity with discrete areas of moderate plasticity clay.

Table 40 Summary of Plasticity Index Test Results

LOCATION	DEPTH (m)	NATURAL MOISTURE CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	PASSING 425 MM SIEVE (%)	MODIFIED PLASTICITY INDEX	NHBC VOLUME CHANGE POTENTIAL
WS101	1.0	20	18	35	17	98	Low	16.6
WS103	2.0	23	23	51	28	100	Medium	28
WS106	1.0	18	20	42	22	100	Medium	22
CP102	2.0	31	23	48	25	67	Low	18.7
CP103	2.0	18	19	37	18	96	Low	17.2

The results of the Atterberg limits testing confirmed that the soils would be deemed to be “Low and Medium Change Potential” in accordance with the classification system utilised by the LABC/NHBC industry guidance.

11.5. PH AND SULPHATE

Chemical analyses for pH and soluble sulphate content contained in APPENDIX VIII (summarised in Table 41), shows that the soils at the site generally meet Class DS-1, Aggressive Chemical Environment for Concrete Classification (ACEC) AC-1s in accordance with BRE *Special Digest 1* (2005).

A single location (TP103) has recorded DS3/AC2 conditions.

Table 41 Summary of pH and Sulphate Data

LOCATION	DEPTH (m)	SO_4 IN 2:1 WATER/SOIL (g/l)	PH VALUE	CLASSIFICATION
WS101	1.2	0.0616	8	DS1/AC1s
WS102	1.5	0.0728	8	DS1/AC1s
WS103	0.3	0.0607	7.6	DS1/AC1s
WS104	1.5	0.366	8.4	DS1/AC1s

LOCATION	DEPTH (m)	SO_4 IN 2:1 WATER/SOIL (g/l)	PH VALUE	CLASSIFICATION
WS105	2.8	0.0455	7.3	DS1/AC1s
TP101	0.2	0.0805	6.8	DS1/AC1s
TP102	1.5	0.255	7.2	DS1/AC1s
TP103	1.0	1.81	7.5	DS3/AC2s
TP108	2.2	0.116	7.4	DS1/AC1s
TP111	0.8	0.199	7.9	DS1/AC1s
TP112	1.2	0.0783	7.9	DS1/AC1s
TP114	1.5	0.217	7.6	DS1/AC1s

11.5.1. HIGHWAYS AND CONCRETE

MCHW Series 600 provides a criterion of 1500 mg/l for water-soluble sulfate within 500 mm of any concrete structure. A second criterion of 300 mg/l is given with respect to soils within 500 mm of steel structures.

11.6. GROUNDWATER

Perched water strikes have been located on-site during the investigation, these were typically associated with Made Ground overlying natural strata. Shallow groundwater may have resulted in reduced density of the SAND in WS101 and WS104.

11.6.1. INFLUENCING FUNCTIONAL WATERBODIES

Monitoring of groundwater is being completed as part of the ground gas assessment but not enough visits have been completed to date to determine any trends. It should be noted that seasonal variation is likely to result in potentially significant changes in groundwater levels beneath the site.

The water table can have significant effects on the foundation of a building, including:

- **Soil settlement**: Changes in the water table can cause soil to expand or contract, which can result in foundation settlement or movement. This can lead to cracks in the foundation, walls, or floors of a building.
- **Soil erosion**: High water tables can cause soil erosion, which can lead to the loss of soil support beneath the foundation. This can result in foundation settling or movement, which can be dangerous for the stability of the structure.
- **Hydrostatic pressure**: When the water table rises, the water exerts hydrostatic pressure on the foundation. This can cause foundation walls to crack or bow, which can compromise the structural integrity of the building.
- **Moisture infiltration**: High water tables can result in moisture infiltration into the foundation and surrounding soil. This can lead to mould growth, decay, and deterioration of building materials.
- **Drainage problems**: Poor drainage around a building can cause water to pool around the foundation, increasing the likelihood of soil erosion and hydrostatic pressure. This can lead to foundation settling or movement, and can also cause flooding in the basement or crawl space.

It is important to consider the effects of the water table on the foundation when designing and constructing a building. Proper drainage and foundation waterproofing can help to mitigate the effects of the water table on the foundation and improve the longevity and stability of the structure.

11.7. SITE PREPARATION

Our assessment has been based on the fact that the site will be cleared and any vegetation below areas of proposed development stripped in accordance with Series 200 of the *Manual of Contract Documents for Highway Works (MCHW).* This should include the following:

- Roots present below the footprint of proposed structures and infrastructure should be grubbed out and the resulting void infilled with suitable compacted engineered fill.
- Demolition of all existing buildings and removal of all concrete hardstanding.
- Redundant services should be sealed off and grubbed out and replaced with suitable compacted engineered fill.
- Buried structures and old foundations have been encountered on site. These should be excavated from below the proposed development footprint with the resulting void backfilled.

11.8. FOUNDATION CONDITIONS AND ASSESSMENT OF POTENTIAL BEARING CAPACITIES

In due consideration of the identified ground conditions, in-situ and laboratory geotechnical testing, E3P has assessed the safe allowable bearing capacity (ABC) within the underlying natural stratum to assist in the detailed design of foundations and infrastructure and determine the target founding stratum. The results of this assessment are summarised in Table 42.

Table 42 Summary of ABC

GRANULAR SOILS			
Description	**Depth (Range m bgl)**	**Relative Density**	**Allowable Bearing Capacity (kN/m^2)**
Gravelly SAND	2.0–3.0	Medium Dense	139–401
Gravelly SAND	4.0–5.0	Loose–Medium Dense	82–295
Fine to medium SAND	5.0–6.5	Medium Dense	171-401
Fine to medium SAND	8.0–9.5	Dense	401
COHESIVE SOILS			
Description	**Depth (range m bgl)**	**Undrained Shear Strength (Cu) (kN/m^2)**	**Allowable Bearing Capacity (kN/m^2)**
Firm to Stiff, sandy CLAY	1.00–2.00	36-86	93–178
Firm to stiff, sandy CLAY	2.00–3.00	54–130	112–268
Gravel Clay (CP101)	8.0	202	416

Reviewing the SPT derived from the Window Sample Probeholes should be taken with care as some of the higher values may be the result of gravel resulting in high penetration values.

Across much of the site, the natural strata comprise CLAY overlying SAND. The CLAY has been shown to have an ABC ranging from 93-178 kN/m^2 at between 1.0 m and 2.0 m bgl and 112-268 kN/m^2 between 2.0 m and 3.0 m bgl. Soft CLAY was identified in TP110 with an ABC of 36 kN/m^2.

The underlying SAND can be described as medium dense increasing to very dense from depths ca. 8.0 m bgl level with ABCs ranging from 139 to 238 kN/m^2 between 2.0 and 3.0 m bgl.

At greater depths of between 4.0 m and 5.0 m bgl two locations recorded loose SAND at ca. 5.0 m bgl. This may be due to perched groundwater. However, as noted above, in the deeper cable percussion boreholes the SAND becomes increasingly dense to refusal at ca 8.0 m bgl with SPTs greater than 50 for between 245 mm and 265 mm. This would indicate an ABC of greater than 400 kN/m^2.

11.9. FOUNDATIONS OPTIONS APPRAISAL

Based on the assessment of the relative undrained shear strength, relative in-situ densities and corresponding safe allowable bearing capacity, the following recommendations have been developed for the site of the potential foundation solutions that may be adopted for future residential development. The suitable target founding stratum has been identified as the underlying firm to very stiff CLAY or underlying medium dense to dense sands.

At this time it is not possible to accurately define the foundation types due to the absence of a detailed tree survey and final development levels; however, based on our extensive experience with similar sites, we would anticipate that the final foundation solution would be a combination of the following:

- Shallow strip foundations bearing on firm to stiff gravelly CLAY from circa 1 m bgl; and
- Trench fill to support reinforced strip foundations in areas of variable ground and/or potential tree influence.
- Vibro Replacement Stone Columns (subject to re-engineering of the Made Ground)
- Piled foundation set within the dense SAND for structures in proximity to sensitive structures or infrastructure.

Given the requirements for a large-scale phase of enabling works it is highly likely that the most suitable foundation solutions for the proposed structures will be Vibro Replacement Stone Columns to support a suitably reinforced spread footing. Consideration must be given to the adjacent canal features and adjacent structures. Should an active culvert be present beneath the site piles may be required to transfer the load below the feature and prevent unacceptable structural loading.

To determine if VRSC is viable at the subject site, E3P has completed a Ground Improvement Design Risk Matrix that is summarised in Table 43.

Table 43 Ground Improvement Design Risk Matrix

RISK ITEM	COMMENT	PASS/FAIL
Soft clays with an undrained shear strength of less than 30 kN/m^2	CLAY soils have been shown to have shear strength in excess of 30 kN/m^2	PASS
Ground with peat layers close to foundation level or the base of the stone column, or where intermediate layers of peat are thicker than 200 mm, either as a single layer or the sum of the thicknesses of individual layers throughout the length of the stone column	No peat or organic layers have been recorded.	PASS
Voided filled ground, e.g. old water tanks, pottery, glass bottles, concrete rubble or brick fill of unsuitable grading	Made Ground beneath the site will require removal and processing to render the site suitable for VSC. Oversize material and relict sub-structures will require processing	PASS – on completion of enabling works

RISK ITEM	COMMENT	PASS/FAIL
	into a graded aggregate suitable for vibro treatment.	
Loose or non-engineered fill not previously subject to rising or fluctuating water levels saturation	None identified.	PASS
Filled ground still settling or expected to settle under its own weight or due to the effects of surcharging/upfilling where there is a high organic content or where decay is continuing	None identified – the site was historically filled circa 70 years ago. It is considered that the material has consolidated under self-weight settlement.	PASS
Fill, containing degradable material where organic material forms more than 15% of fill by volume	None identified.	PASS
Clays with a plasticity index greater than 40%	None identified.	PASS
Highly sensitive soils liable to collapse or remoulding	None identified.	PASS
Cohesive soils with trees in influencing distance	Plots where tree influence has been modelled and will either be subject to a piled or mass trench-fill solution.	PASS
Overall Risk Rating and Suitability for Vibratory Ground Improvement		**PASS**

It is advisable to consult with geotechnical engineers and foundation specialists who can assess the specific ground conditions and design an appropriate Vibro Stone Column system to meet the project's requirements. They will consider factors such as soil composition, depth, and spacing of the stone columns to ensure effective ground improvement and proper load distribution for the strip foundation.

Foundation depths should take account of the presence of existing and proposed trees, with foundations deepened locally to mitigate the potential for volumetric instability attributed to fluctuations in moisture content, in accordance with the requirements of NHBC standards.

It is recommended that at the working drawing stage a foundation schedule is prepared for the development, taking account of the physical change of natural clay soils and the current/proposed locations of trees.

11.10. GROUND FLOOR SLABS

Current building control regulations require that where infilled ground is present to depths in excess of 600 mm, or where the substratum is variable in terms of the structure and settlement potential, or where clay soils are present within the influence of existing or proposed trees, a suspended floor slab is required.

In this instance, it is considered that for the majority of substructures, the underlying stratum would have in excess of 600 mm of infill and, as such, a suspended floor slab will be required.

Where a cast in-situ suspended slab is utilised with no subfloor void, appropriate compressible material (heave precautions) will be required in the construction of the substructure.

In clay soils, if the foundation depth is greater than 1.5 m, allowance should be made in the design for heave. This must incorporate either a clear void of a specified minimum depth under the suspended floor, or a proprietary compressible material/void former below the underside of the floor construction.

Ground-bearing slabs should not be used in ground conditions where heave can occur or where the foundation depth is greater than 1.5 m. Under these circumstances, a suspended floor construction should be used.

11.11. SETTLEMENT

The site has been appraised through desk-based information and site investigation data in order to inform geotechnical risk where possible. Table 44 below has been formulated to determine if settlement risks are required to be further appraised. Where any item is determined to be appraised a settlement appraisal for the site should be prepared upon receipt of development levels and layout.

Table 44 Summary of Geotechnical Information for Settlement

RISK	COMMENT	ASSESSMENT
The site is located in an area deemed to be at Risk from Ground Dissolution from desk based information	The site is in a low risk area of ground dissolution based on BGS data searches.	No further assessment
The site is in an area where geology is reported as having a compressible risk from desk based information	Peat deposits and soft alluvium have not been identified	No further assessment
Do historical maps indicate excavation features such as opencast or ponds that have been infilled?	A landfill is located to the south of the site which encroached into the south of the site. Filling commenced in circa 1945.	Likely that plots in this sector will require an engineered foundation solution.
Has the site been proven to be underlain by anthropogenic materials to an unknown specification?	Yes filled ground to a maximum proven depth of 4.5 m bgl (WS104)	Likely that plots in this sector will require an engineered foundation solution.
Have Oedometers and/or ground conditions reported compressible stratum on site?	Not undertaken as part of this phase of works.	-
Have high walls been identified on site that could result in differential settlement?	None identified.	No further assessment
Has any evidence been observed on site indicating settlement (non structural assessment)	None identified.	No further assessment
Is voided ground present beneath the site?	None identified.	No further assessment
Is the site in an area where a mobile groundwater regime is present in influencing distance of foundations and infrastructure?	None identified.	No further assessment
Will the site be subject to changes in site levels that may induce heave or settlement?	Not determined as part of this phase of works. However significant cut/fill earthworks are not considered likely.	No further assessment

11.12. HEAVE PRECAUTIONS

The site has been proven to be underlain by clay soils which are susceptible to volumetric instability due to fluctuations in moisture content, particularly within influencing distance of trees as per the NHBC/LABC conjectures zones of influence.

The clay has been determined as being of low to medium volume change potential. Table 45 shows where heave precautions are required for a trench fill, pier and beam and pile and beam foundation types which are in the zone of influence of trees which are to remain or be removed.

Table 45 Position of Heave Precautions

SITUATION	TRENCH FILL	PIER AND BEAM	PILE AND BEAM
External trench fill and pier foundations. Unless NHBC is satisfied that the soil is not desiccated compressible material should be provided to the:	Inside faces of external wall foundations deeper than 1.5 m, based on the appropriate tree height.	All faces of pier foundations deeper than 1.5 m, based on the appropriate tree height.	N/A
External ground beams. Unless NHBC is satisfied that the soil is not desiccated, compressible material or void formers should be provided to the:	N/A	Inside faces	Inside faces
Internal trench fill foundations and ground beams. Compressible material required:	No	No	No
External and internal ground beams. Compressible material, void former or void should be provided to the underside of:	N/A	All	All
Heave precautions required for proposed trees where the soil is not desiccated:	No	No	No

Note: Information taken from NHBC Standards 2024, Chapter 4.2, Table 8 – Position of heave precautions

A summary of heave precautions is presented in Table 46.

Table 46 Summary of Heave Precautions

VOLUME CHANGE POTENTIAL	VOID DIMENSION AGAINST SIDE OF FOUNDATION AND GROUND BEAM	VOID DIMENSION UNDER GROUND BEAMS, AND SUSPENDED IN-SITU CONCRETE GROUND FLOOR	VOID DIMENSION UNDER SUSPENDED PRECAST CONCRETE AND TIMBER FLOORS(1)
High	35mm	150mm	300mm
Medium	25mm	100mm	250mm
Low	0mm	50mm	200mm

In addition to the requirements of the 'Drainage' section, drainage near trees should incorporate additional provisions. Where there is a volume change potential within the ground, the provisions include:

- Increased falls to cater for any ground movement.
- Deeper and wider backfill of granular material.

- A drainage system that is capable of movement should heave and shrinkage occur.
- Drainage pipes should not be encased in concrete.
- Additional clearance is required where drains pass through the structure of a building to allow for additional movement.

11.13. HIGHWAYS CONSTRUCTION

A programme of remediation and enabling works will be required to remediate the proposed road subgrade in accordance with the requirements of the Manual of Contract Documents for Highway Works Volume 1 Specification For Highway Works (Series 600-Earthworks) for a method compaction.

11.14. DRAINAGE

Where loose or soft materials have been identified at drainage invert levels, there will need to be a consideration for the use of reinforced pipe bedding.

Shrinkage and heave of clay soils can affect pipelines. To protect against the effects of heave, drainage should be designed:

- To take account of potential ground movement as shown in Table 47, including where pipes and services pass through substructure walls or foundations.
- With gradients which may need to be steeper.
- To use alternative means of catering for the movement when sufficient falls cannot be provided, for example, by deepening the excavation and laying pipework on a granular bedding of suitable thickness to reduce the extent of potential movement.

Table 47 Potential Ground Movement for Drainage

VOLUME CHANGE POTENTIAL	HIGH	MEDIUM	LOW
Potential ground movement	150 mm	100 mm	50 mm

11.15. EXCAVATIONS

Trial pits were generally stable in both granular Made Ground and natural strata; as such, it is considered that near-surface excavations will be feasible. In areas where Made Ground exceeded 2 m, excavations were generally less stable.

Site observations indicated that excavations should be feasible in the near-surface with normal plant; however, obstructions were identified in the near-surface, including former foundations and former floor slabs. It is anticipated that any obstructions will be grubbed out during the reduced-level dig for the substructure works.

However, due to the depth and variability of the Made Ground and the likelihood of trench collapse, it is considered that all excavations are supported or battered back in accordance with guidance contained in CIRIA R97.

If local pumping of groundwater is required during the advancement of excavations for the proposed foundations then consideration should be given to the potential for dewatering gravels in the surrounding areas that may cause structural damage to building substructures in close proximity to the site.

Table 48 Civil Engineering Excavation Risk Matrix

RISK ITEM	PRESENT	COMMENT
Running Sands	No	No running sand has been identified.
Minor Water Ingress	No	Minor water ingress will require localised dewatering/sump pumping during the construction of site drainage infrastructure. Care should be taken when dewatering granular strata so as to cause instability in adjacent structures.
Shallow Bedrock	No	Shallow bedrock has not been identified.

11.16. SLOPE STABILITY

There are no significant slopes at the subject site.

11.17. CONSTRUCTION ACTIVITY AND INSPECTION

The following activities and inspections should be incorporated into the site works:

- Due to the variability of the soils at the site, it is recommended that sufficient allowance is made for the inspection of formations and subformations to foundations and pavement construction.
- Excavations, where access is required, should be subject to a risk assessment from a competent person and, where appropriate, mitigation measures such as benching back the sides or use of support systems in accordance with CIRIA R97 should be utilised.
- It is considered that dewatering may be required, especially following periods of heavy rainfall. Removal of surface water and water within trenches should be possible with conventional sump pumping. Discharge of any water should be agreed with the relevant regulatory body and be undertaken under a trade effluent discharge, where required. Measures to remove silt and suspended solids may be required and consideration should be given to the provision of space for settling tanks or an attenuation pond.
- Where access to confined spaces is required, appropriate mitigation measures should be addressed within the construction stage health and safety plan. Particular account should be taken of the gas results.
- The presence of potential contamination and mitigation measures should be addressed as part of the construction stage health and safety plan and should include measures to design out the risks, reduce their impact and, finally, to include the use of personnel protective equipment (PPE).

11.18. DEVELOPED GEOTECHNICAL RISK REGISTER

POTENTIAL ABNORMAL CONSTRAINT	LOCATION ON-SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Remediation of contaminated soils	On-site	TBC	Metals, PAH and localised ACM have been identified within the Made Ground. There is no specific remediation of the Made Ground required but a cover system will be needed in all garden and landscaped areas of the proposed development in the subject site.
Bedrock	N/A	0	Shallow bedrock has not been identified.
Cohesive Stratum overlying shallow Bedrock (<3.00m)	N/A	0	
Obstructions	All	100	Relict walls, slabs and oversized material have been identified in the sub-surface of the site.
Artificially levelled and filled platforms	On-site	10	The southern sector of the site was identified as being part of a refuse tip historically. Ground investigation has identified up to 4.5 m of Made Ground in this area.
Retaining walls	N/A	0	None have been identified.
Trench collapse	On-site	5	Most excavations remained stable during the ground investigation. Two locations observed collapse (TP108 and TP113)
Drainage Invert levels	TBC	-	To be confirmed.
Infilled canal/Culverts	On-site	5	No infilled canals are present on-site. A culvert is marked on historical maps but its presence has not been confirmed to date. Allowance should be made for it until it can be fully surveyed.
Mature trees	Southern boundary	10	Arboriculture survey is required to determine areas of potential tree influence.
Volume change potential clay	On site	100	The site is likely to be underlain by cohesive and therefore heave precautions may be required at the site.
Peat	N/A	-	None identified.
Running sands	N/A	N/A	Data searches indicate low risk and none was observed during the ground investigation.
Ground dissolution	N/A	N/A	Data searches indicate no hazard.
Concrete design	TBC	-	The majority of locations tested indicated DS1/AC1. One location identifies DS3/AC2
Low-permeability ground	On-site	70	Soakaways are unlikely to be effective in areas where low permeability cohesive deposits are present or where areas of potentially contaminated soil and groundwater are present.

POTENTIAL ABNORMAL CONSTRAINT	LOCATION ON-SITE	ESTIMATED AREA OF SITE AT RISK (%)	ASSESSMENT AND MITIGATION
Services/sensitive structures	On-site	5	Piling may not be possible within close proximity to the culvert, if present.
Abnormal foundation solutions	TBC	TBC	Depending on site levels and layout, however, it is likely that some plots will require an engineered foundation solution.
Areas not investigated	N/A	N/A	-
Surface water features	N/A	N/A	-
Current ponds to be filled	N/A	N/A	-
Historically infilled pond	N/A	N/A	-
Quarry high wall	On-Site	5	A 'high wall' is identified, this represents a risk associated with exaggerated differential settlement to structures and infrastructure. A former refuse tip was identified in the south and with WS104 indicating up to 4.5 m of Made Ground compared with 0.8 m in TP109 there is an inference of a possible high-wall in this area.
Mining	N/A	N/A	No mining risk was identified.
Slope	N/A	N/A	-
Consolidation and Settlement	On-site	80	The presence of variable Made Ground deposits represents a risk associated with the consolidation of materials that could induce settlement to structures and infrastructure. However, it is noted that the Made Ground has been in-situ for a significant period of time and is likely to have undergone self-weight settlement.
Enabling Earthworks	On-site	100	All proposed earthworks will need to be designed by a suitably qualified geotechnical engineer in accordance with NHBC Chapter 4.6. The earthworks design will incorporate a Geotechnical Specification for Earthworks that will define protocols to ensure no unacceptable future risk.

11.19. FURTHER WORKS

Based on the findings of the intrusive site investigation, the following additional works are recommended to be completed in due course:

- Completion of the gas monitoring and assessment.
- Arboricultural survey.
- Plot-specific foundation schedule (upon receipt of the final development levels).
- Geotechnical Design Report (GDR)
- Geotechnical Earthworks Strategy (infrastructure).
- Remediation and enabling works strategy.
- Specification for Mitigation of Hazardous Ground Gasses and Verification Plan.

END OF REPORT

MCI Developments

Ground Investigation Report

for

Crabtree Lane, Openshaw

September 2021

REPORT NO: 21CHE276/DSGI

- *Desk Studies and Site Walkovers*
- *Intrusive Contaminated Land Investigations*
- *Geotechnical Appraisals and Ground Investigations*
- *Landfill Gas Assessments and Remedial Design*
- *Remediation Design and Implementation*
- *Remediation Project Management and Supervision*
- *Site Abnormal Assessments (Foundations and Contaminated Land)*

GEOTECHNICAL - CONTAMINATED LAND - FLOOD RISK

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DOCUMENT ISSUE RECORD

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Client:	MCI Developments
Contract:	Crabtree Lane, Openshaw
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0	Sept 2021	Draft for comments	KR
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ID	Location	Type of water feature	Ground level	Permanence	Name
5	13m N	Lock or flight of locks. An enclosure in a canal or navigable river with gates and sluices at either end.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal

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(i) Off-site Disposal of Surplus Soil Guidance Notes
APPENDIX I
(i) Validation Report Guidance Notes
APPENDIX J 18
(i) Notes on Limitations

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1 EXECUTIVE SUMMARY

Note – *The following summary is not exhaustive and is to be used for guidance purposes only. The full report should be consulted for full details.*

1. Site Location

The site located in the north of Openshaw, between Openshaw and Clayton. The site has an approximate address of B&S Massey, Crabtree Ln, Manchester M11 1BR.

2. Site Description

The site is irregular in shape but is considered roughly rectangular. The site is formed by three main structures in the west with the remaining areas being largely hardstanding which is also generally heavily vegetated with self-seeded trees and bushes.

Access is made on to the site via the main access road in the south of the site, although access has been made by trespassers through the main building on the western boundary.

The buildings are largely empty however, some machinery remains, as does significant amount of waste. Asbestos was noted at the surface across the site but was focussed on the southern end of the western building. Also, within this building was a large 'oil' spill.

3. Proposed Development

Full Planning Application for the development of 115 dwellings (Class C3) with new vehicular accesses from an upgraded Crabtree Lane and associated works, following the demolition of all existing buildings/structures.

4. Site History

On Site

The earliest available map of site is the 1845 1:10,560 map which shows the site to be largely undeveloped land with a culvert crossing the site.

The 1893 1:10,560 map which shows a change of position of the culvert / stream.

The 1908 1:2,500 map which shows the construction of a number of buildings in the north, and central areas of the site. The northern building is labelled as an iron works. The area to the south of the works is detailed as steep slopes indicating removal of materials. A smaller slope is also present in the southwest.

The 1922 1:2,500 map which shows the construction of additional buildings in the north, and demolition in the south with alterations of the steep slopes.

The 1932-1933 1:2,500 map which shows further construction in the north, and demolition with creation of allotment gardens in the south, again with alterations of the steep slopes.

The 1949-1950 1:1,250 map shows significant extension to the buildings in the north of the site with the introduction of travelling cranes and tanks. An electrical substation is also shown on the western boundary. The steep slopes are shown as a refuse heap along Clayton Brook. Steep slope is still shown around the stream in the southwest.

The 1964-19681:1,250 map shows significant changes across the site, with the extension of existing buildings and construction of new ones.

The 1983-1986 1:1,250 map shows significant changes across the site, with the extension of existing buildings and construction of new ones. Clayton Brook no longer shown.

The 1988-1991 1:1,250 map shows additional tanks in the north and the centre of the site.

There were no significant changes until the 2021 1:10,000 map which shows the site in its current state following

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demolition of several buildings.

Offsite
Mixed commercial/industrial and residential setting.

5. Published Geology

The BGS map shows the geology beneath the following:

- **Superficial –** Glacial Till – **Diamicton**
- **Solid** – Manchester Marl Formation – **Mudstone**

6. Hydrogeology and Hydrology

- The superficial deposits of the Glacial Till are classed as Secondary Undifferentiated (low permeability) and Secondary A Aquifer (moderate permeability).
- The bedrock deposits of the Manchester Marls Formation are classed as a Secondary B Aquifer (low permeability).
- The site does not lie within a Groundwater Source Protection Zone as defined by the Environment Agency.
- The closest listed watercourse is the canal adjacent to the northern boundary. However it is not clear from historical mapping whether Clayton Brook is rerouted away from the site, as historical mapping does show it being culverted across the south of the site.

7. Summary of Environmental Data

Possible Contamination Sources

- **Current Site Use – On Site –** Unlikely
- **Historical Land Use – On Site –** Likely
- **Surrounding Land Use – Quarrying –** Possible

Pathways and Receptors

- **Aquifers – Below the Site** – Secondary B Aquifer (solid)
  – Secondary A Aquifer (Superficial)
  – Secondary Undifferentiated (Superficial)

In this qualitative risk assessment, a **Low to Moderate** risk for contamination and ground gas exists across the site. Remedial action is likely to be necessary at the site, the likes of which cannot be confirmed until the geotechnical and contamination ground investigation has been completed.

It is anticipated that elevated risks are generally linked to site history and Made Ground.

8. Scope of Betts Geo 2020 Investigation

The initial fieldwork was carried out between 9th-10th August 2021 and comprised the following;

- Seven (7no) machine excavated trial holes to depths between 0.60mbgl (TP4) and 1.95mbgl (TP7).
- Four (4no) window sample boreholes to depths of up to 4.00mbgl.
- Chemical analysis (Metals, PAH's, TPH's) of ten (10no.) samples.
- Analysis of ten (10no.) samples for asbestos analysis.
- Two (2no) samples for geotechnical analysis, including pH, water soluble sulphate and Atterburg limits.

9. Ground Conditions Encountered

The prevailing ground conditions at the site can generally be summarised as MADE GROUND of various granular deposits to depths of greater than 2.95mbgl.
MADE GROUND was noted overlying NATURAL strata of CLAY in WS101, and TP1 from 1.20mbgl.

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10. Contamination Encountered

Elevated concentrations of various VOCs/SVOCs, metals, asbestos, PAHs and SVOCs have been observed chemical samples in a number of locations across the site, in addition to the surficial, visual and olfactory contamination observed during the site works.

The presence of asbestos within the Made Ground is likely due to poorly managed historical demolition. This is evident from the deposits noted at surface.

11. Remedial Actions

Soils

This methodology of reusing asbestos impacted soils will require carefully managed soil movements, in conjunction with an MMP (Materials Management Plan) and Local Authority agreement and signoff.

Due to the presence of asbestos, it is recommended that a 600mm clean and inert capping layer with a geotextile break layer is installed to impacted plots, as per NHBC guidance. This however, is location specific.

Groundwater and Canal

The underlying aquifer and groundwater are largely protected by cohesive clay strata. No significant mobile contamination has been observed, neither has any perched water.

The risk of contamination to the adjacent canal to the north of the site is deemed low due to the anticipated cohesive superficial geology surrounding the clay preventing any significant contamination migration. A road/access track is also present between the canal and the site, increasing its distance from site.

Protection measures may be required during the construction works to prevent any water ingress during the earthworks and sediment runoff will need to be controlled.

If any unofficial connections are discovered to the canal during the construction works, they will be blocked up to prevent any water from the site draining to the canal.

12. Off-Site Disposal of Surplus Soil

It is recommended that the results of the contamination testing (including the history of the site) be presented to the proposed landfills, to obtain their acceptance of the information to date and to determine the actual WAC limits used by them, (see Appendix J for further guidance). Segregation of made ground/topsoil and natural should be possible given the chemical analysis and very different visual identification.

Site waste management plans will be required due to the size and cost of the proposed scheme.

13. Specialist Ground Gas Measures

BRE211 (2007) Radon: guidance on protective measures for new buildings shows it is in a lower probability area, as less than 1% of homes are above the action level. Therefore, no Radon protective measures are necessary in building of new structures.

Slightly elevated carbon dioxide (greater than 5%) was noted in WS01 on four out of the six visits. Slightly depleted oxygen was also noted in WS01 and WS03 on four of the six visits. Flow rates remained low across all of the visits (max 0.1l/hr).

The previous third party investigation also identified elevated carbon dioxide in WS11 at a concentration of 8%.

Due to the history of the site and the MADE GROUND encountered during the initial ground investigation, it is proposed Amber 1/CS2 ground gas protection is utilized across site. Additional ground gas monitoring is required in the areas that could not be accessed due to dense vegetation/existing buildings (post demo) during the initial investigation.

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14. Foundations

Due to the variability of the ground, a detailed foundation zoning plan should be undertaken once final layouts / levels are known taking in to account the varying ground conditions.

For low-rise properties, strip / trench foundations may be suitable where competent ground is found <2.00mbgl., based on the below;

- Firm CLAY strata with an allowable bearing pressure (ABP) of 100kN/m2
- Stiff CLAY strata with an allowable bearing pressure of 125kN/m2

15. Highway

According to the criteria of Highways Agency HD 25/95 Volume 7 Section 2 Part 2 HD 25/94, a CBR value of 3-5% on the Made Ground anticipated, however confirming in-situ CBR's should be undertaken. Placement of geotextiles within the areas of roads / parking could also be designed to minimise the subgrade thickness.

16. Heave / Shrinkage Potential

Low plasticity is evident across the materials tested. Foundation design for tree heave protection could be designed accordingly following discussion with the NHBC.

17. Ground Floor Construction

Suspended floor construction e.g. either in-situ RC slabs or block and beam flooring is recommended as per NHBC guidance.

18. Control of Groundwater

Shallow perched groundwater has not been observed. The provision of pumping/shuttering may still be necessary during excavation of foundation trenches, especially during wet weather, close to surface water features and to deeper excavations for sewers etc. It is good practice to have such equipment on standby in case of seasonal / abnormal weather conditions.

19. Concrete Design

It is considered for concrete design purposes that a brownfield site and mobile groundwater conditions are applicable, and the results are summarised below:

Area Around WS101

- Design Sulphate Class: DS-1s, ACEC Class: AC-2, Design Chemical Class: DC-2

Rest of Site

- Design Sulphate Class: DS-1s, ACEC Class: AC-1, Design Chemical Class: DC-1

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2 SITE DESCRIPTION

2.1 Introduction

This investigation was carried out on the instruction of MCI Developments Homes. The purpose of the work was to undertake an initial ground investigation works to provide geotechnical and contamination risk information for the proposed construction of 115 dwellings (Class C3) with new vehicular accesses from an upgraded Crabtree Lane and associated works, following the demolition of all existing buildings/structures

2.2 Site Location

The site located in the north of Openshaw, between Openshaw and Clayton. The site has an approximate address of B&S Massey, Crabtree Ln, Manchester M11 1BR. A site location plan is shown in Appendix A.

The proposed site layout is shown below;



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2.3 Site Description

2.3.1 On Site

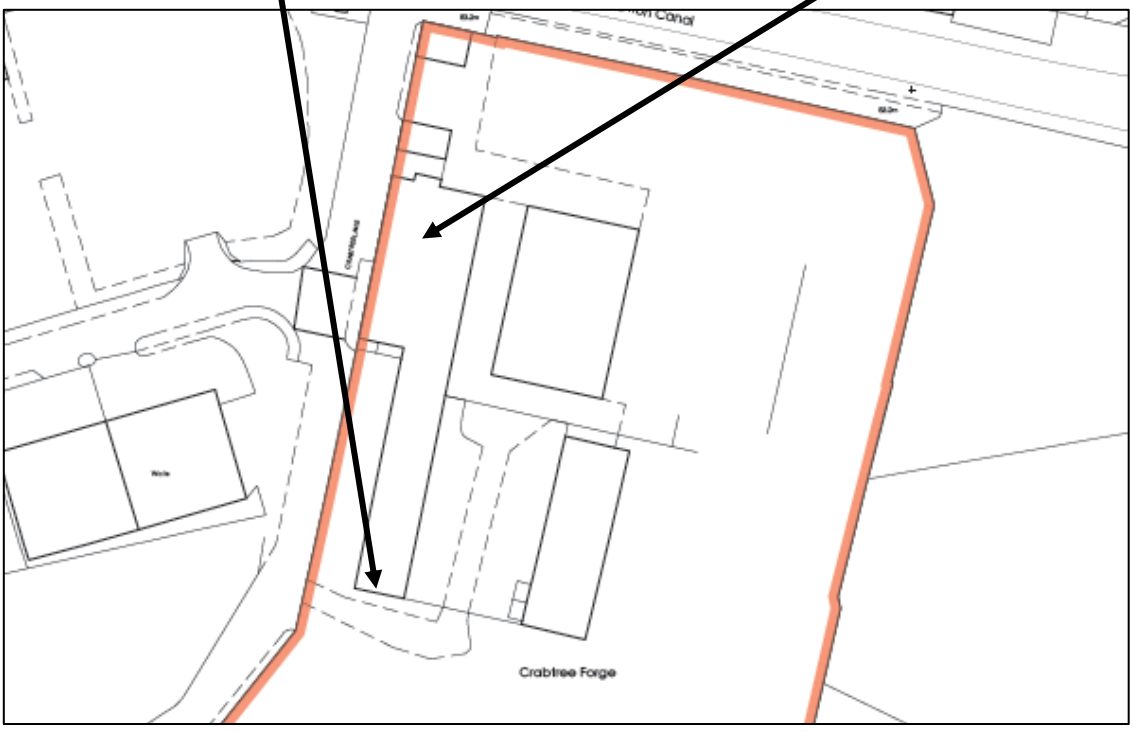
The site is irregular in shape but is considered roughly rectangular. The site is formed by three main structures in the west with the remaining areas being largely hardstanding which is also generally heavily vegetated with self-seeded trees and bushes.

