

Other conditions may exist on the site that have not been taken into account in this assessment as they are outside the scope of works. Groundtech Consulting are not responsible for these circumstances that are not outlined in the report.

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2.0 SITE SETTING

2.1 Location

The site is located circa 2.16 kilometres north of Hitchin Town Centre, as shown on the Project Location Plan 19271 01. The site is approximately centred on National Grid Reference 518218, 231295.



Access to the site is gained off Arlesey Road to the east of the site.

2.2 Site Description

The site is irregular in shape covering an area of approximately 3.7 hectares. Topography is relatively flat lying across the site with the exception of a grassy embankment along the northern boundary of the site.

Office Areas and Car Park

Offices and a laboratory building associated with Bowman's Mill are located in the west of the site, additional office buildings are located in the east of the site. External areas form car parking for the offices and are surfaced with concrete. A small strip of soft landscaping containing mature broad leaved trees is present in the north west of the site adjacent to the laboratory buildings.

A number of interceptors are indicated to be present beneath the concrete surfacing in the west of the site.

Current Production Area

The northern site area largely comprises an active production unit with associated silos, warehouse storage and concrete surfaced service yard for loading and unloading of HGV vehicles. Plastic chemical drums are present in the north of the site adjacent to the active production warehouse.

Derelict Area

The central site area comprises derelict mill buildings and infrastructure including warehouses, flour silos, a boiler house and electricity substation. External site areas are surfaced with concrete. A former diesel underground storage tank (UST) is present adjacent to the warehouse building in the east of the derelict area.

Some plant and machinery remains in the derelict warehouses and buildings. A steel grid covering a potential interceptor is present adjacent to two large disused silos in the central portion of this area.

The roofing to the derelict mill buildings appears to be constructed of asbestos cement sheeting.

Southern Site Area

The southern area of the site comprises a soft landscaped area with mature trees around the perimeter. A feeding area for geese is located in the west of the soft landscaped area.

The River Oughton runs south west to north east across the site, broadly separating the works area from the soft landscaped area. The river appears to have been channelled and has a number of pipes feeding into it, which may be for surface water drainage.

Grass covers the soft landscaped area.

Boundaries and Surrounding Land Uses

The site is bound on all side by security fencing approximately 7 feet high.

Residential properties are located to the north and east of the site, undeveloped fields are located to the south and west.

Site photographs are presented in Appendix 2, and any relevant features are recorded on the Preliminary Development Constraints Plan 19271 02.

3.0 SUMMARY OF PREVIOUS INVESTIGATION

A Preliminary Risk Assessment was undertaken by WSP Parsons Brinckerhoff (Report Ref: 70027704-10670(1)) in December 2016. Below is a summary of the Preliminary Risk Assessment.

3.1 Geology

Made Ground

BGS mapping does not indicate the presence of Made Ground, however due to the historic industrial use of the site Made Ground is anticipated.

Superficial Deposits

Superficial deposits underlying the site are indicated to be Alluvium in the vicinity of the River and Glaciofluvial Deposits beneath the northern portion of the site. These deposits are indicated to be further underlain by the Lowestoft Formation which comprises chalky Glacial Till.

Solid Geology

Solid geology underlying the site is indicated to be the Gault Formation which comprises mostly Mudstone.

3.2 Environmental Setting

The overlaying superficial Alluvium and Glaciofluvial Deposits are classified by the Environment Agency (EA) as Secondary A Aquifers. The underlying Lowestoft Formation superficial deposits are classified as an Undifferentiated Secondary Aquifer.

The Gault Formation Bedrock is classified as an Unproductive Aquifer.

The closest recorded landfill is 383m east of the site. In addition an infilled mill pond and mill race are located in the west of the site.

One recorded on site pollution incident occurred in 1996 relating to discharge of crude sewage to the River Oughton, this was classified as a minor incident. In addition a pollution incident occurred 120m north east of the site relating to organic wastes and other suspended solids into the River Oughton which was classified as a significant incident.

There are no discharge consents within 250m of the site and no fuel stations within 500m of the site.

The site is not in an area which required Radon Protection Measures in the construction of new dwellings.

3.3 Contaminative Sources

A number of potentially contaminative sources were identified by the Preliminary Risk Assessment, these are detailed briefly below:

- General Made Ground associated with the infilled pond/ mill race and construction of the existing buildings on site. Potential Contaminants of Concern (CoCs) may include heavy metals, PAHs and asbestos.
- Contaminants associated with historical uses of the site, particular areas of concern include mechanical workshops, boiler rooms, vehicle cleaning, maintenance and refuelling areas. Potential CoCs include heavy metals, PAHs, VOCs, SVOCs, PCBs and asbestos.

- Hazardous gases associated with significant thickness of Made Ground on and off site, including an infilled gravel pit c.80m south of the site.

3.4 Conceptual Site Model and Risk Assessment

A number of potential receptors were identified by the Preliminary Risk Assessment, the receptors are detailed below along with associated pollution pathways which appear in brackets.

Potential Receptors

- Development workers (dermal contact, inhalation, ingestion of soils and dusts).
- Future residential site users (dermal contact, inhalation, ingestion of soils and dust, consumption of produce from gardens).
- Off-site human health receptors and building structures/services (lateral migration of groundwater and ground gas).
- Controlled water receptors – groundwater (vertical migration to Secondary A Aquifer) and surface water (lateral migration of groundwater).
- Future building structures and services (direct contact with contaminated soils, ingress of ground gases into buildings, notably carbon dioxide, via voids and service entries).

Risk Assessment

The risk assessment from the Preliminary Risk Assessment has determined potentially complete pollutant linkages which could affect redevelopment of the site for residential end use, these are highlighted below:

- Direct contact/ingestion/inhalation of soil-bound contaminants and asbestos by construction workers, neighbouring site users, future site users and future maintenance workers. These are likely to be the dominant potentially complete pollutant linkages driving risks to human health from soil-bound contamination in a future residential development.
- Inhalation of vapours associated with soil and/or groundwater contamination by construction workers, future residents and future maintenance workers.
- Inhalation and accumulation of hazardous ground gases associated with possible in-filled areas by construction workers, future residents and future maintenance workers.
- Migration of contaminants into surface water and underlying aquifers (including preferential pathways associated with on-site structures and services).
- Direct contact between contamination in soil / groundwater and future below ground services and structures.

4.0 SCOPE OF INVESTIGATION AND RATIONALE

4.1 Project Objectives

The aim of the fieldwork was to:

Determine the stratification beneath the site.
 Maintain watching brief for visual and olfactory evidence of contamination.
 Obtain samples using methodology in current guidance for contamination analysis.
 Identify realistic pollution linkages to groundwater.
 Obtain relevant geotechnical parameters for preliminary foundation design to address both ULS and SLS conditions.
 Determine if targeted supplementary investigation in areas of concern is required and for foundation design and remedial design.
 Install monitoring standpipes for gas and groundwater monitoring.
 Assess the identified pollution linkages in the CSM.

4.2 Scope of Works

The following Ground Investigation scope was undertaken at the site between the 9th December and 13th December 2019:

- Thirty window sample boreholes (WS01 to WS30) were drilled to depths of between 0.8m and 5.45m bgl using a tracked Dando Terrier drilling rig.
- Three machine excavated trial pits (TP01 to TP03) were dug to between 0.4m and 4.0m bgl using a wheeled JCB 3CX excavator.

The exploratory hole locations are presented on Groundtech Plan 19271 03, and the exploratory hole logs are presented in Appendix 3.

The exploratory holes were positioned to establish the stratification beneath the site and target areas of concern. The exploratory holes were logged by a suitably experienced geo-environmental engineer in general accordance with the following current guidance:

- BS 5930 'Code of Practice for Site Investigations' 2015.
- BS EN 14688-1:2002 'Geotechnical Investigation and Testing – Identification and classification of soil'.
- BS EN ISO 14689:2002 "Geotechnical investigation and testing – Identification and classification of rock".

4.3 Soil Sampling

During the intrusive investigation, representative samples were taken at regular intervals, changes of strata and where evidence of contamination existed. Laboratory analysis was scheduled on the samples obtained.

The samples obtained are summarised in the table below:

Soil Sample	Number
Environmental Sample	63
Disturbed Sample	44

Undisturbed U100 Sample	14
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The samples have been obtained in accordance with current environmental and geotechnical guidance. The sampling plan has been designed to obtain samples from all required strata using the correct methodology.

Disturbed samples of soil for chemical analysis were placed in the correct sampling containers as required by the laboratory in accordance with their MCERTS and UKAS Accreditation. Transportation was arranged in a timely manner and the samples were at the correct temperature.

The sample locations and depths are recorded on the exploratory logs.

4.4 Geo-Environmental Analysis

To inform the Tier I Generic Quantitative Risk Assessment, the following geo-environmental testing was scheduled to assess the risk from contamination on the site. The testing is based on the potential sources identified in the PRA and observations during the Ground Investigation.

Determinand	Matrix	Number
Arsenic, cadmium, chromium (total and hexavalent), copper, lead, mercury, nickel, selenium, zinc and pH.	Soil	25
Speciated PAH16	Soil	25
TPH CWG	Soil	10
PCBs	Soil	2
Asbestos	Soil	20
Asbestos Quantification	Soil	5
Arsenic, cadmium, chromium (total and hexavalent), copper, lead, mercury, nickel, selenium, zinc and pH.	Groundwater	6
Speciated PAH16	Groundwater	6
TPH CWG	Groundwater	6
PCBs	Groundwater	6
CaCO ₃	Groundwater	6
DOC	Groundwater	6

The Geo-Environmental Laboratory Testing Results are presented in Appendix 4.

Representative disturbed samples were obtained for all soil types encountered. Selected samples were scheduled for testing at an approved laboratory in accordance with BS 1377 'Method of Test for Soils for Civil Engineering Purposes' 1990. The following tests were scheduled:

British Standard	Test Method	Number
Part 2	Water Content	15
Part 2	Plasticity Index Analysis	15
Part 3	pH Value	10
Part 3	Water Soluble Sulphate Content	10
Part 5	One Dimensional Consolidation Test	4
Part 7	Determination of Undrained Shear Strength in Triaxial Compression	5

The Geotechnical Laboratory Testing Results are presented in Appendix 5.

4.5 Gas and Groundwater Monitoring/Sampling

Gas and groundwater monitoring installations were constructed in the boreholes. The standpipes consisted of Polyvinyl Chloride (PVC) pipe - a bentonite seal was placed around the plain pipe and a clean gravel pack was placed around the slotted pipe. A summary of the installation construction is presented in the table below:

Location	Depth (m)	Response Zone (m bgl)	Targeted Strata	Reason
WS02	1.50	1.00 – 1.50	Made Ground	Ground Gas/ Groundwater
WS06	4.00	1.00 – 4.00	Sand, Silt and Clay	Ground Gas/ Groundwater
WS09	3.00	1.00 – 3.00	Made Ground, Sand and Clay	Ground Gas/ Groundwater
WS12	4.00	1.00 – 4.00	Clay	Ground Gas/ Groundwater
WS17	4.00	1.00 – 4.00	Clay	Ground Gas/ Groundwater
WS18	5.00	1.00 – 5.00	Clay	Ground Gas/ Groundwater
WS23	3.00	1.00 – 3.00	Sand and Clay	Ground Gas/ Groundwater
WS25	3.00	1.00 – 3.00	Clay	Ground Gas/ Groundwater
WS28	2.00	1.00 – 2.00	Sand and Clay	Ground Gas/ Groundwater
WS29	3.00	1.00 – 3.00	Silt and Clay	Ground Gas/ Groundwater

Permanent gas and flow rate monitoring was carried out using GFM 436 infrared gas monitor with integral electronic flow analyser. The measurements taken are listed below:

- Oxygen (O₂), carbon dioxide (CO₂) and methane (CH₄) as the percentage volume in air (%v/v).
- Hydrogen sulphide (H₂S) and carbon monoxide (CO) as the percentage volume in air (%v/v).
- Lower Explosive Limit (%LEL) of methane.
- Atmospheric and borehole pressure, including pressure trend.
- Flow measurements (l/hr).
- Weather and ground surface conditions.

Both peak and steady state conditions were monitored to understand the behaviour of the permanent ground gas, the steady state conditions were recorded by allowing the gas monitor to run for a minimum of 3 minutes.

Interim permanent gas and groundwater monitoring results are presented in Appendix 6.

