Geotechnical & Geo-environmental Site Investigation Report: Proposed Residential Development, Agate Street, Splott, Cardiff

Prepared For:
Mr Zafar Malik

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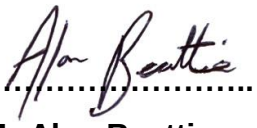
PREPARED BY	**:**	 **Mr Alan Beattie**
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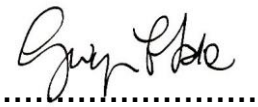
APPROVED BY	**:**	 **Dr Gwyn C Lake**

Executive Summary	
Proposed Development and Site Location	*Mr Zafar Malik is proposing the construction of a six storey building comprising circa 47 apartments with associated underground car parking and associated facilities. The site is located on the corner of Agate Street and Pearl Street, Splott. It is centred on a National Grid Reference of 318650 176440 and is roughly rectangular in shape, occupying a plan area of approximately 0.17 hectares / 1,700m^2.*
Site History	*The 1880 map shows the site to site be occupied by a number of terrace houses which front onto Pearl Street and Agate Street. By the 1919-1920 edition the southern corner is occupied by a picture theatre. The 1938 edition then shows the whole site to be occupied by Splott Cinema. The building is then demolished in 2017*
Geology	*The site is underlain by rocks of the Mercia Mudstone Group, which are Triassic in age. These rocks generally comprise structureless red mudstones, stiff clays, siltstones and sandstones. Superficial glaciofluvial sheet deposits are recorded. Given its history, made ground in the form of demolition material is anticipated to be present across the site.*
Radon	*No radon protection is required for new development.*
Ground Conditions	• ***MADE GROUND:*** *GL to 0.30m/2.20m.* • ***VARIABLE NATURAL****: 0.30m/2.20m to >2.00/3.30m*
Laboratory Chemical Testing	*All determinants with the exception of lead in TP01 at 0.20m and TP02 at 0.60m and dibenzo(ah)anthracene in TP01 at 0.20m were found to be below their respective guideline values. Asbestos in the form of Chrysotile has also been found in three samples from TP02 at 0.20m, TP04 (Stockpile) and TP05 at 0.70m.* *Leachate testing has found the lead to be below guideline values.* *There are no guideline values available for dibenzo(ah)anthracene and the laboratory detection limit of 0.01ug/l has therefore been used. A concentration of 0.02ug/l was detected in the sample from TP01 at 0.20m.*
Proposed Mitigation Measures	*Given the nature of the development a large amount of the impacted material will be removed with the excavation of the undercroft car park. To protect site end users the remaining area of the site will need to be capped. The capping should consist of the proposed building (where levels are not reduced) and hard standings. In soft landscaped areas the capping should consist of 600mm of suitable inert topsoil and subsoil over a no dig barrier.*
Foundation Solution	*The proposed building has an undercroft parking area and will effectively be a retaining structures. It is recommended that an integral reinforced concrete raft/retaining wall structure would be the most appropriate form of foundation for the proposed development.* *The raft can be founded within the medium dense to dense, brown, SAND and GRAVEL.* *For the above foundations within the given founding materials an allowable bearing pressure of 200kN/m2 may be used for design purposes for a maximum total settlement of 30mm. Differential settlement of foundations should not lead to structural distortion of more than 1:750.*

TABLE OF CONTENTS

SECTION 1 Introduction and Proposed Development

1.1 Introduction
1.2 Limitations and Exceptions of Investigation

SECTION 2 Review of Existing Data

2.1 Physical Setting and Current Site Use
2.2 Site History
2.3 Geological Setting
  2.3.1 Geology
  2.3.2 BGS Borehole Records
  2.3.3 Radon
2.4 Environmental Setting
  2.4.1 Hydrogeology and Hydrology
  2.4.2 Groundwater
  2.4.3 Flooding
  2.4.4 Waste
  2.4.5 Pollution
  2.4.6 Sensitive Land Use
2.5 Japanese Knotweed

SECTION 3 Preliminary Human Health and Environmental Risk Assessment

3.1 General
3.2 Preliminary Site Conceptual Model
3.3 Potential Sources of Contamination and Gas
3.4 Potential Receptors and Pollution Pathways
3.5 Preliminary Illustrative Site Conceptual Model

SECTION 4 Field Investigation

4.1 Site Works
4.2 Ground Conditions
4.3 Water Strikes
4.4 Stability and Obstructions
4.5 Laboratory Chemical Testing
  4.5.1 Exploratory Strategy and Sampling Regime
  4.5.2 Laboratory Soil Analysis
  4.5.3 Laboratory Leachate Analysis
4.6 Soil Property Testing
  4.6.1 In-situ Permeability Testing