Access is made on to the site via the main access road in the south of the site, although access has been made by trespassers through the main building on the western boundary.

The buildings are largely empty however, some machinery remains, as does significant amount of waste. Asbestos was noted at the surface across the site but was focussed on the southern end of the western building. Also, within this building was a large 'oil' spill. These are shown on the photos below;







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Surrounding Area

- **North** – Ashton canal, commercial / industrial units with residential beyond.
- **East** – Open waste land and possible materials processing / recycling site.
- **South** – Residential development
- **West** – Commercial / Industrial properties

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3 SITE HISTORY

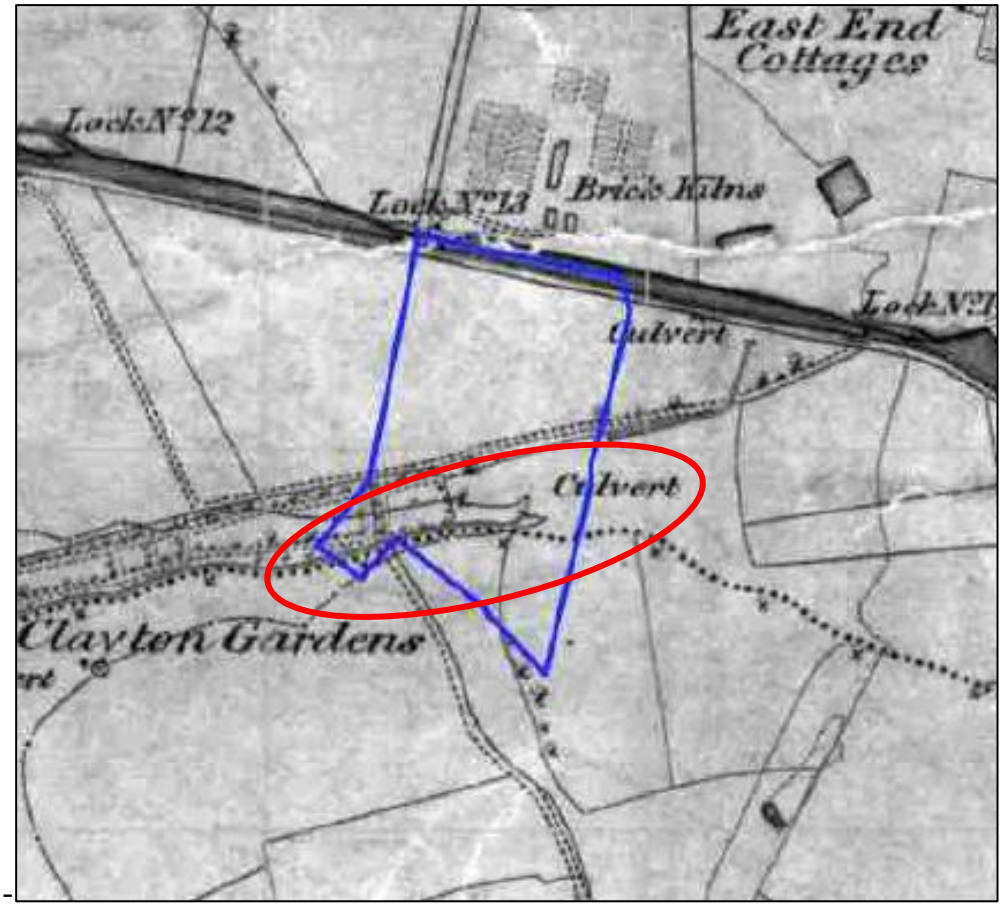
A search of available historic maps was undertaken to establish the land use history of the site. Extracts of the maps discussed below and can be found in full in Appendix F of this report. All maps are Ordnance Survey unless otherwise stated. All distances quoted on OS maps are taken from the site boundary, which is marked on the map, and are approximate.

3.1 Summary of Site History

3.1.1 On Site

The earliest available map of site is the 1845 1:10,560 map which shows the site to be largely undeveloped land with a culvert crossing the site. An extract of this map is shown below;

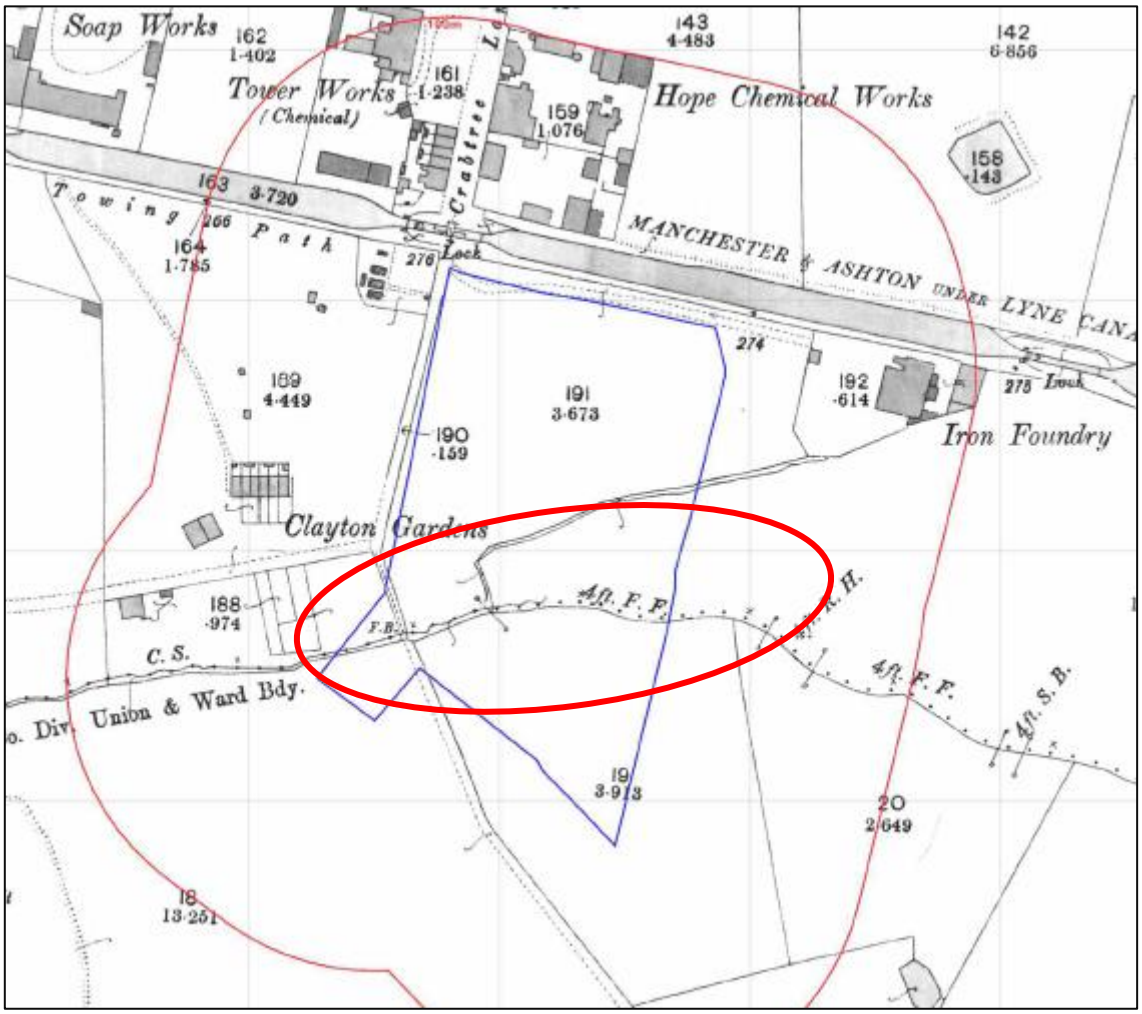
1845 1:10,560 Map



© Betts Geo Environmental Ltd 2021

The 1893 1:10,560 map which shows a change of position of the culvert / stream. An extract of this map is shown below;

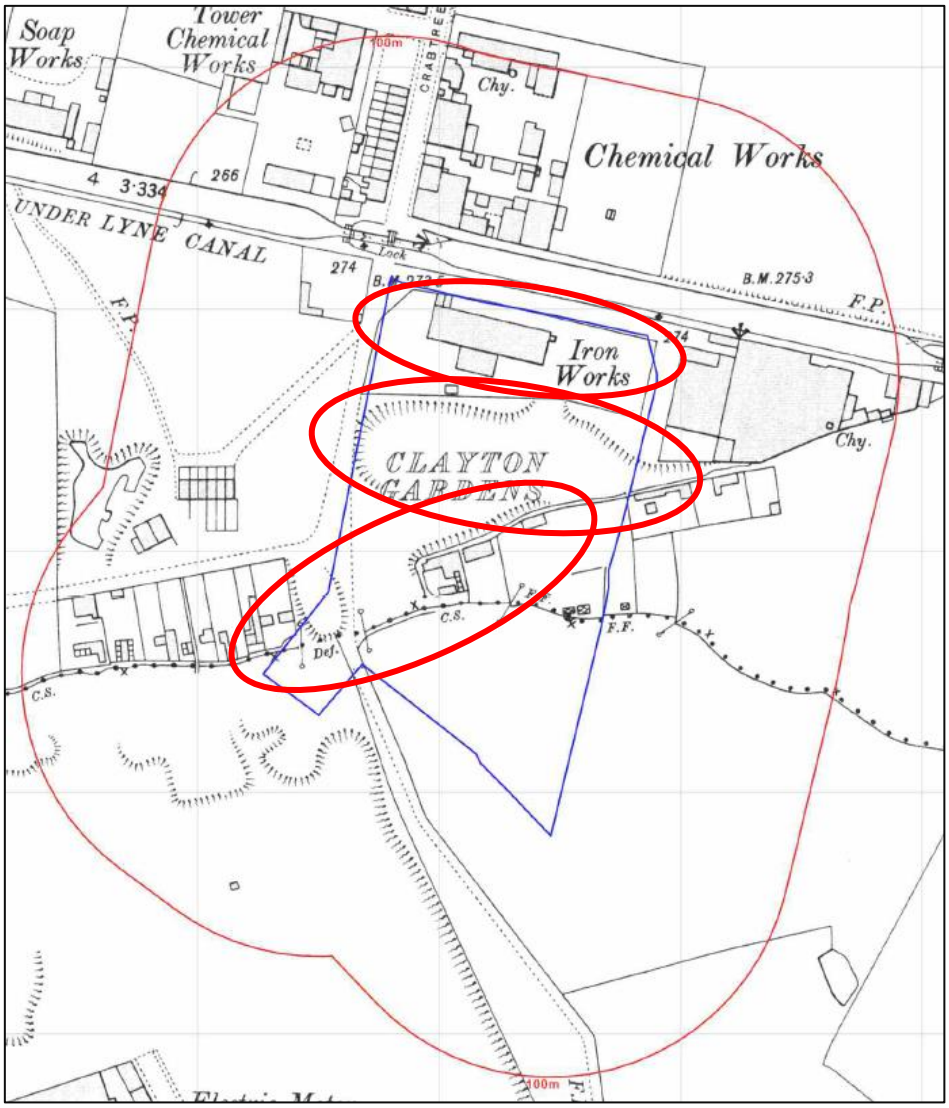
1893 1:2,500 Map



© Betts Geo Environmental Ltd 2021

The 1908 1:2,500 map which shows the construction of a number of buildings in the north, and central areas of the site. The northern building is labelled as an iron works. The area to the south of the works is detailed as steep slopes indicating removal of materials. A smaller slope is also present in the southwest. An extract of this map is shown below;

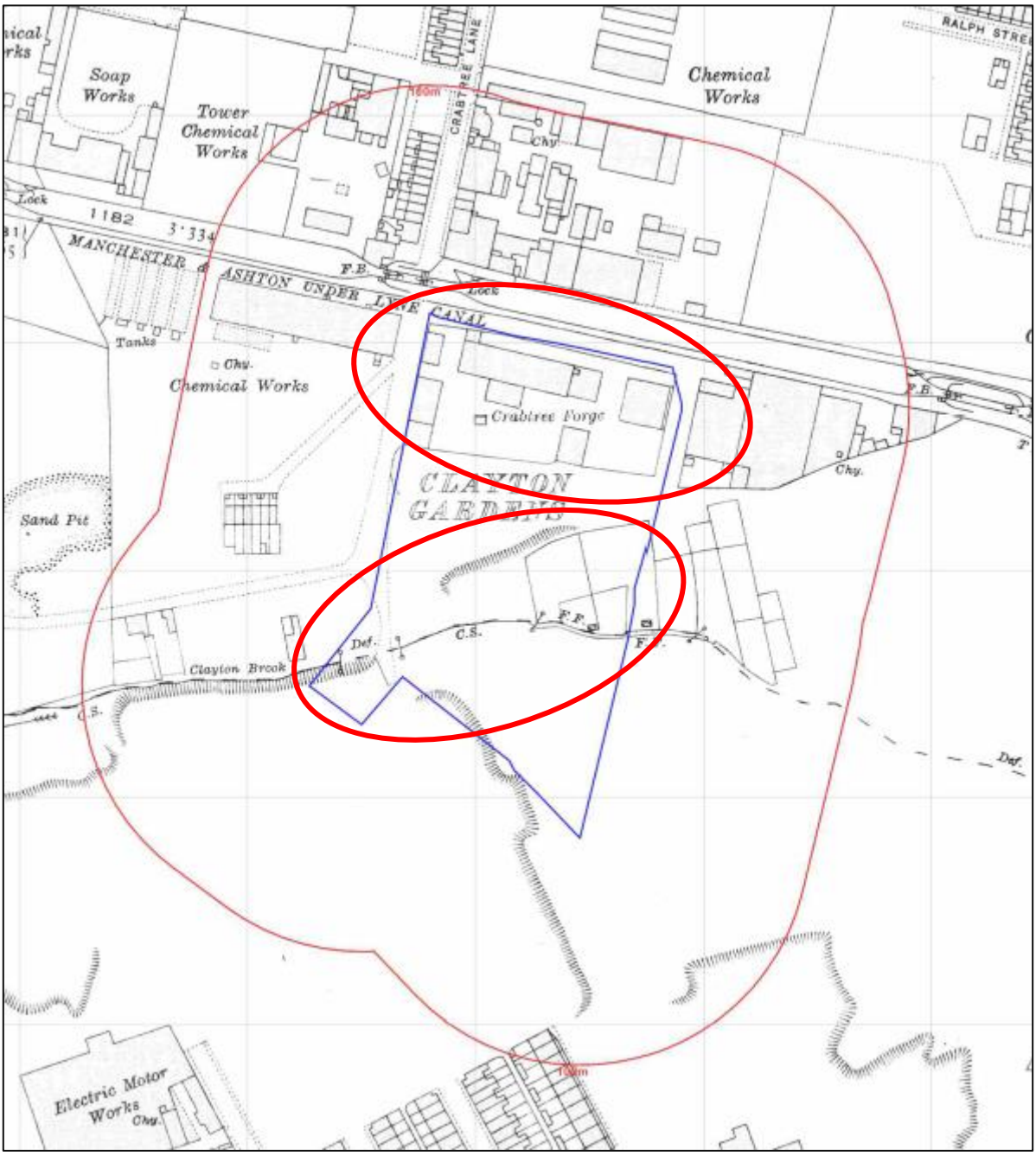
1908 1:2,500 Map



© Betts Geo Environmental Ltd 2021

The 1922 1:2,500 map which shows the construction of additional buildings in the north, and demolition in the south with alterations of the steep slopes. An extract of this map is shown below;

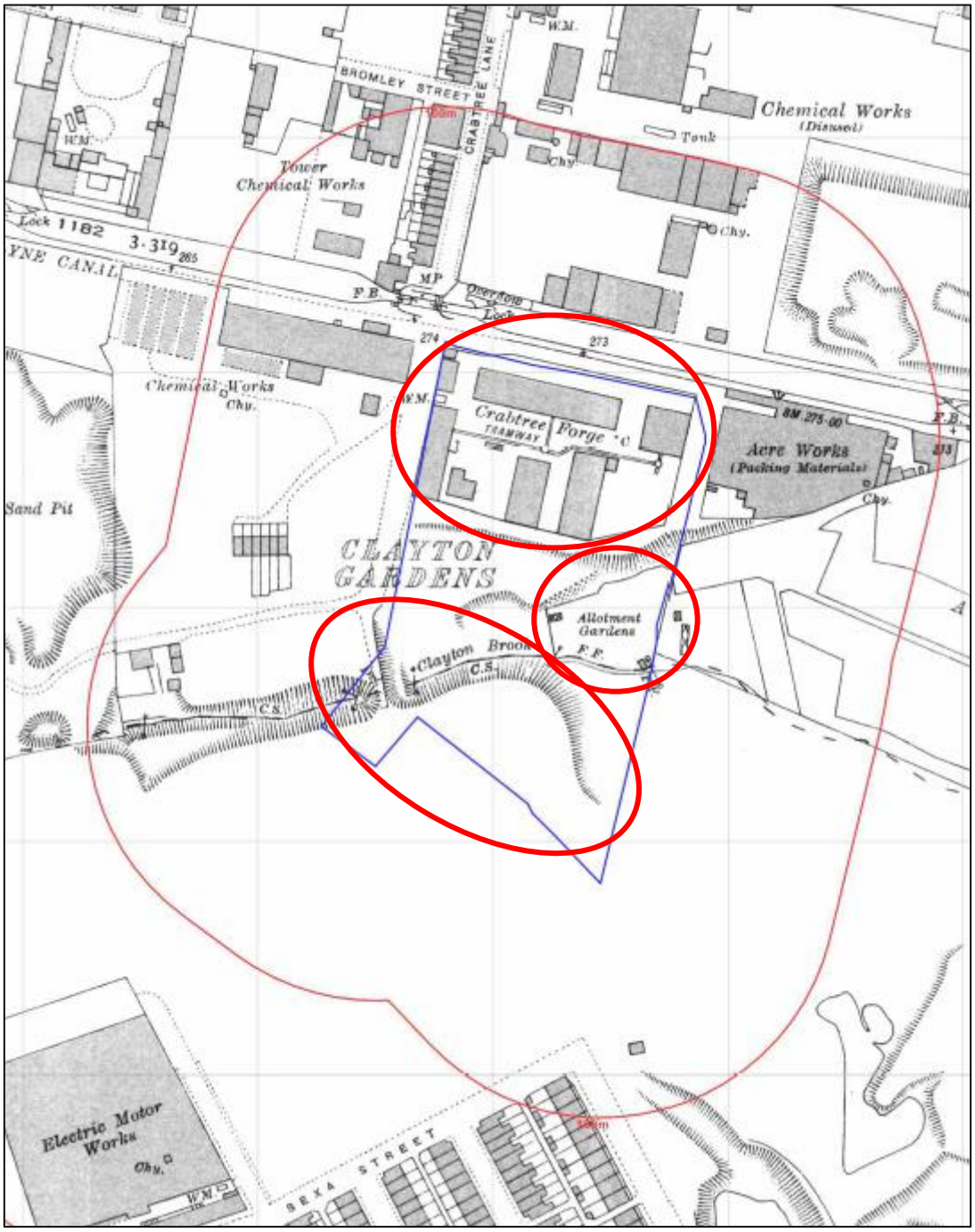
1922 1:2,500 Map



© Betts Geo Environmental Ltd 2021

The 1932-1933 1:2,500 map which shows further construction in the north, and demolition with creation of allotment gardens in the south, again with alterations of the steep slopes. An extract of this map is shown below;

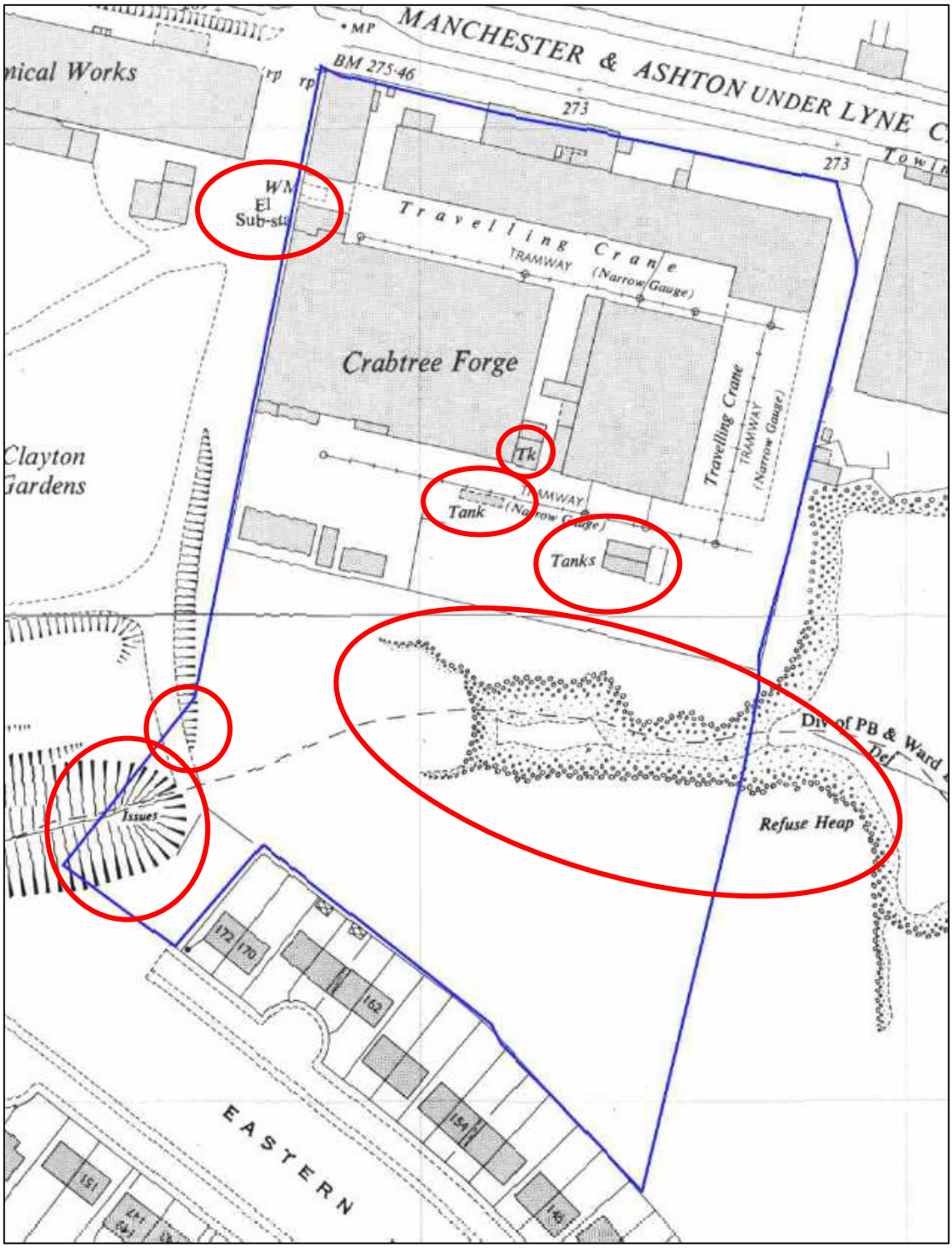
1932-1933 1:2,500 Map



© Betts Geo Environmental Ltd 2021

The 1949-1950 1:1,250 map shows significant extension to the buildings in the north of the site with the introduction of travelling cranes and tanks. An electrical substation is also shown on the western boundary. The steep slopes are shown as a refuse heap along Clayton Brook. Steep slope is still shown around the stream in the southwest. An extract of this map is shown below;

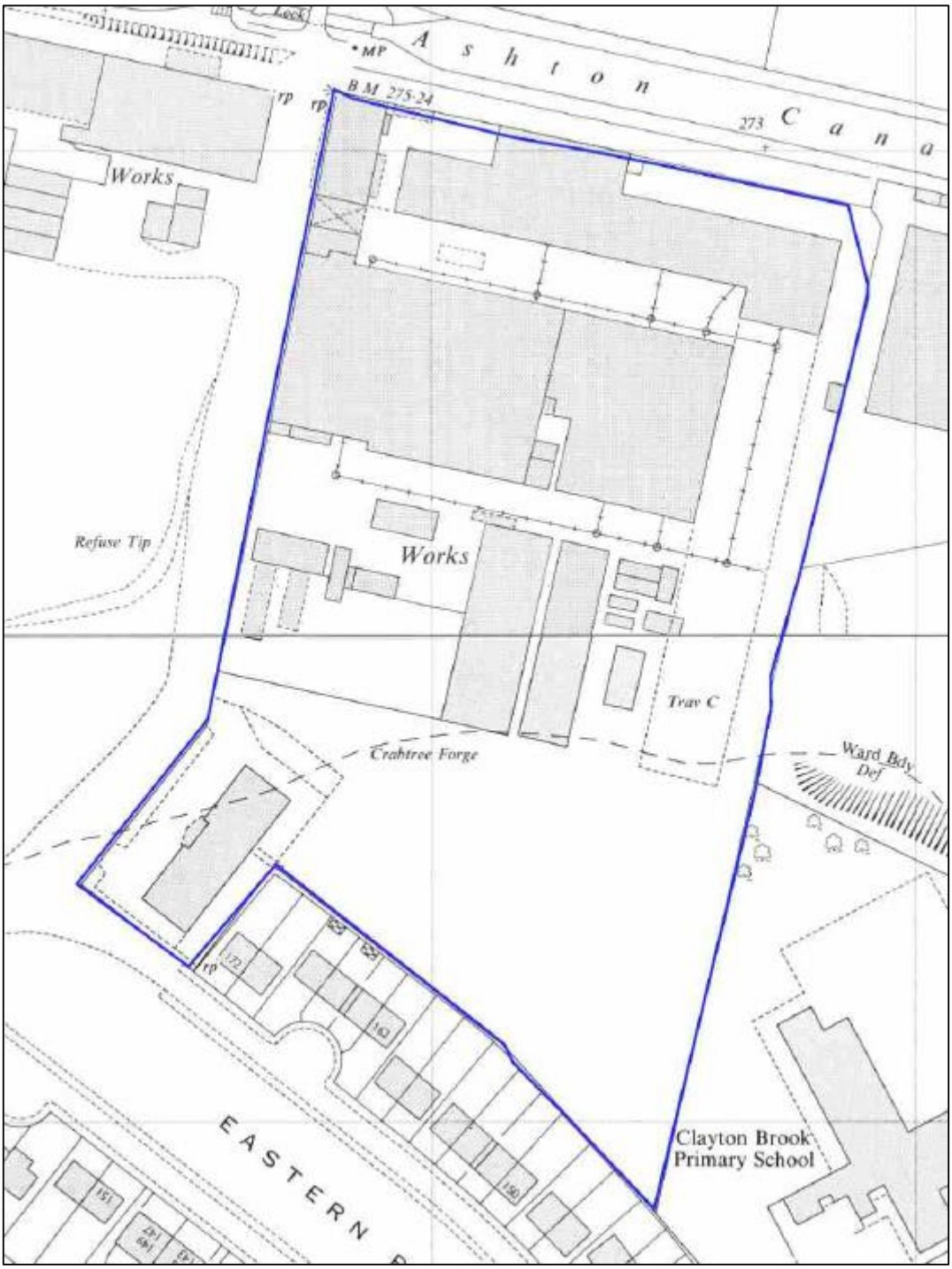
1949-1950 1:1,250 Map



© Betts Geo Environmental Ltd 2021

The 1964-19681:1,250 map shows significant changes across the site, with the extension of existing buildings and construction of new ones. An extract of this map is shown below;

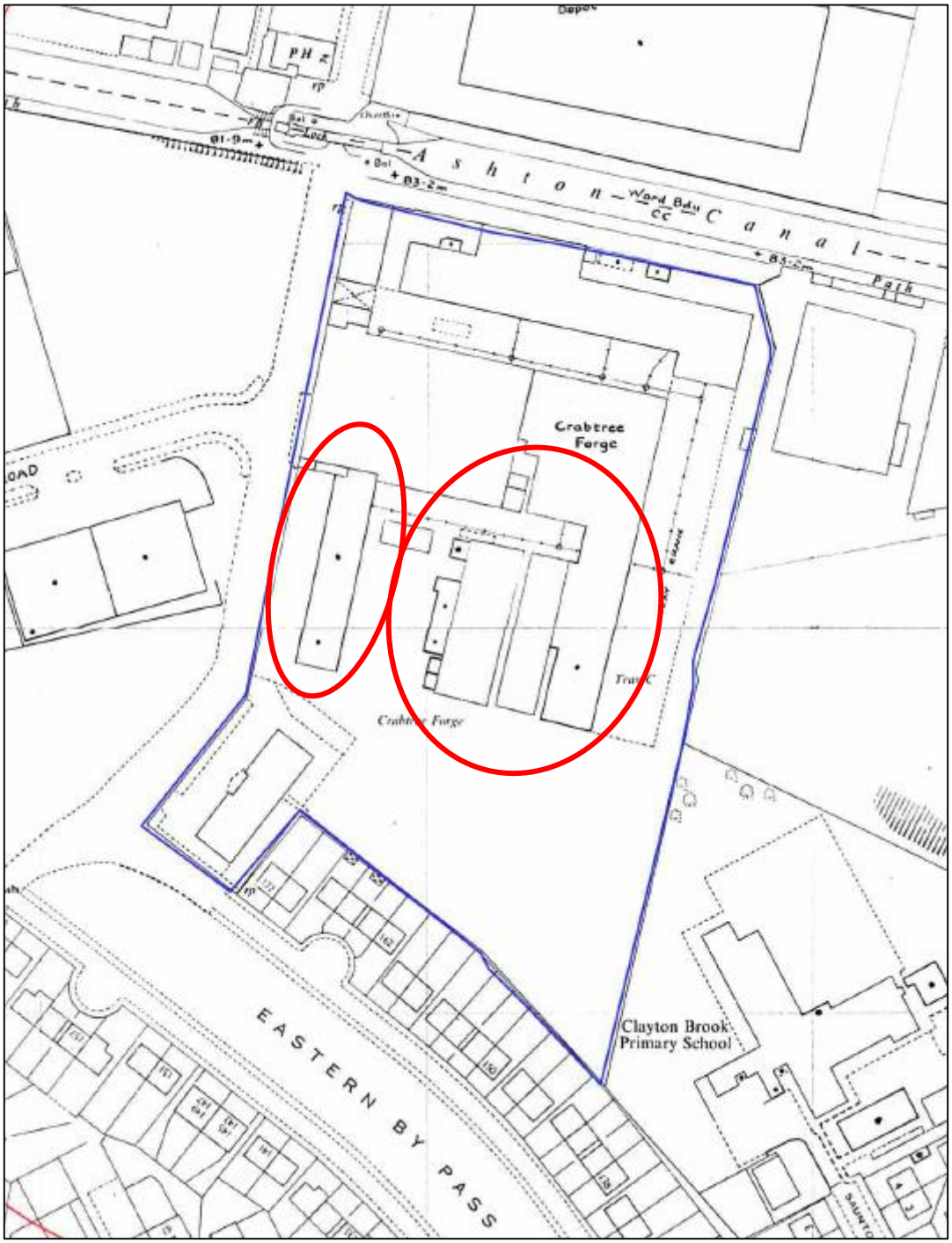
1964-1968 1:1,250 Map



© Betts Geo Environmental Ltd 2021

The 1983-1986 1:1,250 map shows significant changes across the site, with the extension of existing buildings and construction of new ones. Clayton Brook no longer shown. An extract of this map is shown below;

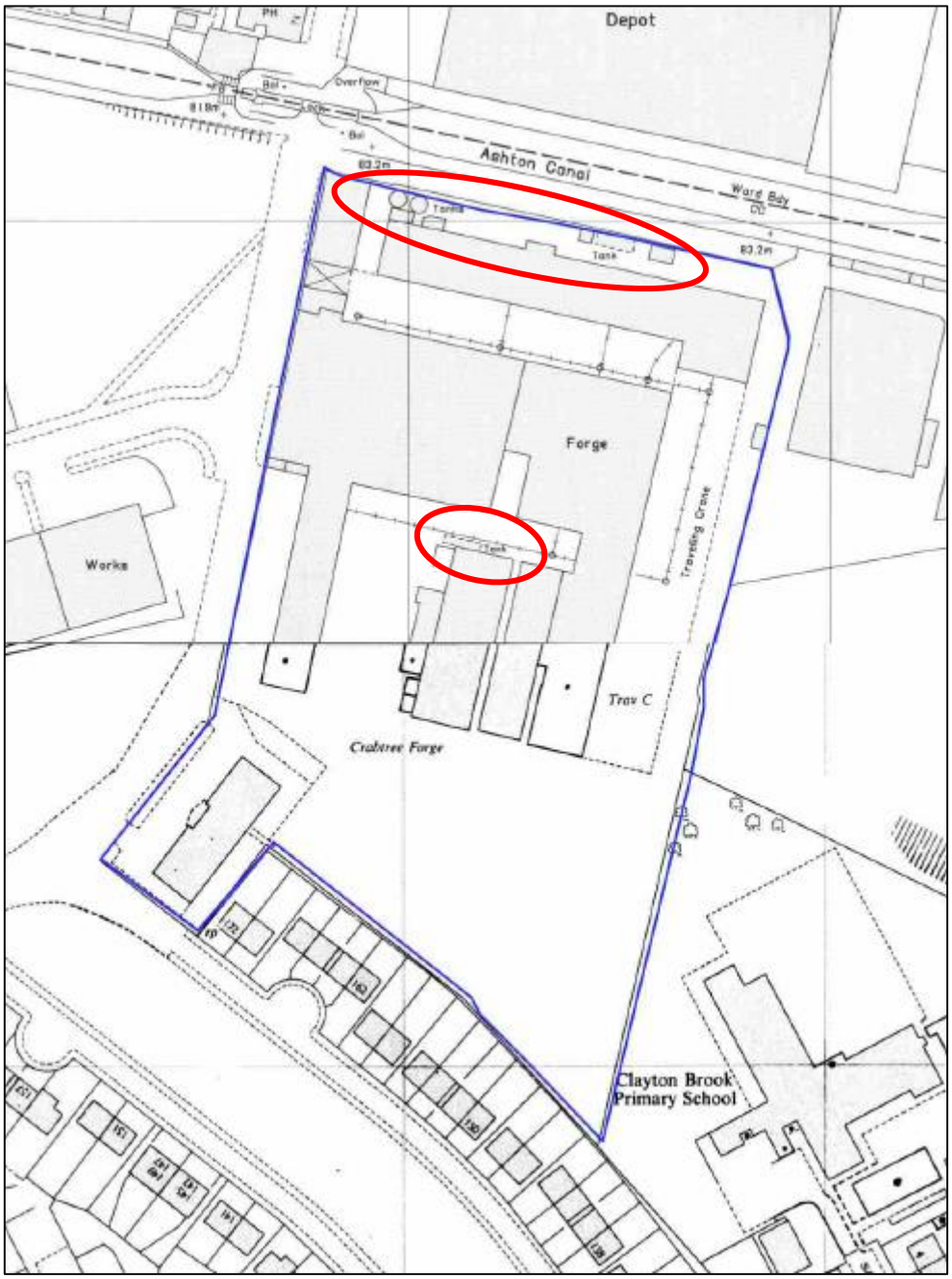
1983-1986 1:1,250 Map



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The 1988-1991 1:1,250 map shows additional tanks in the north and the centre of the site. An extract of this map is shown below;