4.6 Groundwater Sampling

Well development was carried out to ensure no cross contamination from the drilling activities remained in the water column in the well. During the return visit, the installations were purged to a minimum three times the volume of the water column in the borehole prior to sampling, samples were taken between 7 and 17 days after installation.

Purging was undertaken at a slower rate than the well development, and the sampling at a slower rate again.

Samples were sent to the UKAS Accredited laboratory the same day, sampling was carried out in general accordance with BS5930:2015 and BS 5667:2018.

5.0 GROUND MODEL

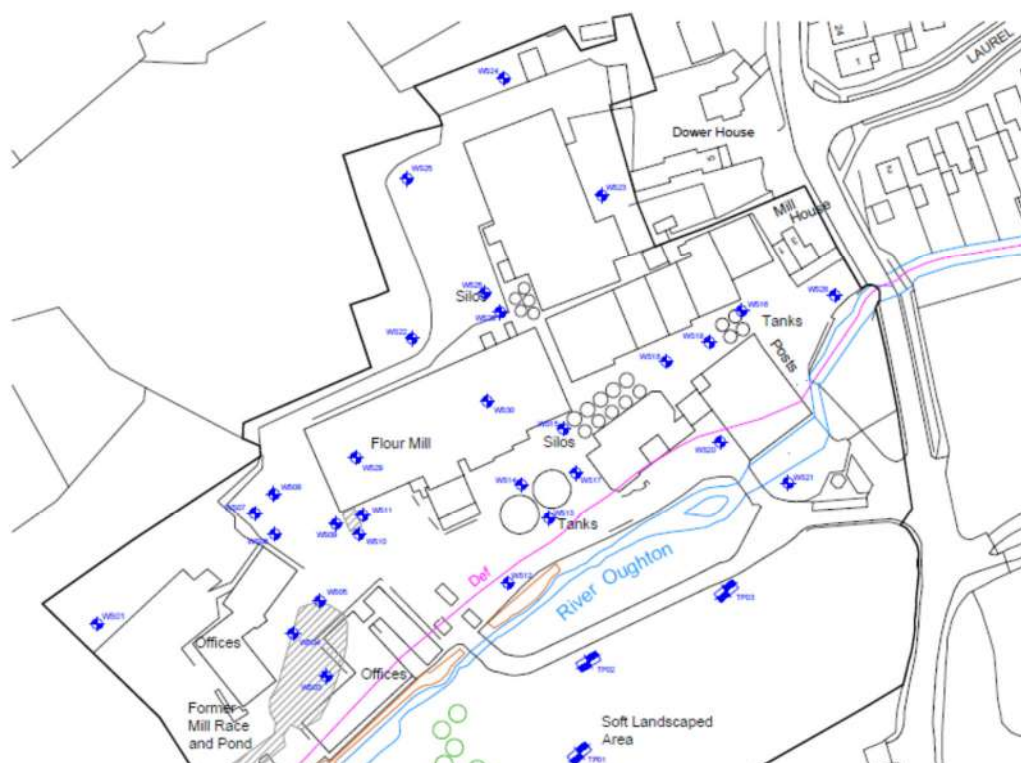
5.1 Made Ground

Made Ground was encountered across the site from ground level to (max) 1.75m bgl, the main Made Ground populations are detailed below:

- Brown clayey topsoil with brick and rare ash from Ground Level to 0.90m bgl (WS01, WS21, WS23, WS24, TP01, TP02 and TP03).
- Light brown gravelly sand with brick from 0.15m to 1.2m bgl (WS02 to WS08, WS10, WS12 to WS15, WS18 to WS20, WS25 to WS30).
- Dark brown/black sand and gravel with ash from 0.18m to 1.75m bgl (WS02, WS11, WS16 and WS18).
- Soft to firm grey brown clay with brick from 0.2m to 1.4m bgl (WS03, WS05, WS09, WS14 and WS23).

The soft landscaped area in the south of the site was surfaced with grass over topsoil, the remainder of the site was surfaced with concrete.

The majority of the Made Ground was granular, with gravelly sand being the most common population of Made Ground across the site.



5.2 Natural Ground

The natural strata encountered generally confirmed the published geological records.

Three main natural stratification encountered during the investigation and are described below:

- Alluvium comprising soft to firm Clay, soft Silt and loose to medium dense Sand was encountered from 0.20m to 4.45m bgl within WS01, WS03, WS04, WS05, WS06, WS08, WS09, WS10, WS12 to WS21, WS23, WS24, WS29, WS30, TP01 and TP02. This strata was extremely variable laterally and with depth, frequently interbedded.
- Glaciofluvial Deposits comprising medium dense to dense Sand and Gravel from 0.6m to 2.45m bgl within WS10, WS16, WS24, WS26 and WS28.
- Lowestoft Formation which comprises firm to stiff Clay with gravel of chalk was encountered from 0.35m to 5.45m bgl within WS07, WS08, WS09, WS13 to WS20, WS22, WS23, WS25, WS26, WS28, WS29, WS30, TP01 and TP02.

Alluvium was encountered across the majority of the site and generally deepened near to the river. Alluvium was absent in the north of the site, the Lowestoft Formation was encountered across the site beneath the Alluvium or Glaciofluvial Deposits. The extent of the Alluvium Deposits is indicated on the Foundation Zone Plan 19271 04.

5.3 Bedrock

Bedrock was not encountered during this investigation.

5.4 Groundwater

Groundwater strikes were observed in the following locations:

Location	Depth (m bgl)	Strata	Rate
WS01	2.45	Clay	Rapid Ingress
WS03	2.00	Clay	Rapid Ingress
WS04	1.70	Clay	Rapid Ingress
WS05	1.40	Sand and Gravel	Rapid Ingress
WS06	3.45	Silt	Rapid Ingress
WS08	1.50	Sand	Rapid Ingress
WS09	1.00	Made Ground	Rapid Ingress
WS10	1.10	Sand and Gravel	Rapid Ingress
WS11	1.20	Made Ground	Rapid Ingress
WS12	2.30	Clay	Rapid Ingress
WS13	2.00	Clay	Rapid Ingress
WS14	1.00	Clay	Rapid Ingress
WS15	1.10	Clay	Rapid Ingress
WS16	1.00	Sand and Gravel	Rapid Ingress
WS17	1.50	Clay	Seepage
WS18	2.40	Clay	Rapid Ingress
WS19	1.10	Sand	Rapid Ingress
WS20	1.65	Clay	Rapid Ingress
WS21	2.00	Clay	Rapid Ingress
WS23	2.00	Sand	Rapid Ingress
WS28	1.00	Sand	Rapid Ingress
WS29	2.00	Silt	Rapid Ingress

5.5 Watching Brief

A watching brief was maintained during the Ground Investigation for visual and olfactory evidence of contamination.

Ash was noted as a minor constituent of the Made Ground in eleven locations across the site. Furthermore a moderate hydrocarbon odour was noted within WS09, WS10 and WS11 in the vicinity of a former diesel Underground Storage Tank (UST).

5.6 Excavation Stability

No evidence of spalling or collapse was noted during excavation of the trial pits.

5.7 Excavation Progress

Slow progress while excavating the trial pit was not experienced.

6.0 GROUND ENGINEERING

6.1 Geotechnical Testing Results

Comparison of water content and the value of 0.4 times the Liquid Limit in accordance with BRE Digest 412 'Desiccation in Clay Soils' suggests significant desiccation has taken place when 0.4 times the Liquid Limit is greater than the actual water measured water content. This is a rudimentary method but also a good guide.

Results of the PI analysis and the volume change potential of the clays is summarised in the table below:

Reference	Depth (m)	Modified PI	Volume Change Potential	Dessicated Y/N
WS03	1.20	45.2	High	Y
WS04	1.50	19.8	Low	N
WS07	1.00	40.9	High	N
WS12	1.00	33.0	Medium	N
WS14	1.50	33.0	Medium	N
WS16	2.00	18.1	Low	N
WS17	1.50	51.0	High	N
WS18	1.00	44.2	High	N
WS20	1.50	52.9	High	N
WS22	1.00	20.0	Medium	N
WS23	1.60	16.3	Low	Y
WS24	0.90	23.0	Medium	N
WS25	1.00	23.2	Medium	N
WS28	1.50 – 1.95	30.1	Medium	N
WS29	2.50 – 2.95	22.9	Medium	N

Five undisturbed samples of clay from across the site were scheduled for quick undrained triaxial testing and the results are summarised below:

Reference	Depth (m)	Shear Strength (kPa)	Relative Strength
WS07	2.50 – 2.95	225	Very High
WS17	1.50 – 1.95	22	Low
WS21	1.50 – 1.95	23	Low
WS25	1.50 – 1.95	135	High
WS28	1.50 – 1.95	34	Low

Four undisturbed samples of clay from across the site were scheduled for one dimensional consolidation testing and the results are summarised below:

Reference	Depth (m)	Pressure Range (kPa)	M_v (m ² /MN)
WS17	1.50 – 1.95	120 – 240	0.469
WS21	1.50 – 1.95	120 – 240	0.146
WS25	1.50 – 1.95	120 – 240	0.104
WS28	1.50 – 1.95	120 – 240	0.161

6.2 Assessment Background

The ground engineering investigation has been undertaken to formulate an accurate ground model in order to undertake preliminary foundation design. The ground model has been constructed with a moderate level of confidence, the ground model has evolved from the information obtained by the PRA.

The proposed development is residential end use comprising low rise housing with associated soft landscaped gardens, roads and infrastructure and public open space.

Ground conditions across the site generally consist of concrete over a variety of Made Ground strata from ground level to depths of between 0.2m and 1.75m bgl. Made Ground is generally underlain by Alluvium deposits consisting of soft to firm Clay, soft Silt and loose to medium dense Sand from 0.2m to 4.45m bgl, the northern most area of the site most distal to the river, Made Ground is underlain by Glaciofluvial Deposits comprising medium dense to dense Sand and Gravel from 0.6m to 2.45m bgl. Alluvium and Glaciofluvial Deposits are further underlain by the Lowestoft Formation which comprises firm to stiff clay with gravel of chalk from 0.35m to 5.45m bgl.

A former mill race was encountered within WS02. The mill race was backfilled with granular Made Ground comprising sand and gravel with ash as a minor constituent. The base of the mill race is indicated to be in-situ at 1.70m bgl where the window sample borehole refused. The former mill race fed a reservoir which was also backfilled, the reservoir was encountered within WS03, WS04 and WS05 and is indicated to be between 0.65m and 1.10m deep.

Groundwater was encountered in most locations across the site between 1.0m and 3.45m bgl.