SECTION 5 Soil Analytical Results

5.1 Soil Assessment Methodology
5.2 Soil Test Results
5.3 Asbestos Test Results
5.4 Leachate Test Results

TABLE OF CONTENTS (Continued)

SECTION 6 Quantitative Risk Assessment

6.1 Contaminants of Concern
6.2 Potential Receptors and Pathways
6.2.1 Human Receptors
6.2.2 Aquatic Environment
6.3 Asbestos Risk Assessment
6.4 Risk Assessment Methodology
6.4.1 General
6.4.2 Local Climate
6.4.3 Calculation of Airborne Respirable Fibre Concentrations
6.4.4 Calculation of Exposure
6.5 Risk Assessment
6.6 Risk Assessment Results
6.6.1 Acceptable Levels of Risk
6.7 Mitigation and Remedial Measures
6.7.1 Human Health
6.7.2 Aquatic Environment
6.8 Refined Illustrative Site Conceptual Model

SECTION 7 Engineering Recommendations

7.1 Preparation of Site
7.2 Foundation and Floor Slab Solution
7.3 Excavations and Formations
7.4 Protection of Buried Concrete
7.5 Car Parking Areas
7.6 Storm Drainage
7.7 Retaining Walls

Tables

Table 2.1 Summary of Historical Map Information
Table 3.1 Preliminary Human Health Risk Assessment
Table 3.2 Preliminary Environmental Risk Assessment
Table 4.1 Summary of Ground Conditions
Table 4.2 Sample Locations and Depths
Table 5.1 Summary of Soil Chemical Test Results: Standard Suite
Table 5.2 Summary of Soil Chemical Test Results: Speciated PAH
Table 5.3 Summary of Soil Chemical Test Results: Petroleum Hydrocarbons
Table 5.4 Summary of Soil Chemical Test Results: Asbestos Screen
Table 5.5 Summary of Soil Chemical Test Results: Asbestos Quantification
Table 5.6 Summary of Leachate Chemical Test Results
Table 6.1 Contaminant Linkage for Assessment
Table 6.2 Model Data: Chrysotile
Table 6.3 Quantitative Risk Assessment Results
Table 7.1 Effective Shear Stress Parameters

TABLE OF CONTENTS (Continued)

Figures

Figure 3.1	Preliminary Illustrative Site Conceptual Model
Figure 6.1	Refined Illustrative Site Conceptual Model

Annexes

Annex A	Envirocheck Historical Maps
Annex B	BGS Borehole Record
Annex C	Envirocheck Datasheet and Maps
Annex D	Risk Assessment Definitions
Annex E	Trial Pit Logs
Annex F	Laboratory Chemical Test Results
Annex G	Soakaway Calculation Sheets

Drawings

Drawing 01	Site Location
Drawing 02	Current Site Layout
Drawing 03	Proposed Site Layout

SECTION 1 Introduction and Proposed Development

1.1 Introduction

Mr Zafar Malik is proposing the construction of a six storey building comprising circa 47 apartments with associated underground car parking and associated facilities. The site is located on the corner of Agate Street and Pearl Street, Splott.

WM Clarke Limited are the Consulting Structural and Civil Engineers for the development.

Terra Firma (Wales) Limited has been commissioned to undertake a geoenvironmental assessment and geotechnical investigation of the site.

The main objectives of the geoenvironmental assessment programme were to:

- Investigate the potential environmental liabilities at the site associated with any soil contamination
- Provide a summary of the environmental conditions at the site, together with any necessary further intrusive works and / or remediation works to render the site fit for its intended use

The main objectives of the geotechnical site investigation were to:

- Determine the type, strength and bearing characteristics of the shallow superficial and underlying solid geology
- Provide engineering foundation and floor slab recommendations for the development
- Provide recommendations with regard to any other geotechnical aspects pertaining to the development

In order to achieve the above objectives, Terra Firma (Wales) Limited carried out an assessment programme including a review of existing data, followed by a field investigation to collect geotechnical and environmental data from selected locations.

1.2 Limitations and Exceptions of Investigation

Mr Zafar Malik has requested that a Geo-environmental Site Assessment (GSA) and Geotechnical Investigation (GI) be performed in order to determine if contamination is present beneath the site and to determine an appropriate foundation and floor slab solution for the proposed development.