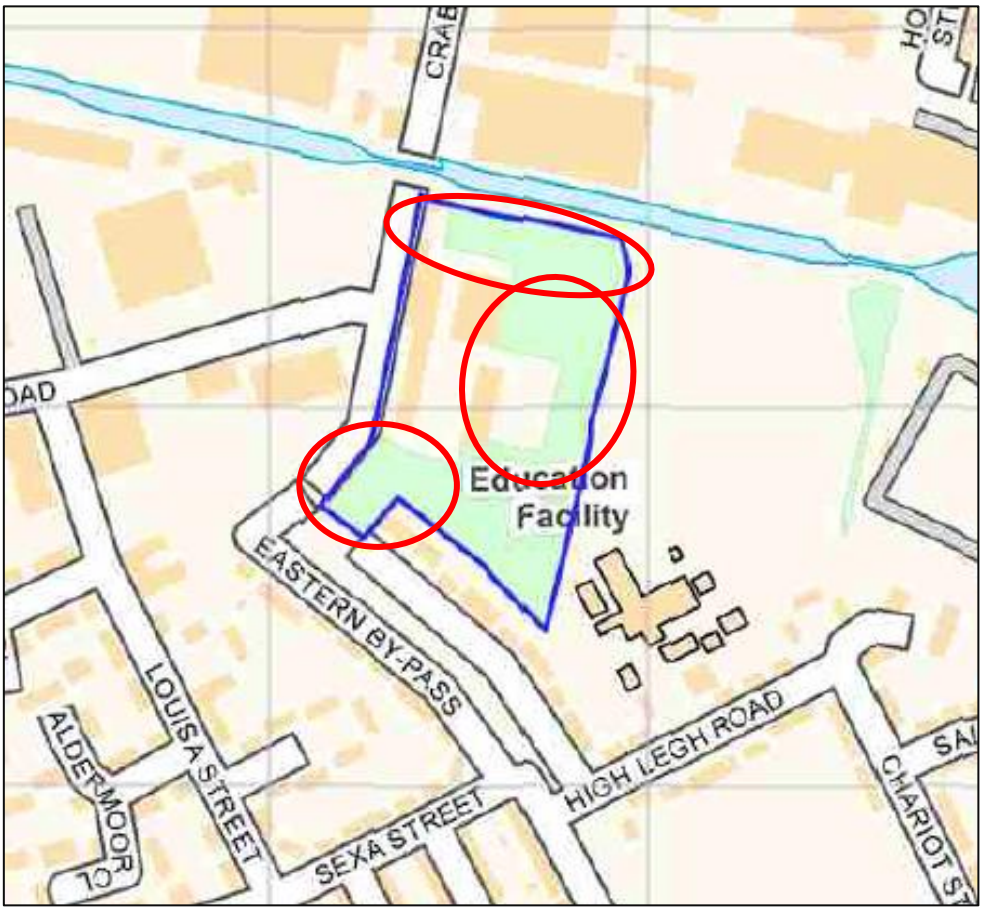
1983-1986 1:1,250 Map



© Betts Geo Environmental Ltd 2021

There were no significant changes until the 2021 1:10,000 map which shows the site in its current state following demolition of several buildings. An extract of this map is shown below;

2021 1:10,000 Map



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3.1.2 Surrounding Area

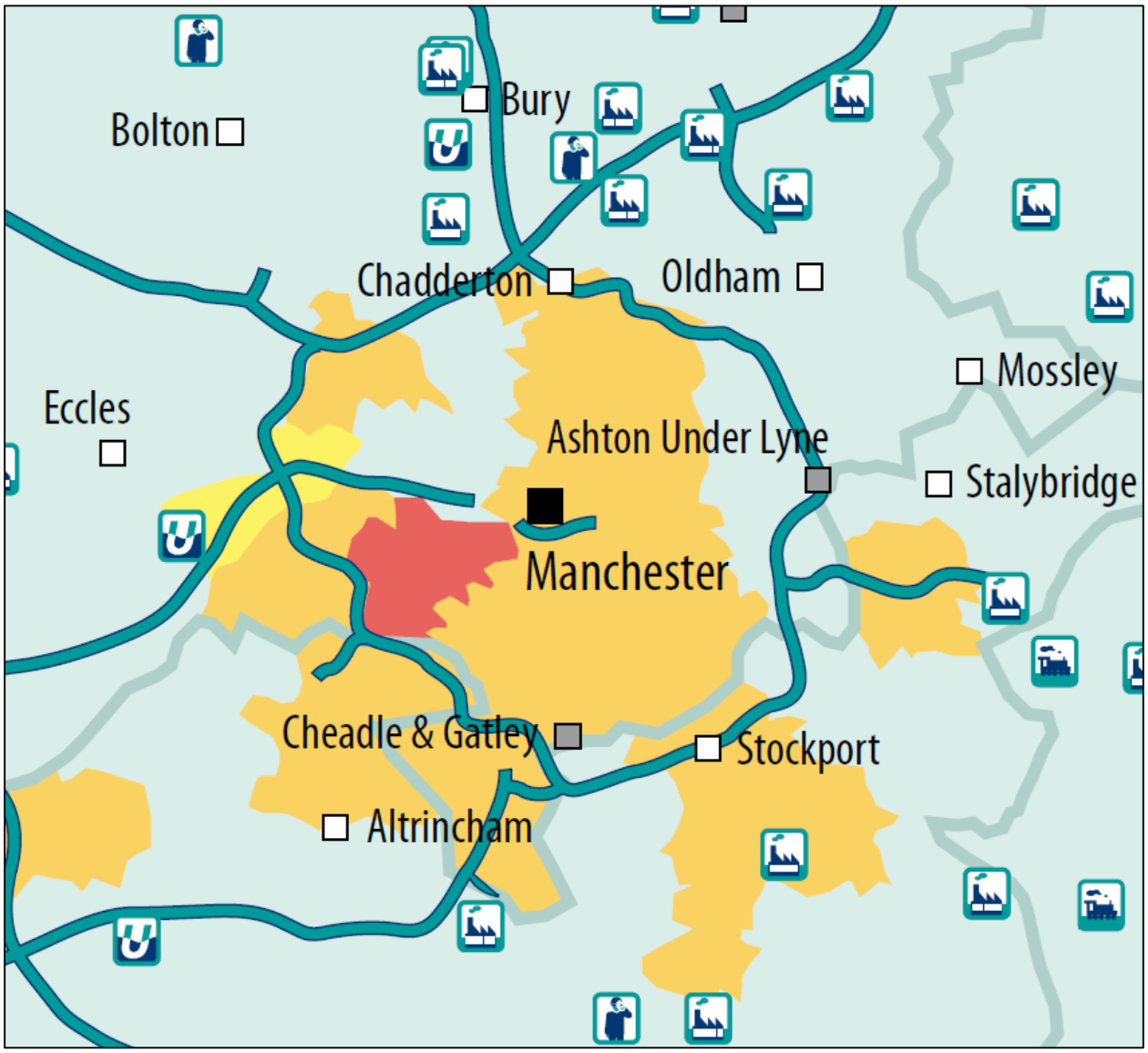
The following table summarises the significant changes in historical use within 500m the site:

Date First Shown	Land Uses
1848	Canal – adjacent to northern boundary. Brick kilns – 50m north on opposite bank of canal. Ponds / reservoirs - 250m north, 125m northeast, 250m-500m east and 400m west. Cotton Mill – 400m east Cotton Mill – 400m south Sand pit – 400m north
1890-1892	Significant development around the site. A number of works have been built north of the canal and an iron foundry built 200m east of site. Refuse tip - 300m south Brick works – 450m southwest Magazine and steep banks/cuts – 300m west
1905-1908	Various works with tanks (chemical, soap) – opposite bank of canal Residential development – north of site 250-500m Mill – 400m east Brick field/sand pits and excavation – adjacent to 350m south, large and varies in size across maps Works, mill and foundry – 300m-400m south and southwest. Magazine – 200m west
1922-1923	Works (various) – adjacent to eastern boundary Rifle range – 250m southwest Chemical works with tanks – adjacent to western boundary
1932-1938	Allotments – 100m east Residential development - All directions from adjacent to boundary
1949-1951	Ruins – Opposite side of canal Refuse heap – 80m north and crossing site boundary in south east. Electric Motor Works (north street works) – extended and now within 150m southwest of site. Continued residential development
1954-1956	Residential development – from southern boundary to southeast Redevelopment of former factory/works areas for residential end use.
1981-1986	Warehouses – west and southwest of boundary
1986 – Present	Alteration and redevelopment of existing industrial and residential areas.

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4 UNEXPLODED ORDNANCE (UXO)

Zetica's indicative UXO risk mapping places Manchester, and the site, within a 'moderate bomb risk' area. As shown below;



A review of historical mapping has shown that the area around the site is rich in primary, secondary and tertiary level targets for Luftwaffe bombing. These targets include the forge/iron works located on site and a signficant number of various works and railways / railway sidings and located in close proximity.

A brief internet search of open source records and historical mapping provided by GroundSure has shown there were a number of bomb strikes on and around the site, with at least one recorded strike on the north of the site (firebombs), as shown on the extracts listed below. This mapping ONLY covers the Blitz period 1940-1941, and is therefore not exhaustive;

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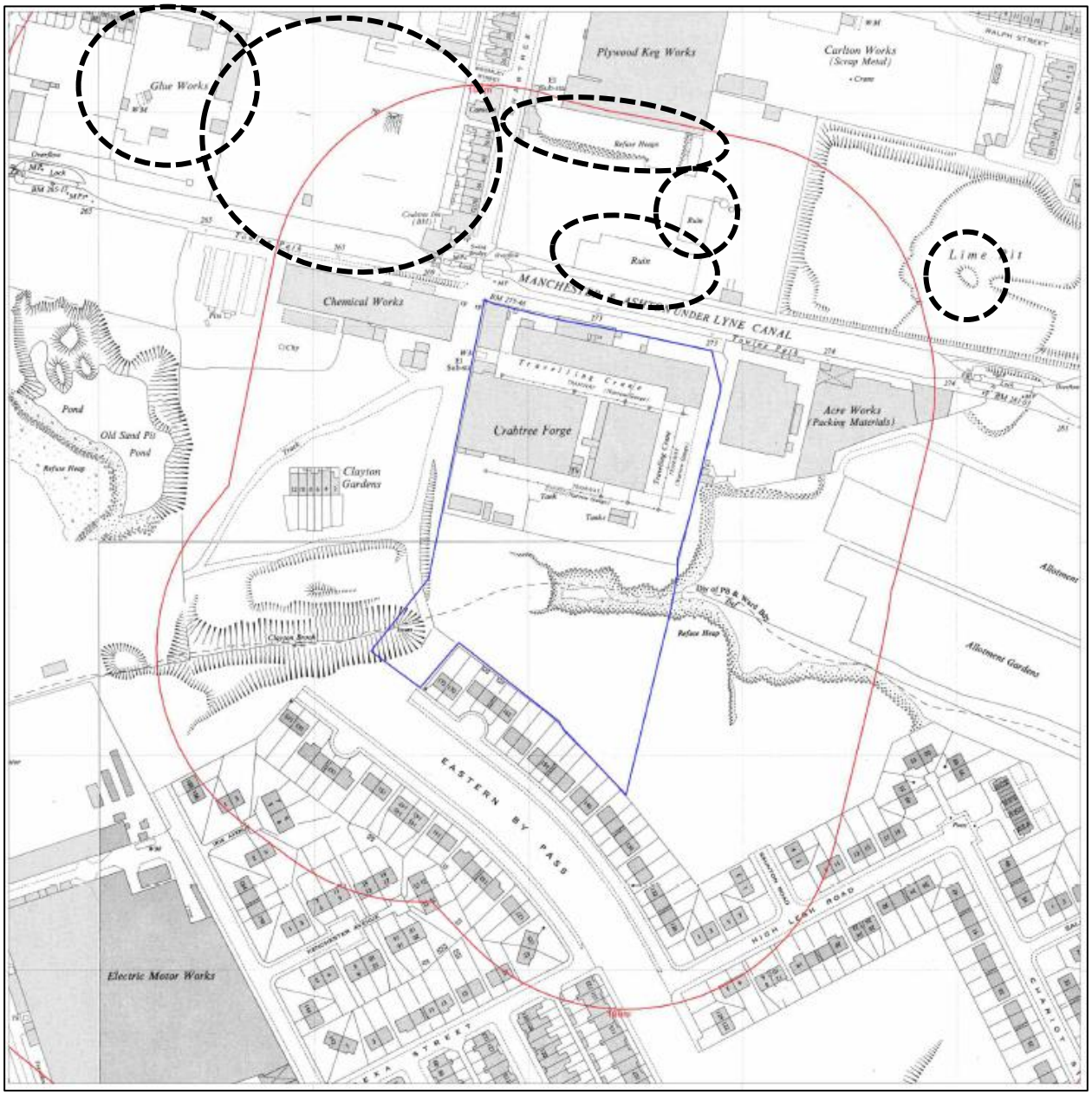


Description:

Original map of Manchester: Ordnance Survey Revisions of 1932-1935. Scale: 25" to 1 mile. Annotated with: red circles for fire bombs; blue circles for high explosives; pink shading for damaged buildings; red shading for demolished buildings; green marks: line mines, indicating bomb damage by the Luftwaffe during the Blitz. Detailing Openshaw and Gorton.

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Mapping from 1949-1950 shows a number of ruins located around the site, as well as the disappearance of buildings not listed as a ruin, but have gone during WWII period. Bomb strikes outside of developed areas are unlikely to be recorded. These are shown on plan below;



As the site has been developed prior to, during and after WWII, the likelihood of UXO remaining on site from a direct strike is considered **unlikely**. However, dropped ordnance can hit the ground outisde of the site boundary and migrate under the boundary in a typical 'J' shape. Due to the number of strikes around the site, and the strikes recorded on the north of the site, discussion with a suitably qualified and experienced UXO consutlant is considered prudent.

A summary of the Zetica Pre-Desk study is shown below;

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zeticaUXO

Pre-Desk Study Assessment

Site:	Crabtree Lane, Manchester
Client:	Betts Geo
Contact:	Kris Rodway
Date:	6th September 2021
Pre-WWI Military Activity on or Affecting the Site	None identified.
WWI Military Activity on or Affecting the Site	None identified.
WWI Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ■ Transport infrastructure and public utilities. ■ Industries important to the war effort, including munitions factories and engineering works. ■ Royal Flying Corps (RFC) Alexandra Park. ■ Anti-Aircraft (AA) guns.
WWI Bombing	None identified on the Site.
Interwar Military Activity on or Affecting the Site	None identified.
WWII Military Activity on or Affecting the Site	None identified.
WWII Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ■ Transport infrastructure and public utilities. ■ Industries important to the war effort, including engineering works. ■ Military camps and training areas. ■ AA and anti-invasion defences.
WWII Bombing Decoys (within 5km of Site)	1No. located approximately 4.8km southeast of the Site.
WWII Bombing	During WWII the Site was located in the County Borough (CB) of Manchester, which officially recorded 737No. High Explosive (HE) bombs with a bombing density of 27 bombs per 405 hectares (ha). The Manchester area was heavily bombed between the 22nd and 24th December 1940 (the 'Manchester Blitz'). Over 400No. HE bombs and more than 30,000 Incendiary Bombs (IBs) fell across the region. Bombing was concentrated on the city centre, approximately 4.7km from the Site. No readily available records have been found to indicate that the Site was bombed.
Post-WWII Military Activity on or Affecting the Site	None identified.
Recommendation	A detailed desk study, whilst always prudent, is not considered essential in this instance.

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5 GEOLOGY

The following section details the published and available geological data available for the site and the surrounding area. This summary is taken from the reports referenced in Section 3.1 above. For full details, please refer to these reports.

5.1 Published Geology

The documented geology of the site is summarised on British Geological Survey map principally:

Geology	Artificial Ground and Land Slip	Drift	Solid
1:50,000	Infilled ground	Glacial Till **- Diamicton**	Manchester Marls Formation – **Mudstone**

5.2 Fault Lines

There are no faults located within 500m of the site.

5.3 Coal Mining

The site is located within a coal mining area, as defined by the Coal Authority, therefore a coal mining report has been obtained. The pertinent points of the report are shown below;

Past underground mining

Colliery	Seam	Mineral	Coal Authority reference	Depth (m)	Direction to working	Dipping rate of seam worked (degrees)	Dipped direction of seam worked	Extraction thickness (cm)	Year last mined
unnamed	BRADFORD FOUR FEET	Coal	35CV	705	North-West	26.7	South-West	120	1961

Withdrawal of support notices

The property is in an area where a notice to withdraw support was given in 1957.

The property is not in an area where a notice has been given under section 41 of the Coal Industry Act 1994, cancelling the entitlement to withdraw support.

5.3.1 Radon

According to the GroundSure report, the site is not in a radon affected area as less than 1% of homes are above the action level. The current UKRadon mapping confirms less than 1% of homes are above action level.

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5.4 Geological Features

The table below summarises the presence/absence of recorded mining, extraction and natural cavities records within 500m of the site. If entries are present within 250m, further details are provided in the relevant section below.

Data Type	On-Site	0m – 50m	50m – 250m	250 – 500m
Geological				
Natural Cavities	-	-	-	-
BritPits	-	-	3	-
Surface Ground Workings	9	16	48	-
Underground Workings	-	-	-	-
Historical Mineral Planning Areas	-	-	-	-
Non-Coal Mining	-	-	-	-
Mining Cavities	-	-	-	-
JPB Mining Areas	-	-	-	-
Coal Mining	-	-	-	-
Brine Areas	-	-	-	-
Gyspum Areas	-	-	-	-
Tin Mining	-	-	-	-
Clay Mining	-	-	-	-

5.4.1 BritPits

ID	Location	Details	Description
4	79m N	Name: East End Brick Field Address: Clayton, MANCHESTER, Lancashire Commodity: Clay & Shale Status: Ceased	Type: A surface mineral working. It may be termed Quarry, Sand Pit, Clay Pit or Opencast Coal Site Status description: Site which, at date of entry, has ceased to extract minerals. May be considered as Closed by operator. May be considered to have Active, Dormant or Expired planning permissions by Mineral Planning Authority
I	167m NW	Name: Clayton Gardens Sand Pit Address: Clayton, MANCHESTER, Lancashire Commodity: Sand & Gravel Status: Ceased	Type: A surface mineral working. It may be termed Quarry, Sand Pit, Clay Pit or Opencast Coal Site Status description: Site which, at date of entry, has ceased to extract minerals. May be considered as Closed by operator. May be considered to have Active, Dormant or Expired planning permissions by Mineral Planning Authority
H	216m SE	Name: Wayne Street Brick Field Address: Openshaw, MANCHESTER, Lancashire Commodity: Clay & Shale Status: Ceased	Type: A surface mineral working. It may be termed Quarry, Sand Pit, Clay Pit or Opencast Coal Site Status description: Site which, at date of entry, has ceased to extract minerals. May be considered as Closed by operator. May be considered to have Active, Dormant or Expired planning permissions by Mineral Planning Authority

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5.4.2 Surface Ground Workings

ID	Location	Land Use	Year of mapping	Mapping scale
A	**On site**	**Refuse Heap**	**1956**	**1:10560**
B	**On site**	**Unspecified Pit**	**1938**	**1:10560**
B	**On site**	**Unspecified Pit**	**1934**	**1:10560**
B	**On site**	**Unspecified Heap**	**1905**	**1:10560**
B	**On site**	**Cuttings**	**1956**	**1:10560**
C	**On site**	**Unspecified Heap**	**1938**	**1:10560**
C	**On site**	**Unspecified Heap**	**1934**	**1:10560**
D	**On site**	**Canal**	**1923**	**1:10560**
E	**On site**	**Unspecified Ground Workings**	**1923**	**1:10560**
1	1m SW	Unspecified Ground Workings	1923	1:10560
D	6m N	Canal	1938	1:10560
D	6m N	Canal	1934	1:10560
D	6m N	Canal	1915	1:10560
D	6m N	Canal	1905	1:10560
D	6m N	Canal	1890	1:10560
B	10m N	Canal	1968	1:10560
B	10m N	Canal	1956	1:10560
2	10m SE	Unspecified Ground Workings	1905	1:10560
A	11m E	Refuse Heap	1968	1:10560
F	11m N	Canal	1991	1:10000
F	14m N	Canal	1985	1:10000
F	14m N	Canal	1978	1:10000
3	17m N	Brick Kilns	1851	1:10560
G	48m NE	Unspecified Ground Workings	1938	1:10560
G	48m NE	Unspecified Ground Workings	1934	1:10560
H	71m SE	Brick Field	1923	1:10560
H	72m SE	Unspecified Pit	1923	1:10560
H	76m SE	Disused Brick Field	1915	1:10560
I	77m NW	Pond	1905	1:10560
H	90m S	Pond	1934	1:10560

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ID	Location	Land Use	Year of mapping	Mapping scale
I	99m NW	Old Sand Pit	1938	1:10560
I	99m NW	Old Sand Pit	1934	1:10560
I	108m NW	Sand Pit	1915	1:10560
E	110m W	Unspecified Pit	1938	1:10560
E	110m W	Unspecified Pit	1934	1:10560
H	110m SE	Pond	1934	1:10560
I	110m NW	Sand Pit	1923	1:10560
I	111m NW	Pond	1956	1:10560
I	113m NW	Refuse Heap	1956	1:10560
I	134m W	Unspecified Ground Workings	1956	1:10560
J	134m SW	Unspecified Pit	1890	1:10560
H	143m SE	Brick Field	1905	1:10560
G	146m E	Unspecified Pit	1968	1:10560
J	156m SW	Unspecified Pit	1923	1:10560
J	156m SW	Unspecified Pit	1905	1:10560
5	171m N	Pond	1851	1:10560
K	175m W	Unspecified Ground Workings	1915	1:10560
H	182m SE	Unspecified Ground Workings	1934	1:10560
H	182m SE	Unspecified Heap	1956	1:10560
K	183m W	Unspecified Pit	1923	1:10560
K	183m W	Unspecified Pit	1905	1:10560
K	183m W	Unspecified Pit	1890	1:10560
K	184m W	Sand Pit	1851	1:10560
6	188m S	Refuse Pit	1890	1:10560
L	191m E	Unspecified Wharf	1923	1:10560
L	201m E	Unspecified Wharf	1938	1:10560
L	201m E	Unspecified Wharf	1934	1:10560
L	201m E	Unspecified Wharf	1915	1:10560

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ID	Location	Land Use	Year of mapping	Mapping scale
K	209m W	Refuse Heap	1968	1:10560
K	209m W	Refuse Heap	1956	1:10560
K	215m W	Pond	1938	1:10560
K	215m W	Pond	1934	1:10560
M	225m W	Canal	1938	1:10560
M	225m W	Canal	1934	1:10560
M	225m W	Canal	1915	1:10560
M	225m W	Canal	1905	1:10560
M	225m W	Canal	1890	1:10560
N	227m NW	Unspecified Heap	1938	1:10560
N	227m NW	Unspecified Heap	1934	1:10560
7	231m E	Pond	1851	1:10560
N	231m NW	Unspecified Heap	1923	1:10560
8	231m NW	Unspecified Pit	1891	1:10560
O	248m NE	Ponds	1891	1:10560

5.5 Hydrogeological and Hydrological Features

The table below summarises the presence/absence of any hydrological licences and incidents within 500m of the proposed site. If entries are present within 250m, further details are provided in the relevant subsection below;

Data Type	On-Site	0m – 50m	50m – 250m	250 – 500m
Hydrogeology & Hydrology				
Licenced Discharge Consents	-	-	-	1
Red List Discharge Consents	-	-	-	-
Ground Water Abstraction Licences	-	-	-	-
Surface Water Abstraction Licences	-	-	-	-
Potable Water Abstraction Licences	-	-	-	-
Source Protection Zones	-	-	-	-
Water Network	-	3	8	-

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5.5.1 Water Network

ID	Location	Type of water feature	Ground level	Permanence	Name
5	13m N	Lock or flight of locks. An enclosure in a canal or navigable river with gates and sluices at either end.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
6	14m N	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
7	23m NW	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	188m W	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	188m W	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	193m W	Manmade watercourse for water transfer.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	198m W	Lock or flight of locks. An enclosure in a canal or navigable river with gates and sluices at either end.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
B	216m E	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
B	216m E	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	223m W	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal
A	246m W	Canal. A manmade watercourse for inland navigation.	On ground surface	Watercourse contains water year round (in normal circumstances)	Ashton Canal

5.6 Hydrogeology

- The superficial deposits of the Glacial Till are classed as Secondary Undifferentiated (low permeability) and Secondary A Aquifer (moderate permeability).
- The bedrock deposits of the Manchester Marls Formation are classed as a Secondary B Aquifer (low permeability).
- The site does not lie within a Groundwater Source Protection Zone as defined by the Environment Agency.
- The closest listed watercourse is the canal adjacent to the northern boundary. However it is not clear from historical mapping whether Clayton Brook is rerouted away from the site, as historical mapping does show it being culverted across the south of the site.

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6 ENVIRONMENTAL DATA

The following section highlights environmental data available for the site and the surrounding area. Full details can be found in the Desk Study Report.

The table below summarises the presence/absence of any waste, hazardous substance sites of industrial land uses within 500m of the proposed site.

Data Type	On Site	0-50m	50 – 250m	250 – 500m
Current Industrial Land Use				
Historic Integrated Pollution Control Authorisations	-	-	-	-
Part A (2) & Part B Activities and Enforcements	-	-	-	-
Licensed Pollutant Release (Part A (2)/B))	-	-	1	1
Radioactive Substances Authorisations	-	-	-	-
Hazardous Substance Storage / Usage	-	-	-	-
EA/NRW Pollution Incidents	-	-	-	1
Control of Major Accident Hazards (COMAH)	-	-	-	1
Electricity Cables	-	-	-	-
Gas Pipelines	-	-	-	-
Recent Industrial Land Uses	5	3	18	-
Current or recent petrol stations	-	-	1	-
Waste and Landfill				
Active or recent landfill (EA/NRW)	-	-	-	-
Historic Landfill (LA)	-	1	-	-
Historic Landfill (BGS)	-	-	-	-
Historic Landfill (EA/ NRW)	-	2	1	-
Historical Waste Sites (LA / OS records)	-	1	4	-
Waste Exemptions	-	2	2	17
Licenced Waste Sites (EA / NRW)	-	-	-	2
Past Land Use				
Historical Industrial Land Uses	20	31	73	103
Historical Tanks	15	-	22	64
Historical Energy Features	2	-	22	46
Historical Petrol Stations	-	-	-	-
Historical Garages	-	-	8	5
Historical Military Land	-	-	-	-
Environmental Designations				
Sites of Special Scientific Interest (SSSI)	-	-	-	-
National Nature Reserves (NNR)	-	-	-	-
Special Areas of Conservation (SAC)	-	-	-	-
Special Protection Areas (SPA)	-	-	-	-
Areas of Outstanding Natural Beauty (AONB)	-	-	-	-
National Parks	-	-	-	-
Green Belt Land	-	-	-	-
Nitrate Vulnerable Zones	-	-	-	-

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6.1 Current Industrial Land Use

6.1.1 Licensed Pollutant Release (Part A (2)/B))

ID	Location	Address	Details	
D	111m N	A Mayne & Sons Ltd, Ashton New Rd, M11 4PD	Process: Petrol Vapour Recovery Status: Historical Permit Permit Type: Part B	Enforcement: No Enforcement Notified Date of enforcement: No Enforcement Notified Comment: No Enforcement Notified

6.1.2 Recent Industrial Land Uses

ID	Location	Company	Address	Activity	Category
A	On site	Tank	Greater Manchester, M11	Tanks (Generic)	Industrial Features
A	On site	Tank	Greater Manchester, M11	Tanks (Generic)	Industrial Features
A	On site	Tanks	Greater Manchester, M11	Tanks (Generic)	Industrial Features

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ID	Location	Company	Address	Activity	Category
B	**On site**	**Travelling Crane**	**Greater Manchester, M11**	**Travelling Cranes and Gantries**	**Industrial Features**
B	**On site**	**Travelling Crane**	**Greater Manchester, M11**	**Travelling Cranes and Gantries**	**Industrial Features**
2	30m W	Mast	Greater Manchester, M11	Telecommunications Features	Infrastructure and Facilities
C	35m W	Compass Mechanical Services Ltd	Unit 11 Clayton Industrial Estate, Crabtree Lane, Manchester, Greater Manchester, M11 1BR	Mechanical Engineers	Engineering Services
C	37m W	Works	Greater Manchester, M11	Unspecified Works Or Factories	Industrial Features
D	79m N	S G B	Clayton Industrial Estate, Crabtree Lane, Manchester, Greater Manchester, M11 1BR	Construction and Tool Hire	Hire Services
D	107m N	Electricity Sub Station	Greater Manchester, M11	Electrical Features	Infrastructure and Facilities
E	115m W	W & W Wholesale Ltd	Unit 14 Clayton Industrial Estate, Crabtree Lane, Manchester, Greater Manchester, M11 1BR	Catering and Non Specific Food Products	Foodstuffs
D	116m N	Walkers Instore	Crabtree Lane, Manchester, Greater Manchester, M11 4GU	Published Goods	Industrial Products
D	120m N	Works	Greater Manchester, M11	Unspecified Works Or Factories	Industrial Features
E	143m NW	Electricity Sub Station	Greater Manchester, M11	Electrical Features	Infrastructure and Facilities
D	156m N	Tank	Greater Manchester, M11	Tanks (Generic)	Industrial Features
F	161m W	Carriages Auto Services Ltd	Invicta House 1, Claytonbrook Road, Openshaw, Manchester, Greater Manchester, M11 1AL	Vehicle Parts and Accessories	Motoring
F	161m W	Garriages Auto Services	Invicta House 1, Claytonbrook Road, Openshaw, Manchester, Greater Manchester, M11 1AL	Vehicle Repair, Testing and Servicing	Repair and Servicing
F	161m W	Knightsbridge Contract & Domestic Furniture	Invicta House 1, Claytonbrook Road, Openshaw, Manchester, Greater Manchester, M11 1AL	Furniture	Consumer Products
7	168m NE	Electricity Sub Station	Greater Manchester, M11	Electrical Features	Infrastructure and Facilities

6.1.3 Current or recent petrol stations

ID	Location	Company	Address	LPG	Status
5	90m E	OBSOLETE	974-998, Ashton New Road, Openshaw, Manchester, Greater Manchester, M11 4PD	Not Applicable	Obsolete

This data is sourced from Experian.