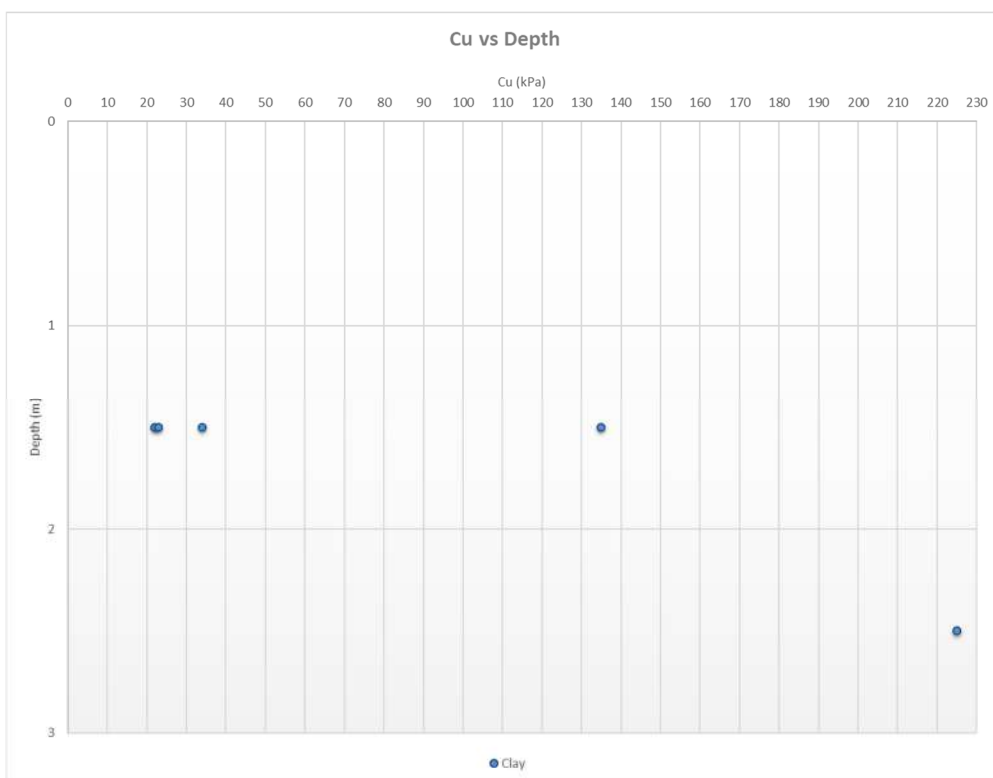
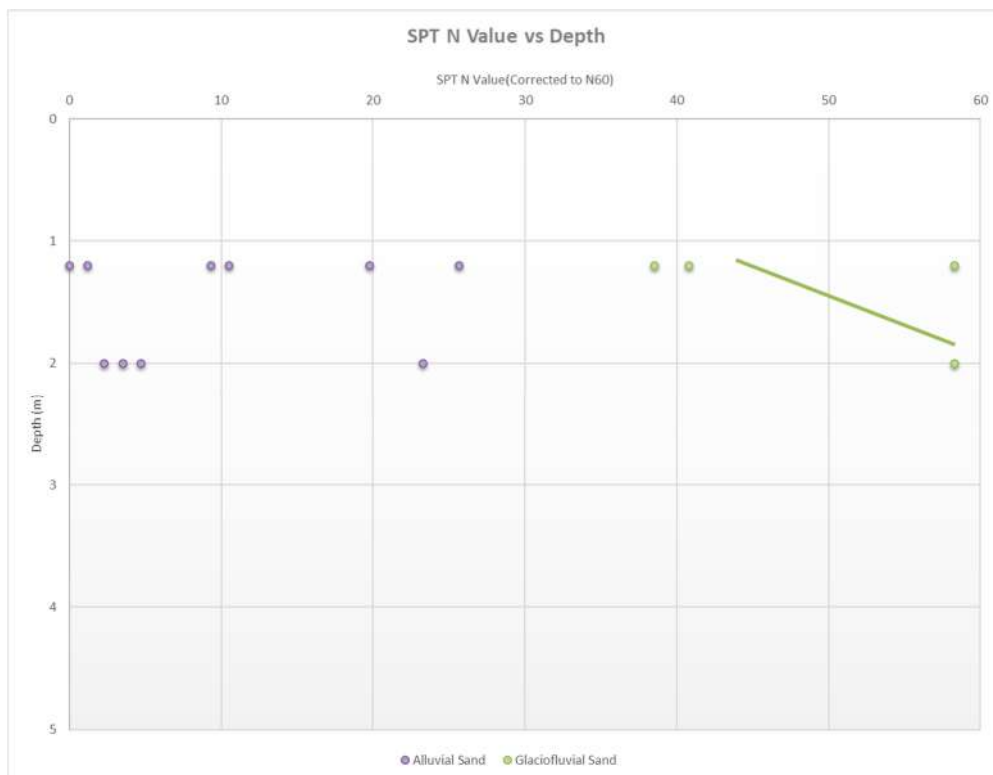
The main limitation associated with the site is considered to be the presence of poorly sorted and often soft/ loose alluvium deposits encountered at traditional founding depth across the site. In some areas of the site (generally closer to the river) suitable bearing strata was not encountered within the window samples boreholes. These areas are identified on the Foundation Zone Plan, drawing 19271 04.

In addition to the above limitation, a large portion of the site was covered by buildings associated with the former Flour Mill operations which historically took place at the site, including factory buildings, boiler rooms, offices and silos. Therefore prior to redevelopment buildings associated with the mill will require demolition with all floor slabs and foundations grubbing up and further investigation is required within the footprint of the buildings.

Soft landscaping in the south of the site will remain as public open space within the proposed development.

6.3 Geotechnical Parameters

The geotechnical test results have been evaluated to derive geotechnical parameters for the soils underlying the site. 'Depth to Cu' and 'Depth to SPT N value' graphs are presented below to provide a generalised ground model for the site.



Characterisation of the geotechnical parameters above has been undertaken to select a characteristic value, which is a cautious estimate of the value affecting the occurrence of the limit state. The selected parameters are summarised below:

- For the loose to medium dense Alluvial Sand at 1.0m bgl, an SPT 'N' value of 8 has been selected and through correlation a ϕ' value of 29° has been selected for Ultimate Limit State (ULS) conditions.
- For the dense Glaciofluvial Sand at 1.0m bgl, an SPT 'N' value of 45 has been selected and through correlation a ϕ' value of 38° has been selected for Ultimate Limit State (ULS) conditions.
- Five Quick Undrained Triaxial tests were scheduled on samples of the natural Clay, shear strengths of between 22kPa and 225kPa were determined indicating low to very high strength Clays.
 - The Alluvial Clay across the site encountered at founding depth is considered to exhibit shear strengths of between 22kPa and 34kPa, a characteristic C_u value of 26kPa has been selected for ULS conditions.
 - The Clay of the Lowestoft Formation is considered to exhibit shear strengths of 135kPa and 225kPa at between 1.0m and 2.0m bgl, a characteristic C_u of 160kPa being selected for ULS conditions.

Two consolidation tests were undertaken on the Clay of the Lowestoft Formation, m_v values of between $0.104\text{m}^2/\text{MN}$ and $0.161\text{m}^2/\text{MN}$ were determined indicating medium compressibility, therefore a characteristic m_v value of $0.140\text{m}^2/\text{MN}$ has been selected for Serviceability Limit State (SLS) conditions.

The clay strata have been proven to be inconsistent in strength across the site and with depth, therefore a Foundation Zone Plan 19271 04 has been provided to determine areas where soft/loose Alluvium Deposits are encountered at founding depth.

6.4 Preliminary Foundation Design

Due to variable shallow ground conditions across the site, two different foundation proposals have been provided and have been determined by the density/strength of the founding strata encountered at traditional founding depths. A Foundation Zone Plan is presented as Plan No. 19271 04 which highlights the areas where each foundation solution is applicable based on the information collected by the window sample boreholes.

Zone 1 – Traditional Shallow Foundations

The most suitable foundation solution for proposed residential dwellings in Zone 1, as illustrated on the Foundation Zone Plan 19271 04, is considered to be traditional strip footings founding within the natural dense Sand or firm to stiff high to very high strength Clay.

Foundations should be deepened through any Made Ground and former construction to be founded within undisturbed natural strata.

The clay is of a medium to high volume change potential, therefore it is assumed that all clays are of high volume change potential. Foundations within the clay should be founded at a minimum depth of 1.0m bgl in accordance with NHBC Chapter 4.2. Foundations within the sand should be at a minimum depth of 0.60m bgl.

Design by Calculation

Preliminary foundation design has been undertaken by calculation, a safe allowable bearing pressure of 140kN/m^2 for ultimate limit state design has been calculated for a 0.6m wide strip foundation within the dense Sand at 0.60m bgl and 125kN/m^2 for the high strength Clay strata at 0.9m bgl.

Settlement within the sand strata beneath the site will be immediate and also minimal, occurring predominantly during the construction phase. Primary settlement within the clay strata will occur, the

degree of settlement based on the bearing capacities provided is less than 25mm, therefore Serviceability Limit State conditions will be satisfied.

If variable strata are encountered at the base of foundation excavations, then foundations should be deepened to found on the similar strata or reinforced to mitigate the potential for differential settlement.

If the ground conditions encountered during the construction phase differ significantly to the conditions encountered during Ground Investigation, work should cease and Groundtech Consulting contacted for further advice.

During the construction phase, supervision should be on a continuous basis to check the design assumptions are correct and construction conforms to design. Supervision should include inspections, Control Ground Investigations and monitoring.

Zone 2 – Vibro Ground Improvement or Piled Foundations

The most suitable foundation solution for residential dwellings constructed in Zone 2, as illustrated on the Foundation Zone Plan 19271 04, is considered to be reinforced strip footings constructed over vibro improved ground or driven piles. Due to low C_u values of the clay in Zone 2 vibro stone columns are not likely to be considered feasible in accordance with NHBC Chapter 4.5. Sufficient information for design of deep foundations is not currently available, therefore the information below is general. Further Ground Investigation is recommended in order to determine the best solution for areas of poor shallow ground conditions and to allow the preliminary design by calculation.

Controlled Modulus Columns

The most suitable foundation solution for the residential dwellings in Zone 2 is considered to be Ground Improvement with Controlled Modulus Columns utilising bottom feed technique due to the relatively high groundwater level that has been encountered.

Vibro stone columns are considered to be unsuitable for the ground conditions in accordance with NHBC Chapter 4.5 due to some of the clays being of high volume change potential and having a shear strength of less than 30kN/m².

A preliminary design resistance for ultimate limit state and serviceability limit state conditions will be the provided by the specialist vibro contractor in their detailed design. The specialist contractor should provide fitness for purpose cover for the treated zones and depth of treatment.

The depth of foundations is to be a minimum of 0.35m below the surface of the vibro treated ground as the integrity of the columns is not validated to this depth. The reinforced concrete foundation should be designed to span between the centres of adjacent stone columns.

Driven Piles

An alternative foundation solution for the proposed residential dwellings is driven piles transferring loads through the Made Ground and loose/soft Alluvium to the underlying high to very high strength Clay.

The proposed development is for a residential housing estate, at this stage the loadings are not available. Pile caps and a reinforced ring beam should be constructed to span between each pile cap and support loadings from walls.

An appropriate working platform should be constructed in accordance with BR470 guidance.

The piling type, length, depth of reinforcement and design should be discussed with a specialist piling contractor. They can then undertake the detailed design including drawings and specifications to provide fitness for purpose design.

6.5 Building Near Trees

Foundation excavations will encounter cohesive strata in the vicinity of existing, proposed or recently removed trees, foundations should be adjusted in full accordance with NHBC Standards Chapter 4.2. Proposed houses around the perimeters of the site are likely to be within the zone of influence of trees, and due to variable ground conditions Clay may be at founding depth.

All foundations should be deepened below roots of greater than 5mm diameter during excavations for footings. The clay is typically of a Medium to high volume change potential, therefore it is assumed that all of the clay materials at this site are of high shrinkage/swelling potential.

A survey of all trees and hedges on the site and within 30m of the site boundary should be undertaken to identify tree species, locations and heights. This information will be required in order to assess the effects of trees on the cohesive strata and inform a foundation schedule.

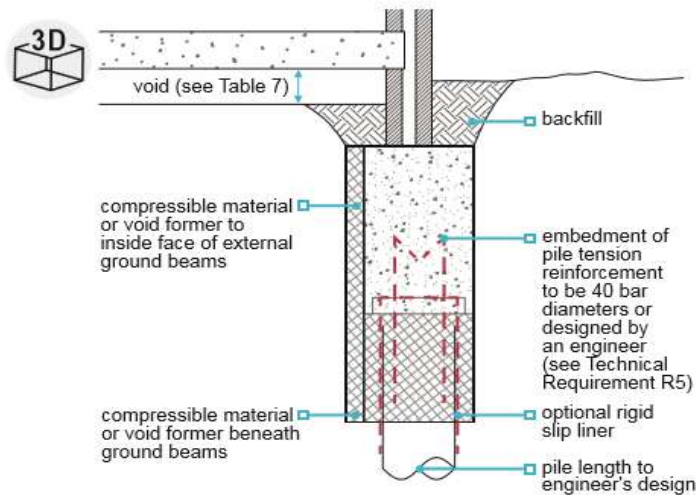
Where foundation depths in clay due to trees already present or recently removed exceeds 1.50m, there is a possibility for heave to occur on removal of the tree. NHBC Guidance states that in areas where volume change potential is medium the following void or void former dimensions should be provided:

- Against side of foundation and ground beam – 35mm
- Underground beams, and suspended in-situ concrete ground floor – 150mm

Due to the proposed piled/ vibro solution across areas of the site, NHBC Chapter 4.2 dictates that heave precautions are required on the inside faces of external ground beams, on the underside of all internal and external ground beams and beneath floor slabs. Heave precautions can comprise a void, void former or compressible material.

Where heave precautions are deemed necessary, the pile/ vibro installation design will need to accommodate the following precautions in the design.

Figure 6: Heave precautions for pile and beam foundations



It is essential that heave material is provided to the entire areas shown. Particular care should be taken to ensure that the full width of the ground beam and the areas around the piles are protected.

Measurements of foundation depths where ground levels are reduced or increased, either recent past or during construction, should be carried out in accordance with NHBC Chapter 4.2.