The GSA and GI were conducted and this report has been prepared for the sole internal reliance of Mr Zafar Malik and his design and construction team. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Terra Firma (Wales) Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill. The report represents the findings and opinions of experienced geo-environmental and geotechnical consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may be required.

The subsurface geological profiles, any contamination and other plots are generalised by necessity and have been based on the information found at the locations of the exploratory holes and depths sampled and tested.

The site investigation was limited by a large stockpile present on the site.

SECTION 2 Review of Existing Data

2.1 Physical Setting and Current Site Use

The site is located on the corner of Agate Street and Pearl Street, Splott. It is centred on a National Grid Reference of 318650 176440 and is roughly rectangular in shape, occupying a plan area of approximately 0.17 hectares / 1,700m^2.

The boundaries of the development area are defined by Agate Street to the south and Pearl Street to the east. The western and northern boundaries are formed by existing property boundaries.

No structures are currently present on site and the former bingo hall which occupied the site has been demolished. A stockpile of demolition material from the former structure is present in the north of the site.

A site location plan is provided in **Drawing 01** and **Drawing 02** and **Drawing 03** provide current and proposed layout plans for the site.

2.2 Site History

Historical maps of the site have been obtained in an Envirocheck History Report, provided by Landmark Information Group. The history plans are supplied in **Annex A** of this report, and the most relevant editions are summarised below in **Table 2.1**. Distances are approximate, and any changes occurring completely between map editions may not be recorded.

Table 2.1 Summary of Historical Map Information

Map Date and Scale	Key Features On Site	Key Features Off Site
1880 (1:500)	The site is occupied by a number of terrace houses with rear gardens. Five properties front onto Pearle Street and six front onto Agate Street. A single building also locates on the eastern boundary. The boundaries are formed by Agate Street, Pearl Street and the neighbouring properties.	The surrounding area is well developed with many rows of terrace housing. A south west to north east trending rail line locates 40m to the east of the site. Beyond this is an area of field land.
1901 (1:2,500)	No significant changes.	The area beyond the rail line has now been developed with primarily residential properties.
1919-1920 (1:2,500)	The terrace properties in the southern corner of the site have been removed and a Picture Theatre now occupies the space.	No significant changes.
1938 (1:10,560)	The site is now occupied by a single building which cover the footprint of the site.	No significant changes.
1953-1954 (1:1,250)	The large building occupying the site is identified as Splott Cinema.	No significant changes.
1965 (1:10,000)	No significant changes.	No significant changes.
1975 (1:10,000)	No significant changes.	No Significant changes.
1986-1989 (1:10,000)	No significant changes.	No Significant changes.
1999 / 2006 and 2017 (1:10,000)	The existing building is still present on the 2017 historical map however it is known to have been demolished.	No significant changes.

2.3 Geological Setting

2.3.1 Geology

The 1:50,000-scale geological map of the area (Sheet 263) was consulted. The site is underlain by rocks of the Mercia Mudstone Group, which are Triassic in age. These rocks generally comprise structureless red mudstones, stiff clays, siltstones and sandstones.

The superficial geology records Glaciofluvial Sheet Deposits overlying the Mercia Mudstone bedrock. These are likely to comprise sand and gravel deposits with small amounts of clay and silt.

Given its history, made ground in the form of demolition rubble is anticipated to be present across the site following demolition of former buildings.

The bedrock geology is at negligible risk of dissolution features.

2.3.2 BGS Borehole Records

The BGS borehole database was checked to see if there were any borehole records in close proximity to the site.

The borehole found firm silty CLAY to a depth of 2.29m over dense and very dense clay bound SAND and GRAVEL to a depth of 4.88m. This was then seen to be underlain by stiff weathered red brown marl to 6.25m, finally underlain by hard interlayered grey and blue mudstone and marl and hard red brown friable marl.

The BGS borehole log can be found in **Annex B**.

2.3.3 Radon

The Envirocheck Report (**Annex C**) details that **no** radon protection will be required for new buildings on site.

2.4 Environmental Setting

The following sections have been compiled using the Envirocheck datasheet and maps which can be found in **Annex C**.

2.4.1 Hydrogeology and Hydrology

The underlying Mercia Mudstone Group has been classed by the Environment Agency as a Secondary B Aquifer. Secondary B aquifers are described as predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering

The superficial glaciofluvial sheet deposits are classed as a Secondary A aquifer. These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The nearest surface water feature is a small stream located 977m north of the site and the Severn Estuary locates 1.7km to the south east of the site. Shallow groundwater flow in the area will be towards the Severn Estuary.