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6.2 Waste and Landfill

6.2.1 Historic Landfill (LA)

ID	Location	Site address	Source	Data type
A	12m W	Refuse Tip	1963 mapping	Polygon

6.2.2 Historic Landfill (EA/ NRW)

ID	Location	Details		
1	**On site**	**Site Address: Crabtree Forge, Crabtree Lane, Forge Lane, Clayton, Manchester** **Licence Holder Address: -**	**Waste Licence: Yes** **Site Reference: RD/LIC/216/81, GDO F049** **Waste Type: Inert, Industrial** **Environmental Permitting Regulations (Waste) Reference: -** **Licence Issue: 28/04/1982** **Licence Surrender: -**	**Operator: -** **Licence Holder: Eva Brothers** **First Recorded 31/12/1942** **Last Recorded: 31/12/1992**
2	11m W	Site Address: Clayton Industrial Estate, Greater Manchester Licence Holder Address: -	Waste Licence: - Site Reference: F048 Waste Type: - Environmental Permitting Regulations (Waste) Reference: - Licence Issue: - Licence Surrender: -	Operator: - Licence Holder: - First Recorded - Last Recorded: -
5	205m W	Site Address: Stockport Branch Canal, Greater Manchester Licence Holder Address: -	Waste Licence: - Site Reference: F056 Waste Type: Inert, Liquid sludge Environmental Permitting Regulations (Waste) Reference: - Licence Issue: - Licence Surrender: -	Operator: - Licence Holder: - First Recorded - Last Recorded: -

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6.2.3 Historic Waste Sites (LA / OS Records)

ID	Location	Address	Further Details	Date
3	20m N	Site Address: Acre Works, Crabtree Lane, Clayton, MANCHESTER, Greater Manchester, M11 1BR	Type of Site: Waste Transfer Depot Planning application reference: 49492 Description: Change of use of industrial into a waste transfer depot. 20 car parking spaces. An application (ref: 49492) for Detailed Planning permission was submitted to Manchester C.C. on 8th March 1996. Data source: Historic Planning Application Data Type: Point	-
B	117m N	Site Address: N/A	Type of Site: Scrap Metal Works Planning application reference: N/A Description: N/A Data source: Historic Mapping Data Type: Polygon	1950
B	117m N	Site Address: N/A	Type of Site: Scrap Yard Planning application reference: N/A Description: N/A Data source: Historic Mapping Data Type: Polygon	1988
B	117m N	Site Address: N/A	Type of Site: Scrap Metal Works Planning application reference: N/A Description: N/A Data source: Historic Mapping Data Type: Polygon	1950
4	191m W	Site Address: N/A	Type of Site: Incinerator Planning application reference: N/A Description: N/A Data source: Historic Mapping Data Type: Polygon	1949

6.2.4 Waste Exemptions

ID	Location	Site	Reference	Category	Sub-Category	Description
A	32m W	Yard 1, Crabtree lane, Manchester, M11 1BR	WEX158614	Using waste exemption	Not on a Farm	Use of waste in construction
A	32m W	Yard 1, Crabtree lane, Manchester, M11 1BR	WEX158614	Storing waste exemption	Not on a Farm	Storage of waste in a secure place
C	233m SW	67 Louisa Street Higher Openshaw Manchester M11 1AD	EPR/JF0101MG/A001	Storing waste exemption	Non-Agricultural Waste Only	Storage of waste in a secure place
C	233m SW	69 Louisa Street MANCHESTER M11 1AD	EPR/JF0801MY/A001	Storing waste exemption	Non-Agricultural Waste Only	Storage of waste in a secure place

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6.3 Past Land Use

6.3.1 Historic Industrial Land Use

ID	Location	Land Use	Date	Group ID
1	On site	Unspecified Heap	1905	976853
2	On site	Corporation Yard	1915	833876
A	On site	Unspecified Pit	1938	891092
A	On site	Cuttings	1956	795828
B	On site	Forge	1938	927324
B	On site	Railway Sidings	1938	953757
B	On site	Railway Sidings	1934	953757
B	On site	Forge	1934	927324
B	On site	Forge	1915	883950
B	On site	Unspecified Works	1985	968646
B	On site	Unspecified Works	1991	968646
B	On site	Railway Sidings	1991	944933
B	On site	Unspecified Works	1968	969086
B	On site	Forge	1923	974769
C	On site	Unspecified Heap	1938	851266
C	On site	Unspecified Heap	1934	851266
D	On site	Refuse Heap	1956	875678
E	On site	Unspecified Commercial/Industrial	1923	796798
F	On site	Unspecified Ground Workings	1923	880372
3	1m SW	Unspecified Ground Workings	1923	800748
E	2m E	Unspecified Works	1978	962653
E	2m E	Unspecified Works	1968	962653
E	3m E	Unspecified Works	1938	926650
E	3m E	Unspecified Works	1934	926650
E	3m E	Unspecified Works	1915	859228
4	10m SE	Unspecified Ground Workings	1905	901924
5	11m W	Unspecified Works	1968	830505
D	11m E	Refuse Heap	1968	875678
G	11m W	Chemical Works	1938	915443
G	11m W	Chemical Works	1934	915443

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ID	Location	Land Use	Date	Group ID
G	11m W	Chemical Works	1915	985767
H	14m N	Chemical Works	1923	898608
H	16m N	Chemical Works	1890	923576
H	17m N	Brick Kilns	1851	827902
G	19m W	Chemical Works	1923	850414
H	19m N	Chemical Works	1905	901354
H	21m N	Chemical Works	1915	898608
I	23m NW	Chemical Works	1915	848810
E	27m E	Iron Foundry	1890	835199
I	29m NW	Unspecified Works	1985	972239
I	29m NW	Unspecified Works	1991	972239
I	31m W	Chemical Works	1923	848810
H	33m N	Unspecified Works	1978	968175
J	33m NE	Chemical Works	1938	865007
J	33m NE	Chemical Works	1934	865007
H	34m N	Unspecified Depot	1985	903448
H	34m N	Unspecified Depot	1991	903448
J	48m NE	Unspecified Ground Workings	1938	887584
J	48m NE	Unspecified Ground Workings	1934	887584
I	49m NW	Unspecified Works	1968	910923
G	55m W	Unspecified Commercial/Industrial	1985	965355
G	55m W	Unspecified Commercial/Industrial	1991	965355
I	67m NW	Unspecified Works	1978	910923
K	71m SE	Brick Field	1923	933262
K	72m SE	Unspecified Pit	1923	840714
H	73m N	Unspecified Works	1991	940609
H	75m N	Unspecified Works	1968	965096
K	76m SE	Disused Brick Field	1915	834328

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ID	Location	Land Use	Date	Group ID
H	86m N	Unspecified Works	1985	940609
H	87m N	Unspecified Works	1978	870097
L	99m NW	Old Sand Pit	1938	913850
L	99m NW	Old Sand Pit	1934	913850
L	108m NW	Sand Pit	1915	929098
F	110m W	Unspecified Pit	1938	982746
F	110m W	Unspecified Pit	1934	982746
L	110m NW	Sand Pit	1923	929098
L	113m NW	Refuse Heap	1956	829161
M	118m SW	Electric Motor Works	1934	896972
M	121m SW	Unspecified Commercial/Industrial	1978	886658
M	121m SW	Unspecified Works	1968	830499
M	123m SW	Unspecified Commercial/Industrial	1956	845443
N	133m W	Soap Works	1915	875760
6	134m W	Unspecified Ground Workings	1956	800750
M	134m SW	Unspecified Pit	1890	950240
N	136m W	Soap Works	1890	991004
N	137m W	Soap Works	1905	933371
N	137m W	Soap Works	1923	975047
K	143m SE	Brick Field	1905	924404
N	144m W	Chemical Works	1915	967087
J	146m E	Unspecified Pit	1968	840715
J	155m E	Unspecified Works	1991	830504
M	156m SW	Unspecified Pit	1905	898168
M	156m SW	Unspecified Pit	1923	868357
M	164m SW	Electric Motor Works	1915	926827
M	171m SW	Electric Motor Works	1923	926827
M	171m SW	Electricity Motor Works	1905	811645

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ID	Location	Land Use	Date	Group ID
P	174m NW	Unspecified Warehouse	1985	969361
P	174m NW	Unspecified Warehouse	1978	931301
P	174m NW	Unspecified Warehouse	1991	969361
P	175m W	Unspecified Ground Workings	1915	800749
K	182m SE	Unspecified Ground Workings	1934	800747
K	182m SE	Unspecified Heap	1956	804176
P	183m W	Unspecified Pit	1905	934039
P	183m W	Unspecified Pit	1890	934039
P	183m W	Unspecified Pit	1923	975009
P	184m W	Sand Pit	1851	797602
7	188m S	Refuse Pit	1890	834314
Q	191m E	Unspecified Wharf	1923	886240
Q	192m E	Chemical Works	1923	979717
N	194m NW	Chemical Works	1905	946148
N	194m NW	Chemical Works	1923	855125
Q	201m E	Unspecified Wharf	1938	866923
Q	201m E	Unspecified Wharf	1934	866923
Q	201m E	Unspecified Wharf	1915	895650
Q	201m E	Chemical Works	1915	979717
P	209m W	Refuse Heap	1956	948721
P	209m W	Refuse Heap	1968	948721
Q	213m E	Unspecified Works	1968	830503
R	214m SW	Unspecified Commercial/Industrial	1985	979765
R	214m SW	Unspecified Commercial/Industrial	1991	979765
P	227m NW	Unspecified Heap	1938	906104
P	227m NW	Unspecified Heap	1934	906104
P	231m NW	Unspecified Heap	1923	906104
8	231m NW	Unspecified Pit	1891	840566

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ID	Location	Land Use	Date	Group ID
S	234m SW	Unspecified Commercial/Industrial	1978	796803
T	236m SW	Corporation Yard	1934	883427
U	241m W	Steel Works	1956	810023
U	241m W	Railway Sidings	1956	877918
R	243m SW	Iron Foundry	1968	904598
U	244m W	Railway Sidings	1934	882010
U	244m W	Engineering Works	1934	912693
U	244m W	Railway Sidings	1915	870808
T	250m SW	Corporation Yard	1923	883427

6.3.2 Historic Tanks

ID	Location	Land use	Dates present	Group ID
C	**On site**	**Tanks**	**1988 - 1994**	**132381**
C	**On site**	**Unspecified Tank**	**1950**	**124985**
C	**On site**	**Tanks**	**1950**	**127740**
C	**On site**	**Unspecified Tank**	**1950 - 1988**	**138112**
C	**On site**	**Tanks**	**1994**	**140257**
C	**On site**	**Unspecified Tank**	**1988**	**143474**
C	**On site**	**Unspecified Tank**	**1994**	**148786**
F	94m N	Unspecified Tank	1893	116254
F	96m N	Unspecified Tank	1933	116256
E	103m W	Tanks	1922	107022
F	156m N	Unspecified Tank	1988 - 1994	127243
F	157m N	Unspecified Tank	1985	128826
K	214m SW	Tanks	1968 - 1979	126978

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ID	Location	Land use	Dates present	Group ID
L	217m W	Unspecified Tank	1922	116253
K	223m SW	Unspecified Tank	1949	116166
K	225m SW	Tanks	1949 - 1968	133526
K	234m SW	Unspecified Tank	1949	116168
N	235m E	Unspecified Tank	1985 - 1991	131003
N	235m E	Unspecified Tank	1972	131457
N	236m E	Unspecified Tank	1950	123381
N	236m E	Unspecified Tank	1950	140830
N	242m E	Unspecified Tank	1950 - 1972	147122

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6.3.3 Historic Energy Features

ID	Location	Land Use	Date	Group ID
B	**On site**	**Electricity Substation**	**1950**	**73249**
B	**On site**	**Electricity Substation**	**1950**	**73249**
H	92m N	Electricity Substation	1994	77163
H	92m N	Electricity Substation	1994	77163
H	93m N	Electricity Substation	1950	77163
H	93m N	Electricity Substation	1985	77163
H	93m N	Electricity Substation	1950	84691
H	93m N	Electricity Substation	1988	77163
L	143m NW	Electricity Substation	1980	75348
L	143m NW	Electricity Substation	1985	75348
L	143m NW	Electricity Substation	1994	82356
L	143m NW	Electricity Substation	1994	82356
L	144m NW	Electricity Substation	1988	68694
M	161m SW	Electricity Substation	1991	62222
M	170m SW	Electricity Substation	1996	76489
M	170m SW	Electricity Substation	1999	76489
O	173m NE	Electricity Substation	1994	84429
O	173m NE	Electricity Substation	1994	84429
P	211m W	Electricity Substation	1972	73239
P	211m W	Electricity Substation	1983	73239
P	211m W	Electricity Substation	1979	66068
P	211m W	Electricity Substation	1983	66068
P	211m W	Electricity Substation	1996	66068
P	211m W	Electricity Substation	1995	66068

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7 PREVIOUS NORWEST HOLST SOIL ENGINEERING (NHSEL) INVESTIGATION (APRIL 2005)

7.1 General

The NHSEL investigation was undertaken at the request of Manchester City Council (MCC).

The fieldwork was carried out between 18th and 24th January 2005, and comprised;

- Eleven (11no.) window sample boreholes to depths of between 3.30mbgl and 8.55mbgl
  - Where appropriate, U100s or CPTs were used
- Monitoring pipes were installed in BH01, BH07 and BH11
- Collection of twelve (12no.) environmental samples
- Geotechnical analysis for moisture content, atterberg limit, 1D consolidation and multistage undrained triaxial compression.

A summary of the report is given below.

7.2 Summary

7.2.1 Made Ground

MADE GROUND was observed between 1.80mbgl and 8.10mbgl in all locations.

This material was commonly observed as ash, brick, clinker, concrete, limestone, coal, clay and road planings. The thickest MADE GROUND was observed in the centre of the site in an east/west trend.

7.2.2 Superficial Deposits

Underlying the MADE GROUND, in the majority of locations, was a firm to stiff boulder CLAY which was recorded to depths of between 2.85mbgl and 7.05mbgl. The CLAY had a maximum proven thickness of 3.20m in BH02.

In BH01, BH03 and BH11 the CLAY was underlain by medium dense and dense brown silty gravelly SAND from depths of between 2.85mbgl and 4.00mbgl. These three boreholes were all completed in SAND.

BH09 and BH10 showed thickly laminated grey organic SILT below MADE GROUND. BH09 the SILT was found at 8.10mbgl and was proved to base of borehole at 8.55mbgl. In BH10 the SILT was noted from 4.55mbgl to 4.95mbgl and was underlain by boulder CLAY.

7.2.3 Groundwater

Groundwater was not observed during the investigation.

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7.2.4 Foundations

Consideration to use of vibro-compaction to form deep stone columns after discussion with a suitable contactor. Alternatively, a piled solution may be applicable, however, the investigation did not acquire suitable information to allow for design.

Ground floor slabs could be constructed on vibro-improved ground. A suspended slab would be required if a piled solution was implemented.

7.2.5 Concrete Design

pH levels were recorded between 5.4 and 9.8 and sulphate levels were recorded up to 1.61g/l. These levels indicate a Design Sulphate Class of DS-2.

7.2.6 Contamination Testing Results

Determinant	Reference Value	Highest Value	True Mean (US_{95})
Arsenic	20	48.8	23.31
Cadmium	2	0.75	1.86
Chromium	130	47.54	68.1
Copper	190	607.2	216.26
Lead	450	322	162.31
TPH	1000	1074.3	520.68
PAH	20	254.4	96.54

The table indicates that there elevated concentrations of Metals, TPHs and PAHs.

Statistical analysis of the Cadmium and chromium indicate that they are associate with local hotspots, whilst the remaining metal exceedances are representative of the wider sampled population.

Similarly, TPHs are shown to be localised hotspots, PAHs are representative of the wider site soils.

Betts Geo note that some of these thresholds have now been adjusted, this will be taken into account during the Betts Geo Assessment.

7.2.7 Soil Contamination – Recommendations

Data suggests that the contamination is found within the MADE GROUND strata. Due to the large volumes of MADE GROUND, removal is unlikely to be considered appropriate. Table 4 of the NHSEL report indicates that the contamination is not mobile, and the site was found to be dry, and therefore the site poses little risk to groundwater.

Installation of clean and inert capping to gardens and landscaped areas will be sufficient to remove risk to human health.

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7.2.8 Gas Contamination

No elevated methane was recorded; however, carbon dioxide was noted in WS11 at a concentration of 8%. The use of gas protection measures will be required for the site.

Betts Geo note that gas flow was not checked during the gas monitoring, an no visits were undertaken below 1000mb atmospheric pressure.

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8 SUMMARY OF ENVIRONMENTAL SENSITIVITY

The following section is a review of the environmental sensitivity of the site as discussed in Sections 2-6. Significant potential risks are discussed in the following subsections and will then be evaluated as part of the Site Conceptual Model in Section 8.

Sources are defined as where pollution comes from, pathways are a route in which the pollution travels and receptors are anything affected by a pollutant. Further details on Source-Pathway-Receptor methodology can be found in Appendix F.

The table below focuses on significant site-specific sources, pathways and receptors. More 'generic' pathways and receptors (such as site end users) will be covered as part of the full Site Conceptual Model in Section 14.

8.1 Sources

Source	Distance/ Direction	Details	Significant Risk
Current Land Use	On Site	The site is currently largely unused but the historical development has only been partially demolished. Ground investigation required to determine historical site impact. Potential risk of heavy metals, VOC/SVOC, TPH's, PAH's, asbestos, where made ground remains onsite.	**Likely**
Historic Land Use	On Site	Significant industrial usage. Risk of heavy metals, TPH's, PAH's, VOC/SVOC, asbestos.	**Likely**
Surrounding Land use	Adjacent to site boundary	The land surrounding the site has been mixed residential and industrial/commercial. Significant industry has been limited. Ground investigation to determine contamination impact. Potential risk of heavy metals, TPH's, PAH's, asbestos from these sources, however anticipated cohesive superficial geology surrounds the site limiting any migration onto site.	**Possible (Localised)**

8.2 Pathways / Receptors

Pathways and Receptors	Distance/ Direction	Details	Significant Risk
Aquifers	Below Site	For the majority of the site, bedrock deposits are classed as low to moderate permeability aquifer, however they are overlain by cohesive deposits of glacial till. Further ground investigation to confirm risk. The site is not within a Groundwater Protection Zone.	**Unlikely**

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9 INITIAL CONCEPTUAL SITE MODEL

For details on how the conceptual model is evaluated please refer to Appendix F

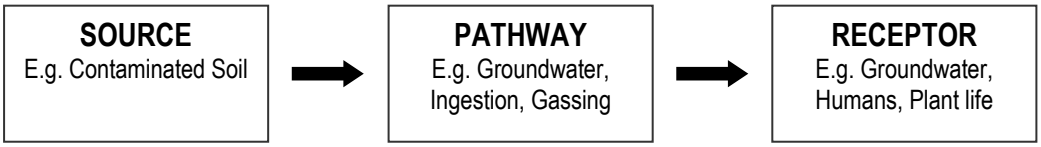
This section of the report aims to identify land which could potentially be affected by contamination, such that it could affect the value or re-use of the land, or such that mitigation would be required for certain proposed end uses of the land.

Potential contamination sources and environmentally sensitive receptors have been discussed in Section 7. Potentially significant risks are evaluated as part of the subsequent sub-sections.

9.1 Source-Pathway-Receptor Linkages

The risk assessment uses a 'Source-Pathway-Receptor' methodology for assessing whether a source of contamination could potentially lead to harmful consequences. This means that there needs to be a pollutant linkage from source to receptor for harm to be caused, this linkage consisting of: a source of pollution; a pathway for the pollutant to move along; a receptor that is affected by the pollutant.

The current potential risks to site arising from various source-pathway-receptor linkages are assessed below. A risk may be considered significant if all three of the stages are present and therefore providing a pollution linkage. The various sources, pathways and receptors are considered separately. The assessment is based on the future use, which is understood to be residential with garden area.



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Type of Contamination	Potential Sources	Potential Pathway	Potential Receptors	Pollution Linkage	Comment	Estimated Level of Risk
Ground Gas	Current Land Use- onsite Historic Land use Made Ground Surrounding Land Use	Inhalation of Vapours	Construction/ Maintenance Workers	**Potentially Active**	Made Ground anticipated due to former development which is a potential source for ground gas. Ground investigation and ground gas monitoring to confirm.	**Low / Moderate**
		Vapours Penetrating Unprotected Buildings	Future Site Users	**Potentially Active**	Made Ground anticipated due to former development which is a potential source for ground gas. Ground investigation and ground gas monitoring to confirm.	**Low / Moderate**
Surface and Near Surface Contaminants Within Soils	Current Land Use- onsite Historic Land use Made Ground Surrounding Land Use	Ingestion, Inhalation, Dermal Contact	Current Site Users	**Potentially Active**	Made Ground anticipated due to historical development. Possible contaminants include heavy metals, TPH's, VOC/SVOC, PAH's and asbestos. Ground investigation and ground gas monitoring to confirm.	**Moderate**
			Construction Workers	**Potentially Active**	Made Ground anticipated due to historical development. Possible contaminants include heavy metals, TPH's, VOC/SVOC, PAH's and asbestos. Ground investigation and ground gas monitoring to confirm.	**Moderate**
			Future Site Users	**Potentially Active**	Made Ground anticipated due to historical development. Possible contaminants include heavy metals, TPH's, VOC/SVOC, PAH's and asbestos. Ground investigation and ground gas monitoring to confirm.	**Moderate**
			Adjacent Land Users	**Potentially Active**	Made Ground anticipated due to historical development. Possible contaminants include heavy metals, TPH's, VOC/SVOC, PAH's and asbestos. Ground investigation and ground gas monitoring to confirm.	**Low**
		Direct Contact	Structures	**Potentially Active**	Made Ground anticipated due to historical development. Possible contaminants include heavy metals, TPH's, VOC/SVOC, PAH's and asbestos. Ground investigation and ground gas monitoring to confirm.	**Low / Moderate**
		Absorption in Root Zone	Plants	**Potentially Active**	Possible TPH, PAH, VOC/SVOC, heavy metals and sulphates within Made Ground. Ground investigation to confirm.	**Low**
Mobile Contaminants, Leachables e.g. from Pollution Sources Adjacent to Site/On Site	Current Land Use- onsite Historic Land use Made Ground Surrounding Land Use	Leaching into Groundwater	Groundwater	**Potentially Active**	Cohesive superficial deposits are recorded as secondary A and undifferentiated Aquifers. Cohesive strata will limit migration. Solid geology recorded as Secondary B Aquifer.	**Low / Moderate**
		Off-site Migration in Groundwater	Abstractions	**Potentially Active**	There are no potable groundwater abstractions within 500m of site.	**Low**
			Controlled Waters	**Potentially Active**	Nearest surface water features are located onsite and adjacent to the site boundary. Superficial deposits are recorded as secondary undifferentiated and are cohesive.	**Low**
Organic and Inorganic Contaminants Within Soils / Groundwater	Current Land Use- onsite Historic Land use Made Ground Surrounding Land Use	Potable Water Supply Pipes	Utilities Workers	**Potentially Active**	Possible TPH, PAH and VOC contamination from Made Ground on site. Ground investigation to confirm, then liaise with local water authority supplier.	**Low / Moderate**

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9.2 Summary

In this qualitative risk assessment, a **Low to Moderate** risk for contamination and ground gas exists across the site. Remedial action is likely to be necessary at the site, the likes of which cannot be confirmed until the geotechnical and contamination ground investigation has been completed.

It is anticipated that elevated risks are generally linked to extensive industrial site history and likelihood of Deep made ground.

9.3 Geotechnical Risk

- Depth of Made Ground from former foundations, demolition material and infilled land
- Possible heave / shrink in cohesive strata due to trees (predominantly in the west of the site)
- Buried foundations and other underground structures
- Possible culverted stream below south of site

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10 FIELDWORK

10.1 Fieldwork Objectives

The objectives of the intrusive ground investigation will be to:

- Clarify the shallow ground conditions encountered within the Third-Party Reports provided by the client.
- Clarify deeper ground conditions for piled foundation design.
- Clarify the 'Initial Contamination Conceptual Model'.
- Clarify the Initial Risk Assessment.
- Benchmark the contamination status of the site.
- Provide data for the design of any remedial works that may be required.
- Provide a geotechnical appraisal for the site area.

10.2 Fieldwork Scope

The initial fieldwork was carried out between 9th-10th August 2021 and comprised the following;

- Seven (7no) machine excavated trial holes to depths between 0.60mbgl (TP4) and 1.95mbgl (TP7).
- Four (4no) window sample boreholes to depths of up to 4.00mbgl.
- Chemical analysis (Metals, PAH's, TPH's) of ten (10no.) samples.
- Analysis of ten (10no.) samples for asbestos analysis.
- Two (2no) samples for geotechnical analysis, including pH, water soluble sulphate and Atterburg limits.

The exploratory hole positions were selected and set out by Betts Geo as shown on the Exploratory Hole Location Plan in Appendix B.

Prior to any intrusive works, each location was checked for services using a cable avoidance tool (CAT) and review of statutory service plans.

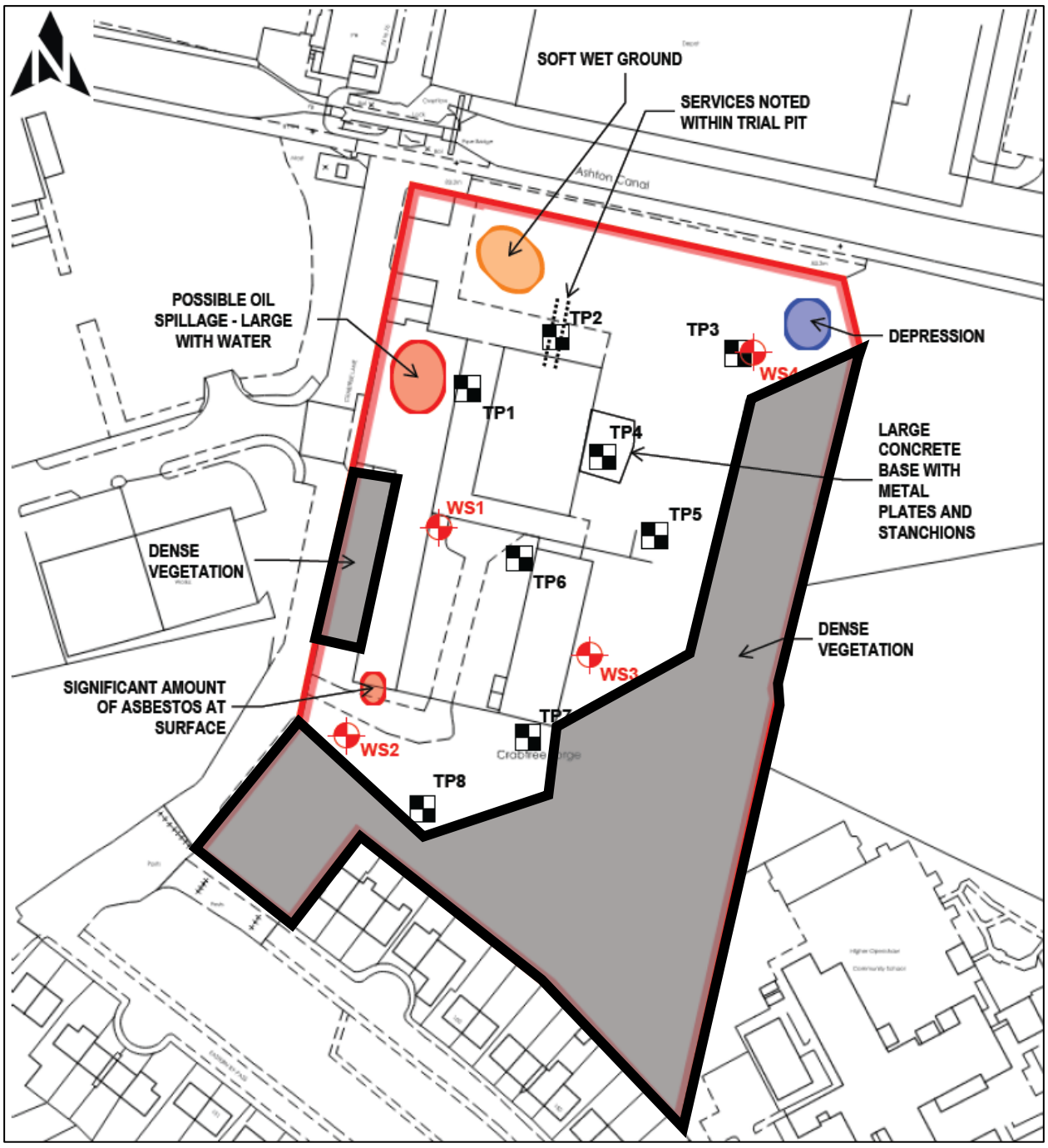
10.3 Targeted Investigation

The holes were generally positioned to achieve a general spread across the various site areas, however, TO was positioned near to a former tank.

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10.4 Areas Not Accessed

As shown on the sketch below, some areas were not accessible due to dense vegetation.



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11 GROUND CONDITIONS

11.1 General

The exploratory holes were logged by an Engineer in general accordance with the recommendations of BS5930:1999+A2:2010 Detailed descriptions, together with relevant comments, are given in the exploratory hole logs included in Appendix C.

11.2 Ground Conditions Summary

The prevailing ground conditions at the site can generally be summarised as MADE GROUND of various granular deposits to depths of greater than 2.95mbgl.

MADE GROUND was noted overlying NATURAL strata of CLAY in WS101, and TP1 from 1.20mbgl.

11.3 MADE GROUND

MADE GROUND was observed in all locations and was commonly described as 'Medium dense black fine to coarse SAND & GRAVEL. Gravel is fine to coarse angular to subrounded of ash, clinker and brick'. This is in line with the findings of 'infilled land' in the desk study section of this report and the previous investigation. This stratum was noted to a maximum observed depth of 4.00mbgl.

Minor amounts of differing MADE GROUND were observed in various locations across the site and comprised of both granular and cohesive deposits with anthropogenic components such as limestone gravel (possible MOT Type 1) and crushed brick.

A 'pulpy' type material was observed in WS102 from 3.80-4.00mbgl (base not proven). The material was described as 'Soft to firm black and yellow clayey PULP like material'. This material is of unknown origin and depth.

MADE GROUND was observed to a maximum depth of 4.00mbgl in WS102 and WS103, the base was not proven.

11.4 COHESIVE – Natural

Natural cohesive strata were recorded in TP1 and WS101. The CLAY was generally described 'Firm to stiff light brown and grey sandy silty CLAY. Becoming dark and stiff to very stiff with depth' or 'Firm yellowish brown slightly sandy CLAY' and were recorded to depths of between 1.20mbgl and 2.35mbgl (TP1) and 3.50mbgl and 4.00mbgl (WS101), the base was not proven.

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11.5 Obstructions

Obstructions were noted in the locations detailed below:

Location	Depth (mbgl)	Description
TP2	0.95	Two services (pipework) spanning pit – likely live
TP4	0.60	Very dense concrete slab edged by metal boards/strips with stanchions. Probable machine base or similar. Slab at least 3m x 3m
WS104/TP3	0.90	Concrete base – very dense

11.6 Possible Void

A possible void was noted WS101, based on the SPT results, as shown below;

WS101

Depth (mbgl)						
1.20-1.65	1	2	1	1	1	2
2.00-2.45	**1**	**0**	**0**	**0**	**0**	**0**
3.00-3.45	3	2	1	2	2	2
4.00-4.45	2	2	2	2	2	3

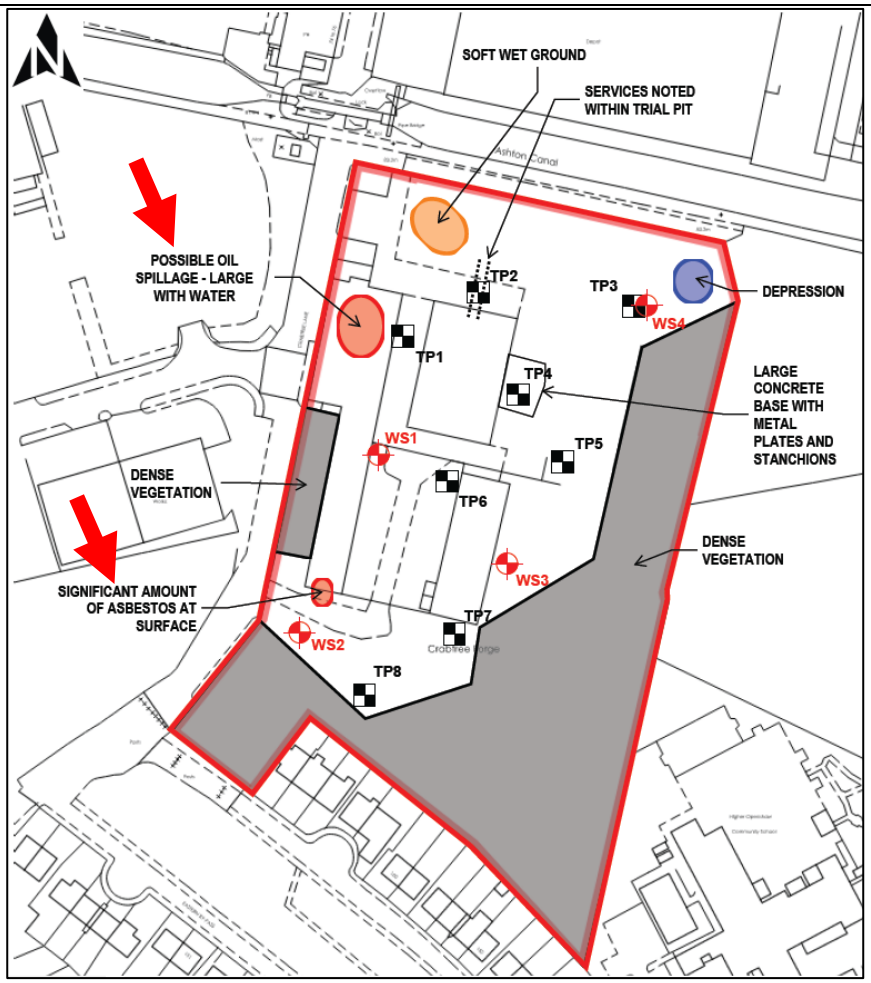
11.7 Visual and Olfactory Contamination

Other than the MADE GROUND, visual / olfactory information was noted in the following locations;

Location	Depth (mbgl)	Description
TP2	0.95	Creosote odour
TP8	0.45-1.90	Multiple pieces of asbestos – possible chrysotile sheeting

Surface contamination was noted in the locations below;

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11.8 Groundwater – Fieldwork

No groundwater was observed during the investigation.

11.9 Groundwater – Post Fieldwork Monitoring

Monitoring is underway and will be updated once the first visits have been carried out.

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12 LABORATORY TESTING GENERAL

An assessment of potential determinants associated with the current / former site uses has been undertaken. Determinants originating from the current/former site uses may include metals, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs) and asbestos. A general suite of testing should detect most potential contaminants.

12.1 Scheduled Chemical Testing: Soils

Soil was sent to a UKAS accredited laboratory and were generally analysed in accordance with ISO 17025 and/or MCERTS accreditation. The results are summarised in tabular and/or graphical form in Appendix D.

Chemical Test	No. of Samples	Comment/Method
pH Values	12	Determination of pH (using Cyberscan pH meter).
Sulphate - Soluble 2:1 Extract	12	Dionex.
Arsenic, Cadmium, Chromium VI, Chromium III, Total Chromium, Lead, Mercury, Selenium, Copper, Nickel, Complex and Free Cyanide and Zinc.	10	Soil samples were analysed in accordance with UKAS/MCERTS standards Inductively coupled plasma atomic emission spectroscopy (ICP-OES)
Speciated Polycyclic Aromatic Hydrocarbons (PAH),	10	Determination of Polycyclic Aromatic Hydrocarbons by GC-MS. End/end extraction using DCM on as received sample. In house method modified USEPA 8270. Include coronene if required.
TPH CWG	10	TPH CWG (Aliphatics C5-6,>6-8,>8-10,>10-12,>12-16,>16-21,>2-35) (aromatics >C5-7,>7-8,>8-10,>10-12,>12-16,>16-21,>21-35) C5-8 fractions by Headspace GC-MS (003S). C8-35 fractions on as received sample extracted with hexane/acetone, aliphatic/aromatic splits run by GC-FID (005S), banded as listed above.
GRO/BTEX/MTBE by GC-FID (C5-10; C10-C12)	10	Determination of Gasoline Range Hydrocarbons (GRO) and BTEX (MTBE) compounds by Headspace GC-FID (C4-C12).
Organic Matter	10	Determination of Organic Matter by combustion.
Asbestos Screen	10 (3)	Visual Screening for Fibres (No. of Quantified samples).
Atterburg Limits	10	BS1377 Part 2. 1990, 4.3,5.3,5.4
Moisture Content	2	BS1377 Part 2. 1990, 3.2
VOC / SVOC	5	GC-MS

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13 CONTAMINATION ASSESSMENT

13.1 General

Contaminants of concern recorded at concentrations above relevant screening values are summarised below. For ease of description, the identification of contaminant sources and possible re-use of material, Topsoil, Made Ground, Natural Strata and Groundwater will be dealt with in separate sub-headings in this section of the report where required.