6.6 Floor Slabs

Made Ground is up to 1.75m deep and generally more than 0.6m deep across the site therefore, floor slabs should be suspended with a 300mm void under suspended pre-cast concrete or timber floors.

If a Controlled Modulus Column foundation solution is selected it is recommended that stone columns are also installed beneath the floor slab, this would enable the use of a ground bearing floor slab.

6.7 Construction

Instability of the Made Ground and Alluvium is a possibility and should be considered in the groundworks method statements.

Relatively shallow groundwater was encountered across the site, instability of soils beneath the groundwater table is expected and foundation excavations will require dewatering where excavations are below the groundwater table.

Tracked high specification plant is recommended to maintain the build programme. Breaking equipment will also be required locally to penetrate obstructions in the vicinity of the former mill, including concrete floor slabs, foundations and silo bases.

6.8 Concrete Classification

Made Ground

Water soluble sulphate testing was undertaken on twenty-five samples of the Made Ground. The range of soluble sulphate (SO_4) recorded is <0.0015g/l to 1.6222g/l. Associated pH values ranged between 7.57 and 11.88 indicating neutral to alkaline conditions.

Twenty-five samples of Made Ground were tested, therefore the mean of the highest 20% of the sulphate test results and lowest 20% pH results should be taken as the characteristic values. For the Made Ground, a characteristic sulphate concentration of 1.3283g/l and a pH value of 7.82 have been selected.

Natural Strata

Water soluble sulphate testing was undertaken on ten samples of the Natural Strata. The range of soluble sulphate (SO₄) recorded is 0.0065g/l to 1.5766g/l. Associated pH values ranged between 7.58 and 8.83 indicating neutral to slightly alkaline conditions.

Ten samples of Natural Strata were tested, therefore the mean of the highest 20% of the sulphate test results and lowest 20% pH results should be taken as the characteristic values. For the Natural Strata, a characteristic sulphate concentration of 0.8953g/l and a pH value of 7.61 have been selected.

Groundwater is considered to be mobile due to the granular nature of the Made Ground and some of the superficial deposits underlying the site.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-2 and sulphate class DS-2 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005. The specific concrete mixes (the Design Concrete Class) to be used on site will be determined by the site specific concrete requirements in terms of the durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need for Additional Protective Measures (APM) detailed in Part D of BRE Special Digest 1 with further guidance in Pt E and F.

6.9 Highway Design

Made Ground is present at proposed formation level across the majority of the site.

Untreated Made Ground should be assumed to have a CBR value of <2.5%, unless proven otherwise. Highways Agency document HD25 'Interim Advice Note 73/06 Revision 1' (2009) states that where a subgrade has a CBR value lower than 2.5%, it is considered unsuitable support for a pavement foundation since it would tend to deform under construction traffic, and must be improved.

Where highways are proposed in areas underlain by Made Ground, it is recommended that Made Ground to a depth of 1.0m below subgrade level is excavated, sorted and classified in accordance with Series 600 (Earthworks) of the Highways Agency "Specification for Highways Works". Following the above, any suitable material which can be used as part of highway construction shall be compacted in accordance with the earthworks specification.

The soils beneath the site are considered to be frost susceptible due to the fines content and highway construction should be a minimum thickness of 450mm to mitigate the risk.

6.10 Sustainable Urban Drainage System (SuDS)

Soil percolation testing was not undertaken as part of this investigation, however the use of SuDS is unlikely to be feasible due to the presence of widespread impermeable clay deposits and the presence of shallow groundwater beneath the site.

If the use of SuDS is to be considered, soil percolation testing in accordance with BRE 365 should be undertaken in order to obtain soil infiltration rates.

If drainage of the highway to soakaways is to be considered it is suggested that this is discussed with the Local Authority at the earliest opportunity, to confirm the adequacy of proposed testing and to allow their inspection of any testing.

7.0 LAND QUALITY

7.1 Geo-Environmental Testing Results - Soils

Samples of Made Ground have been tested for a range of relevant determinands. In accordance with CLR11 (DEFRA & EA, 2004), a Generic Quantitative Risk Assessment (GQRA) has been undertaken to determine the significance of the concentrations as derived through Geo-Environmental analysis.

The GQRA process comprises the comparison of the actual concentrations measured on site with Generic Assessment Criteria (GACs) for the protection of human health.

The GACs used for the assessment of soil concentrations have been derived using the CLEA model. The GACs used and their ranking of importance are listed below:

- Soil Guideline Values (SGVs) which demonstrate minimal risk,
- LQM/CIEH S4ULs which use the same toxicological data as the SGVs but different exposure criteria.
- C4SLs which demonstrate low risk.

In deriving the GACs for use on Brownfield sites we have assumed a 1.0% Soil Organic Matter, unless the results indicate otherwise.

The proposed end-use for the site is a residential development comprising housing with private domestic gardens with associated driveways, pavements and access roads. We have therefore undertaken the GQRA on the basis that the proposed development site falls under the Residential (with Plant Uptake) land-use scenario as defined in SR3 (EA, 2009b).

A summary of the Geo-Environmental Testing results is presented below and the GQRA Tier I screening Values are presented in Appendix 7:

Metals				
Contaminant	Range of Results (mg/kg unless stated)	Screening Value (mg/kg unless stated)	Number of Exceedances	Locations of Exceedances
Arsenic	2.5 – 23.7	32	0	-
Cadmium	<0.1 – 0.2	10	0	-
Chromium	40.4 – 109.4	910	0	-
Hexavalent Chromium	<0.3	21	0	-
Copper	<1 – 43	2400	0	-
Lead	6 – 77	200	0	-
Mercury	<0.1 – 0.2	1	0	-
Nickel	8.8 – 37.9	130	0	-
Selenium	<1	350	0	-
Zinc	21 – 271	3700	0	-
Polycyclic Aromatic Hydrocarbons (PAHs)				
Contaminant	Range of Results (mg/kg unless stated)	Screening Value (mg/kg unless stated)	Number of Exceedances	Locations of Exceedances
Naphthalene	<0.04 – 0.44	2.3	0	-
Acenaphthylene	<0.03 – 0.45	170	0	-
Acenaphthene	<0.05 – 1.0	210	0	-
Fluorene	<0.04 – 2.38	170	0	-
Phenanthrene	<0.03 – 4.57	95	0	-

Anthracene	<0.04 – 1.48	2400	0	-
Fluoranthene	<0.03 – 6.93	280	0	-
Pyrene	<0.03 – 5.24	620	0	-
Benzo(a)anthracene	<0.06 – 3.35	7.2	0	-
Chrysene	<0.02 – 2.81	15	0	-
Benzo(b)fluoranthene	<0.05 – 3.76	2.6	4	WS02 – 1.00m WS18 – 0.50m WS21 – 0.40m WS28 – 0.50m
Benzo(k)fluoranthene	<0.02 – 1.46	77	0	-
Benzo(a)pyrene	<0.04 – 2.82	2.2	2	WS02 – 1.00m WS21 – 0.40m
Indeno(123cd)pyrene	<0.04 – 1.82	27	0	-
Dibenzo(ah)anthracene	<0.04 – 0.50	0.24	2	WS02 – 1.00m WS21 – 0.40m
Benzo(ghi)perylene	<0.04 – 2.27	320	0	-
TPH CWG – Aliphatics				
Contaminant	Range of Results (mg/kg unless stated)	Screening Value (mg/kg unless stated)	Number of Exceedances	Locations of Exceedances
>C5-C6	<0.10	42	0	-
>C6-C8	<0.10 – 0.9	100	0	-
>C8-C10	<0.10 – 14	27	0	-
>C10-C12	<0.20 – 901.4	130	3	WS09 – 1.00m WS11 – 1.00m WS11 – 1.50m
>C12-C16	<4.00 – 2519	1,100	1	WS11 – 1.50m
>C16-C35	<14 – 3719	65,000	0	-
Total aliphatics C5-35	<19 - 7154	-	-	-
TPH CWG – Aromatics				
Contaminant	Range of Results (mg/kg unless stated)	Screening Value (mg/kg unless stated)	Number of Exceedances	Locations of Exceedances
>C5-EC7	<0.10	70	0	-
>EC7-EC8	<0.10	130	0	-
>EC8-EC10	<0.10 – 0.5	34	0	-
>EC10-EC12	<0.2 – 390.7	74	4	WS09 – 0.50m WS09 – 1.00m WS11 – 1.00m WS11 – 1.50m
>EC12-EC16	<4.00 – 1687	140	4	WS09 – 0.50m WS09 – 1.00m WS11 – 1.00m WS11 – 1.50m
>EC16-EC21	<7 – 1776	260	4	WS09 – 0.50m WS09 – 1.00m WS11 – 1.00m WS11 – 1.50m
>EC21-EC35	<7 – 552	1,100	0	-
Total aromatics C5-35	<19 – 4406	N/A	N/A	-
Total aliphatics and aromatics(C5-35)	<38 – 11,560	N/A	N/A	-
MTBE	<0.005	49	0	-

Benzene	<0.005	0.33	0	-
Toluene	<0.005	610	0	-
Ethylbenzene	<0.005 – 0.170	350	0	-
m/p-Xylene	<0.005 – 0.331	230	0	-
o-Xylene	<0.005	250	0	-
Others				
Organic Matter (%)		<0.2 – 7.1		
Asbestos Screen				
Position	Depth (m bgl)	Asbestos Type	Asbestos Quantity (mass %)	
WS01	0.50	None Detected	-	
WS02	1.00	None Detected	-	
WS05	1.00	None Detected	-	
WS08	0.50	None Detected	-	
WS10	0.50	None Detected	-	
WS12	0.30	None Detected	-	
WS13	0.50	Chrysotile	<0.001	
WS14	0.50	None Detected	-	
WS16	0.40	Chrysotile	<0.001	
WS17	0.60	None Detected	-	
WS18	0.50	Amosite	<0.001	
WS19	0.50	Chrysotile and Amosite	0.002	
WS21	0.40	None Detected	-	
WS22	0.30	None Detected	-	
WS23	0.10	None Detected	-	
WS24	0.40	None Detected	-	
WS25	0.40	None Detected	-	
WS29	0.50	None Detected	-	
TP01	0.05	None Detected	-	
TP02	0.10	Chrysotile	<0.001	

7.2 Tier I Generic Quantitative Risk Assessment - Soils

Made Ground

Made Ground was encountered across the entire site from ground level to a maximum depth of 1.75m bgl, and was generally deeper in the west of the site. In the centre, north, east and south of the site the Made Ground was generally less than 1.0m deep. These soils generally comprised concrete over granular strata with brick as a minor constituent and ash within four locations (WS02, WS11, WS14 and WS23).

Made Ground topsoil was encountered within seven locations across the site (WS01, WS21, WS23, WS24, TP01, TP02 and TP03) which contained brick and ash as a minor constituent, furthermore Made Ground clay was encountered within five locations across the site (WS03, WS05, WS09, WS14 and WS23). A moderate hydrocarbon odour was noted within the soils in the vicinity of WS09, WS10 and WS11.

A backfilled mill race was encountered in WS02, the base of which was still intact at 1.75m bgl. The mill race was backfilled with granular Made Ground which included ash as a minor constituent. The former reservoir fed by the mill race was encountered in WS03, WS04 and WS05, Made Ground was between 0.65m and 1.10m deep and comprised granular and cohesive strata with ash and brick as minor constituents, no putrescible material was noted.

The soft landscaped area to the south of the site and the area beneath the existing building will require further investigation following demolition.

Asbestos was noted in the Preliminary Risk Assessment along the southern bank of the river, which may be related to trace asbestos fibres which were detected within the Made Ground topsoil from TP02.

No visual or olfactory evidence of impaction from interceptors on site was noted within the soils in close proximity. The interceptors were opened during the investigation and appeared to be separating solids out of the waste water from the nearby laboratory building.

pH values of above 11 were noted within Made Ground soils from WS10, WS12, WS14 and WS16 which are all in the vicinity of the derelict mill buildings. There is no clear source for this within the soils, and is likely due to historic industrial uses on the site. These soils are near the surface and pose a risk to site end users as soft landscaping is proposed within plots in these areas.

Heavy Metals

No elevated heavy metal concentrations were detected across the site for residential with plant uptake end use.

Speciated Polycyclic Aromatic Hydrocarbons (PAHs)

Elevated PAH concentrations were detected within four locations across the site (WS02 at 1.0m, WS18 at 0.5m, WS21 at 0.4m and WS28 at 0.5m), ash was noted within the samples from WS02 and WS21 which is likely to be the source of elevated concentrations. Concentrations of Benzo(b)fluoranthene were only marginally elevated within samples from WS18 and WS28.

Statistical Analysis Made Ground – PAHs

Statistical analysis was undertaken using the total concentrations for the Made Ground. The aim of statistical analysis is to demonstrate suitability for reuse, therefore the Null Hypothesis is that the level of contamination (in the land of interest) is the same as, or higher than, the Critical Concentration and the Alternative Hypothesis is that the level of contamination is lower than the Critical Concentration. Therefore, if the Null Hypothesis is rejected with a high degree of confidence then the Alternative Hypothesis is likely to be true indicating that contaminant concentrations are low relative to the Critical Concentration and that, potentially, the land is suitable for use. The results of the statistical analysis are presented in Appendix 8 and are summarised in the points below:

- The statistical analysis for benzo(a)pyrene shows that the Upper Confidence Limit (1.52mg/kg) is less than the Critical Concentration (2.2mg/kg) with an evidence level of 98%, meaning that the Null Hypothesis is rejected with a high degree of confidence. Therefore, despite the elevated benzo(a)pyrene concentrations within two samples of Made Ground, the Made Ground across the site as a whole is reusable based on the concentrations of benzo(a)pyrene that have been recorded. Furthermore, significant mixing and dilution of these concentrations will occur during the site strip and storage of the Made Ground which will reduce localised anomalous results.
- The statistical analysis for dibenz(ah)anthracene shows that the Upper Confidence Limit (0.23mg/kg) is less than the Critical Concentration (0.24mg/kg) with an evidence level of 96%, meaning that the Null Hypothesis is rejected with a high degree of confidence. Therefore, despite the elevated dibenz(ah)anthracene concentrations within two samples of Made Ground, the Made Ground across the site as a whole is reusable based on the concentrations of dibenz(ah)anthracene that have been recorded. Furthermore, significant mixing and dilution of these concentrations will occur during the site strip and storage of the Made Ground which will reduce localised anomalous results.

- The statistical analysis for benzo(b)fluoranthene shows that the Upper Confidence Limit (2.10mg/kg) is less than the Critical Concentration (2.60mg/kg) with an evidence level of 97%, meaning that the Null Hypothesis is rejected with a high degree of confidence. Therefore, despite the elevated benzo(b)fluoranthene concentrations within four samples of Made Ground, the Made Ground across the site as a whole is reusable based on the concentrations of benzo(b)fluoranthene that have been recorded. Furthermore, significant mixing and dilution of these concentrations will occur during the site strip and storage of the Made Ground which will reduce localised anomalous results.

Total Petroleum Hydrocarbons (TPH)

Elevated aliphatic and aromatic TPH concentrations within the diesel range were noted within WS09 at 0.5m and 1.0m / WS11 at 1.0m and 1.5m bgl. A moderate hydrocarbon odour was noted within WS09, WS10 and WS11 which is in the vicinity of a former underground diesel storage tank. Some of the concentrations are significantly elevated at over ten times the screening value. No elevated concentrations of Benzene, Toluene, Ethylbenzene or Xylene (BTEX) were detected across the site.

Hydrocarbon contamination was limited to an area of approximately 25m² in the vicinity the former diesel UST noted on the Preliminary Development Constraints Plan 19271 02. No fuel derived hydrocarbons were observed or recorded within soils across the remainder of the site, including free phase.

Contaminated soils extended to c.1.00 – 1.50m bgl. The interpretation undertaken by the laboratory indicates that degraded diesel is responsible for the elevated concentrations. Elevated concentration were noted within the vapour range (>C10 – C12) within WS09 and WS11 at between 0.50m and 1.50m bgl.

Asbestos in Soils

Asbestos was detected within five samples (WS13 at 0.5m, WS16 at 0.3m, WS18 at 0.5m, WS19 at 0.5m and TP02 at 0.1m) of the total twenty tested from across the site. Chrysotile was detected within four samples and was determined to be trace within samples from WS13, WS16, and TP02, concentrations were marginally above trace within WS19 (0.002%). Amosite was noted within WS18 and WS19 and was determined to be trace within WS18 and marginally above trace within WS19 (0.002%). Chrysotile and amosite was noted within the sample from WS19.

Four samples containing asbestos relate to sand or gravel Made Ground underlying the concrete slabs in the eastern part of the derelict mill area as highlighted on the Contamination Plan 19271 05. One sample of Made Ground topsoil from TP02 to the south of the River Oughton also contained trace asbestos.

Southern Area

Minimal coverage was obtained in the southern area of the site which is indicated by the proposed development plan to become public open space. Two samples of Made Ground topsoil were tested for a range of Contaminants of Concern (COCs) as detailed in Section 4.4.

No elevated concentrations of heavy metals or PAHs were detected within either sample.

Trace quantities of chrysotile asbestos was detected within the sample tested from TP01 at 0.10m bgl.

Areas of concern are shown on the Contamination Plan 19271 05.

7.3 Geo-Environmental Testing Results - Groundwater

Six samples of groundwater were taken from WS06, WS09, WS17, WS18, WS25 and WS29 and were tested for the same suite of determinands as the soils. Samples from WS06, WS09 and WS29 were selected as they

are close to the former UST, the sample from WS17 was selected as it is adjacent to the boiler house and between the former UST and River Oughton, WS18 was selected due to the proximity to the electricity substation and WS25 was selected as it is up gradient of the former UST, to determine if groundwater migrating from off site is contaminated.

The implementation of the Water Framework Directive (WFD) is to protect and enhance the quality of groundwater and groundwater-dependent ecosystems. The objective of the WFD requires all groundwater bodies (GWBs) are of 'good' status in terms of water quality. This status is based on thresholds for the chemical constituents of groundwater and their impact on ecosystems. Preventing pollution is by far the most sustainable and cost-effective way of maintaining good groundwater quality. The EA are committed to the 'prevent or limit' approach reflected in EU and domestic legislation.

Priority is under the Water Framework Directive to protect water supplies intended for human consumption and ensure protection of groundwater quality that supplies dependent ecosystems. After first guidance in 1992 the following significant guidance has been introduced:

- Water Framework Directive (2000/60/EC) and the Water Act 2003.
- The State of Groundwater in England and Wales 2006.
- Second phase of the environmental permitting regime in 2010 replacing the Groundwater Regulations (1999, 2009).
- Groundwater Daughter Directive.

Pollutants can be divided into those that break down easily (degradable pollutants) and those that do not (non-degradable pollutants). The Water Framework Directive introduced the concept of 'hazardous substances' and 'non-hazardous pollutants', which replaced the previous List I and List II of substances considered to pose the greatest threat to the environment.

- *Hazardous substances* are the most toxic and must be prevented from entering groundwater. Substances in this list may be disposed of to the ground, under a permit, but must not reach groundwater. They include pesticides, sheep dip, solvents, hydrocarbons, mercury, cadmium and cyanide.
- *Non-hazardous pollutants* are less dangerous and can be discharged to groundwater under a permit but must not cause pollution. Examples include sewage, trade effluent and most wastes. Non-hazardous pollutants include any substance capable of causing pollution and the list is much wider than the previous List II of substances. For example, nitrate is now a non-hazardous pollutant whereas before it was not a List II substance.

Polluting substances in groundwater can occur as a gas (gaseous phase) or dissolved in water (aqueous phase), or as a non-aqueous phase liquid (NAPL). Some pollutants include substances that dissolve readily in water. These are said to have high solubility; an example is MTBE. Substances that have low solubility (such as oil) are referred to as non-aqueous phase liquids (NAPLs). NAPLs behave differently in groundwater depending on whether they are lighter or heavier than water. Light non-aqueous phase liquids (LNAPLs) may float on the water table whereas dense non-aqueous phase liquids (DNAPLs) may sink through the aquifer until they reach an impermeable layer. They may then generate plumes of contamination. In both cases, the slowly dissolving pollutant may form a plume of dissolved contamination which moves with the groundwater flow.

A table summarising the groundwater testing results is presented below:

Metals				
Contaminant	Range of Results (ug/l unless stated)	EQS Screening Value (ug/l)	Number of Exceedances	Locations of Exceedances
Arsenic	<2.5 – 5.5	50	0	-
Cadmium	<0.5	5	0	-
Chromium	<1.5	50	0	-
Hexavalent Chromium	<0.006	12	0	-
Copper	<7	20	0	-
Lead	<5	50	0	-
Mercury	<1	1	0	-
Nickel	<2 – 9	50	0	-
Selenium	<3	10*	0	-
Zinc	<3 – 5	3000	0	-
Polycyclic Aromatic Hydrocarbons (PAHs)				
Contaminant	Range of Results (ug/l unless stated)	EQS Screening Value (ug/l)	Number of Exceedances	Locations of Exceedances
Benzo(a)pyrene	<0.016 – 0.170	0.00017	1	WS17
Indeno(123cd)pyrene	<0.011 – 0.103	See Note 1	-	-
Benzo(ghi)perylene	<0.011 – 0.078	See Note 1	-	-
Benzo(b)fluoranthene	<0.01 – 0.20	See Note 1	-	-
TPH CWG – Aliphatics				
Contaminant	Range of Results (ug/l unless stated)	WHO (ug/l)	Number of Exceedances	Locations of Exceedances
>C5-C6	<10	10	0	-
>C6-C8	<10	10	0	-
>C8-C10	<10 – 601	30	1	WS09
>C10-C12	<5 – 10,678	300*	2	WS09, WS17
>C12-C16	<10 – 36,770	300*	2	WS09, WS17
>C16-C35	<10 – 62,140	300*	2	WS09, WS17
Total aliphatics C5-35	<10 – 110,189	-	-	
TPH CWG – Aromatics				
Contaminant	Range of Results (ug/l unless stated)	EQS Screening Value (ug/l)	Number of Exceedances	Locations of Exceedances
>C5-EC7	<10	10	0	
>EC7-EC8	<10	10	0	
>EC8-EC10	<10 – 20	30	1	WS09
>EC10-EC12	<5 – 4716	90*	2	WS09, WS17
>EC12-EC16	<10 – 25,510	90*	2	WS09, WS17
>EC16-EC21	<10 – 30,860	90*	2	WS09, WS17
>EC21-EC35	<10 – 10,200	90*	2	WS09, WS17
Total aromatics C5-35	<10 – 71,306	-	-	
Total aliphatics and aromatics(C5-35)	<10 – 181,495	-	-	
MTBE	<5		0	
Benzene	<5	10	0	
Toluene	<5	74	0	
Ethylbenzene	<5	30	0	
m/p-Xylene	<5 – 8	30	0	
o-Xylene	<1 – 12	30	0	
Others				
Total Alkalinity as CaCO3		664 mg/l – 14,860 mg/l		

Dissolved Organic Carbon	<2 mg/l – 30 mg/l
Total Organic Carbon	<2 mg/l – 42 mg/l

Note 1 - For the group of priority substances of polyaromatic hydrocarbons (PAH) (No 28), the biota EQS and corresponding AA-EQS in water refer to the concentration of benzo(a)pyrene, on the toxicity of which they are based. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene must be monitored for comparison with the biota EQS or the corresponding AA-EQS in water.

** A list of potentially applicable water quality standards is given in Environment Agency (2006b). In the absence of EQS values, World Health Organisation (WHO) Guide Values for Drinking Water have been used.*

All of the PCBs tested for were recorded at concentrations below the laboratory limits of detection.

7.4 Tier I Quantitative Risk Assessment - Groundwater

Controlled Waters Setting

Strata underlying the majority of the site consists of Made Ground over Alluvium deposits of Sand, Silt and Clay underlain by the Lowestoft Formation consisting of Clay. In the north of the site Made Ground is underlain by Glaciofluvial Sand and Gravel deposits. Groundwater was frequently encountered within the Alluvium deposits across the site, with the likely flow direction being to the south east toward the River Oughton which flows through the site.

The Alluvium and Glaciofluvial Deposits are both considered to be Secondary A Aquifers. The bedrock was not encountered during this investigation, however it is determined to be an Unproductive Aquifer and is therefore not considered to be a sensitive receptor. The closest recorded groundwater abstraction is 900m north of the site. The site is not within a Source Protection Zone.

The River Oughton crossing the site is indicated to be a secondary river which flows into the River Purwell and later becomes the River Hiz as it continues north. The nearest surface water abstraction is from the River Hiz 464m north east of the site.