Our assessment is based on the following assumptions:

- The proposed site end use in of a high-risk rating (residential housing with gardens). For analysis purposes, 'residential with home grown produce' is deemed most appropriate end use.
- The Manchester Marl beneath site is classed as a Secondary B Aquifer (Low Permeability).
- Glacial Till deposits are likely to be generally low permeability, but also may be variable due to the nature of the deposits.
- It is deemed that some statistical analysis is appropriate. Where sample data numbers are low and/or targeted, each determinant result is however reviewed further as an individual result as opposed to an average across the site.
- Site history has indicated a **High** risk of contamination.
- Statistical analysis of the chemical test results has been undertaken in general accordance with Environment Agency 2009 SGV Guidance and AtRisk 2015 using the combined assessment criterion given by CLEA (Note: all SSVs for EA derivation are for a SOM of 6%, in line with Environment Agency Report SC050021/SR4 – this figure is deemed representative as an average value for a sandy loam soil). AtRisk 2015 are used to the nearest SOM percentage deemed appropriate. Where appropriate C4SL's could be utilised, when the site is not grossly contaminated.
- Other than sheens, no free product was noted within the exploratory holes.
- Following the withdrawal of CLR 7-10 Guidance documents by the Environment Agency, statistical analysis has been undertaken in accordance with the CIEH/CL:AIRE 'Guidance on Comparing Soil Contamination Data with a Critical Concentration' (May 2008). As such, the use of the mean value test alone is not considered.

A full risk assessment is detailed within Section 12 of this report.

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13.2 Soils Contamination Summary

13.2.1 Made Ground

All determinants for Metals, TPHs and PAHs fell below the residential home grown produce guidance levels within Made Ground strata, with the exception of the following;

Betts Geo Investigation					
Location	**Depth (mbgl)**	**Determinand**	**Observed Concentration (mg/kg)**	**AtRisk 2017 (mg/kg)**	**DEFRA C4SL 2017 6%SOM (mg/kg)**
WS102	3.80	Arsenic Copper Chrysotile & Amosite	52 6570 3.822%	32 4790 <0.001%	37 - <0.001%
WS103	2.00	Chrysotile	0.025%	<0.001%	<0.001%
TP6	1.00	Chrysotile	<0.001%	<0.001%	<0.001%
TP8	1.00	Benzo(a)pyrene	1.84	1.51	4.95
NHSE Investigation - 2005					
Location	**Depth (mbgl)**	**Determinand**	**Observed Concentration (mg/kg)**	**AtRisk 2017 (mg/kg)**	**DEFRA C4SL 2017 6%SOM (mg/kg)**
BH04	0.00	Benzo(a)pyrene Naphthalene	2 3.1	1.51 0.829	4.95 -
BH07	4.85	Arsenic Lead Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(ah)anthracene Naphthalene	48.8 322 9 11.6 13.1 1.6 2.1	32 - 4.52 1.51 7.72 0.838 0.829	37 200 - 4.95 - - -
BH08	4.85	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(ah)anthracene	10.9 14.4 14.6 1.7	4.52 1.51 7.72 0.838	- 4.95 - -
BH10	2.75	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(ah)anthracene Naphthalene	17.5 21 17.9 4.1 1.5	4.52 1.51 7.72 0.838 0.829	- 4.95 - - -
BH11	4.85	Lead	261	-	200

13.2.2 VOC / SVOC Testing

The vast majority of the VOC / SVOC do not have regulatory guidance levels, therefore where levels have returned above the laboratories limit of detection, they have been included in the tables below.

It is important to note that guidance values given are in mg/kg while the concentrations found on site are given in ug/kg, therefore care must be taken when converting these values.

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All areas where VOCs/SVOCs have been detected have been shown below, although no thresholds were available for the determinants detected.

Location	Depth (mbgl)	Determinand	Observed Concentration (µg/kg)	AtRisk 2017 (mg/kg)
WS101	0.50	Dibenzofuran Carbazole 2-Methylnaphthalene Perylene	384 465 317 523	- - - -
WS102	3.80	2-Methylnaphthalene	322	-
TP2	0.85	Carbazole 2-Methylnaphthalene Perylene	140 269 537	- - -
TP6	1.00	Perylene	187	-

13.2.3 Natural Strata

All determinants for Metals, TPHs and PAHs fell below the residential home grown produce guidance levels within natural strata.

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14 ENVIRONMENTAL RISK ASSESSMENT

14.1 General

This section assesses likely risks to the identified receptors, arising from potential contamination sources. It provides a final qualitative assessment of the risks involved, indicating whether (where appropriate) any immediate action is required to mitigate certain risks.

In assessing the risk qualitatively, it is appropriate to use the methods outlined in the CIRIA document C552, "Contaminated Land Risk Assessment a Guide to Good Practice". It uses a classification of risk based on the magnitude of the potential consequence or severity of risk occurring, compared with the magnitude of the probability or likelihood of the risk occurring. These are indicated on the attached tables in Appendix H.

The superficial deposits are classed as being of variable permeability and the bedrock is classed a Secondary B Aquifer and is negligible-low permeability. Therefore, the site's environmental setting is considered to be a low to moderate environmental sensitivity. With respect to human health, the proposed end use (residential use with home-grown produce) is of high sensitivity. Transient risks to construction workers can be addressed by the adoption of appropriate health and safety measures (see Section 14.2).

14.2 Assessment of Soil Contamination Results

Elevated concentrations of various metals, asbestos, PAHs and SVOCs have been observed chemical samples in a number of locations across the site, in addition to the surficial, visual and olfactory contamination observed during the site works.

The presence of asbestos within the Made Ground is likely due to poorly managed historical demolition. This is evident from the deposits noted at surface.

ICRCL Guidance Note 64/85 "Asbestos on Contaminated Sites" (1990) is still the most current guidance for asbestos in soil and suggest asbestos fibres should be <0.001% w/w within soil. Dutch and Australian Guidance also suggest the use of a threshold of 0.001% as a threshold for asbestos in soil. The Dutch Guidelines consider the risk from Chrysotile to be ten times less than Amphibole (includes Amosite) asbestos but the HSE, WHO, the Australian DoH and the USEPA have chosen not to distinguish between different asbestos fibre types.

The concentrations of asbestos within made ground potentially poses a risk to end users and construction workers, if the material is exposed and soil and asbestos fibres allowed to become airborne in particular, the chrysotile and amosite in WS102 (3.822%) Groundworks should follow CAR-SOILTM Guidance. Given that the material used to back fill comprises some demolition waste, the presence of further asbestos is possible.

Due to the presence of Naphthalene at depth in a number, the use of VOC vapour resistant membranes may be required. This may be reassessed during further investigation or demolition works.

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Other VOCs / SVOCs detected do not have regulatory guidance levels and were detected at relatively low concentrations. They may however still pose a risk to human health, further investigation may be required to adequately address that potential risk.

Due to the widespread nature of contamination, remedial measures will be required across the site. These measures are addressed in Section 17.

14.2.1 Groundwater and Aquifer Risk

The underlying aquifer and groundwater are largely protected by cohesive clay strata. No significant mobile contamination has been observed, neither has any perched water.

14.2.2 Risk To Canal

The risk of contamination to the adjacent canal to the north of the site is deemed low due to the anticipated cohesive superficial geology surrounding the clay preventing any significant contamination migration. A road/access track is also present between the canal and the site, increasing its distance from site.

Protection measures may be required during the construction works to prevent any water ingress during the earthworks and sediment runoff will need to be controlled.

If any unofficial connections are discovered to the canal during the construction works, they will be blocked up to prevent any water from the site draining to the canal.

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15 GROUND GAS ASSESSMENT - PRELIMINARY

15.1 Ground Gas Requirements – Radon

BRE211 (2007) Radon: guidance on protective measures for new buildings shows it is in a lower probability area, as less than 1% of homes are above the action level. Therefore, no Radon protective measures are necessary in the construction of new dwellings or extensions.

15.1.1 Guidance

Three recent publications are used for ground gas risk assessment:

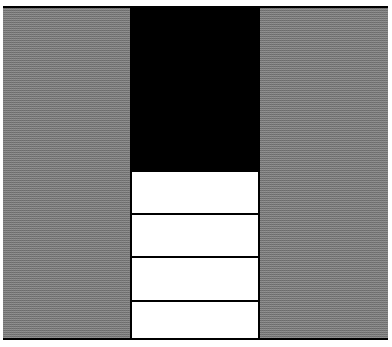
- 'Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present', Report Edition No.04 March 2007 NHBC – designed for use with low rise residential properties
- CIRIA C665 'Assessing risks posed by hazardous ground gases for buildings' 2007 - for high rise residential / flats
- BS8485:2015 'Code of practice for the characterization and remediation from ground gas in affected developments'

Further details / accompanying notes for the following gas risk assessment are enclosed in Appendix I. The proposed development at the site is private residential two-storey houses, therefore assessments using the NHBC Guidance are deemed most appropriate.

15.2 Ground Gas Assessment

15.2.1 Ground Gas Boreholes Installations

Three (3 No.) window sample boreholes were all installed to depths between 3.00mbgl and 4.00mbgl into both Made Ground. An example installation is shown below;



15.2.2 Summary of Results

Ground gas monitoring is complete (6/6 visits have been undertaken). WS4 had been destroyed on the first visit, therefore no readings were possible from this well.

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Slightly elevated carbon dioxide (greater than 5%) was noted in WS01 on four out of the six visits. Slightly depleted oxygen was also noted in WS01 and WS03 on four of the six visits. Flow rates remained low across all of the visits (max 0.1l/hr).

The previous third party investigation also identified elevated carbon dioxide in WS11 at a concentration of 8%.

Due to the history of the site and the MADE GROUND encountered during the initial ground investigation, it is proposed Amber 1/CS2 ground gas protection is utilized across site. Additional ground gas monitoring is required in the areas that could not be accessed due to dense vegetation/existing buildings (post demo) during the initial investigation.

15.2.3 Gas Recommendations

The Betts Geo ground gas assessment is shown below;

Site Area	Site Classification	Recommended Ground Gas Protection Measures
Whole Site	Amber 1 / CS2	Low-level ground gas protection measures are required, using a membrane and ventilated sub-floor void that creates a permeability contrast to limit the ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.

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16 REVISED CONCEPTUAL SITE MODEL

16.1 General

The Initial Conceptual Site Model has been amended in light of data obtained during the ground investigation, most notably the absence of any contaminated soil in relation to the screening criteria for the proposed end use.

16.2 Final Conceptual Site Model

This section reassesses likely risks to the identified receptors, arising from potential contamination sources. It provides a final qualitative assessment of the risks involved, indicating whether (where appropriate) any immediate action is required to mitigate certain risks. It also discusses (where appropriate) what longer term measures or remedial works may be required in the future if the site were to be developed. It is considered that the site has not been assessed by the Local Authority as a contaminated site under the terms of the Environmental Protection Act 1990 Part IIa.

Target (Receptor)	Potential Source-Pathway Linkage	Remedial Action Required (where appropriate)	Est. Degree of Risk to Target Following Remedial Action Where Necessary
Site End Users	Inhalation of soil gases, odours or dust.	Amber 1/CS2 ground gas protection is recommended across site. Additional ground gas monitoring is required in the areas that could not be accessed due to dense vegetation/existing buildings (post demo) during the initial investigation.	Low
Site End Users	Ingestion of, and skin contact with, contaminated soil.	Whole site requires 600mm/1000mm minimum clean and inert capping with geotextile break layer as per NHBC guidance.	Low*
Site End Users	Ingestion of contaminants in vegetables etc. or in soils adhering to vegetables, etc	Whole site requires 600mm/1000mm minimum clean and inert capping with geotextile break layer as per NHBC guidance	Low *
Construction/ Maintenance Workers.	Inhalation of soil gases, odours or dust.	PPE	Low **
Construction/ Maintenance Workers.	Ingestion of, and skin contact with, contaminated soil	PPE	Low **
Plants	Adverse effects on growth caused by presence of contaminants in soil	Whole site requires 600mm/1000mm minimum clean and inert capping with geotextile break layer as per NHBC guidance	Low*
Buildings and Structures	Flow of ground gas into buildings. Asphyxiation, toxicity, explosion and fire hazards	Amber 1/CS2 ground gas protection is recommended across site. Additional ground gas monitoring is required in the areas that could not be accessed due to dense vegetation/existing buildings (post demo) during the initial investigation.	Low
Foundations	Sulphate attack of foundations	Foundations to be designed as per section 16.9	Low

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Water Supplies	Hydrocarbons penetrating plastic water supply pipes.	United Utilities pipeline risk assessment required. Protect-a-Line due to elevated TPH/VOC/SVOC pipes anticipated.	Low
Groundwater	Migration of soluble contaminants into groundwater on or off site	No remedial action required. Significant thickness of cohesive strata will limit vertical migration.	Low
Surface Water	Migration of soluble contaminants and/or direct run-off of contaminants	No highly mobile, with regards to water, contamination observed at site. No significant risk anticipated to the nearby canal however protection measures may be required during the construction works to prevent any water ingress during the earthworks and sediment runoff will need to be controlled.	Low

** assumes basic PPE is used

* Site levels within garden areas may need lowering to allow for the 600mm cover system.

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17 OUTLINE STRATEGY FOR RISK REDUCTION/REMEDIATION STRATEGY

17.1 General

The following section details any recommendations and to reduce risk on site and recommended remedial actions (as per the previous sections of this report). For clarity, the section is split into sub-sections as per the conceptual site model (Section 14).

17.2 Construction/Maintenance Workers

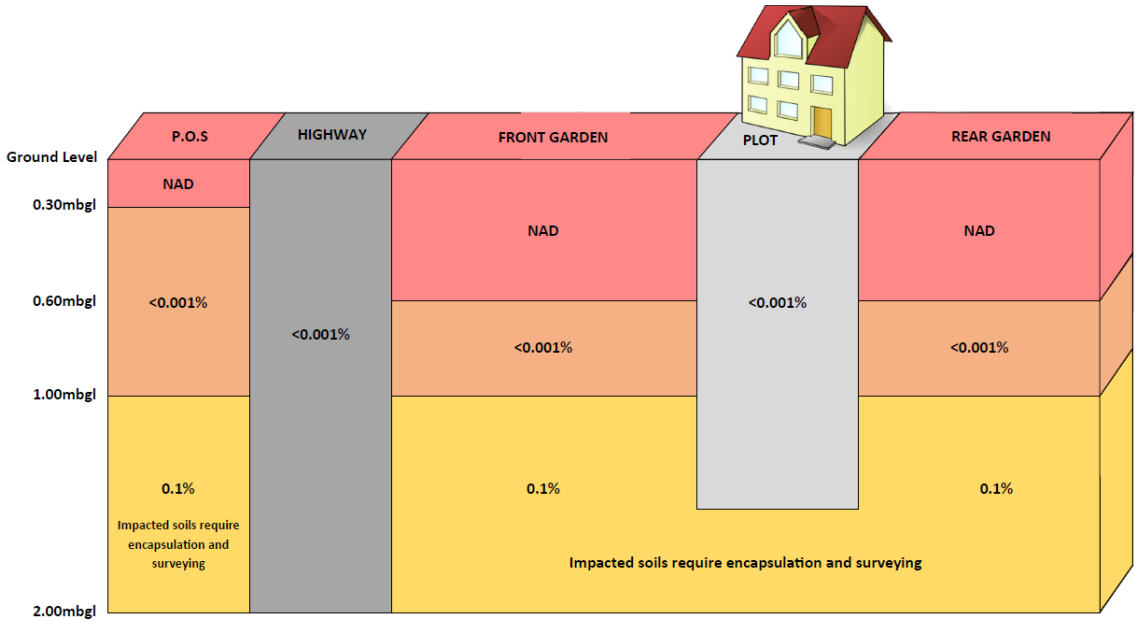
The following recommendations should be adhered to during site works:

- Toolbox talk on asbestos.
- Consideration to dampening down during work within made ground.
- Site workers should wear gloves, boots and overalls and wash their hands before eating, drinking and smoking. Excessive dust generation should be avoided.
- It is recommended that during all excavations adequate ventilation should be maintained. If man entry is required, gas monitoring should be carried out as a precaution.
- If areas of suspected contamination are found then a suitably qualified person should undertake appropriate sampling, testing and further risk assessment.

17.3 Site-End Users

Below is a sketch showing levels of asbestos concentrations and locations where they are commonly accepted / unacceptable. This should be confirmed with the Local Authority prior to implementation, and should therefore only be used as a guide;

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Notes:

P.O.S - Public Open Space

NAD - No Asbestos Detected

0.001% - Soils may contain ≤0.001% using composite testing to ensure there is no potential risk to human health. Value is present where there may be short-term low level exposure of soils containing trace asbestos fibres by construction workers where an appropriate level of asbestos management is employed (e.g. dust suppression).

0.1% - Soils at depth of >1.00mbgl may contain <0.1% asbestos using composite testing where they will be not likely not be disturbed in the future and will therefore be in an area of Low Sensitivity. Risk assessment completed in accordance with the Asbestos JIWG Risk Assessment Tools.

Undefined - Dependant upon soils encountered during earthworks, which may be placed at depths to ensure no potential risk to human health.

Burial and encapsulation of asbestos should be agreed with regulators and consultant prior to the works being undertaken. Consideration should also be made to CAR-SOIL ™.

This methodology of reusing asbestos impacted soils will require carefully managed soil movements, in conjunction with an MMP (Materials Management Plan) and Local Authority agreement and signoff.

Discussion with a suitably qualified asbestos consultant is advised.

If the soils are to be excavated and removed, then delineation of these locations will be required, dampening down techniques will also be required to ensure fibres cannot migrate.

Due to the concentrations of the asbestos in WS102 (3.822%), it must be placed at a depth greater than 2.00m and must be surveyed and encapsulated with proper demarcation and must not be below a road. It must also be positioned where it is unlikely to be disturbed in the future.

The materials within WS103 (0.025%) should be place below a depth of 1.00m, and must not be below a road, they must be surveyed and encapsulated with proper demarcation. It must also be positioned where it is unlikely to be disturbed in the future.

The material within TP6 (<0.001%), could be placed within private gardens areas with a clean and inert cover of 600mm with geotextile breaklayer. They could also be placed in public open space below 300mm capping and geotextile breaklayer. They could also be used within roadboxes and below plot footprints.

Agreement and signoff by MCC will be required and should be agreed before undertaking the works.

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Removal of materials may be required within roadbox and plot footprints, depending on the concentrations listed. Locations and concentrations of asbestos shown in table below;

Location	Depth (mbgl)	Determinand	Observed Concentration (mg/kg)	AtRisk 2017 (mg/kg)	DEFRA C4SL 2017 6%SOM (mg/kg)
WS102	3.80	Chrysotile & Amosite	**3.822%**	<0.001%	<0.001%
WS103	2.00	Chrysotile	**0.025%**	<0.001%	<0.001%
TP6	1.00	Chrysotile	<0.001%	<0.001%	<0.001%

Slightly elevated carbon dioxide (greater than 5%) was noted in WS01 on four out of the six visits. Slightly depleted oxygen was also noted in WS01 and WS03 on four of the six visits. Flow rates remained low across all of the visits (max 0.1l/hr). Due to the history of the site and the MADE GROUND encountered during the initial ground investigation, it is proposed Amber 1/CS2 ground gas protection is utilized across site. Additional ground gas monitoring is required in the areas that could not be accessed due to dense vegetation/existing buildings (post demo) during the initial investigation.

The Betts Geo ground gas assessment is shown below;

Site Area	Site Classification	Recommended Ground Gas Protection Measures
Whole Site	Amber 1 / CS2	Low-level ground gas protection measures are required, using a membrane and ventilated sub-floor void that creates a permeability contrast to limit the ingress of gas into buildings. Gas protection measures are to be installed as prescribed in BRE 414. Ventilation of the sub-floor void should be designed to provide a minimum of one complete volume change per 24 hours.

17.6 Controlled Waters

No significant mobile contamination has been observed, neither has any perched water.

The underlying aquifer and groundwater are largely protected by cohesive clay strata, which will limit migration. The underlying solid geology is the Manchester Marls, which has been classified as a Secondary B Aquifer and is of low permeability which will inhibit vertical and horizontal migration.

There are no potable abstractions within 500m of the site.

The possible culvert that may or may not be present on the site is likely to be a solid construction and encapsulated by clay. Risk to be aquifers and surface waters, including the culvert is deemed to be low.

The risk of contamination to the adjacent canal to the north of the site is deemed low due to the anticipated cohesive superficial geology surrounding the clay preventing any significant contamination migration. A road/access track is also present between the canal and the site, increasing its distance from site.

Protection measures may be required during the construction works to prevent any water ingress during the earthworks and sediment runoff will need to be controlled.

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If any unofficial connections are discovered to the canal during the construction works, they will be blocked up to prevent any water from the site draining to the canal.

17.7 Piped Drinking Water Supplies

The use of Protect-A-Line is anticipated; a UU risk assessment should be completed to confirm.

17.8 Off-Site Disposal of Surplus Soil

It is recommended that the results of the contamination testing (including the history of the site) be presented to any proposed landfills, to obtain their acceptance of the information to date and to determine the actual WAC limits used by them, (see Appendix J for further guidance). Segregation of made ground/topsoil and natural should be possible given the chemical analysis and very different visual identification.

Site waste management plans will be required due to the size and cost of the proposed scheme.

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18 GEOTECHNICAL ASSESSMENT

18.1 Introduction

It is understood that the proposed development will consist of construction of residential properties with associated rear gardens, associated infrastructure and public open space. The properties are expected to be multiple storey.

18.2 Site Preparation and Excavation

All excavations should be planned, and due consideration should be given to providing temporary support or suitable battering. Excavations should be regularly inspected by a competent person to ensure continued safety. Further advice on the safety of excavations is given *in Health and Safety in Construction.* Shallow (<1.20mbgl) excavations for service trenches could be complicated by collapsing ground, and care should be taken.

Stability of the ash is questionable and should be considered during construction.

18.3 Control of Groundwater

Shallow perched groundwater has been observed. The provision of pumping/shuttering will be necessary during excavation of foundation trenches, especially during wet weather, close to surface water features and to deeper excavations for sewers etc. It is good practice to have such equipment on standby in case of seasonal / abnormal weather conditions.

18.4 Foundations

Due to the variability of the ground, a detailed foundation zoning plan should be undertaken once final layouts / levels are known taking in to account the varying ground conditions.

For low-rise properties, strip / trench foundations may be suitable where competent ground is found <2.00mbgl., based on the below;

- Firm CLAY strata with an allowable bearing pressure (ABP) of 100kN/m^2
- Stiff CLAY strata with an allowable bearing pressure of 125kN/m^2

However, due to the prevalence and depth of made ground, previous infrastructure and contamination (arisings), it would be prudent to allow for a piled foundation solution across the site until further site investigation can be undertaken post demolition. Made ground has been recorded to a depth of around 8.00mbgl. Deeper Boreholes are advised for piled foundation design.

Where groundwater is present with granular strata, half the stated ABP value may be expected in granular soils.

Due to variable ground conditions, a detailed foundation zoning plan is advised.

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Localised deepening of foundations and / or piled foundations are likely to be required in areas of reduced ground strength.

Possibility of culverts and air ducts from the former use cannot be discounted.

Allowance for pre-digging pile locations should be made due to possibility of unknown obstructions.

Foundations should be excavated wholly on one stratum. Should proposed foundations span different strata, trenching and stepping of foundations and/or nominal reinforcement will be required.

Calculations on the allowable bearing capacity indicate settlements of less than 25mm for a square pad using the above allowable bearing capacity.

For any multi-storey structures, a piled foundation solution will be required based on greater expected loadings. A specialised piling foundation contractor should be consulted with regards to pile design.

18.5 Ground Floor Construction

Suspended floor construction e.g. either in-situ RC slabs or block and beam flooring is recommended as per NHBC guidance.

18.6 Soakaways

Soakaway tests were not undertaken during the fieldwork due to the anticipated made ground and underlying cohesive strata.

18.7 Heave / Shrinkage Potential

A summary of Atterburg limit tests is shown below. Full results are located in Appendix D.

Exploratory Position ID	Depth (m)	Plasticity Index %	% <425um	Modified Plasticity Index %	NHBC Volume Change Level
TP1	1.20	20	95	19	Low
WS101	3.70	20	97	19	Low

Low plasticity is evident across the materials tested. Foundation design for tree heave protection could be designed accordingly following discussion with the NHBC.

18.8 Highway

According to the criteria of Highways Agency HD 25/95 Volume 7 Section 2 Part 2 HD 25/94, a CBR value of 3-5% on the Made Ground anticipated, however confirming in-situ CBR's should be undertaken. Placement of geotextiles within the areas of roads / parking could also be designed to minimise the subgrade thickness.

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18.9 Protection of Buried Concrete

It is considered for concrete design purposes that brownfield site and mobile groundwater conditions are applicable, the results are summarised in the tables below:

Area Around WS101

Concrete Classification	
Design Sulphate Class	DS-1s
ACEC Class	AC-2
Design Chemical Class	DC-2

Rest of Site

Concrete Classification	
Design Sulphate Class	DS-1s
ACEC Class	AC-1
Design Chemical Class	DC-1

18.10 Additional Works – Post-demolition

Further works will be required, as listed below;

- Trial pitting to delineate CLAY / MADE GROUND interface and inaccessible areas, with geotechnical and environmental sample collection
- Cable percussive boreholes, with gas monitoring installs

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19 REFERENCES

19.1 *BS 5930:1999+A2 Code of Practice for Site Investigation.*

19.2 *BS1377: 1990 Methods of Test for Soils for Civil Engineering Purposes.*

19.3 Assessment of risks to human health from land contamination: an overview of the development of guideline values and related research. EA, 2002

19.4 *Contaminated Land Risk Assessment; A Guide to Good Practice; CIRIA C552: 2001.*

19.5 *Health and Safety in Construction, HSG150, HSE, 1996.*

19.6 *Hazardous Waste: Interpretation of the Definition and Classification of Hazardous Waste, Environment Agency, WM2 Version 1.0, June 2003.*

19.7 *DoE (1991), The Building Regulations Approved Document C, Site Preparation and Resistance to Moisture, HMSO*

19.8 *Baker W (1987), Investigation Strategy - lecture at City of Birmingham Development Department Symposium on Methane Generating Sites, 9 December 1987, Industrial Research Laboratories, Birmingham*

19.9 *NHBC Standards, Chapter 4.2, 2017 Building Near Trees*

19.10 *Highways Agency HD 25/95 volume 7 section 2 Part 2 HD 25/94*

19.11 *Water Regulations Advisory Scheme (2002) The selection of materials for water supply pipes to be laid in contaminated land*

19.12 *Anon (1997) Dutch in Policy Retreat on Contaminated Land ENDS (Environmental Data Services), 269, 46*

19.13 *Water Regulations Advisory Scheme (2002) The selection of materials for water supply pipes to be laid in contaminated land*

19.14 *Piling In Layered Ground: Risks to Groundwater and Archaeology Science Report SC020074/SR Environment Agency October 2006*

19.15 *Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention National Groundwater & Contaminated Land Centre report NC/99/73 F J Westcott, C M B Lean & M L Cunningham May 2001*

19.16 *'Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present', Report Edition No.04 March 2007 NHBC – designed for use with low rise residential properties*

19.17 *CIRIA C665 'Assessing risks posed by hazardous ground gases for buildings' 2007 - for high rise residential / flats*

19.18 *BS8485:2007 'Code of practice for the characterization and remediation from ground gas in affected developments'*

19.19 *BRE 414 'Protective measures for housing on gas-contaminated land' Roger Johnson, Parkman Environment 2001*

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19.20 *BS 8500- 1:2006 'Concrete – Complementary British Standard to BS EN 206-1 – Part 1: Method of specifying and guidance for the specifier' November 2006*

19.21 *'Planning Policy 23: Planning and Pollution Control' Office of the Deputy Prime Minister 2004*

19.22 *CLR11 'Model Procedures for the Management of Land Contamination' DEFRA 2004*

19.23 *BRE 465 'Cover Systems for Land Regeneration' 2004*

19.24 *'The UK Approach for Evaluating the Human Health Risks from Petroleum Hydrocarbons in Soils, Environment Agency Science Report P5-080/TR3', Environment Agency (May 2005)*

19.25 *TOX12- Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Dioxins, Furans and Dioxin-like PCBs' Environment Agency 2003*

19.26 *The LQM/CIEH GAC for Human Health Risk Assessment 2009 second edition*

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APPENDIX C -

SPECIFICATION FOR ENGINEERED FILLS

BSH
remediation

TABLE 6/1: (11/05) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
GENERAL GRANULAR FILL	1	A	-	Well graded granular material	General Fill	Any material, or combination of materials, other than material designated as Class 3 in the Contract. (Properties (i), (ii) and (iv) in next column, shall not apply to chalk). Recycled aggregate	(i) grading	BS 1377 : part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	1	A	-
							(ii) uniformity coefficient	See Note 5	10	-				
							(iii) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(iv) MCV	Clause 632	App 6/1	App 6/1				
							(v) IDD of chalk	Clause 634	-	App 6/1				
	1	B	-	Uniformly graded granular material	General Fill	Any material, or combination of materials, other than chalk. Recycled aggregate	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 3	1	B	-
							(ii) uniformity coefficient	See Note 5	-	10				
							(iii) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(iv) MCV	Clause 632	App 6/1	App 6/1				
	1	C	-	Coarse granular material	General Fill	Any material, or combination of materials, other than material designated as Class 3 in the Contract. (Properties (i) and (ii) in next column, shall not apply to chalk). Recycled aggregate	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 5	1	C	-
							(ii) uniformity coefficient	See Note 5	5	-				
							(iii) Los Angeles coefficient	Clause 635	-	50				

TABLE 6/1: (11/05) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
GENERAL COHESIVE FILL	2	A	-	Wet cohesive material	General Fill	Any material, or combination of materials, other than chalk.	(i) grading	BS 1377 : part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 1 except for materials with liquid limit greater than 50, determined by BS1377 : Part 2, only deadweight tamping or vibratory tamping rollers or grid rollers shall be used.	2	A	-
							(ii) plastic limit (PL)	BS 1377 : part 2	-	-				
							(iii) mc	BS 1377 : Part 2	PL -4%	App 6/1				
							(iv) MCV	Clause 632	App 6/1	App 6/1				
							(v) Undrained shear strength of remoulded material	Clause 633	App 6/1	App 6/1				
	2	B	-	Dry cohesive material	General Fill	Any material, or combination of materials, other than chalk	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	2	B	-
							(ii) plastic limit (PL)	BS 1377 : Part 2	-	-				
							(iii) mc	BS 1377 : Part 2	App 6/1	PL -4%				
							(iv) MCV	Clause 632	App 6/1	App 6/1				
							(v) undrained shear strength of remoulded material	Clause 633	App 6/1	App 6/1				

TABLE 6/1: Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
GENERAL COHESIVE FILL	2	C	-	Stony cohesive material	General Fill	Any material, or combination of materials, other than chalk	(i) grading	BS 1377 : part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	2	C	-
							(ii) plastic limit (PL)	BS 1377 : part 2	-	-				
							(iii) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(iv) MCV	Clause 632	App 6/1	-				
							(v) Undrained shear strength of remoulded material	Clause 633	App 6/1	-				
	2	D	-	Silty cohesive material	General Fill	Any material, or combination of materials, other than chalk	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 3	2	D	-
							(ii) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(iii) MCV	Clause 632	App 6/1	App 6/1				
							(iv) undrained shear strength of remoulded material	Clause 633	App 6/1	App 6/1				
	2	E	-	Reclaimed pulverised fuel ash cohesive material	General Fill	Reclaimed material from lagoon or stockpile containing not more than 20% furnace bottom ash	(i) mc	BS 1377 : Part 2	To enable compaction to Clause 612		End product 95% of maximum dry density of BS 1377 : Part 4 (2.5 kg rammer method)	2	E	-
							(ii) bulk density	BS 1377 : Part 9	App 6/1	App 6/1				

TABLE 6/1: (11/09) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
SELECTED GRANULAR FILL	6	F	1	Selected granular material (fine grading)	Capping	Any material, or combination of materials - including recycled aggregates with not more than 50% by mass of recycled bituminous planings and granulated asphalt, but excluding materials that contain tar and tar-bitumen binders, unburnt colliery spoil, argillaceous rock and chalk. Property (vi) in the next column shall not apply if the Class Ra (asphalt) content of any recycled aggregate is 20% or less.	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 6	6	F	1
							(ii) optimum mc	BS 1377 : Part 4 (vibrating hammer method)	-	-				
							(iii) mc	BS 1377 : Part 2	Optimum mc - 2%	Optimum mc				
							(iv) Los Angeles coefficient	Clause 635	-	60				
							(v) Class Ra (asphalt) content	Clause 710	-	50%				
							(vi) bitumen content	BS EN 12697-1 or BS EN 12697-39	-	2.0%				
	6	F	2	Selected granular material (coarse grading)	Capping	Any material, or combination of materials - including recycled aggregates with not more than 50% by mass of recycled bituminous planings and granulated asphalt, but excluding materials that contain tar and tar-bitumen binders, unburnt colliery spoil and argillaceous rock. Property (i) in the next column shall not apply to chalk. Property (vi) in the next column shall not apply if the Class Ra (asphalt) content of any recycled aggregate is 20% or less.	(i) grading	BS 1377 : Part 2	Tab 6/2	Tab 6/2	Tab 6/4 Method 6	6	F	2
							(ii) optimum mc	BS 1377 : Part 4 (vibrating hammer method)	-	-				
							(iii) mc	BS 1377 : Part 2	Optimum mc - 2%	Optimum mc				
							(iv) Los Angeles coefficient	Clause 635	-	50				
							(v) Class Ra (asphalt) content	Clause 710	-	50%				
							(vi) bitumen content	BS EN 12697-1 or BS EN 12697-39	-	2.0%				

TABLE 6/1: (11/09) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
SELECTED GRANULAR FILL	6	F	3	Selected granular material	Capping	Any material, or combination of materials with not less than 50% by mass of recycled bituminous planings and granulated asphalt, but excluding materials that contain tar and tar-bitumen binders, unburnt colliery spoil and argillaceous rock	(i) grading	BS 1377 : Part 2 (On-site)	Tab 6/2	Tab 6/2	Tab 6/4 Method 6 Maximum Compacted layer thickness shall be 200 mm	6	F	3
								BS EN 933-2 (Off-site)	Tab 6/5	Tab 6/5				
							(ii) optimum mc	Clause 613	-	-				
							(iii) mc	Clause 613	Optimum mc - 2%	Optimum mc				
							(iv) Class Ra (asphalt) content	Clause 710	50%					
							(v) bitumen content	BS EN 12697-1 or BS EN 12697-39	-	10%				
	6	F	4	Selected granular material (fine grading) - imported on to the Site	Capping	Unbound mixture complying with BS EN 13285. Any material, or combination of materials - including recycled aggregates with not more than 50% by mass of recycled bituminous planings and granulated asphalt, but excluding materials that contain tar and tar-bitumen binders, unburnt colliery spoil, argillaceous rock and chalk. Property (x) in the next column shall not apply if the Class Ra (asphalt) content of any recycled aggregate is 20% or less.	(i) Size designation and overall grading category	BS EN 13285 - 0/31.5 and G_E	Tab 6/5	Tab 6/5	Tab 6/4 Method 6	6	F	4
							(ii) Maximum fines and oversize categories	BS EN 13285 - UF_{15} and OC_{75}	Tab 6/5	Tab 6/5				
							(iii) Los Angeles coefficient	BS EN 13242 - LA_{60}	-	60				
							(iv) Volume stability of blast furnace slag	BS EN 13242 - free from dicalcium silicate and iron disintegration	-	-				