During the Ground Investigation groundwater was encountered at depths of between 1.0m and 3.45m bgl across the site, which is considered to be in continuity with the River Oughton. This should be confirmed by carrying out surveying of the boreholes and the watercourse.

The contaminants tested for have been compared to EQS screening levels given the close proximity of the River Oughton on site.

Geo-Environmental/Chemical Testing Results

Significantly elevated levels of aliphatic hydrocarbons were recorded in WS09 and WS17 at concentrations of up to 601ug/l, 10,678ug/l, 36,770ug/l and 62,140ug/l when compared to the EQS and WHO guideline values of 30ug/l (EQS: >C8-C10) and 300ug/l (WHO: >C10-C12, >C12-C16 and >C16-C35) for CWG banding. Concentrations were generally lower within the groundwater sample collected from WS17.

Furthermore significantly elevated levels of aromatic hydrocarbons were recorded within WS09 and WS17 at concentrations of up to 20ug/l, 4716ug/l, 25,510ug/l, 30,860ug/l and 10,200ug/l when compared to the EQS and WHO guideline values of 30ug/l (EQS: >EC8-EC10) and 90ug/l (WHO: >EC10-EC12, >EC12-EC16 and >EC16-EC35) for CWG banding. Again, concentrations were lower within WS17. This was interpreted as being degraded diesel by the Geo-Environmental testing results.

Based on the concentrations of hydrocarbons recorded in WS09 and WS17, the groundwater that is in hydraulic continuity has been impacted by hazardous substances in the form of fuel derived hydrocarbons within the soils. Interpretation of the groundwater results indicates that the source of the elevated hydrocarbon results is degraded diesel – although the USTs have been removed, the source of the impacted soils and groundwater is the historic USTs. The source of the contamination plume in the groundwater is subsequently the degraded diesel encountered in the Made Ground in WS09, WS10 and WS11. A good coverage of the area surrounding the USTs was achieved and the Contamination Plan 19271 05 indicates the exploratory holes where hydrocarbon odours were detected in the soils and the postulated hydrocarbon groundwater plume.

Contamination stemming from residual degraded diesel within the soils in the vicinity of the former UST is highly localised to the soils in this area. No hydrocarbon contamination was noted within any soils across the remainder of the site. Furthermore no free phase was noted during the investigation.

Other Contaminants

Within WS09 and WS17, slightly elevated concentrations of a limited number of speciated PAHs were encountered. Using Benzo(a)Pyrene as a marker, the source of the elevated concentrations is considered to be ash within the Made Ground as Benzo(a)Pyrene is indicative of incomplete combustion of solid fuels.

Surface Waters

There is a potential risk to the River Oughton passing through the site from hydrocarbons present within the groundwater, in particular in the vicinity of WS09. It is recommended that surface water samples are collected from the River Oughton upstream and downstream of where the contamination was encountered within WS09 and WS17.

7.5 Permanent Ground Gases

Gas Monitoring Results

One ground gas monitoring visit has been carried out to date on 23 December 2019. No concentrations of methane (CH₄) have been recorded within the boreholes however, detectable levels of carbon dioxide (CO₂) were recorded within the standpipes, up to a maximum level of 0.4%v/v together with associated oxygen (O₂) concentrations of 19.0%v/v.

In addition, flow rates of between <0.1l/hr and 1.0l/hr have been recorded during the monitoring period. The visit was completed during a period of steady atmospheric pressure which ranged between 1000mb and 1003mb.

Groundwater was encountered within the standpipes during the monitoring period from 0.29m to 2.83m bgl. No groundwater was encountered within WS02.

Key sources targeted by the ground gas monitoring installations include the backfilled mill race, backfilled reservoir and the former UST.

Characterisation of the Gas Screening Value (GSV)

In accordance with CIRIA Report C665, November 2007 it is felt that an adequate risk assessment can be undertaken based on the following limiting factors:

- The proposed development has been considered as **high sensitivity** based on the site being proposed residential houses with garden areas (Table 5.5 – Typical/Idealised frequency and period of monitoring, after Wilson et al, 2005).

- The risk associated with the generation potential of a source is considered as **Low**, (assessment based on the environmental setting as well as ground gas results collected).
- Monitoring over a **minimum of three months** with **six recorded** readings (Table 5.5 – Typical /idealised frequency and period of monitoring after Wilson et al, 2005).
- **Low** flow rates have been recorded (Table 8.5 – Modified Wilson & Card classification). For this site, the monitoring visit undertaken correlated with a steady atmospheric pressure trend.

Based upon the results recorded, in accordance with CIRIA Report C665, the risk to the site from ground gases has been assessed by converting the results to gas screening values (GSVs), calculated by multiplying the typical maximum gas concentrations with the recorded maximum positive flow rates. In addition, individual “hazardous gas flow rates” (Qhg) have been derived for each monitoring point. As no levels of methane have been recorded a GSV for carbon dioxide only has been calculated.

$$GSV (l/hr) = \text{max borehole flow rate (l/hr)} \times \text{max gas concentration (\%)}$$

For this interim assessment, the maximum recorded concentration of carbon dioxide of 0.4%v/v has been used with a gas flow rate of 1.0l/hr to calculate the GSV.

$$\text{Carbon Dioxide GSV} = 0.004 (0.4\%) \times 1.0 = 0.004 \text{ l/hr}$$

Assessment

In order to assess the ground gas regime beneath the site and the need to incorporate ground gas precautions, guidance was taken from CIRIA C665 ‘Assessing risks posed by hazardous ground gases to buildings’.

Based on the site being developed with low-rise housing, the Boyle and Witherington, 2006 method has been used to carry out the assessment. This is a risk-based approach that is designed to allow an identification of gas protection for a low-rise housing development by comparing the measured gas emission rates to generic ‘traffic lights’ scenarios. The traffic lights include ‘typical maximum concentrations’ and are provided for initial screening purposes and risk-based gas screening values for consideration in situations where the typical maximum concentrations are exceeded.

When considering the results, in accordance with CIRIA C665 (Situation B – Low-rise housing with a ventilated underfloor void (min 150mm) and Table 8.7 – NHBC Traffic light system for 150mm void) it can be seen that the GSV value for carbon dioxide is below the assessment GSV of <0.78l/hr and falls within the Green traffic light zone.

NHBC - Green Traffic Light

At this stage, a negligible gas regime has been identified and no gas precautions are required. This will be confirmed on completion of the gas monitoring programme. An extract of the table is presented below.

Traffic Light Classification	Methane ¹		Carbon Dioxide ¹	
	Typical Maximum Concentration ³ (%v/v)	Gas Screening Value ^{2,4} (l/hr)	Typical Maximum Concentration ³ (%v/v)	Gas Screening Value ^{2,4} (l/hr)
Green	1	0.16	5	0.78
Amber 1	5	0.63	10	1.56
Amber 2	20	1.56	30	3.10
Red				

Notes:

1. 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 will be the decider as to what Traffic Light is allocated;
2. Gas Screening Value is the Borehole Gas Volume Flow Rate, in litres per hour, as defined in Wilson and Card (1999), which is the borehole flow rate multiplied by the concentration in the air stream of the particular gas being considered;
3. The Typical Maximum Concentrations can be exceeded in certain circumstances should the Conceptual Site Model indicate it is safe to do so;
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.

In addition due to the potential for ground bearing floor slabs, guidance was taken from CIRIA C665 'Assessing risks posed by hazardous ground gases to buildings'. Based on the site being developed with residential homes with ground bearing floor slabs, the Wilson and Card method has been used to carry out the assessment.

When considering the results, in accordance with CIRIA C665 (Section A Development and Table 8.5 – Modified Wilson and Card Classification) it can be seen that the GSV value for carbon dioxide is below the assessment GSV of <0.07l/hr and falls within Characteristic Situation 1 resulting in no gas protection measures being required.

Characteristic Situation 1

An extract of the table is presented below.

Modified Wilson and Card classification

	Characteristic situation (CIRIA R149)	Comparable classification in DETR et al (1999)	Risk classification	Gas screening value (GSV) (CH ₄ or CO ₂) (l/hr) ¹ Threshold	Additional factors	Typical source of generation
	1	A	Very low risk	<0.07	Typically methane <1 % and/or Carbon dioxide <5 %. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" made ground
	2	B	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content. "Typical" made ground
	3	C	Moderate risk	<3.5		Old landfill, inert waste, mineworking flooded
	4	D	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking – susceptible to flooding, completed landfill (WMP 2GB criteria)
	5	E	High risk	<70		Mineworking unflooded inactive with shallow workings near surface
	6	F	Very high risk	>70		Recent landfill site

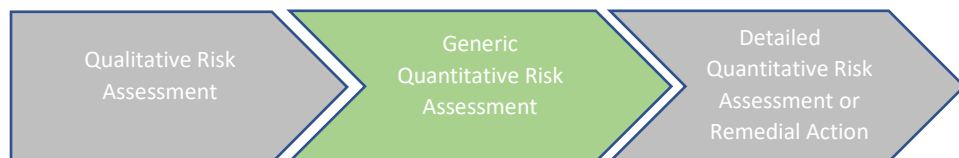
Radon Gas

In accordance with BRE 211 'Radon Guidance on Protective Measures for New Buildings' 2015 and UKRadon the site falls in an area where <1% of homes are affected by radon gas, therefore no radon precautions would be required.

7.6 Revised Pollution Linkage Assessment

A revised pollution linkage assessment has been undertaken in accordance with CLR11 and CIRIA C552 to identify any realistic pollution linkages in order to quantify the risks to human health and controlled waters. The risk classification has been estimated in accordance with the CIRIA C552 assessment criteria outlined in Appendix 9. An Illustrative Revised CSM is presented as Plan No. 19271 06.

Human Health Pollution Linkage Assessment



- The table below represents the second stage in the land quality risk assessment process - **the Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed 'suitable for use' the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

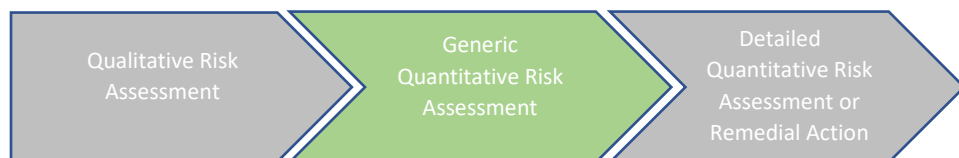
Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
PL1	Contaminated Soils	Ingestion of soil and dust. Dermal contact with soil.	Likely	Medium	Moderate	Pollution Linkage 1 refers to proposed site users coming into contact with contaminated soils on the site. Made Ground is present across the entire site from ground level to a maximum depth of 1.75m bgl. Elevated PAHs were noted within four samples of Made Ground from across the site and are likely a result of ash within the Made Ground strata. Asbestos was detected within five samples of Made Ground from across the site and was confirmed to be trace in all but one sample from WS19 which was quantified as 0.002 mass %. Asbestos is generally associated with the sand and gravel Made Ground beneath the concrete covering the site, however one sample from TP02 at 0.1m bgl detected trace concentrations of asbestos within the Made Ground topsoil. The Joint Industry Working Group (JIWG) Receptor Ranking Tool indicates that the overall risk from asbestos to site end users is considered to be very low. The JIWG Receptor Ranking is presented in Appendix 9. A moderate hydrocarbon odour was noted within the soils in the vicinity of WS09, WS10 and WS11 which were drilled in the vicinity of a former diesel UST. Geo-Environmental testing has revealed elevated TPHs within samples from WS09 and WS11 at depths of between 0.5m and 1.5m bgl

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
						No PCBs were detected by the Geo-Environmental testing. The proposed development is for low rise housing with associated soft landscaped gardens and infrastructure. Therefore, a pollution linkage exists within garden areas of plots, specifically in the vicinity of the former UST. Furthermore, large areas of the site were not investigated due to the presence of the existing mill buildings, therefore additional investigation following demolition is required. There is considered to be a plausible pollution linkage and supplementary Ground Investigation/remedial works will be required.
PL2	Contaminated Soils	Inhalation of vapour.	Likely	Medium to Severe	Moderate to Low	Pollution linkage 2 refers to hydrocarbon vapours migrating into confined spaces within the proposed development. Elevated concentrations of TPHs within the volatile range were detected in the vicinity of WS09, WS10 and WS11 where a former UST was located. Significant hydrocarbon contamination has been detected in a very localised area, therefore a small number of plots in the vicinity will be at risk of migration of vapours into confined spaces within the dwellings and remediation to remove contaminated soils is recommended. The area affected is extremely localised, covering an area of approximately 25m² and likely only affecting 2 – 3 plots. With the exception of localised hydrocarbon contamination, the development is not likely to be affected by vapours migrating into confined spaces A pollution linkage is considered to exist in a very localised area of the site.
PL3	Contaminated Soils	Inhalation of soil dust by adjacent site users.	Unlikely	Medium	Low	Pollution Linkage 3 relates to contamination on the subject site affecting adjacent site users. The site is currently covered with hardsurfacing, limiting the potential

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
						for contaminated dusts to spread to adjacent sites. Mobile hydrocarbon contamination has been detected within soils, however the contamination is isolated to an area where a former UST was located near the centre of the large site and it is not considered likely that contamination will migrate off-site as clay strata will inhibit lateral migration of contaminants. Therefore, no viable pollution linkage is considered to exist.
PL4	Contaminated Soils	Attacking potable water supply pipe.	Likely	Medium	Moderate	Pollution Linkage 4 refers to the possible contaminants permeating potable water pipes and consumption by the future residents of the tainted water supply. Contaminated Made Ground is present at the likely installation depth of the potable water supply pipes across the site. Localised hydrocarbon contamination was detected within soils in the vicinity of a former diesel UST, therefore currently locally a pollution linkage is considered to exist. A local water company risk assessment is required prior to construction to advise on the level of protection required for the potable water supply.
PL5	Ground Gas	Migration and accumulation of ground gas in internal spaces.	Unlikely to Low Likelihood	Medium to Severe	Moderate to Low	Deep Made Ground was not generally encountered at the site. Furthermore, putrescible material was not noted within any of the window sample boreholes and trial pits. Preliminary monitoring undertaken to date indicates that the site falls within NHBC Green Traffic Light Zone and no gas protection measures will be required. This will be confirmed upon completion of the ground gas monitoring.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential Source	Pollution Linkage	Likelihood	Consequence/ Severity	Risk Rating	Rationale and Action
						The site is not within an area requiring radon precautions within foundations.

Controlled Waters Pollution Linkage Assessment



- The table below represents the second stage in the land quality risk assessment process – **Generic Quantitative Risk Assessment**.
- In order for a development site to be deemed ‘suitable for use’ the level of risk needs to be reduced to an acceptable level - low to negligible risk. The purpose of each stage of risk assessment is to establish if there is a requirement for additional stages of assessment in order to have sufficient confidence to support a risk characterisation or remedial action.

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	Rationale
PL6	Contaminated Soils	Impaction of groundwater from soil contamination (diffuse and point). Impaction of groundwater from groundwater plume.	Likely	Medium	Moderate to Low	Made Ground was encountered across the site from ground level to a maximum depth of 1.75m bgl. Geo-Environmental testing has revealed that fuel derived hydrocarbon contamination exists within the groundwater in the vicinity of WS09 and WS17 Geological maps indicate that the site is underlain by Alluvium and Glaciofluvial Sand and Gravel, this is further underlain by the Lowestoft Formation which comprises Clay. The bedrock underlying the site is the Gault Formation which comprises Mudstone. The superficial Alluvium deposits have been impacted by hydrocarbons as shown on the Contamination Plan 19271 05. The site is not within 500m of a SPZ and is not considered a sensitive resource, the nearest potable groundwater abstraction is 900m north of the site which is sufficient to allow considerable attenuation. Groundwater was encountered within the Sand and Gravel deposits at 1.10m bgl, the full thickness of the Sand and Gravel was not determined due to the density of the soils. The bedrock is considered unproductive as an aquifer, however the Secondary A Aquifer has been impacted by hydrocarbon contamination from the former UST on site. However the UST was previously removed and contamination is considered to be

Conceptual Site Model					Generic Quantitative Risk Assessment	
PL	Potential source	Pollution linkage	Likelihood	Severity	Level of risk	Rationale
						<i>residual within very localised soils. Therefore, a minor pollution linkage is considered to exist and remediation is required.</i>
PL7	Contaminated Soils	Migration of soil and groundwater contamination impacting surface waters.	Likely	Severe	Moderate	<i>Pollution Linkage 7 refers to the impact of The River Oughton which crosses the site from contaminated soils and groundwater.</i> <i>Geo-Environmental testing has revealed that the groundwater which is considered to be in continuity with the River Oughton is contaminated with hydrocarbons in two locations (WS09 and WS17). Interpretation of the results indicates that the source of contamination is degraded diesel. Contamination is considered to be highly localised to the impacted soils in the vicinity of the former diesel UST. Removal of the affected soils is recommended as a form of remediation.</i> <i>It is considered likely that the groundwater will flow toward the River Oughton. The Alluvium deposits underlying the site are a mix of granular and cohesive soils, which will inhibit migration of groundwater to the river, furthermore areas of the river are channelled, which will stop migration of groundwater into the river.</i> <i>The former diesel UST in the vicinity of WS09 is considered to be the source of contamination in this area, however no obvious source exists in the vicinity of WS17 as the soils appeared to be clean. It is possible that the source of contamination is the nearby boiler room, which will be investigated following demolition of the existing buildings.</i> <i>In conclusion, a realistic pollution linkage is considered to exist.</i>

7.7 Outline Remedial Strategy

Cover System

The proposed development is for low rise housing with associate soft landscaped garden areas. Due to the presence of asbestos in the eastern portion of the disused mill area a 500mm clean cover system with an additional 100mm hard dig layer should be adopted within the proposed soft landscaped gardens in the area determined to be affected by asbestos within the soils, as indicated on the Contamination Plan 19271 05. As a minimum the topsoil should be 150mm thick.

For the remainder of the site a minimum of 150mm topsoil should be provided within garden areas of proposed plots where natural strata is encountered at formation level and 300mm topsoil/ subsoil where Made Ground is encountered at formation level.

Where public open space is proposed in the south of the site a 500mm clean cover system with an additional 100mm hard dig layer is recommended due to the presence of asbestos within the topsoil. Alternatively the source of asbestos can be removed and a nominal cover system of 150mm topsoil should be placed where natural strata is encountered at formation level and 300mm topsoil/ subsoil where Made Ground is at formation level.

Cover layer requirements may change based on what is encountered in inaccessible areas following demolition of the mill buildings and supplementary investigation.

The depth and chemical suitability of the cover system should be validated after placement.

Hydrocarbon Contamination - Soils

Significant hydrocarbon contamination was detected within soils in the vicinity of WS09, WS10 and WS11 to depths of up to 1.5m bgl. This contamination should be chased out and excavated and stockpiled separately in a sealed bund before being classified and disposed of at a suitable waste site. The area of affected soils is indicated on the Contamination Plan 19271.

A Detailed Quantitative Risk Assessment (DQRA) is required to determine the Remedial Target Values prior to remediation being undertaken.

Hydrocarbon Contamination - Groundwater

Elevated contaminants have been recorded within the groundwater of WS09 and WS17, in particular hydrocarbons associated with degraded diesel. The source is likely to be the impacted soils from the previous Diesel UST which was located off the south west corner of the former flour mill in the central area of the site. Therefore, it is proposed to remove the impacted soils which is the source in the vicinity of WS09, WS10 and WS11 to prevent any further impaction of the groundwater by the hazardous substance. The groundwater plume is shown on the Contamination Plan 19271 05.

Remediation will comprise the removal of any free product during excavation of soils as a minimum, the contamination is a LNAPL and will exist at the surface of the groundwater. As the source of hydrocarbons will be removed, remediation of dissolved phase hydrocarbons by natural attenuation is proposed in accordance with the Environment Agency 'Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater' 2000. Additional groundwater monitoring will be undertaken post remediation as validation. The remedial target values will be agreed with the relevant regulators.

Surface Waters

Testing of the surface water from the River Oughton is currently underway to determine if the surface water has been impacted.

Permanent Ground Gas

Ground gas monitoring to date indicates that the site falls within the NHBC Green Traffic Light Zone and ground gas precautions will not be required within the proposed dwellings at the site, however this will be confirmed within the final ground gas risk assessment.

A vapour resistant membrane may be required within approximately two plots in the vicinity of the former diesel UST to protect against any potential residual contamination following remediation of the area. This will be confirmed upon validation of the hotspot removal.

General

Further remedial actions may be required which will be determined by investigation of inaccessible areas post demolition.

A watching brief is recommended during future ground works for any previously unseen contamination. If identified, work should cease in that area and advice sought from Groundtech Consulting Limited.

Approval from the regulators should be obtained prior to the development commencing to avoid any delays at the construction stage.

7.8 Asbestos in Soils

The presence of asbestos within the ground will require, a safe system of work to be set up on site to deal with the asbestos risk from the made ground. This may include but be not limited to:

- The use of qualified personnel where required.
- Careful segregation of stockpiles on site.
- Defining transport routes.
- Cleaning down of machinery in designated areas.
- Decontamination unit for ground workers.
- Damping down of soils to prevent dust migration.

All such works will need to be agreed with the regulatory bodies (HSE, LA).

The JIWG decision support tool for CAR2012 work categories indicates that the combined hazard ranking to construction workers from asbestos within soils is considered to be low. The work is considered to be non-licenced. Basic precautions should be taken including EN149 type FFP3 disposable masks, manual/ localised dust suppression and localised and basic personal decontamination facilities. The JIWG decision tools are presented in Appendix 10.

7.9 Health and Safety - Construction and Ground Workers

During the reclamation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. The risk to construction and ground workers is assessed in the table below:

Pollution Linkage Ref	Potential Source	Pollution Linkage	Likelihood	Severity	Level of Risk
PL8	Made Ground	Ingestion, direct contact, inhalation of dusts.	Likely	Medium	Moderate
PL9	Asbestos	Ingestion, direct contact, inhalation of dusts.	Unlikely	Medium	Low

General Made Ground is not considered to be significantly contaminated, however soils in the vicinity of WS09, WS10 and WS11 have relatively high concentrations of TPHs, therefore extra care should be taken to ensure the correct PPE is used when excavating in this area. General PPE including protective gloves should be used at all times when handling Made Ground soils at the site. Furthermore, if work is carried out during hot/dry weather dust suppression may be required when excavating granular Made Ground to prevent the generation of potentially harmful dusts. The risk should be communicated to site workers through inductions and information boards.

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”. In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with the relevant protective clothing, footwear and gloves. These protective items should not be removed from the site and personnel should be instructed as to why and how they are to be used.
- Hand-washing and boot-washing facilities should be provided.
- Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.
- Good practices relating to personal hygiene should be adopted on the site.
- The contractor shall satisfy the Health and Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.

7.10 Waste Classification by Assessment

We have reviewed the testing results and inputted them into the HazWasteOnline model which allows users to code and classify waste as defined in the EWC (European Waste Catalogue 2002) based on EC Regulation 1272/2008 on the Classification, labelling and packaging of substances and mixtures (CLP) and latest Environment Agency guidance (WM3 “Guidance on the classification and assessment of waste (1st edition 2015)-Technical Guidance”).

This is a useful tool as waste producers have the legal responsibility to classify any waste they produce.

Thirty-seven samples of Made Ground were screened for a selection of determinands detailed in Section 5 and the results input into the HazWasteOnline program. Eight samples are considered to be hazardous, and twenty-nine samples are considered to be non-hazardous, a summary table of results is given below. The full HazWasteOnline report can be found in Appendix 11.