TABLE 6/1: (11/05) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within:					
									Lower	Upper				
SELECTED GRANULAR FILL	6	I	-	Selected well graded granular material	Fill to reinforced soil and anchored earth structures	Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, slag, chalk, well burnt colliery spoil or any combination thereof except that chalk shall not be combined with any other constituent. None of these constituents shall include any argillaceous rock. (Properties (i), (ii) and (v) in next column shall not apply to chalk.) (Properties (viii), (ix), (x), (xi), (xii), (xiii) and (xiv) only apply when metallic reinforcing or anchor elements, facing units or fastenings are used.) Recycled aggregate except recycled asphalt	(i) grading	BS 1377 : Part 2 (On-site)	Tab 6/2	Tab 6/2	Tab 6/4 Method 2	6	I	-
								BS EN 933-2 (Off-site)	Tab 6/5	Tab 6/5				
							(ii) uniformity coefficient	See Note 5	10	-				
							(iii) SMC of chalk	Clause 634	-	20%				
							(iv) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(v) MCV	Clause 632	App 6/1	App 6/1				
							(vi) effective angle of friction (φ') and effective cohesion (c')	Clause 636	App 6/1	-				
							(vii) coefficient of friction and adhesion (fill/elements)	Clause 639	App 6/1	-				
							(viii) pH value	BS 1377 : Part 3	Tab 6/3	Tab 6/3				
							(ix) chloride ion content	BS EN 1744-1	-	Tab 6/3				
							(x) water soluble (WS) sulfate content	TRL Report 447, Test No. 1	-	Tab 6/3				
							(xi) oxidisable sulfides (OS) content	TRL Report 447, Tests Nos. 2 and 4	-	Tab 6/3				
							(xii) resistivity	Clause 637	Tab 6/3	-				
							(xiii) redox potential	Clause 638	Tab 6/3	-				
							(xiv) organic content	BS 1377 : Part 3	-	Tab 6/3				
							(xv) microbial activity index	Table 6/3	-	Tab 6/3				

TABLE 6/1: (11/05) **Acceptable Earthworks Materials: Classification and Compaction Requirements (See footnotes) (continued)**

Class				General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601 and Appendix 6/1)	Material Properties Required for Acceptability (In Addition to Requirements on Use of Fill Materials in Clause 601 and Testing in Clause 631)			Compaction Requirements in Clause 612	Class		
							Property (See Exceptions in Previous Column)	Defined and Tested in Accordance with:	Acceptable Limits Within: Lower	Acceptable Limits Within: Upper				
SELECTED GRANULAR FILL	6	J	-	Selected uniformly graded granular material	Fill to reinforced soil and anchored earth	Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, slag, chalk, well burnt colliery spoil or any combination thereof, except that chalk shall not be combined with any other constituent. None of these constituents shall include any argillaceous rock. (Properties (viii), (ix), (x), (xi), (xii), (xiii) and (xiv) in next column only apply when metallic reinforcing or anchor elements, facing units or fastenings are used.) (Properties (i), (ii) and (v) in next column shall not apply to chalk.) Recycled aggregate except recycled asphalt	(i) grading	BS 1377 : Part 2 (On-site)	Tab 6/2	Tab 6/2	Tab 6/4 Method 3	6	J	-
								BS EN 933-2 (Off-site)	Tab 6/5	Tab 6/5				
							(ii) uniformity coefficient	See Note 5	5	10				
							(iii) SMC of chalk	Clause 634	-	20%				
							(iv) mc	BS 1377 : Part 2	App 6/1	App 6/1				
							(v) MCV	Clause 632	App 6/1	App 6/1				
							(vi) effective angle of friction (φ') and effective cohesion (c')	Clause 636	App 6/1	-				
							(vii) coefficient of friction and adhesion (fill/elements)	Clause 639	App 6/1	-				
							(viii) pH value	BS 1377 : Part 3	Tab 6/3	Tab 6/3				
							(ix) chloride ion content	BS EN 1744-1	-	Tab 6/3				
							(x) water soluble (WS) sulfate content	TRL Report 447, Test No. 1	-	Tab 6/3				
							(xi) oxidisable sulfides (OS) content	TRL Report 447, Tests Nos 2 and 4	-	Tab 6/3				
							(xii) resistivity	Clause 637	Tab 6/3	-				
							(xiii) redox potential	Clause 638	Tab 6/3	-				
							(xiv) organic content	BS 1377 : Part 3	-	Tab 6/3				
							(xv) microbial activity index	Table 6/3	-	Tab 6/3				

TABLE 6/2: (05/04) **Grading Requirements for Acceptable Earthworks Materials Other Than Classes 6F4, 6F5 and 6S**

Percentage by Mass Passing the Size Shown																					
Class	**Size (mm)**		**Size(mm) BS Series**													**Size (microns) BS Series**				**Size (micr-ons)**	**Class**
	500	**300**	**125**	**90**	**75**	**37.5**	**28**	**20**	**14**	**10**	**6.3**	**5**	**3.35**	**2**	**1.18**	**600**	**300**	**150**	**63**	**2**	
1A		100	95-100																<15		1A
1B			100																<15		1B
1C	100		10-95													0-25			<15		1C
2A & 2B			100											80-100					15-100		2A & 2B
2C			100											15-80					15-80		2C
2D			100																80-100	0-20	2D
6A	100									0-100		0-85				0-45			0-5		6A
6B	100		0-10																		6B
6C			100			0-100					0-100		0-35	0-10		0-2					6C
6D										100		89-100		60-100	30-100	15-80	5-48	0-15 except 0-20 for crushed rock			6D
6E & 6R			100	85-100						25-100						10-100			<15		6E & 2R
6F1					100	75-100				40-95		30-85				10-50			<15		6F1
6F2			100	80-100	65-100	45-100				15-60		10-45				0-25			0-12		6F2
6F3			100	80-100	65-100	45-100				15-60		10-45				0-25			0-12		6F3
6H								100				60-100			15-45	0-25		0-5			6H
6I & 6J			100		85-100				25-100					15-100		9-100			<15		6I & 6J
6K								100											0-10		6K
6L										100		89-100		60-100	30-100	15-100	5-70	0-15 except 0-20 for crushed rock			6L

TABLE 6/4: Method Compaction for Earthworks Materials: Plant and Methods (Method 1 to Method 6)
(This Table is to be read in conjunction with sub-Clause 612.10)

Type of Compaction Plant	Ref No.	Category	Method 1		Method 2		Method 3		Method 4		Method 5		Method 6		
			D	N#	D	N#	D	N#	D	N	D	N	N for D = 110 mm	N for D = 150 mm	N for D = 250 mm
Smoothed wheeled roller (or vibratory roller operating without vibration)		Mass per metre width of roll:													
	1	over 2100 kg up to 2700 kg	125	8	125	10	125	10*	175	4	unsuitable		unsuitable	unsuitable	unsuitable
	2	over 2700 kg up to 5400 kg	125	6	125	8	125	8*	200	4	unsuitable		16	unsuitable	unsuitable
	3	over 5400 kg	150	4	150	8	unsuitable		300	4	unsuitable		8	16	unsuitable
Grid roller		Mass per metre width of roll:													
	1	over 2700 kg up to 5400 kg	150	10	unsuitable		150	10	250	4	unsuitable		unsuitable	unsuitable	unsuitable
	2	over 5400 kg up to 8000 kg	150	8	125	12	unsuitable		325	4	unsuitable		20	unsuitable	unsuitable
	3	over 8000 kg	150	4	150	12	unsuitable		400	4	unsuitable		12	20	unsuitable
Deadweight tamping roller		Mass per metre width of roll:													
	1	over 4000 kg up to 6000 kg	225	4	150	12	250	4	350	4	unsuitable		12	20	unsuitable
	2	over 6000 kg	300	5	200	12	300	3	400	4	unsuitable		8	12	20
Pneumatic-tyred roller		Mass per wheel:													
	1	over 1000 kg up to 1500 kg	125	6	unsuitable		150	10*	240	4	unsuitable		unsuitable	unsuitable	unsuitable
	2	over 1500 kg up to 2000 kg	150	5	unsuitable		unsuitable		300	4	unsuitable		unsuitable	unsuitable	unsuitable
	3	over 2000 kg up to 2500 kg	175	4	125	12	unsuitable		350	4	unsuitable		unsuitable	unsuitable	unsuitable
	4	over 2500 kg up to 4000 kg	225	4	125	10	unsuitable		400	4	unsuitable		unsuitable	unsuitable	unsuitable
	5	over 4000 kg up to 6000 kg	300	4	125	10	unsuitable		unsuitable		unsuitable		12	unsuitable	unsuitable
	6	over 6000 kg up to 8000 kg	350	4	150	8	unsuitable		unsuitable		unsuitable		12	unsuitable	unsuitable
	7	over 8000 kg up to 12000 kg	400	4	150	8	unsuitable		unsuitable		unsuitable		10	16	unsuitable
	8	over 12000 kg	450	4	175	6	unsuitable		unsuitable		unsuitable		8	12	unsuitable
Vibratory tamping roller		Mass per metre width of a vibrating roll:													
	1	over 700 kg up to 1300 kg	100	12	100	12	150	12	100	10	unsuitable		unsuitable	unsuitable	unsuitable
	2	over 1300 kg up to 1800 kg	125	12	125	12	175	12*	175	8	unsuitable		12	unsuitable	unsuitable
	3	over 1800 kg up to 2300 kg	150	12	150	12	200	12*	unsuitable		unsuitable		8	12	unsuitable
	4	over 2300 kg up to 2900 kg	150	9	150	9	250	12*	unsuitable		400	5	6	10	unsuitable
	5	over 2900 kg up to 3600 kg	200	9	200	9	275	12*	unsuitable		500	6	6	10	unsuitable
	6	over 3600 kg up to 4300 kg	225	9	225	9	300	12*	unsuitable		600	6	4	8	unsuitable
	7	over 4300 kg up to 5000 kg	250	9	250	9	300	9*	unsuitable		700	6	3	7	12
	8	over 5000 kg	275	9	275	9	300	7*	unsuitable		800	6	3	6	10

TABLE 6/4: Method Compaction for Earthworks Materials: plant and Methods (Method 1 to Method 6)
(This Table is to be read in conjunction with sub-Clause 612.10)

Type of Compaction Plant	Ref No.	Category	Method 1		Method 2		Method 3		Method 4		Method 5		Method 6		
			D	N#	D	N#	D	N#	D	N	D	N	N for D = 110 mm	N for D = 150 mm	N for D = 250 mm
Vibratory roller		Mass per metre width of a vibratory roll:													
	1	over 270 kg up to 450 kg	unsuitable		75	16	150	16	unsuitable		unsuitable		unsuitable	unsuitable	unsuitable
	2	over 450 kg up to 700 kg	unsuitable		75	12	150	12	unsuitable		unsuitable		unsuitable	unsuitable	unsuitable
	3	over 700 kg up to 1300 kg	100	12	125	10	150	6	125	10	unsuitable		16	unsuitable	unsuitable
	4	over 1300 kg up to 1800 kg	125	8	150	8	200	10*	175	4	unsuitable		6	16	unsuitable
	5	over 1800 kg up to 2300 kg	150	4	150	4	225	12*	unsuitable		unsuitable		4	6	12
	6	over 2300 kg up to 2900 kg	175	4	175	4	250	10*	unsuitable		400	5	3	5	11
	7	over 2900 kg up to 3600 kg	200	4	200	4	275	8*	unsuitable		500	5	3	5	10
	8	over 3600 kg up to 4300 kg	225	4	225	4	300	8*	unsuitable		600	5	2	4	8
	9	over 4300 kg up to 5000 kg	250	4	250	4	300	6*	unsuitable		700	5	2	4	7
	10	over 5000 kg	275	4	275	4	300	4*	unsuitable		800	5	2	3	6
Vibrating plate compactor		Mass per m^2 of base plate:													
	1	over 880 kg up to 1100 kg	unsuitable		unsuitable		75	6	unsuitable		unsuitable		unsuitable	unsuitable	unsuitable
	2	over 1100 kg up to 1200 kg	unsuitable		75	10	100	6	75	10	unsuitable		unsuitable	unsuitable	unsuitable
	3	over 1200 kg up to 1400 kg	unsuitable		75	6	150	6	150	8	unsuitable		unsuitable	unsuitable	unsuitable
	4	over 1400 kg up to 1800 kg	100	6	125	6	150	4	unsuitable		unsuitable		8	unsuitable	unsuitable
	5	over 1800 kg up to 2100 kg	150	6	150	5	200	4	unsuitable		unsuitable		5	8	unsuitable
	6	over 2100 kg	200	6	200	5	250	4	unsuitable		unsuitable		3	6	12
Vibro-tamper		Mass:													
	1	over 50 kg up to 65 kg	100	3	100	3	150	3	125	3	unsuitable		4	8	unsuitable
	2	over 65 kg up to 75 kg	125	3	125	3	200	3	150	3	unsuitable		3	6	12
	3	over 75 kg up to 100 kg	150	3	150	3	225	3	175	3	unsuitable		2	4	10
	4	over 100 kg	225	3	200	3	225	3	250	3	unsuitable		2	4	10
Power rammer		Mass:													
	1	100 kg up to 500 kg	150	4	150	6	unsuitable		200	4	unsuitable		5	8	unsuitable
	2	over 500 kg	275	8	275	12	unsuitable		400	4	unsuitable		5	8	14
Dropping-weight compactor		Mass of rammer over 500 kg weight drop:													
	1	over 1 m up to 2 m	600	4	600	8	450	8	unsuitable		unsuitable		unsuitable	unsuitable	unsuitable
	2	over 2 m	600	2	600	8	unsuitable		unsuitable		unsuitable		unsuitable	unsuitable	unsuitable

TABLE 6/4: Method Compaction for Earthworks Materials: Plant and Methods (Method 7)
(This Table is to be read in conjunction with sub-Clause 612.10)

Type of Compaction Plant	Ref No.	Category	Method 7	
			N for D = 150 mm	N for D = 250 mm
Smooth wheeled roller (or vibratory roller operating without vibration)		Mass per metre width of roll:		
	1	over 2100 kg up to 2700 kg	unsuitable	unsuitable
	2	over 2700 kg up to 5400 kg	unsuitable	unsuitable
	3	over 5400 kg	12	unsuitable
Grid roller		Mass per metre width of roll:		
	1	over 2700 kg up to 5400 kg	unsuitable	unsuitable
	2	over 5400 kg up to 8000 kg	16	unsuitable
	3	over 8000 kg	8	unsuitable
Deadweight tamping roller		Mass per metre width of roll:		
	1	over 4000 kg up to 6000 kg	4	8
	2	over 6000 kg	3	6
Pneumatic-tyred roller		Mass per wheel:		
	1	over 1000 kg up to 1500 kg	unsuitable	unsuitable
	2	over 1500 kg up to 2000 kg	12	unsuitable
	3	over 2000 kg up to 2500 kg	6	unsuitable
	4	over 2500 kg up to 4000 kg	5	unsuitable
	5	over 4000 kg up to 6000 kg	4	16
	6	over 6000 kg up to 8000 kg	unsuitable	8
	7	over 8000 kg up to 12000 kg	unsuitable	4
	8	over 12000 kg	unsuitable	4
Vibratory tamping roller		Mass per metre width of vibrating roll:		
	1	over 700 kg up to 1300 kg	unsuitable	unsuitable
	2	over 1300 kg up to 1800 kg	unsuitable	unsuitable
	3	over 1800 kg up to 2300 kg	16	unsuitable
	4	over 2300 kg up to 2900 kg	12	unsuitable
	5	over 2900 kg up to 3600 kg	10	unsuitable
	6	over 3600 kg up to 4300 kg	8	16
	7	over 4300 kg up to 5000 kg	7	14
	8	over 5000 kg	6	12
Vibratory roller		Mass per metre width of vibrating roll:		
	1	over 270 kg up to 450 kg	unsuitable	unsuitable
	2	over 450 kg up to 700 kg	unsuitable	unsuitable
	3	over 700 kg up to 1300 kg	unsuitable	unsuitable
	4	over 1300 kg up to 1800 kg	unsuitable	unsuitable
	5	over 1800 kg up to 2300 kg	12	unsuitable
	6	over 2300 kg up to 2900 kg	10	unsuitable
	7	over 2900 kg up to 3600 kg	10	unsuitable
	8	over 3600 kg up to 4300 kg	8	unsuitable
	9	over 4300 kg up to 5000 kg	8	unsuitable
	10	over 5000 kg	6	12
Vibratory plate compactor		Mass per m^2 of base plate:		
	1	over 880 kg up to 1100 kg	unsuitable	unsuitable
	2	over 1100 kg up to 1200 kg	unsuitable	unsuitable
	3	over 1200 kg up to 1400 kg	unsuitable	unsuitable
	4	over 1400 kg up to 1800 kg	10	unsuitable
	5	over 1800 kg up to 2100 kg	8	unsuitable
	6	over 2100 kg	6	unsuitable
Vibro-tamper		Mass:		
	1	over 50 kg up to 65 kg	unsuitable	unsuitable
	2	over 65 kg up to 75 kg	unsuitable	unsuitable
	3	over 75 kg up to 100 kg	unsuitable	unsuitable
	4	over 100 kg	8	unsuitable
Power rammer		Mass:		
	1	100 kg up to 500 kg	8	unsuitable
	2	over 500 kg	6	10
Dropping weight compactor		Mass of rammer over 500 kg height drop:		
	1	over 1 m up to 2 m	unsuitable	unsuitable
	2	over 2 m	unsuitable	unsuitable

Chapter

4.6

Engineered fill

This chapter gives guidance on meeting the Technical Requirements and recommendations for using engineered fill to support residential developments, external works, and infrastructures.

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Introduction

On construction sites, filling or earthworks is often required for various purposes, such as preventing flooding, enhancing drainage, planning roads, or establishing a suitable ground profile. Engineered fill may also be used to replace existing made ground overlying competent strata at shallow to moderate depths to form the new development platform or be used below raft foundations on sites with shrinkable clays and trees in lieu of deep trench fill foundations.

This chapter details the information that NHBC requires to ensure that engineered fill is correctly placed to support low rise residential building structures, external works, and infrastructure while avoiding potential risks of excessive settlement or ground failure.

Scope

This chapter gives guidance for engineered fill to be placed for the support of the proposed development.

The interaction between engineered fill, underlying ground conditions and the development are important and site-specific. The primary objectives of this chapter are to ensure that:

- the ground investigation is appropriate to the proposed development, site conditions and nature of the filling
- geotechnical ground model(s) are developed taking into account the proposed development and underlying ground and groundwater conditions
- the engineered fill is placed to a suitable earthworks specification
- appropriate geotechnical laboratory acceptability testing and in situ, compliance testing is undertaken and documented, and verification is provided to NHBC
- engineered fills do not settle excessively or have the potential to cause excessive differential settlement between properties founded upon the fill and external areas
- engineered fill and the underlying ground supporting building foundations shall limit building settlements to less than 25mm and minimise angular distortion or tilt to 1:400
- the design and detailing of foundations, infrastructure and external works suit the placed fill and underlying ground conditions taking account of the overall ground model and any geohazards in the ground beneath or nearby.

The geotechnical and environmental suitability of historic fill or fill placed without full reporting should not be relied upon without appropriate site investigation, characterisation, compliance testing and assessment being undertaken like other made ground deposits would be assessed. This may need to include long-term monitoring or loading trials to determine performance.

Assessment of historic fill within land reclamation schemes and marginal sites is generally outside the scope of this chapter. For sites with uncertainty about the site's suitability for future residential development, please consult NHBC or consider using NHBC Land Quality Service for a bespoke consultation. You can find details about this service at:

- www.nhbc.co.uk/builders/products-and-services/consultancy/land-quality-service, or
- Email: lqs@nhbc.co.uk

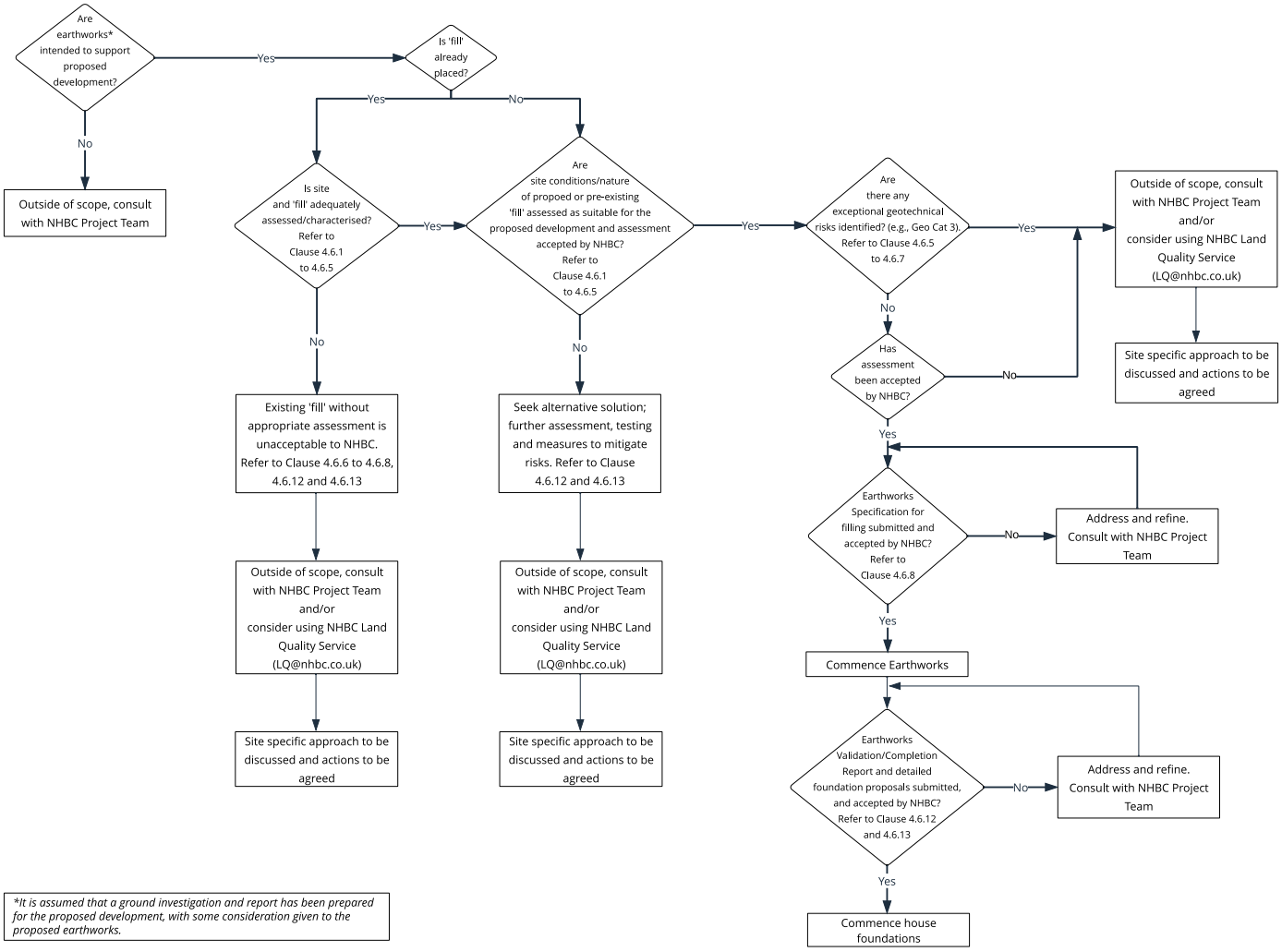
The following are not considered in this chapter and will require more specific guidance from other sources:

- backfilling to retaining walls, buried features such as culverts, services or access chambers
- capping and sub-bases to roads, drives, parking, and hardstanding areas
- filling beneath adoptable highways
- soil stabilisation or soil mixing
- piling mats or other specific forms of working surface for construction activities
- fill containing hazardous substances or required to provide mitigation against the presence of contamination, or to be placed on contaminated sites
- use of reinforcing geogrids.

The builder is responsible for ensuring that any earthworks filling proposals do not breach planning requirements or waste and environmental regulations.

The following Figure 1 is to assist users in navigating through this chapter and it outlines how a proposed or existing earthworks fit into the applicability and use of this standard.

Figure 1: Fill assessment and chapter applicability process



**It is assumed that a ground investigation and report has been prepared for the proposed development, with some consideration given to the proposed earthworks.*

Definitions for this chapter

Acceptability testing	Geotechnical and chemical suitability testing of the source material(s) intended to be used as engineered fill
Beam grillage	A reinforced concrete foundation designed to support load-bearing walls or structure and to span a loss of support and reinforced with traditionally cut and bent rebars and closed-loop links
Buried batter	An inclined buried interface of natural soil and made ground or between made ground and engineered fill and potentially liable to cause differential settlement at the ground surface
Cohesive fill	Containing clay of natural origin, comprising greater than 15% fines passing a 0.063mm sieve. Suitable for use as engineered fill but requires greater moisture control than granular material. Behaves in a plastic manner and can be deformed and remoulded by hand. Suitability is typically dependent on moisture content. Only clays with a plasticity index of less than 40% are acceptable as fill, where they are required to support building foundations. This includes Class 2 (general fill) and Class 7 (selected fill) in accordance with the Specification for Highway works (Series 600 'Earthworks')
Compliance testing	Geotechnical suitability testing of the engineered fill as it is being placed in layers on site
Differential settlement	Settlement of one part of a building or structure relative to another. While the total settlement of a structure may interfere with functions such as service connections, it is the differential settlement that causes structural damage
Earthworks	Permanent change in ground profile and/or level, which may be due to the placement of fill (filling), the raising of the ground level (embankment) or the removal of material (cutting)
Earthworks specification	An earthworks specification describes the design requirements of proposed earthworks and contain how the earthworks should be undertaken and what acceptance criteria should be used to demonstrate its suitability
End-use	The nature of the proposed final development located over the fill, including the buildings and their foundations, external works and infrastructure features and associated activities in their normal use
Engineered fill (referred to as 'fill')	Fill that is selected, placed and compacted to an appropriate specification so that it will exhibit the required engineering behaviour to support structural loadings for buildings, external works (drives, paths, external walls) and infrastructure (roads, drains and services) without excessive settlement or risk of shear failure. Selected (structural) fill and General fill are examples of Engineered fill
Formation level	The prepared surface on which the engineered fill or the superstructure is built
General fill	Suitable for the support of access roads, drainage, driveways, and services buried within it or supported on it. Elements supported on general fill are usually less sensitive to differential ground movements than shallow foundations for residential buildings. Some degree of variability can be accepted in the completed fill, and fewer tests may be acceptable than for structural fill, however it will still require a suitable regime of compliance and verification testing
Geotechnical Design Report	A report that is used to develop a suitable and functional earthworks design for a proposed end use, which includes the full details on the interpretation of design data and justification for the design including relevant layout drawings. They are produced for Geo Category 2 and 3 projects where engineered fill is being used to support building foundations
Geotechnical Design Statement	A brief and abridged version of a Geotechnical Design Report for Geo Category 1 projects where engineered fill is not being used to support building foundations
Granular fill	Free draining material predominantly comprising sands and/or gravels Good for use as engineered fill Having less than 15% fines (less than 0.063mm sieve size) Behaves in a non-plastic manner This includes Class 1 (general fill) and Class 6 (selected fill) in accordance with the Specification for Highway works (Series 600 'Earthworks')
Ground improvement	Techniques used to stabilise or improve the strength of soils in situ. This includes dynamic compaction, rapid or high energy impact compaction, surcharging, and installation of vertical drains or vibro stone columns. These techniques may be applied to historic uncontrolled fill, loose native soils upon which engineered fills are to be placed or following placement of fill
Highwall	The steep edge of quarry or opencast workings. Where the quarry is backfilled, it usually forms a zone of contrasting material behaviour where ground movements could be excessive and affected by significant differential settlement
Historic fill	Comprises 'Made Ground' and is not suitable for supporting building foundations, access roads, drainage, driveways and buried services without full investigation and assessment which should be provided in a Ground Investigation Report
Immediate settlement	Settlement which takes place during the application of a load as a result of elastic deformation without change in the water content

Inundation settlement/ collapse compression	Occurs in poorly compacted Made Ground or fill placed dry of optimum moisture content and with high air voids. The failure mechanism is typically attributed to the subsequent rising of groundwater or surface water percolation, where the voids are filled with water and cause delamination. Burst pipes and leaking drains present a risk. It can occur in both cohesive and granular soils, with greater risk in cohesive soils
Landscape fill	Unsuitable to support shallow foundations for buildings, ground floor slabs for buildings, other critical elements sensitive to differential ground movements, or any external works such as pavements, services or garden walls. Loading may be limited to construction equipment. There may be no geotechnical testing requirements for landscape fill other than for workability reasons. Landscape fill may be specified for garden areas alongside earthwork slopes and bunds in some developments. They are sometimes referred to as Bulk fill
Made ground	Material that has been placed but to an unknown or unrecorded filling specification. Its geotechnical and geo-environmental properties need to be established by appropriate ground investigation and testing, for it to be reclassified and its suitability for reuse established
Material classification	Assignment of materials into groups and classes for earthwork purposes. The groups and classes are established by testing of the geotechnical properties of a material to determine its suitability for use as fill. The properties may include moisture content, grading, plasticity, compaction and recompacted CBR and shear strength etc. Testing continues during earthworks placement to ensure material properties remain consistent and within defined limits to achieve the required compaction or fill performance
Performance testing	Load-settlement testing of the completed engineered fill at its surface and ahead of building foundations
Primary settlement or consolidation	Occurs after immediate settlement of material on loading. It occurs as pore water pressures dissipate and usually comprises the most significant element of the total settlement of a cohesive fill. Completion of primary settlement is most easily identified by graphical analysis of settlement data showing a 'levelling off' behaviour as secondary settlement then commences
Raft foundation (Semi-rigid raft)	A foundation consisting of continuous slab elements and down stand beams designed in accordance with Chapter 4.4 to spread superstructure loads over the building footprint and provide a capacity to span a defined loss of support
Reinforced strip	A reinforced concrete foundation designed to support load-bearing walls or structure and to span a loss of support and typically reinforced with two layers of mesh reinforcement
Secondary settlement or consolidation	Occurs after Primary settlement (ie, creep) and may continue for many years including during the life of the development depending on the soil types
Selected and Structural fill	Suitable for the support of shallow foundations for buildings and other critical elements sensitive to differential ground movements or as backfill underneath ground-bearing slabs against earth-retaining structures. The completed fill is required to have a high degree of uniformity, high stiffness and low settlement potential and requires high degree of supervision and control and a high frequency of selection classification, compliance and verification testing
Self-weight settlement	Settlement induced in a fill due to its own mass. The magnitude of self-weight settlement is a function of both the stiffness of the fill, and its overall thickness. The contribution of self-weight settlement can be significant in cohesive soils
Soil Modification	Mechanical and/or chemical treatment of soils to create a suitable moisture content of an engineered fill to achieve the specified requirements of minimum relative compaction and maximum air voids. Processes include (non-exhaustively); destoning, formation of windrows with mechanical mixing or turning to promote air drying, addition of low-dosage (no greater than 2% by dry weight) binders such as lime and/or cement in order to moisture condition, lower plasticity and/or control silt fraction to promote optimal compactibility
Soil Stabilisation	Mechanical and / or chemical treatment of soils to create substantial gain in strength to produce structural soil layers contributing significantly towards the performance or stability of earthworks. This would include (non-exhaustively) soil mixing with high dosage chemical admixtures or grouts, hydraulically bound materials and reinforced soils overlying weaker strata. It is currently outside the scope of this Chapter and not accepted for the support of foundations
Specification for earthworks	Are acceptable methods by which satisfactory compaction of fill materials can be achieved. The three main types of 'Specification for earthworks' used in the UK are Method, End Product and Performance
Total settlement	The combined magnitude of immediate, primary and secondary settlements

4.6.1 Compliance

Also see: Chapter 2.1

Engineered fill shall comply with the Technical Requirements and provide adequate support for the proposed end-use. A suitably qualified and experienced Engineer shall be responsible for the design, specification, supervision and validation reporting to be submitted to NHBC for assessment.

Engineered fill placed to a suitable earthworks specification that complies with the guidance in this chapter will generally be acceptable to NHBC. Reference shall also be made to Chapter 4.1 'Land quality - managing ground conditions', for both geotechnical and contamination risks.

This chapter gives guidance for a wide range of circumstances where engineered fill is required. It is not the intention to describe all combinations of site conditions, end-uses, fill material types and filling techniques. Where conditions fall outside those described and detailed within this chapter, it is recommended that early engagement with NHBC should be undertaken prior to preparation of the earthworks specification.

The earthworks specification should be produced by a suitably qualified and experienced person acceptable to NHBC. Where engineered fill is to support building foundations, the earthworks specification should be produced by a suitably qualified Engineer - refer to Technical Requirement R5 for detail on requirements.

The earthworks specification should be supported by a Geotechnical Design Report, where engineered fill is being used to support building foundations. A Geotechnical Design Statement is acceptable where engineered fill is not being used to support building foundations.

British Standards, codes of practice and authoritative documents relevant to Engineered fill, Earthworks and Structures formed upon engineered fill are detailed in Table 1.

Table 1: British Standards, relevant codes of practice and authoritative documents

Relevant standard	Additional guidance
BS EN 1997-1	Geotechnical design. General rules
BS EN 1997-2	Geotechnical design. Ground investigation and testing
BS 6031:2009	Code of Practice for Earthworks
BS EN 16907	Earthworks. All parts
BS EN ISO 14688	Geotechnical investigation and testing – Identification and classification of soil. Parts 1 & 2
BS EN ISO 14689	Geotechnical investigation and testing – Identification, description and classification of rock
BS EN ISO 17892	Geotechnical investigation and testing – Laboratory testing of soil
BS EN ISO 22476	Geotechnical investigation and testing – Field testing. All parts
BS 1377	Methods of test for soils for civil engineering purposes. All parts
BS 10175	Investigation of potentially contaminated sites – Code of practice
BRE FB 75	Building on fill: geotechnical aspects
BRE IP 5/97	Building on fill: collapse compression on inundation
BRE 427	Low-rise buildings on fill. All parts
BRE 433	Recycled Aggregates
BRE SD1	Concrete in aggressive ground
ICE	Earthworks: a guide (by Nowak & Gilbert)
National Highways	Specification for highway works: Series 600 - Earthworks
National Highways	CD 622 – Managing geotechnical risk
CIRIA C574	Engineering in chalk
CIRIA C504	Engineering in glacial tills
CIRIA C570	Engineering in Mercia mudstone

4.6.2 Provision of information

Earthworks design and specifications shall be produced in a clearly understandable format, including all relevant information and shall be distributed to all appropriate parties.

The earthworks specification and accompanying information including relevant drawings should be submitted to NHBC at least eight weeks prior to the commencement of filling or associated works. The earthworks specification should also be issued to site supervisors, the earthworks contractor and relevant specialist subcontractors. See clause 4.6.7 for details of what should be included within an Earthworks Specification.

An earthworks method statement, from the Earthworks Contractor or equivalent, should be produced and issued to all relevant personnel, which describes how the requirements of the specification are to be delivered, the plant to be used and arrangements for supervision and reporting.

In addition, the following supporting information should also be provided to NHBC:

- desk study and ground investigation report
- geotechnical design report or geotechnical design statement (depending on which is relevant)
- materials classification (acceptability) assessment
- earthworks verification report.

This list is not exhaustive and additional content may be required depending on site specific circumstances.

4.6.3 Hazardous sites and ground hazards

Also see: Chapters 2.1, 4.1 and 4.2

Placement of engineered fill on hazardous sites shall be reported to NHBC before work on site commences and shall be specified to take account of any ground hazards.

Hazardous sites, as defined in the NHBC Rules, should be reported to NHBC in writing at least eight weeks before earthworks begin.

Details of ground hazards to be taken into consideration are given in Chapter 4.1 ‘Land quality - managing ground conditions’ and Chapter 4.2 ‘Building near trees’.

4.6.4 Desk study and ground investigation

Also see: Chapters 2.1, 4.1 and 4.2

A desk study and ground investigation shall be undertaken, and the findings used to inform the design of the filling and earthworks specification.

A desk study and sufficient ground investigations should have been undertaken to characterise the site and identify all the features and potential geotechnical and environmental ground hazards relevant to the earthworks, including classification of the fill material itself.

The ground investigation should take account of the findings of the desk study and relevant standards listed in clause 4.6.1. Further guidance is given within Chapter 4.1 ‘Land quality - managing ground conditions’.

The desk study and ground investigation should determine the following items listed in Table 2, as a minimum:

Table 2: Typical items to be covered by desk study and ground investigation

Item to be determined	Guidance
Site history and past usage (eg, agricultural, residential, commercial or industrial)	To aid in determining a ground model for the site and potential areas of concern
Known areas of made ground	As shown on BGS Geo-index, other geodata services, historical site investigations and their reports
The nature of the underlying geology	To determine the potential for soft, loose soils, instability, voids, or highly compressible soils and to allow an assessment of pre or post treatment of the existing ground
The proximity of any existing buildings, roads or services	To assess whether these could be affected by ground movement caused by filling
The strength/density, compressibility and stability of soils beneath the proposed fill and for the potential re-use for fill earthworks	To enable the level of risk to be determined including settlement of the underlying soils and whether unsuitable material needs to be removed or if any form of pre-treatment is required. To assess the acceptability of site derived fills
The nature (presence and extent) of any groundwater and surface watercourses	To assess whether groundwater (or surface water) may affect the existing made ground/ natural soils or newly placed fill – for example by causing inundation settlement or washout of 'fines'
The geotechnical properties of soils including sulphate content and pH	To determine the suitability of soils for use as engineered fill and for the design of buried concrete
The presence of any slopes, embankments, cuttings, quarry highwalls, buried batters or earth faces	To assess the potential negative effect of earthworks on existing ground stability and the potential effect of features on the performance of earthworks and foundations bearing upon the placed fill
The presence of any buried services, culverts, tunnels or other buried structures	To assess the effect of structural loading from earthworks and associated earthworks machinery and whether protection or mitigation measures are required
The presence of contaminated substances or materials suspected to be contaminated	To assess whether cut earthworks and placement of filling may cause, or increase, the release of contaminants such as leachate, hazardous ground gases, etc refer to Chapter 4.1 'Land quality - managing ground conditions'
Geotechnical Risks	An initial geotechnical risk register to ensure that all known or anticipated natural or man-made geohazards are identified and can be investigated and considered within evolving stages of investigation, designs and earthworks execution

Other items to consider in addition to Table 2, but not repeated here, are listed in Table 1 of Chapter 4.5 'Vibratory ground improvement techniques' and in Chapter 4.2 'Building near trees'.

Where a ground investigation has been undertaken without considering the proposed earthworks, it may be necessary to carry out further supplementary investigation, sampling, testing, and/or monitoring to inform the earthworks design and earthworks specification.

4.6.5 Suitability of ground conditions

Also see: Chapters 2.1, 4.1 and 4.5

The ground to be filled over shall be suitably stable and appropriate for the proposed earthworks and end-use. Issues to be taken into account include:

1) **unsuitable ground conditions**
2) **obstructions**
3) **compressible soils**
4) **unstable ground**
5) **groundwater conditions.**

The geotechnical design should be prepared by a suitably qualified and experienced Engineer who should assess the ground and be satisfied that it is suitable for engineered fill. Prior to earthworks commencing, the formation level should be inspected and tested in accordance with the earthworks specification.

Engineered fill may be placed on natural ground or made ground – both need to have been appropriately investigated to assess their suitability to provide long-term support to the engineered fill and proposed end-use. Where engineered fill is to be placed on made ground, the made ground will be considered as a residual geotechnical risk for the purposes of geotechnical design.

It may be acceptable to partially excavate existing ground and recompact it in place in order to provide a stiffened layer with improved bearing capacity, settlement characteristics and reduced permeability (as required). Settlement of both the engineered fill layer and the ground beneath should be assessed.

4.6.5.1 Unsuitable ground conditions

Prior to the execution of earthworks filling, unsuitable materials should be removed from the formation level including:

- topsoil, tree roots, highly organic matters, or other degradable materials
- frozen soils
- excessively wet or soft soils such as silty soils or clays with an undrained shear strength of less than 40kPa, where not treated to adjust their soil properties
- contaminated soils, and soils containing slag or combustible materials.

Unsuitable materials may be treated, in some circumstances, to adjust and improve the soil properties. Further assessment would be required to determine their suitability after treatment and prior to any subsequent placement as engineered fill.

4.6.5.2 Obstructions

Obstructions including oversized materials or relic foundations that may impede future works in the ground or adversely affect earthworks filling or drainage of the ground should be removed.

It may be impractical to remove some obstructions beneath engineered fill such as former piles etc. These should be adequately surveyed, and their locations accurately recorded. Any retained relic structure or obstructions should be a minimum of 2m beneath the underside of proposed building foundations.

4.6.5.3 Compressible soils

Where compressible soils are present such as soft clays, disturbed ground or peat, the effects of earthworks should be assessed including the magnitude and duration of induced settlements.

Where significant settlements of the underlying soils are predicted, it may be necessary to undertake compaction works, removal or ground improvement works, such as the installation of vertical drainage, or surcharging prior to filling of earthworks.

The effects of ‘drying out’ of compressible soils such as peat beneath engineered fill, should be assessed where earthworks may reduce water infiltration, or the development may cause lowering of groundwater levels.

4.6.5.4 Unstable ground

Voids that might collapse or cause excessive settlement (ie, dissolution features, mine workings and entries, sewers and drains) should be adequately investigated and suitably infilled or grouted prior to the commencement of any earthworks filling or building foundations.

Unstable natural deposits or materials susceptible to solifluction (materials that have undergone progressive, gravitation and downslope movement) should be adequately investigated and addressed by the geotechnical design.

4.6.5.5 Groundwater conditions

The following conditions may adversely affect the long-term performance of engineered fill, if not properly considered and allowed for within the design and specification:

- lowering of the water table to facilitate filling may cause settlement of existing adjacent buildings
- rising or recovery of groundwater levels after filling may cause inundation settlement of fill or wash-out of ‘fines’ and settlement
- falling groundwater could cause settlement of soft strata, including peat
- lack of surface water management (ie, non-provision of adequate capping and drainage) following earthworks to ensure no subsequent deterioration over time.

4.6.6 Materials for use as engineered fill

Also see: BRE SD 1-Part 1, BRE Digest 433, BS EN 771 and ICE's Earthworks: a guide.

Engineered fill materials shall be suitable for the site conditions, proposed end-use and techniques of placement and compaction. Issues to be taken into account include:

1) suitable sources of engineered fill materials

2) treatment of fill materials.

The earthworks specification should indicate the materials to be used for filling including their geotechnical classification and range of properties that should be subject to monitoring and testing. Material classification should be clearly stated eg Class 1C Coarse Granular General fill or a Class 6N Well Graded Selected Granular fill in accordance with Specification for Highway Works.

Materials that do not fully comply with the earthworks specification must not be used as engineered fill.

4.6.6.1 Suitable sources for engineered fill materials

Engineered fill material may be site-won or imported from appropriate suppliers or donor sites. Where differing engineered fill types are placed in subsequent layers or distinct zones, it is important to ensure compatibility – for example, to ensure that fines are not washed out of one material into a more coarsely graded material, geotextile separators may be required.

Where material is obtained from stockpiles, the homogeneity should be confirmed. Different forms of stockpiling can affect particle size and grading. The outside of a stockpile may be weathered and may not be the same as the unweathered material within. The use of recycled aggregate as fill should comply with BRE Digest 433 or other suitable guidance as agreed with NHBC.

Details of considerations regarding the acceptability of materials for re-use as engineered fill are provided in Table 3. Tests undertaken to confirm acceptability should be carried out by a UKAS and/or MCERT Accredited laboratory (or other specialist laboratories) in accordance with the earthworks specification, appropriate standards and industry guidance, with a detailed knowledge of the materials to be tested and proposed end use. The samples which are tested must be representative of the true nature of the material.

Table 3: Acceptability of materials for re-use as engineered fill

Material Description	Examples of Material	Details on Acceptability for re-use as fill
Suitable sources for fill materials	• Natural sands and gravels • Clays with a plasticity index of less than 40% and undrained shear strength in excess of 40kPa • Chalk (structured chalk of grades C5 - A1 only) • Crushed rock • Crushed concrete, brick or stone	Typically, the material would be acceptable to NHBC for engineered fill, provided that they comply with appropriate classification criteria. For material that is solely crushed brick, further assessment of strength will be required to ensure its durability
Hazardous materials	• Reactive materials • Materials that include sulphides or sulphates, eg gypsum • Organic materials • Materials that cause noxious fumes, rot, undue settlement, or damage to surrounding materials	Appropriate testing required to demonstrate their suitability
Fill material requiring NHBC acceptance	• Unburnt colliery spoil or shale (Carbonaceous Mudstone) with excessive coal or pyrite content • Colliery shale (ie, burnt shale, or red blaze) • Steel slags • Furnace ashes and other products of combustion • Material obtained from demolition without screening, crushing and processing • Soils with a silt content greater than 20% • Highly variable materials • On wet sites, or sites with a high-water table, crushed or broken bricks which have no limit on their soluble salt content (as defined in BS EN 771)	Not to be used as engineered fill unless a written agreement has been obtained from NHBC
Unsuitable fill materials	• Soils containing topsoil or significant organic matter (such as leaves or wood) greater than 6% by volume • Degradable, reactive, or non-durable materials • Expansive materials, (ie, steel slag and gypsum containing materials) where testing has not determined their risk • Materials capable of releasing contaminants or hazardous gases • Combustible materials (ie, materials with a high calorific value greater than 7MJ/kg) placed within the top 1m of the finished development platform • Materials containing significant amounts of plaster, plastic or rubber up to 2% by weight • Materials containing harmful substances, which pose a risk to human health and the environment • Materials with high sulphate content where Total Potential Sulphate (TPS) is in excess of 0.25% • Structureless chalk (with grades Dm and Dc) • Materials that are not generally used as engineered fill on residential sites	Fill containing these constituents are **NOT** acceptable for use

4.6.6.2 Treatment of fill materials

The following techniques may be used to modify the moisture content of materials to render them suitable for use as engineered fill:

- placement in windrows or layers with mechanical turning as required for drying purposes
- the addition of lime and/or cement, typically up to 2% by weight to reduce the moisture content to nearer the optimum moisture content (OMC) for maximum dry density
- the addition of water by spraying or similar to increase the moisture content to nearer the OMC for maximum dry density.

The following techniques are not acceptable to NHBC for the treatment of materials for use as engineered fill:

- stabilisation to improve strength by the addition of over 2% lime or the addition of any cement or other hydraulic materials
- the addition of chemical binders or grouts.

4.6.7 Design and specification of earthworks

Also see: BS EN 1997-1, BS EN 16907-1, BS 6031

A suitably qualified engineer shall be responsible for the design and specification of earthworks taking into account future development and type of building foundations. Engineered fill shall be placed in accordance with a suitable Earthworks Specification. Items to be taken into account include:

1) **geotechnical design**
2) **earthworks specification**
3) **types of specification.**

Engineered fill should be placed to a suitable earthworks specification – the scope, details and requirements of the specification should be appropriate to the site, the nature of the fill, the techniques of placement and the end-use of the site.

4.6.7.1 Geotechnical design

On engineered fill sites, an element of geotechnical design will be required by NHBC. The complexity of the design and its supporting earthworks specification should reflect the scope of works and the associated risk. Geotechnical design is covered in BS EN 1997, with earthworks specifically covered by the requirements set out in BS 6031 (Code of practice for earthworks) and BS EN 16907 (Earthworks).

It is recognised that on certain residential developments, the level of earthworks required can be minimal, with a low to negligible risk associated with the project. Where the scope of the earthworks is defined as Geotechnical Category 1 (Geo Cat 1), based on the Table below, a Geotechnical Design Statement (GDS) shall be prepared and submitted to NHBC.

Most earthworks are classified as Geotechnical Category 2 (Geo Cat 2) in accordance with BS EN 1997-1 and are required to be designed by an appropriately qualified and experienced person. Where the scope of the earthworks is defined as Geo Cat 2 or 3, a Geotechnical Design Report (GDR) shall be prepared and submitted to NHBC.

The content lists of a GDS or GDR may be prepared using guidance from DMRB CD 622 as a guide. Both the GDS and GDR should be prepared by a suitably qualified Engineer.

The following Table 4 – ‘Geotechnical design categories’ should be used to attribute a geotechnical category to projects, and the subsequent requirements for Geotechnical Design Statement (GDS) or Report (GDR).

Table 4: Geotechnical design categories

Assessment of the site and proposals
Geohazards – legacy of mining/quarrying, un-engineered fill, low strength/bearing capacity, slope stability, etc
Preparatory works – removal of remnant foundations, obstructions, settlement monitoring, mining treatment, etc
Requirement for ground improvement – preloading, surcharging, dynamic compaction, etc

Category	Scale and extent of earthworks and end-use	Required information
Geo Cat 1 SIMPLE	Considered to have negligible geotechnical risk and may be designed adopting a qualifiable approach. The Geotechnical Design Statement and earthworks specification should clearly define the scope of works covered by the Geo Cat 1 design and can be presented on drawings, accompanied by appropriate risk assessment Typical sites would include: • greenfield sites • no geotechnical hazards • suitable existing ground conditions, no or minimal preparatory works and ground improvement measures • placement of engineered fill limited to proposed infrastructure, external works and earthworks slopes no steeper than 1V:5H • use of General fill only	A Geotechnical Design Statement (GDS) Summary based on good local experience and ground conditions that are well known and uncomplicated
Geo Cat 2 CONVENTIONAL	Considered to have no exceptional geotechnical risk associated with them, either during or post construction. The records of the quantifiable design shall be presented in the Geotechnical Design Report which should be accompanied by the earthworks specification Typical sites would include: • brownfield sites • some or many geotechnical hazards to be removed or suitably mitigated. • some or many preparatory works to be undertaken, the requirement for one or more ground improvement measures • placement of engineered fill limited to proposed infrastructure, external works and earthworks slopes steeper than 1V:5H, and • placement of engineered fill supporting building foundations and settlement sensitive elements • use of Selected and General fill	A Geotechnical Design Report (GDR) Based on the current BS EN 1997-1
Geo Cat 3 COMPLEX	Considered to have exceptional geotechnical risk with unstable ground conditions. Geo Cat 3 designs require an independent third-party check and are not covered by the requirements of this Chapter Typical characteristics include: • mostly brownfield sites • many geotechnical hazards to be removed or suitability mitigated • requiring a wide range of preparatory works to be undertaken • exceptionally difficult ground conditions with ongoing instability, ground movements or requiring investigation and special measures • placement of engineered fill supporting very large or unusual structures/buildings	A Geotechnical Design Report (GDR) Typically, outside the scope of this standard Consultation with the NHBC and/or the Land Quality Service lqs@nhbc.co.uk

4.6.7.2 Earthworks Specification

The earthworks specification should be prepared once the earthworks design has been undertaken and the properties of the proposed fill material have been established. It should clearly describe the design requirements to be satisfied, ie, detail how the engineered fill is to be placed and what criteria will apply to prove its compliance and include the information detailed below. An earthworks specification should be practicable and capable of both measurement and enforcement and should be capable of being monitored by an effective form of quality assurance procedure.

Typical Earthworks Specification should include the following:

1. Description of scope and aims of the earthworks including reference and brief summaries of supporting documents:
   a. Desk study and Ground Investigation Report
   b. Geotechnical Design Report or Geotechnical Design Statement
   c. Materials Classification (Acceptability) Assessment
2. The intended end-use of the engineered fill should be defined
3. Details of any site preparation works required prior to earthworks filling and the treatment of exposed surfaces to prevent deterioration
4. Types of materials permitted for use together with material properties. This should include arrangements to prevent the deterioration of cohesive materials
5. Classification testing may include particle size distribution, plasticity (Atterberg limits), compaction tests, or moisture content tests should be undertaken to confirm that the fill materials remain within the earthworks specification
6. The types and frequency of classification tests should be site and material specific and should be confirmed in the specification. Acceptable test methods and frequencies of classification tests are given in Tables 9 and 10 of BS 6031: 2009
7. Requirements for the placement, spreading and compaction of earthwork materials, including compliance criteria
8. Requirements for the disposal of unsuitable material
9. Testing proposals for the verification of compliance criteria and performance requirements to be met for End Product and Performance specifications, including load-settlement testing
10. Arrangements for supervision
11. Proposed as-built records to reflect the completed works
12. Construction drawings showing the proposed extent of the filling works (including thickness)
13. All other site-specific requirements and relevant construction drawings showing retained features, constraints, etc
14. The form and proposed content of an Earthworks Validation Report

4.6.7.3 Types of specification

Three types of standard Specifications for Earthworks are acceptable to NHBC, and these are:

- method
- end product and
- performance.

Method specification defines how compaction should be conducted in terms of the types of compaction plant, method of operation, number of passes of the plant and the final thickness of the compacted layer.

The End Product specification defines the degree of compaction necessary, and if appropriate stiffness requirement, for the given material by reference to criteria linked to either serviceability or ultimate limit states. The level of compaction required is normally expressed in terms of selected geotechnical properties eg, percentage of maximum dry density or prescribed minimum stiffness and is supported by on-site earthworks testing. Where an end product specification is used, the requirements normally define overall targets to be achieved without detailing the methods to be used to achieve the targets.

Performance specifications require the works to be defined relative to long-term project requirements, which are commonly set at a relatively high level. For example, the criteria may be defined based on the long-term fitness for use of a building that is to be formed upon the completed earthwork. NHBC requires a performance specification to be used in combination with an end product specification.

NHBC specification requirements for use on residential development are summarised in the following Tables 5 & 6.

Table 5: Types of Specification for earthworks acceptable to NHBC

Specification	Specification requirements
Method	• The thickness of fill layers to be compacted • Type of compaction plant • Number of passes required • Compaction requirements (typically 90% maximum dry density and <10% air voids)
End Product	• The geotechnical properties to be achieved following placement of engineered fill - typically dry density, moisture content and air voids • The criteria for acceptable compliance and compaction requirements (see Table 6) • Proposals in the event of non-compliance
Performance	• Defined by relative long-term projects requirements eg, engineered fill and the underlying ground supporting building foundations shall limit building settlements to less than 25mm and minimise angular distortion or tilt to 1:400 for 60-year design life • NHBC requires a Performance Specification to be used in combination with an End Product Specification • The behaviour the completed engineered fill is required to achieve under testing – usually limits of settlement under specified load and/or over time • Details of the performance testing to be undertaken, including testing frequency • Proposals in the event of non-compliance during placement and of performance testing

Table 6 provides the minimum level of compaction required throughout the placement of all engineered fill for both the support of building foundations and external and infrastructure works.

Table 6: End product acceptance criteria

End Use	Acceptance criteria
Building Foundations	>95% MDD* and <5% air voids (4.5kg or vibrating rammer) >98% MDD* and <5% air voids (2.5kg rammer)
External/Infrastructure	>95% MDD and <5% air voids where fill > 5m thick (2.5kg / 4.5kg rammer) >90% MDD and <10% air voids where fill <5m thick (2.5kg / 4.5kg rammer)

*MDD = Maximum Dry Density

It may be appropriate for a project technical specification to incorporate different forms of earthworks specification for different types of fill material, eg method compaction for general fills and end product compaction for coarse granular fills.

The earthworks technical specification shall include relevant conditions to be satisfied during construction to ensure the following are met:

- materials are chemically suitable for the project and the surrounding environment
- materials should be durable, and not prone to deterioration or non-biodegradable
- earthworks should provide a stable finished surface that will limit post-construction settlement or movement within the engineered fill
- the earthworks should provide a surface of sufficient stiffness and/or shear strength for the intended use.

Once agreed with NHBC, the earthworks specification should not be amended on site without prior agreement with the NHBC.

The earthworks specification should be based on industry guidance such as the Specification for Highway Works, BS EN 16907 ‘Earthworks’, ICE Publishing – Earthworks: A Guide ‘2nd Edition’, or on trials/previous experience, that is acceptable to NHBC.

The earthworks specification should outline if placing, testing and verification of earthworks fill is to be completed on the whole site, or be undertaken and presented in a phased approach to facilitate the build programme.

Table 7 shows the types of earthworks specification that are acceptable to NHBC for different types of engineered fill and subsequent end-use, considering the starting ground (formation) level has been assessed as suitably stable and appropriate for the proposed earthworks and end-use (as per clause 4.6.5).

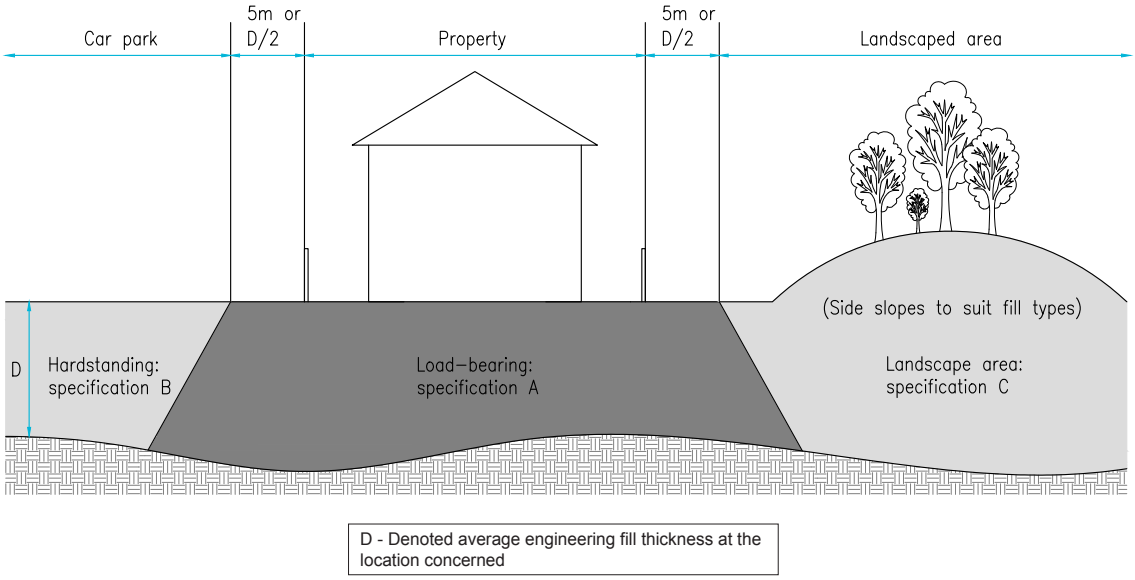
Table 7: Matrix for determining appropriate types of earthworks specification

End-use	Support of foundations	Support of external works	
Depth of fill	N/A[1]	<5m	>5m
Granular and Cohesive fill types (including mixed fills)	End Product plus Performance (Reinforced Strip and Beam Grillage)	Method	End Product
	End Product (Semi-Raft)		

Notes
1 Acceptable minimum depth of engineered fill beneath building foundations = 600mm.

Figure 2 illustrates the guidelines for the use of differing earthwork specification for different end-use, located in close proximity.

Figure 2: Compaction and differing end use



NOTES:
1. Specifications A & B to be to Table 7
2. Specifications C may be Method or End Product or no defined compaction regime

4.6.8 Compatibility of fill with foundations, infrastructure and external works

Placed engineered fill shall support foundations, infrastructure and external works as required without excessive settlement. Items to be taken into account include:

1) building and foundation types
2) engineered fill performance and Foundation Options
3) building settlements and relative movements
4) external works and infrastucture.

This section provides guidance on building foundations that will generally be acceptable to NHBC. Where more rigorous structural or geotechnical analysis is carried out alternative solutions may be acceptable, but these must be agreed with NHBC in advance of development.

4.6.8.1 Building and foundation types

Engineered fill covered within this chapter should be capable of supporting foundation loads from buildings of three storeys or equivalent weight.

Where compliance testing of engineered fill demonstrates a high level of consistency and quality in combination with a high level of supervision and control, a suitably structurally designed reinforced strip foundation may be acceptable. This can be so in conjunction with ground hazards and risks associated with excessive settlements being suitably addressed. A suitably structurally designed beam grillage will also be acceptable.

Where engineered fill has been placed to a suitable earthworks specification with a satisfactory verification testing, a semi-rigid raft foundation in accordance with Chapter 4.4 will be acceptable to support buildings.

Reference should also be made to the requirements of Chapters 4.2 'Building near trees' and Chapter 4.3 'Strip and trench fill foundations' as appropriate. Cohesive fill material should be taken as having a similar volume change potential (and requirement for minimum foundation depths) as natural clays of the same plasticity index.

4.6.8.2 Engineered fill performance and Foundation Options

Residential developments founded on engineered fill are more sensitive than other structures or infrastructure founded on the same material and requires foundation solutions that will mitigate the potential for both aesthetic and structural damage over the design life of the building. Any foundation solution adopted should be sufficiently robust to accommodate the predicted future settlements and prevent damage to building superstructures. To provide the required stiffness, rigidity and robustness against unwanted movements, all foundations on engineered fills should be reinforced. Unreinforced strip footing would not be acceptable to NHBC under any circumstances.

Table 8 indicates the minimum requirements necessary for a shallow foundation to be used on engineered fill and considers different foundation types that may be used based on the achieved compaction of the engineered fill only. The table should only be used where no other residual geotechnical risks are present and assumes that the engineered fill is placed on competent natural ground.

The foundation specified should consider the holistic geotechnical design (eg, bearing capacity and settlement) and also allow for any retained geotechnical risks outside or below the engineered fill. Table 8 should not be used to justify a less robust foundation where unresolved geotechnical risks remain.

Where the requirements of Table 8 have not been significantly achieved, for example poor execution or poor site supervision or inadequate testing or reporting, or where the verification of the earthworks falls outside the minimum requirements given below, an alternative foundation solution outside this chapter will need to be considered – ie, solutions from Chapter 4.4 'Raft, pile, pier and beam foundations' or Chapter 4.5 'Vibratory ground improvement techniques'. Where piles are considered, the potential for negative skin friction on the piles due to creep settlement of the placed engineered fill and/or the consolidation of any underlying soils should be assessed.

Table 8: Engineered fill Performance and Acceptable Foundation Options

Proposed outcome	Reinforced strip	Beam grillage	Semi-raft
Minimum relative compaction (% maximum dry density)[1]	>95	Majority of results >95 However, results show some variability and non-compliances (see Figure 7) No results <90	Majority of results >95 However, results show some variability and non-compliances (see Figure 7) No results <90
Maximum air voids (%)	<5	Majority of results <5 However, results show some variability and non-compliances (see Figure 7) No results >10	Majority of results <5 However, results show some variability and non-compliances (see Figure 7) No results >10
Supervision	A very high degree of independent supervision Full time independent resident geotechnical engineer dedicated to inspection, supervision and testing of the fill	A high degree of independent supervision Full-time inspection of the filling by an independent resident geotechnical engineer	Good/normal supervision Part-time inspection of the filling by an independent geotechnical engineer
Contractor	Experienced/specialist earthworks contractor	Experienced earthworks contractor	Suitably experienced groundworker or earthworks contractor

Engineered Fill	Fill generally of consistent depth and properties throughout Fill behaviour should have been proven by precedent or trials	Fill generally of consistent or steadily varying depth Little variation in fill properties	Effects of variations in fill depth and properties should be assessed with predicted settlements established
Foundation performance testing	Zone load tests and/or mini zone load tests and Plate load tests across fill depth and at surface[2]	Mini zone load tests and Plate load tests across fill depth and at surface[2]	Plate load tests across fill depth and at surface[2]
Verification	Earthworks Verification Report produced by a third-party organisation	Earthworks Verification Report produced by an experienced earthworks contractor	Earthworks Verification Report produced by an experienced earthworks contractor/groundworker
Foundation design	Design by a suitably qualified Engineer to relevant British Standards Designed for moment to span 2m as simply supported and 1.0m as a cantilever[3]	Design by a suitably qualified Engineer to relevant British Standards Designed to span 3m as simply supported and 1.5m as a cantilever	Design by a suitably qualified Engineer to Chapter 4.4 'Raft, pile, pier and beam foundations'

Notes
1 Modified Proctor hammer (4.5kg).
2 Minimum 600mm diameter.
3 Foundations to be typically reinforced with mesh reinforcement at top & bottom.

In circumstances where there is a potential increased or significant geotechnical residual risk of long-term creep settlements, for example as a result of the type or thickness of placed engineered fill or underlying thickness of made ground beneath the engineered fill, a stiff reinforced concrete raft or stiff beam grillage foundation may be required.

4.6.8.3 Building settlement and relative movements

The total settlement between any part of the building foundation and the surrounding ground or external area, should not normally exceed 25mm over the 60-year design life.

Where engineered fill or the underlying ground, is undergoing steady uniform settlement a total foundation settlement of over 25mm may be acceptable, provided the differential settlement is compliant with the guidance below and the foundation solution is sufficiently robust.

The tilt or distortion (differential settlement) of any part of the foundation should not exceed 1 in 400. The potential differential settlement of any foundation should be assessed where:

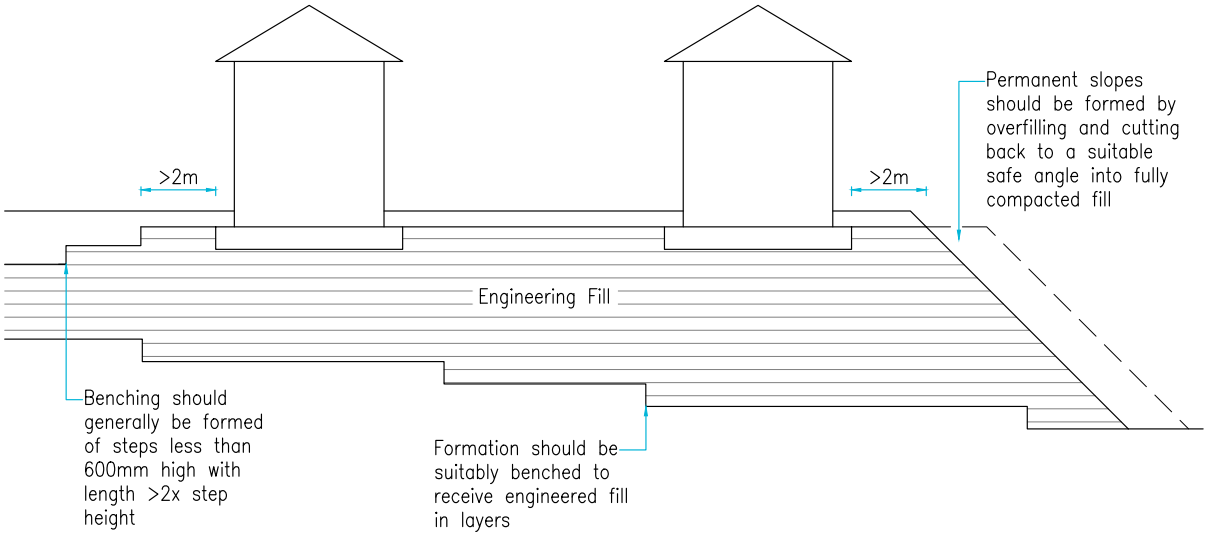
- the depth of fill significantly varies,
- there is a tapered layer of compressible material,
- a quarry highwall or buried batter is present.

Where predicted total or differential settlements of any part of the building foundation exceed the above criteria further assessment will be required to determine suitable alternative foundation solutions. The presence of highwalls, in particular will require rigorous assessment including their location, geometry, and observed load-settlement behaviour of the engineered fill following remediation, if they are to be considered by NHBC to be suitable to build residential development upon.

The effects of differential settlement between external areas and buildings should be assessed in particular where these are piled or supported on vibro columns. Additional means of support or measures to mitigate ground movement may be required where excessive settlements could be realised, ie, the use of flexible drainage and/or surcharging.

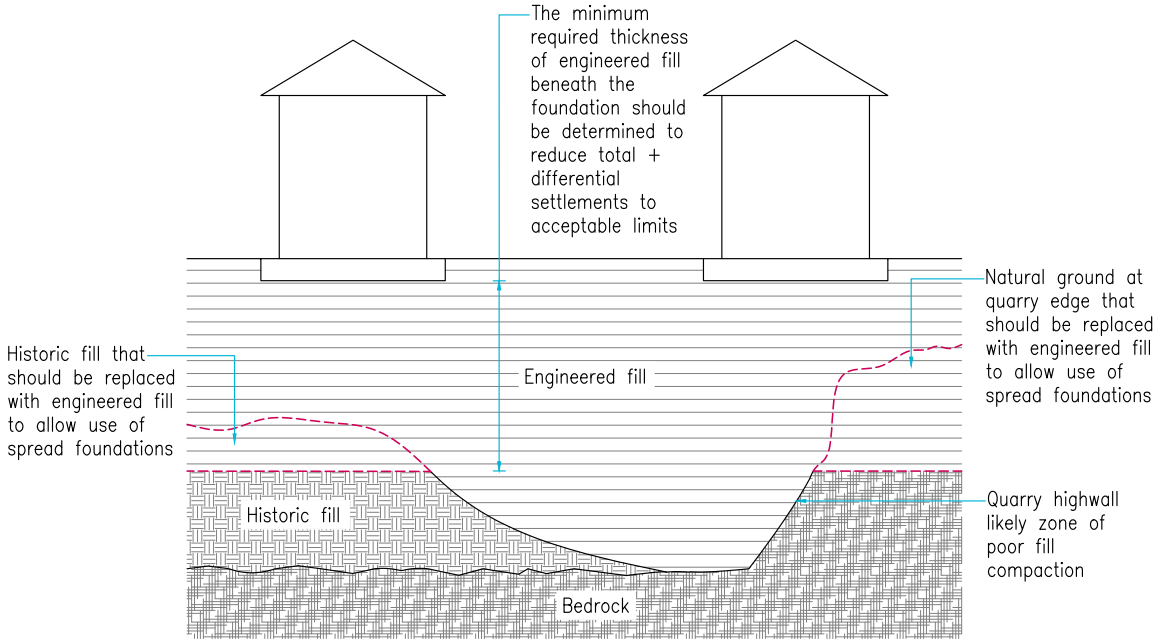
The following Figures 3 and 4 show examples of engineered fill over rolling landscape and over buried features where part removal of the feature was necessary to mitigate excessive tilts.