Reference	Depth (m)	Strata Type	Classification by Assessment
WS01	0.50	Made Ground	Non-hazardous

WS01	1.00	Natural Strata	Non-hazardous
WS02	1.00	Made Ground	Non-hazardous
WS03	0.50	Made Ground	Non-hazardous
WS03	1.10	Natural Strata	Non-hazardous
WS05	1.00	Made Ground	Non-hazardous
WS06	0.50	Made Ground	Non-hazardous
WS08	0.50	Made Ground	Non-hazardous
WS09	0.50	Made Ground	Hazardous
WS09	1.00	Made Ground	Hazardous
WS09	1.50	Made Ground	Non-hazardous
WS10	0.50	Made Ground	Hazardous
WS10	1.00	Made Ground	Non-hazardous
WS11	1.00	Made Ground	Hazardous
WS11	1.50	Made Ground	Hazardous
WS12	0.30	Made Ground	Hazardous
WS12	0.50	Natural Strata	Non-hazardous
WS13	0.50	Made Ground	Non-hazardous
WS14	0.50	Made Ground	Hazardous
WS16	0.40	Made Ground	Hazardous
WS17	0.60	Natural Strata	Non-hazardous
WS17	1.00	Natural Strata	Non-hazardous
WS18	0.50	Made Ground	Non-hazardous
WS19	0.50	Made Ground	Non-hazardous
WS19	1.00	Natural Strata	Non-hazardous
WS21	0.40	Made Ground	Non-hazardous
WS22	0.30	Made Ground	Non-hazardous
WS22	1.00	Natural Strata	Non-hazardous
WS23	0.10	Made Ground	Non-hazardous
WS24	0.40	Made Ground	Non-hazardous
WS25	0.40	Made Ground	Non-hazardous
WS25	1.00	Natural Strata	Non-hazardous
WS28	0.50	Made Ground	Non-hazardous
WS28	1.00	Natural Strata	Non-hazardous
WS29	0.50	Made Ground	Non-hazardous
TP01	0.05	Made Ground	Non-hazardous
TP02	0.10	Made Ground	Non-hazardous

Six samples are considered to be hazardous in the vicinity of WS09, WS10 and WS11, this is due to the presence of degraded diesel in the vicinity of the former UST. The hazardous properties include carcinogenic, mutagenic and corrosive. It is recommended that soils should be excavated and placed in a bunded stockpile separate from any other excavated materials on site for further classification prior to removal off site.

Two further samples from WS14 and WS16 are considered to be hazardous due to significantly high pH values of 11.85 and 11.88 respectively. The hazardous properties include carcinogenic, mutagenic and corrosive. Yellow brown gravelly sand in the vicinity of WS14 and black sandy gravel in the vicinity of these WS16 may be left insitu, however if the soils in this area require excavation, soil mixing will occur and likely dilute the pH value of the soils, therefore they may still be suitable for placement beneath hardstanding areas across the site.

Four samples of granular Made Ground from the central area of the site and one sample of Made Ground topsoil from the south of the site contain asbestos, however asbestos concentration have been determined to be below the hazardous limit of 0.1mass%, therefore the asbestos quantities do not affect the waste classification.

7.11 Waste Acceptance Criteria (WAC) Results

Waste Acceptance Criteria (WAC) testing was outside the scope of this investigation and the guidance given below is general.

The possibility of automatic inert classification of the natural soils should be explored in accordance with Section 4.3 of the EA guidance document. The Council Decision includes a list of wastes in Section 2.1.1 of the document that are assumed to be inert and therefore acceptable at a landfill for inert waste without testing, this is the case if:

- *They are single stream waste of a single waste type (although different waste types from the list may be accepted together if they are from a single source) and*
- *There is no suspicion of material or substances such as metals, asbestos, plastics, chemicals, etc to an extent which increases the risk associated with the waste sufficiently to justify contamination and they do not contain other their disposal in other classes of landfill.*

Organic contaminated material was encountered during the investigation in the vicinity of WS09, WS11 and WS12 which has been classified as hazardous. Following excavation and stockpiling of the impacted soils, additional testing should be undertaken to determine if the soils will be accepted at a hazardous landfill or if they require treatment prior to landfill.

Materials should be segregated and where necessary sufficient time is allowed to further classify the material properly, including discussion with landfill sites and waste transfer stations to find the best disposal route. It is recommended that where possible that the soils could be recycled at a suitable local waste treatment plant or transfer station rather than a landfill disposal route.

The reuse of soils on the site this should be done in accordance with the CL:AIRE “Development Industry Code of Practice for the Definition of Waste” (CL:AIRE CoP). Any re-use scheme should be designed to minimise disposal costs.

After a cut and fill balance plan/volume calculation has been carried out, a U1 and T5 exemption could be registered. This will allow the use of the following soils without a waste permit or under Dow CoP MMP:

- 1,000 tonnes (c. 600m³) of non-hazardous soil
- 5,000 tonnes (c. 3,000m³) of natural sand and gravels.
- 50,000 tonnes (c. 25,000m³) of bituminous material to be used in roadways.
- 5,000 tonnes (c. 3,000m³) of crushed concrete / stone.

8.0 FINAL APPRAISAL

8.1 Land Quality

Gross hydrocarbon contamination was encountered within the soils in the vicinity of a former diesel UST, furthermore geo-environmental testing results have highlighted that hydrocarbons have impacted the groundwater in the vicinity of the former UST.

Elevated concentrations of PAHs were detected within four locations across the site, however statistical analysis was undertaken which reveals Upper Confidence Limit is below the Critical Concentration for all elevated PAHs. Therefore there is not considered to be a risk from PAH contamination.

Asbestos was detected within five samples from across the site. Asbestos was determined to be trace in all but one sample, where it was quantified as 0.002 mass%.

Based on the findings of the Ground Investigation the risk to site end users and groundwater is considered to be Moderate to Low and the risk to surface waters is considered to be Moderate.

Based on the lack of putrescible material encountered during the investigation and the initial ground gas monitoring results, the risk from ground gases is considered to be Moderate to Low, however a vapour resistant membrane may be required within plots in the vicinity of the former diesel UST. The site is not in an area requiring radon precautions within foundations. These recommendations will be confirmed upon completion of the ground gas monitoring program.

Geo-environmental testing results indicate that based on total concentrations, the majority of the soils across the site are considered to be non-hazardous. Soils excavated in the vicinity of the former UST are considered to be hazardous based on the TPH concentrations. A further two samples from WS14 and WS16 are considered to be hazardous based on high pH concentrations. Asbestos is below the hazardous threshold of 0.1%, therefore the presence of asbestos does not affect the classification.

Further investigation is required in inaccessible areas including the existing mill and office buildings on the site. Additional investigation is also required in the southern area of the site as only a limited number of locations were undertaken on the soft landscaping.

8.2 Ground Engineering

The type of foundations most suitable for the development varies across the site as detailed on the Foundation Zone Plan. Traditional Strip footings are most suitable in Zone 1 area in the north and east of the site, Controlled Modulus Columns or driven piles are most suitable in Zone 2 area in the central and west of the site.

Made Ground across the site generally exceeds 0.60m deep, therefore suspended floor slabs are recommended. If CMCs are the preferred foundation solution ground bearing floor slabs may be adopted subject to confirmation by a specialist vibro contractor.

Further investigation is required in previously inaccessible areas and deeper investigation is required where poor shallow ground conditions were encountered to obtain parameters for deep foundation design.

Soil percolation testing was not undertaken as part of this investigation, however the use of SuDS drainage is not likely to be feasible due to the presence of Clay beneath the majority of the site and the relatively high groundwater table.

8.3 Required Supplementary Investigation

The following further work is considered necessary to progress the site to construction phase:

Completion of gas monitoring programme.
Issue gas assessment.
Investigation in areas previously inaccessible.
Intrusive site investigations comprising Cable Percussive Boreholes to obtain parameters for deep foundation design.
Demolition Asbestos survey.
Design of Remedial Specification.
Confirmation of Remedial Specification with the Local Authority.
Tree survey by qualified arboriculturist.
Detailed foundation design and foundation schedule.
Confirmation of recommendations made within this report with the Local Authority.

9.0 RELEVANT INDUSTRY REFERENCES

British Standards Institution. *Investigation of Potentially Contaminated sites - code of practice*. BS 10175:2017.

British Standards Institution '*Code of Practice for Site Investigations*' BS 5930:2015

British Standards Institution "*Geotechnical investigation and testing – Identification and classification of soil*" BS EN ISO 14688:2002.

British Standards Institution "*Geotechnical investigation and testing – Identification and classification of rock*" BS EN ISO 14689:2002.

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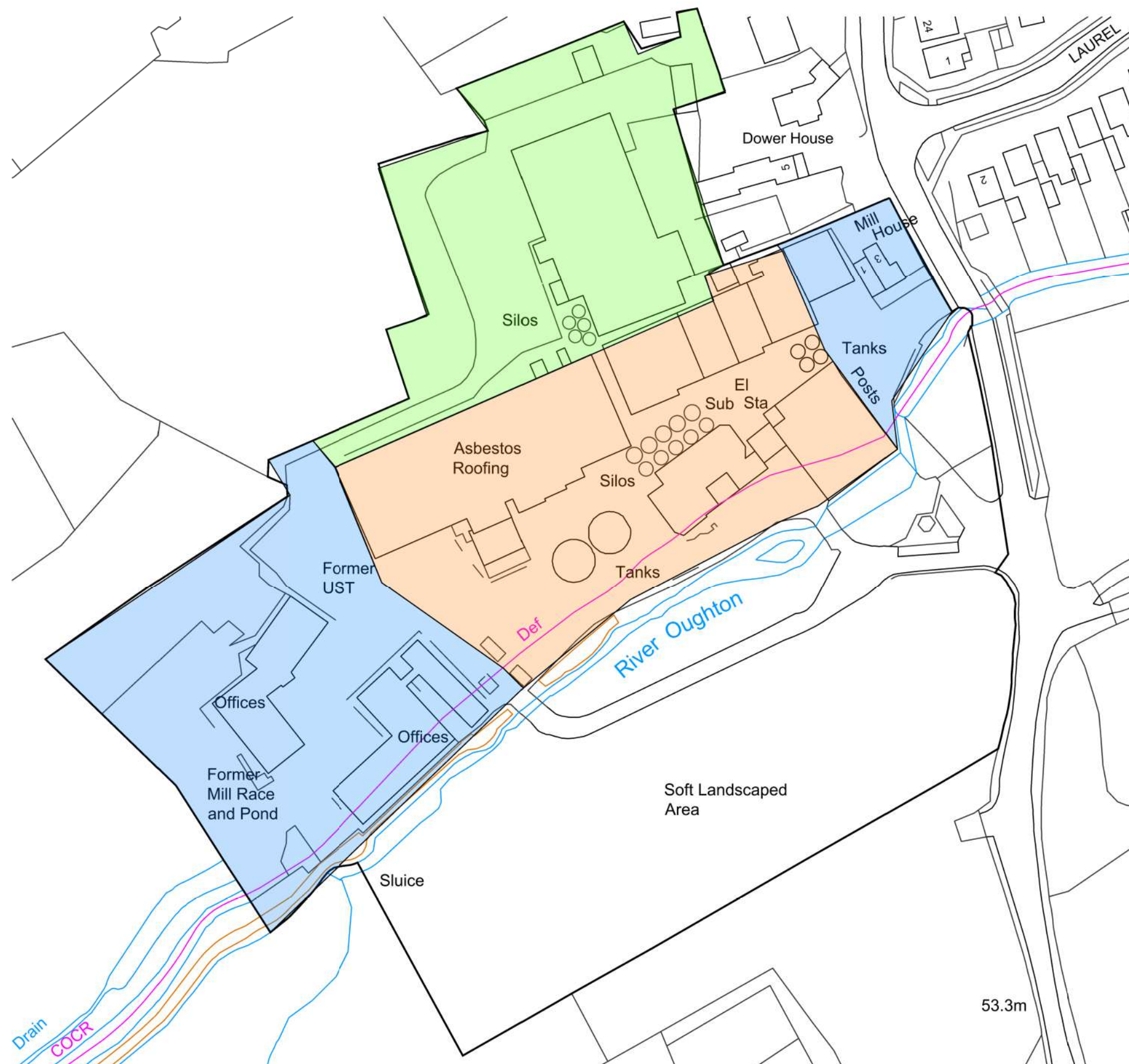
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APPENDIX 1 - Plans



 GROUNDTECH CONSULTING	CLIENT	DATE			Status		Notes  Location of the Site
	BOWMAN'S INGREDIENTS LTD	JANUARY 2020			Preliminary		
	PROJECT TITLE	SCALE			Draft		
	BOWMANS MILL, ICKLEFORD	NTS			Issued	●	
	PLAN TITLE	PLAN NUMBER			For Comment		
PROJECT LOCATION PLAN	19271 01	Rev.	Details	Date	Approved		



CLIENT	BOWMAN'S INGREDIENTS LTD
PROJECT TITLE	BOWMAN'S MILL, ICKLEFORD
PLAN TITLE	PRELIMINARY DEVELOPMENT CONSTRAINTS PLAN

DATE	JANUARY 2020
SCALE	NTS
PLAN NUMBER	19271 02

Rev.	Details	Date

Status	
Preliminary	
Draft	
Issued	●
For Comment	
Approved	

Notes	
Existing offices.	
Existing production plant.	
Derelict mill buildings.	