Figure 3: Engineered fill over gentle rolling landscape



LAND RAISING AREAS SHOULD BE SUFFICIENTLY LARGE ON PLAN TO PERMIT PLANT AND FILL MOVEMENTS AND FOR BENCHING AND TRIMMING AT EDGES.

Figure 4: Engineered fill over buried features



FOUNDATIONS ON ENGINEERED FILL SHOULD NOT BE USED WHERE MAJOR CHANGES IN FILL DEPTH OCCUR OR WHERE POOR COMPACTION MAY RESULT – SUCH AS AT HIGHWALLS WITHOUT MITIGATION.

4.6.8.4 External works and infrastructure

It will generally be acceptable to support low height retaining walls and boundary walls on mass concrete or reinforced foundations placed on engineered fill. Walls should be provided with joints and/or reinforcement as considered appropriate to provide flexibility and structural integrity while accommodating ground movements particularly at locations where depths of engineered fill and settlements may vary. Geotechnical and structural designs are required where retaining walls are in excess of 0.6m in height.

Wall foundations, hardstandings and roads should be designed according to appropriate guidance and achieved geotechnical properties of the engineered fill.

Where external works and infrastructure pass from engineered fill to the natural ground or where the depth of engineered fill varies significantly, the potential for differential ground movements should be assessed and catered for. Additional measures should be provided as necessary eg, the use of geogrid or futureproofing drains by potentially laying to steeper falls and the use of flexible jointing.

For areas not within the influence of building foundations (ie, hardstanding, gardens, infrastructure or external works areas), a maximum total long term settlement of over 25mm would generally be acceptable subject to serviceability design limits. See Figure 2 above for an approximate delineation of these areas.

4.6.9 Acceptable methods of earthworks filling

Also see: SHW Series 600

Earthworks filling shall only be undertaken using methods acceptable to NHBC that are appropriate to the materials, site conditions and end-use. Items to be taken into account include:

1) **conventional compaction**
2) **non-standard compaction**
3) **preloading and surcharging.**

4.6.9.1 Conventional compaction

Placement and compaction of engineered fill should be undertaken in layers of controlled depth using appropriate plant. Acceptable methods are considered to be those based on the recommendations from The Specification for Highways Works (SHW) Table 6/4.

The type and size of the compaction plant should be based on the volume or depth of engineered fill to be placed, the classification of the fill to be compacted, and the specification requirements.

4.6.9.2 Non-standard compaction

This aspect covers all methods of compaction, which are not covered by SHW Table 6/4. Details of non-standard plant and techniques should be submitted to NHBC in writing at least eight weeks before site works begin. Non-standard techniques include, but are not limited to:

- rapid impact compaction (RIC), utilising a rammer
- high energy impact compaction (HEIC), utilising polygon or triangular rollers
- dynamic compaction, utilising heavy drop weights dropped from a crane.

NHBC will require evidence of the effectiveness of non-standard plant or techniques, or demonstration of the suitability of proposals for the site conditions by trials as appropriate, particularly for large or complex projects. Site trials including testing requirements should be designed and agreed with NHBC prior to commencement. Trials must accurately reflect the proposed filling techniques and achieve specified performance requirements and may require post treatment investigation and load testing.

4.6.9.3 Preloading / Surcharging

Placement of a surcharge may be an acceptable form of ground improvement but should not be used in place of the compaction techniques described previously. The design of surcharge including the magnitude and duration of the surcharge requires careful analysis.

The effectiveness of surcharging should be demonstrated by monitoring or by trials. The requirements for monitoring and supervision are outlined in BS EN 1997-1 and BS 6031 and should be presented in the GDR. The surcharge load should be maintained until the achievement of the design requirements has been demonstrated. Refer to BRE FB 75 for further guidance.

4.6.10 Site work

Also see: BS EN 16907-5 and BS 6031

The developer or builder shall ensure suitable supervision, sampling and testing are performed throughout the entire duration of the earthworks. Filling shall be undertaken by a competent Contractor using materials, personnel and plant appropriate for the nature of the site conditions and proposed end-use. Issues to be taken into account include:

1) **supervision and records**
2) **site preparation**
3) **material handling**
4) **material acceptability and compliance testing**
5) **actions in respect of non-compliant fill**
6) **protection of fill.**

4.6.10.1 Supervision and records

The developer or builder must arrange for a suitable site supervision and recording of the works appropriate to the scale and complexity of the project and proposed end-use of the fill. The recording of the site works should be in accordance with the requirements of the earthworks specification. Guidance on the level of information that is required to demonstrate the quality of the works is available in BS EN 16907-5.

4.6.10.2 Site Preparation

The site should be prepared in accordance with the earthworks specification with all vegetation, topsoil, fly tipped, and unsuitable materials removed prior to filling. If suitable, topsoil should be placed in segregated stockpiles for reuse onsite or elsewhere. Where excess topsoil is present, this may be removed under the Material Management Plan (MMP).

The formation should be prepared by proof rolling with any hard or soft spots identified and remediated in accordance with the earthworks specification. Temporary drainage may be required to keep the formation dry.

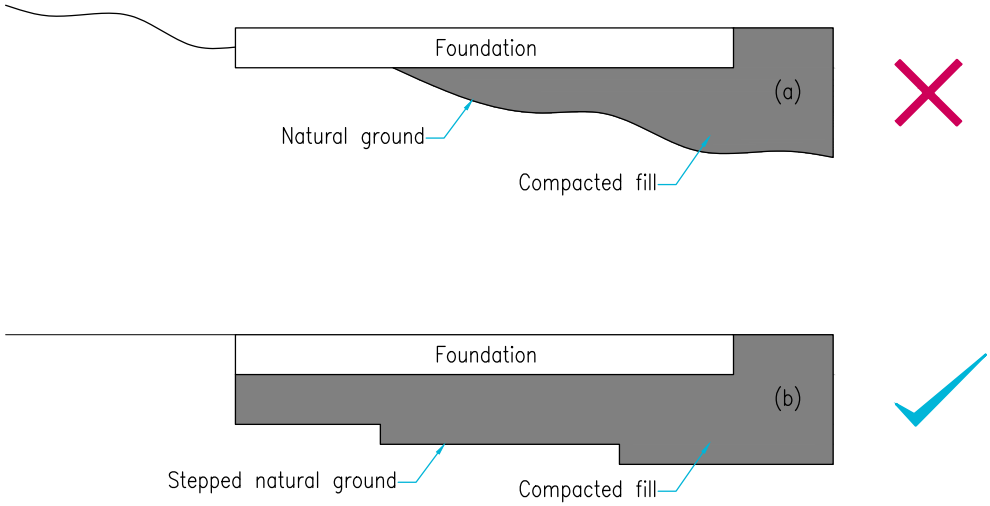
Relic structures, for example old foundations and hard standings, should be removed from below engineered fill areas in their entirety wherever practicable. As a minimum, relic structures and obstructions should be removed to at least 2m below any proposed foundation. All structures or uncharacteristic elements (including boulders) greater than 1.0m in diameter/length left in the ground at formation should be surveyed and their positions recorded.

When recording the depth of engineered fill, it is essential (eg, for use in subsequent pile designs) that the formation should be surveyed prior to filling on a maximum 10m grid arrangement.

Site constraints and features to be preserved (for example monitoring wells, public rights of way, watercourses and trees to be retained) must be clearly identified and all necessary protection and safety measures must be implemented. Alternatively, their removal or any reinstatement measures should be specified as appropriate.

Where the sub formation is sloped, the sides should be stepped at a maximum height of 600mm to allow the engineered fill to be benched into the existing natural ground or achieved otherwise as stated in the earthworks specification. Figure 5 shows what may be required on a sloping site close to the development platform where filling is required.

Figure 5: Benching of sloping natural ground



NOTES:
a. Proposed development platform straddling over natural and fill areas
b. Preferred development platform with well prepared and stepped fill area beneath

4.6.10.3 Material handling

In addition to the required classification testing, site-derived materials should be routinely inspected during excavation to ensure consistency and correlation with the expected ground model.

Imported fill should be subject to periodic inspection from the donor site prior to arrival at the site and regular inspections once delivered. Classification testing should be undertaken as required prior to placement, particularly where the material is not provided with independent certification and where visual assessment suggests the material classification varies.

Engineered filling should not be undertaken in inclement weather conditions. Where the engineered fill is cohesive, placement and filling should be paused during extended periods of rain. For sensitive materials like chalk, care should be taken not to over-compact the fill further than specified.

Engineered fill must be placed and compacted in accordance with the specification, within a defined moisture content range close to the optimum moisture content as derived from relevant laboratory testing.

For cohesive fill materials, the moisture content is critical in achieving the desired dry density. Engineered fill that is compacted too dry of the optimum moisture content (OMC) risks being vulnerable to collapse settlement or heave when wetted. Engineered fill that is compacted too wet of optimum moisture content risks being too weak to provide adequate support without excessive settlement.

Engineered fill should proceed in near horizontal layers (to assist in shedding surface waters) with each layer fully compacted before commencing the following layer. The maximum layer thickness for method compaction should be based on the type of fill material, the classification of the fill material, placement and the method and plant employed.

For end product compaction, an uncompacted layer thickness of up to 250mm subject to site-specific requirements would be acceptable. The maximum particle size should not be greater than 1/3 of the compacted layer thickness or 75mm, whichever is lower.

Differing engineered fill material types should not be placed in the same layer, they should be placed at predetermined layers and defined depths appropriate to their properties and the proposed end-use.

Filling activities should be planned and carried out so that:

- vibrations do not disturb existing or nearby properties, excavations, slopes, buildings, services or infrastructure
- filling and earthwork machinery does not overload retaining features, slopes, buried services or infrastructure
- ground movement including around the area of filling does not harm adjacent buildings, services or infrastructure
- temporary slopes (filled or in cut) are safe and stable
- under compaction and over-compaction are avoided
- the rate of placement of fill does not result in excess pore water pressure leading to failure of the underlying ground.

4.6.10.4 Material acceptability and compliance testing

Classification and compliance testing should be in accordance with BS EN 16907-5 and BS 6031:2009. Laboratory testing should be undertaken by a UKAS and/or MCERTS accredited specialist. All testing should be to a current British or EN Standards eg, BS 1377, using appropriately calibrated equipment. Testing should be undertaken throughout the duration of the fill placement in accordance with the guidance in clause 4.6.12.

4.6.10.5 Actions in respect of non-compliant fill

Where testing indicates compacted engineered fill does not fully comply with the requirements of the earthworks specification, appropriate action should be agreed as soon as possible with NHBC. Possible actions include:

- drying of engineered fill material prior to further placement of subsequent layers
- excavation and replacement of the engineered fill represented by the test failure
- additional compaction (if the failure is shallow or at the surface) and retesting
- if the non-compliance is regarded as a marginal outlier and represents part of a normal spread of test data, it may potentially be deemed acceptable without further action. It should be recorded in the Earthworks Verification Report
- undertaking appropriate performance testing.

The possible extent of non-compliant engineered fill needs to be carefully assessed and whether the non-compliance may indicate unsuitable placement and compaction techniques or poor site conditions or excessively variable fill or unsuitable material. Where there is a divergence from the earthworks specification the Designer should be notified, and advice sought.

Remedial action needs to be carefully undertaken and recorded avoiding disturbance to previously placed compliant engineered fill.

4.6.10.6 Protection of fill

Compacted engineered fill should be protected from deterioration due to trafficking, poor weather and pooling surface water. Suitable measures include laying the surface to falls to assist drainage or use of a durable granular sealing layer or sacrificial layer.

4.6.11 Adjacent excavations

The builder shall ensure that foundations within engineered fill are not disturbed by adjacent excavations.

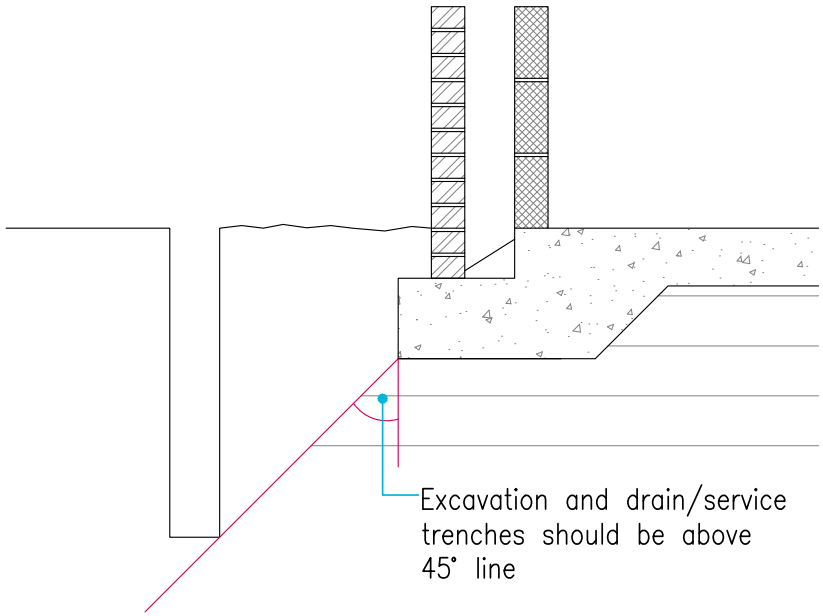
The Engineer should consider the influence of drainage and other service trenches on the stability of the complete works.

Excavations in engineered fill may require additional trench support, even at relatively shallow depths. Health and Safety Executives' (HSE) advice with respect to the design and management of below ground temporary works, including those for excavations, man-entry, etc must be adhered to.

The Earthworks Verification Report should identify and duly reference any constraints to excavation because of buried features, contamination or unusual ground conditions.

The minimum horizontal clearance between excavations and foundations must not be less than the depth of excavation minus the depth of the structural foundation. Particular attention is needed for excavation below the water table, where encountered.

Figure 6: Placement of excavation adjacent foundation on engineered fill



4.6.12 Verification of engineered fill

Also see: BS EN 16907-5, BS 6031 and BRE 427

Verification testing of engineered fill shall be undertaken to confirm compliance with the earthworks specification and its fitness for purpose. Items to be taken into account include:

1) **fill classification**
2) **end product testing**
3) **performance testing**
4) **settlement measurement**
5) **testing frequency.**

Validation and verification of the filling should be in accordance with BS EN 16907-5 and BS 6031:2009. Laboratory testing should be undertaken by a UKAS and/or MCERTS accredited specialist. All testing should be to a current British or EN Standards eg, BS 1377, using appropriately calibrated equipment.

Testing should be undertaken on a combination of random and targeted locations through the full depth of the fill to ensure consistency across the site. Higher risk locations (for example deeper engineered fill, heavier/larger buildings or where engineered fill was placed in less suitable conditions) should have a robust data set to confirm that fill has achieved the required geotechnical compliance criteria.

The testing frequency should be set out in advance of the works in the Earthworks specification.

4.6.12.1 Fill classification

Classification testing including particle size distribution (grading), plasticity (Atterberg limits), 4.5kg rammer compaction tests or moisture content tests, should be undertaken throughout the earthworks to confirm that the engineered fill materials remain within the acceptability limits set out in the earthworks specification.

The type and frequency of classification tests should be site and material specific and should be confirmed in the earthworks specification. Acceptable test methods and frequencies of classification tests are given in Tables 9 and 10 of BS 6031:2009.

4.6.12.2 End product testing

Fill compaction is most commonly established by comparing the in-situ dry densities and moisture contents with the laboratory determined maximum dry density and optimum moisture content. NHBC will normally accept engineered fill verified to achieve the criteria given in Table 6. There may be variation to these requirements where differing material types or foundations are adopted, or where there is a risk of future inundation of the fill.

The in-situ densities of engineered fill may be measured using sand replacement tests (SRTs), nuclear density tests (NDTs) or electromagnetic density gauges (EDGs). Where NDTs or EDGs are used, the results should be regularly calibrated against SRTs. Where there is variation in the fill materials, the use of NDT results to assess compaction may not be reliable.

4.6.12.3 Performance testing

Table 9 indicates suitable tests to assess earthworks performance. The type and frequency of testing should be appropriate for specific site conditions and the proposed end-use. It is recommended that a minimum of three tests of each type are undertaken, so that a trend can be observed from the results with the exception of preloading by surcharge.

Table 9: Types of Performance Testing

Test /Parameter	Description	Application
Preloading by surcharge	An area usually greater than 50m^2 is raised above the proposed development level with soils or fill to model the proposed development loadings	For large sites or areas of deep fill (over 5m deep) or where highly compressible soils exist at depth, usually in conjunction with other performance tests such as zone tests, plate tests or probing
Zone load	A rigid base (usually made up of concrete) with areas related to the width of the proposed foundations, typically between 4-10m^2 Suited to modelling the loading and depth of influence of a building on raft foundation The test duration to be sufficient to identify the magnitude and timescale for completion of primary settlement, the clear trend of any secondary settlement (creep) and to confirm that load-settlement behaviour is in accordance with calculated predictions	For large sites or areas of deep fill usually in conjunction with other performance tests such as plate tests or probing undertaken to identify suitable locations for the zone test Care must be exercised during the zone tests, pads/bases are susceptible to ground vibrations/ movement resulting from machinery/plant
Mini zone load/pad	Smaller than a zone test – with an area less than 4m^2 and designed to model a typical (or heaviest) part of a spread (beam grillage or reinforced strip) foundation The test duration to be sufficient to identify the magnitude and timescale for completion of primary settlement, the clear trend of any creep and to confirm that load-settlement behaviour is in accordance with calculated predictions	Usually in conjunction with other performance tests such as plate tests or probing to identify suitable locations for the zone test Care must be exercised during the mini zone load tests, pads/bases are susceptible to ground vibrations/movement resulting from machinery/plant
Surface points settlement	A stable concrete or steel level monitoring point set at the surface or at shallow depth to determine the nature of any fill settlement without applied loading – usually over a prolonged period to model self-weight consolidation and creep settlement as required	Where self-weight consolidation or creep settlement may be significant – usually associated with deep cohesive fill
Settlement rods	Plates placed at the underside of engineered fill to measure settlement caused by the placement of fill	Usually in conjunction with other performance tests such as zone tests and mini zone load tests
Magnetic extensometers	Can be placed at varying depths within engineered fill or underlying made ground in deep fill sites to record settlement from targeted zones	Usually in conjunction with other performance tests such as zone tests and mini zone load tests

Plate test	Usually 600-900mm diameter plate and loaded incrementally to 1.5-3.0 times the highest proposed bearing pressure The peak load is held for up to 1 hour or until the rate of settlement does not exceed an agreed limit The use of dual cycle plate load tests can provide a significant improvement on the assessment and interpretation of the data. Wherever possible, dual cycle plate testing should be employed	Inexpensive but may not load the fill as deeply as a foundation, limited to approximately 1.5x the plate diameter Most suitable during fill placement
Probing	A range of techniques are available	Static cone testing can provide data on the surface to depth of soil, including soil stiffness and other important soil properties Shallow techniques (including hand-held) may be limited in data quality
Permeability	Infiltration testing in boreholes or trial pits at the depth of interest	Where low permeability is required to limit groundwater (or ground gas) movement
Inundation	Similar to permeability testing but with added settlement monitoring	To assess the susceptibility of fill to settlement when it becomes saturated (from surface water, service trenches or rising groundwater)
Hand vane	Undrained shear strength of cohesive fill. Quick and easy but of limited reliability and accuracy	For cohesive fill Any gravel within the soil matrix that comes into contact with the cruciform pattern of the 4no. vanes can significantly alter the results. It should only be used in conjunction with other tests as a confirmatory tool

Proposals for testing should be agreed in advance of the works and should be set out in the earthworks specification with supporting test plan(s). Test locations should be selected to allow a satisfactory spatial and lateral spread of results.

The pass criteria for the performance tests should be detailed in the earthworks specification and Geotechnical Design Report/ Geotechnical Design Statement and should be appropriate for the proposed end use and foundation type. Load-settlement zone load tests should be a minimum of 1.2 times the anticipated design load of the foundations and with the loaded area of a comparable scale.

4.6.12.4 Settlement measurement

Settlement measurement of load tests or surface points should be undertaken by a suitably qualified land surveyor to a suitable accuracy, no greater than to the millimetre and less where site conditions are considered appropriate or are likely to reduce uncertainty and the required duration of monitoring. It is critical that over the long term, survey points are not damaged, disturbed, or affected by other activities. Additionally, the data should be related to stable datum outside the influence of any earthworks or Made Ground or existing unstable ground. A minimum of two datum points should be established to provide redundancy in case one is lost or damaged.

Extensometers in boreholes can be effective at determining the depth at which settlements are occurring where preloading or surcharge mounds are positioned upon underlying ground and self-weight consolidation is being assessed.

Plates with extension rods also provide means of measurement of settlement at sub formation and the underlying ground.

Settlement data should be plotted at both natural time and logarithm time to aid assessment of the data.

4.6.12.5 Testing frequency

The frequency of testing for classification, compliance and performance purposes should be determined according to site conditions, fill materials and their consistency, filling techniques and the proposed end use as stated in the earthworks specification. Testing frequencies should be specified in accordance with industry guidance such as BRE 427 and also see additional guidance within Clause 4.6.1.

Where a Method Specification is utilised, in situ testing is required but typically would be based on the total volume of engineered fill to confirm that the degree of compaction achieved by the adopted method on site is as expected. When End Product specification is utilised, in situ testing should be based on a minimum number and grid with each and every layer tested, eg, 1 per 25m x 25m grid per layer and a minimum of 3 per layer per day. Where a performance specification is adopted, it will be necessary to undertake performance testing during fill placement, as well as upon completion, to ensure compliance with the earthworks specification.

The testing frequency based on Table 10 is generally considered as an acceptable minimum requirement.

Table 10: End Product compliance testing of placed engineered fill*

Fill volume (m^3)	Minimum no. of tests required
>100,000	2no. per 1,000m^3
10,000 to 100,000	3no. per 1,000m^3
<10,000	5no. per 1,000m^3

*Note: Variation to the above may be necessary where differing material types or foundations are to be used.

Test types and frequencies should be reviewed according to the results obtained and site conditions. Where there is greater variation in site conditions or results than anticipated, an increased frequency of testing will be required. Conversely and where agreed with NHBC, a decrease in test frequency may be acceptable where consistency in test results is being achieved.

4.6.13 Reporting

Also see: BS EN 16907-5 and BS 6031

A detailed Earthworks Verification Report shall be provided to the NHBC on completion of the earthworks filling and testing. Where appropriate, the contents shall be agreed with the NHBC prior to the work being done.

A comprehensive Earthworks Verification Report for the filling works should be provided to the NHBC as soon as practicable. It should provide an interpretation and assessment of the factual data contained within the report as well as a detailed summary of the works undertaken including testing. A site wide or phased reporting approach is acceptable.

Where reinforced strip foundations are proposed, the report should be produced by a third-party organisation separate from those undertaking the works, ie, by the overseeing supervising engineer, with all factual information made available. The report, where beam grillage or semi-raft foundations are proposed, can be produced solely by a suitably experienced earthworks contractor.

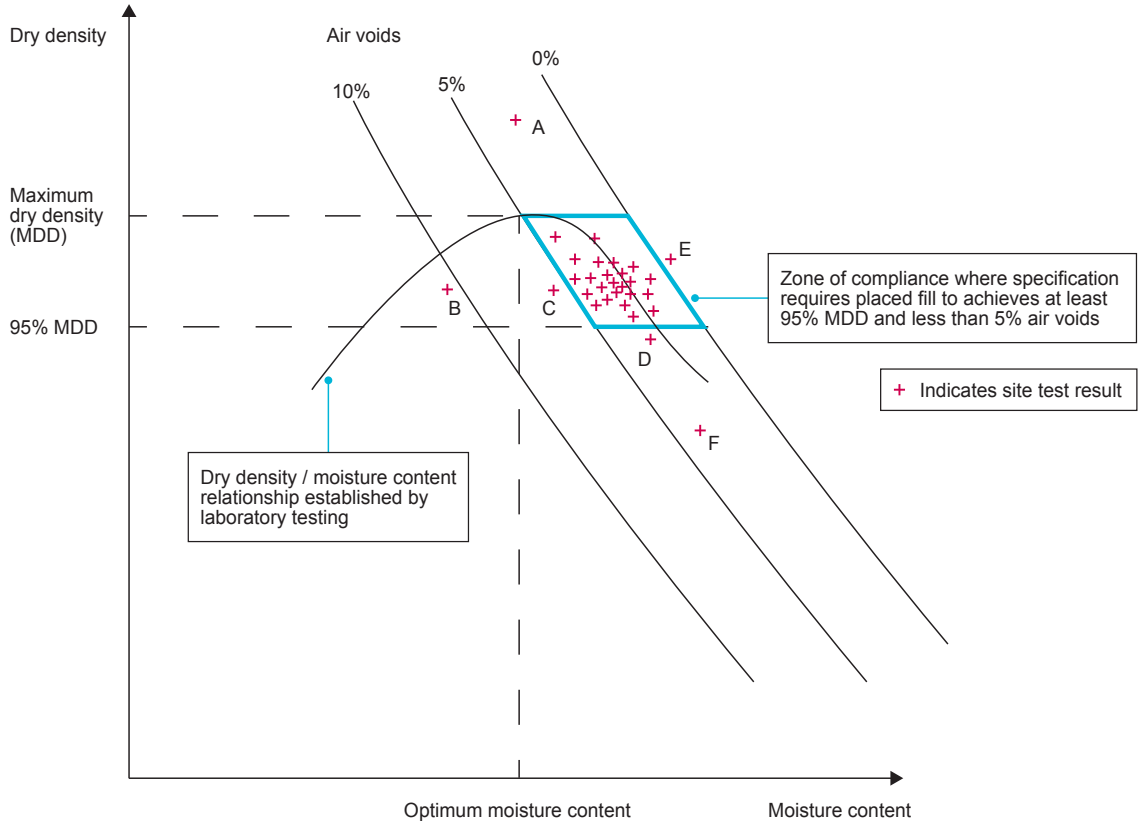
The content of the Earthworks Verification Report shall be defined within the earthworks specification. Guidance on the contents and structure of the detailed report may be based on information within DRMB CD 622, where it is termed a Geotechnical Feedback Report.

It is important that the report is in an appropriate format. Test results should be suitably summarised and presented to provide clear understanding using graphs and charts as necessary.

The Earthworks Verification Report should give details as appropriate of the following:

1. The contractors and personnel responsible for the filling work including details of supervision and testing
2. Preparation works prior to earthworks filling
3. Reference to the earthwork specification and method statement(s)
4. Sources of material used as engineered fill and their material classification
5. Any treatment, reconditioning or remediation of proposed engineered fill
6. Plant and methods used
7. As built survey records including post topsoil strip level or formation level for the earthworks, reduced levels following earthworks cuttings, final as-built or post earthworks filling formation level, plan(s) and other drawings as appropriate that show the extent and depth of earthworks filling
8. All test results and certificates
9. Progress photographs and surveys
10. Progress reports, site diaries, with details of weather/site conditions and any agreed variations or changes to the specification
11. Graphical representation of the classification and compliance test data as show in Figure 7 below
12. Changes and amendments to design and earthworks specification
13. Records of remedial actions in areas of non-compliance
14. Problems experienced and solutions and methods used to overcome the issues
15. Confirmation that the works comply with the earthworks specification and are suitable to support the proposed foundation types, where applicable. All non-compliances or departures from the earthworks specification should be clearly identified and suitably assessed
16. Drawings showing known obstructions and any relevant features under or within the engineered fill
17. Graphical representation of the load-settlement tests, surcharge trials or post-completion monitoring over time with plots of settlement versus natural and log time presented to demonstrate that primary settlements are complete, with a clear trend of any remaining creep settlement projected to allow for a satisfactory building performance over a 60-year design life
18. Information required by the builder to safely undertake follow-on works in the ground including any special precautions which should be undertaken or unusual constraints that exist, and any residual risks for example further measures may be required where upfilling or an increase in ground levels post-remediation are likely to be proposed

Figure 7: Basis for design: Plot of moisture contents vs dry densities for each fill type



Notes:

A – Indicates placed fill is of significantly higher density than achieved in the laboratory – the fill classification is likely not complying with the specification. Repeated results higher than the MDD indicates the laboratory testing was not on representative material or the method of laboratory compaction was too light.

B – Indicates placed fill has been compacted too dry of optimum and may therefore, where cohesive fill has been used, be liable to settlement when wetted.

C, D & E – Marginally outside of the compliance zone. As part of a large set of results that are otherwise compliant these marginal failures may be acceptable provided, they are not part of non-compliant clusters.

F – Indicates fill placed wet of optimum and may be liable to settlement under load or over time.

Results of type A, B & F should be assessed further, and explanation provided of remedial actions, further testing or reasons for acceptance.

Further guidance on acceptability testing of proposed source fills and compliance testing of placed engineered fill is provided in BS 6031:2009. In setting the compliance curve of dry density/moisture content relationship all tests should be presented/ or made available such that the target basis of design (for each fill type) can be agreed with NHBC, noting the degree of interpretation and assessment including outliers. Updated targets may be appropriate in variable materials and should be detailed and agreed with the NHBC.

Compliance test results should be summarised and presented so that any non-compliances can be easily identified.

If the site has been filled some years before the intended construction works or for an alternative end use such as commercial buildings, then a retrospective validation may be appropriate. Assessment of historic fill within land reclamation schemes and marginal sites are generally outside the scope of this Chapter. Consult NHBC or consider using NHBC Land Quality Service for a bespoke consultation.

Figure reference table

Figure reference table 4.6			
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Standards 2024

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APPENDIX D – CLEAN COVER SCREENING VALUES

BSH
remediation

Determinand	Units	Residential with Produce	Public Open Space (400mm cover)	Ref.
This is a list of Tier 1 Screening Values (T1SVs) for SOILS				
Heavy Metals & Inorganics				
Arsenic	mg/kg	37	79	*c*
Boron	mg/kg	290	21000	*c*
Cadmium	mg/kg	11	120	*c*
Chromium (VI)	mg/kg	6	7.7	*c*
Lead	mg/kg	200	630	*a*
Nickel	mg/kg	130	230	*c*
Copper	mg/kg	2400	12000	*c*
Zinc	mg/kg	3700	81000	*c*
Elemental Mercury	mg/kg	1.2	16	*c,x*
Phenol[1]	mg/kg	280	760 (11000)	*c*
Polycyclic Aromatic Hydrocarbons[1]				
Naphthalene	mg/kg	2.3	4900	*c,x*
Acenaphthylene	mg/kg	170	15000	*c,x*
Acenaphthene	mg/kg	210	15000	*c,x*
Fluorene	mg/kg	170	9900	*c,x*
Phenanthrene	mg/kg	95	3100	*c,x*
Anthracene	mg/kg	2400	74000	*c,x*
Fluoranthene	mg/kg	280	3100	*c*
Pyrene	mg/kg	620	7400	*c*
Benzo(a)anthracene	mg/kg	7.2	29	*c*
Chrysene	mg/kg	15	57	*c*
Benzo(b)fluoranthene	mg/kg	2.6	7.1	*c*

Determinand	Units	Residential with Produce	Public Open Space (400mm cover)	Ref.
Benzo(k)fluoranthene	mg/kg	77	190	*c*
Benzo(a)pyrene[2]	mg/kg	2.2	5.7	*c*
Indeno(1,2,3-cd)pyrene	mg/kg	27	82	*c*
Dibenz(a,h)anthracene	mg/kg	0.24	0.57	*c*
Benzo(ghi)perylene	mg/kg	320	640	*c*
Total Petroleum Hydrocarbons				
TPH Aliphatic >C_5-C_6	mg/kg	42	570000 (304)	*c,x*
TPH Aliphatic >C_6-C_8	mg/kg	100	600000	*c,x*
TPH Aliphatic >C_8-C_{10}	mg/kg	27	13000	*c,x*
TPH Aliphatic >C_{10}-C_{12}	mg/kg	130 (48)	13000	*c,x*
TPH Aliphatic >C_{12}-C_{16}	mg/kg	1100 (24)	13000	*c,x*
TPH Aliphatic >C_{16}-C_{21}	mg/kg	65000 (8.48)	250000	*c,x*
TPH Aliphatic >C_{21}-C_{35}	mg/kg	65000 (8.48)	250000	*c,x*
TPH Aromatic >C_5-C_7	mg/kg	70	56000	*c,x*
TPH Aromatic >C_7-C_8	mg/kg	130	56000	*c,x*
TPH Aromatic >C_8-C_{10}	mg/kg	34	5000	*c,x*
TPH Aromatic >C_{10}-C_{12}	mg/kg	74	5000	*c,x*
TPH Aromatic >C_{12}-C_{16}	mg/kg	140	5100	*c,x*
TPH Aromatic >C_{16}-C_{21}	mg/kg	260	3800	*c*
TPH Aromatic >C_{21}-C_{35}	mg/kg	1100	3800	*c*
TPH Aromatic >C_{35}-C_{44}	mg/kg	1100	3800	*c*

Determinand	Units	Residential with Produce	Public Open Space (400mm cover)	Ref.
TPH C_6-C_{10}	mg/kg	27	5000	*c*
TPH C_{10}-C_{25}	mg/kg	74	3800	*c*
TPH C_{25}-C_{44}	mg/kg	1100	3800	*c*
Asbestos	Fibres Volume Weight (%)	NFD	NFD	

NFD - No Fibres Detected

Reference	Comments
a	**DEFRA -** SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamina
b	**CL:AIRE / EIC** - Soil Generic Assessment Criteria for Human Health Risk Assessment. January 2010
c	LQM - The LQM / CIEH S4ULs for Human Health Risk Assessment. 2015
d	US EPA Regional Screening Values (THQ = 0.1). Use as initial benchmarking values, these are CERCLA (superfur
w	For chlorophenol compounds, please use a **sum** of compounds for 2-chlorophenol, 2,4-dichlorophenol, 2,4,6-t
x	Value shown in brackets are at, or in excess of, vapour limits.
y	See EIC report. This GAC is 1/3 of the GAC (presented as total cresols '(2-, 3- and 4-methylphenol)
z	Value for 1,3-dichloropropene (cis and trans isomers) taken to be identical and from US EPA value for -1,3-dich