2.4.1 Hydrogeology and Hydrology (Continued)

Deeper groundwater flow within the underlying bedrock will be controlled by the strata dip and any fractures or bedding planes within the rock units.

Given the urban nature of area surrounding the site surface run off is likely to be collected by the surface water drainage systems.

2.4.2 Groundwater

The Envirocheck Report confirms that the site does not situate within a groundwater source protection zone.

There is one groundwater abstraction point within 1km of the site, located at a distance of 134m to the north. The location description is not available however the operator is Cardiff City Council with a well and borehole for a general industrial use.

No premises with consent to discharge waste waters is present within 500m of the site.

2.4.3 Flooding

The site is not shown to be at risk from flooding.

2.4.4 Waste

There are no active or historic landfills located within 250m of the site.

There is no potentially infilled land (water and non-water) recorded within 250m of the site.

2.4.5 Pollution

There are no records on the Contaminated Land Register Entries and Notices within 1km of the site.

No pollution incidents to controlled waters are detailed to have occurred within a 500m radial area around the site.

2.4.6 Sensitive Land Use

The site does not situate within, or within 1km of, an area with a designated sensitive land use.

2.5 Japanese Knotweed

A site walk over was undertaken to identify any potential occurrences of Japanese Knotweed. No occurrences were identified on the site.

Further information on Japanese Knotweed can be found in the Environment Agency's document Managing Japanese Knotweed on Development Sites (The Knotweed Code of Practice).

Please note that Terra Firma (Wales) Limited are not specialists in this field and the advice of experts may be required.

SECTION 3 Preliminary Human Health and Environmental Risk Assessment

3.1 General

The contaminated land regime is set out in Part IIA of the Environmental Protection Act (EPA) 1990 and was introduced on the 1st April 2000 in England and 1st July 2001 in Wales. A similar regime was introduced in Scotland on 14th July 2000. Part IIA was introduced to achieve two aims:

(1) The identification of contaminated land
(2) The remediation of contaminated land that poses an unacceptable risk to human health and/or the environment

Under Part IIA the statutory definition of 'contaminated land' is: any land which appears to the local authority in whose area it is situated, to be in such a condition, by reason of substances in, on, or under the land, that:

(a) Significant harm is being caused or there is a significant possibility of such harm being caused; or
(b) Pollution of controlled waters is being, or is likely to be, caused."

For land to be classified as 'Contaminated Land' there must be a 'pollutant linkage'.

For our definitions of pollution linkage and how we define risk please refer to **Annex D** which includes our classifications of consequence and probability and risk assessment matrix.

3.2 Preliminary Site Conceptual Model

The preceding sections enable a preliminary conceptual model of the site to be drawn up, to illustrate the likely ground conditions beneath the site together with a preliminary assessment of the nature of any underlying aquifers and groundwater movement. The preliminary site conceptual model is used as a model for the design and implementation of the site investigation, whereby areas of potential contamination can be targeted as well as investigating the site as a whole.

3.3 Potential Sources of Contamination and Gas

The potential contamination beneath the site, whether in the matrix of soil or any groundwater will be related to the sites past use and the history of the surrounding area.

The site has been occupied by terraced housing before it was occupied by a cinema. Later this building was then used as a bingo hall before being recently demolished.

Made ground in the form of building rubble material is present in relation to the demolition of the building which previously occupied the site. The demolition material is a potential source of asbestos containing materials.

Made ground on site is considered to be a potential source of ground gas.

There are no historic or active landfills within influencing distance and there is no risk from landfill gas.

3.4 Potential Receptors and Pollution Pathways

There are both human and hydrological receptors to be considered should any contamination be detected on site.

Construction workers will be excavating in soils and will be exposed via dermal contact with soils and dust, ingestion of soil /soil dust and inhalation of soil dust. Workers may also be exposed to asbestos fibres, if present in fill soils.

A residential end use is proposed. Once developed, future residents will potentially be at risk from any contamination from the same pathways as well as through intake of potable water, and inhalation of gas. As no garden areas are proposed there will be no risk for the consumption of home grown produce.

If any contamination is identified this may be leachable, enabling it to mobilise through perched groundwater within site soils and impact the surrounding surface water features or deeper groundwater.

A qualitative preliminary Human Health and Environmental Risk Assessment summarises the above and is detailed in the **Tables 3.1 and 3.2** on the following pages.

3.5 Preliminary Illustrative Site Conceptual Model

The following illustration represents a theorised cross section through the site. The drawing is generalised and not to scale.

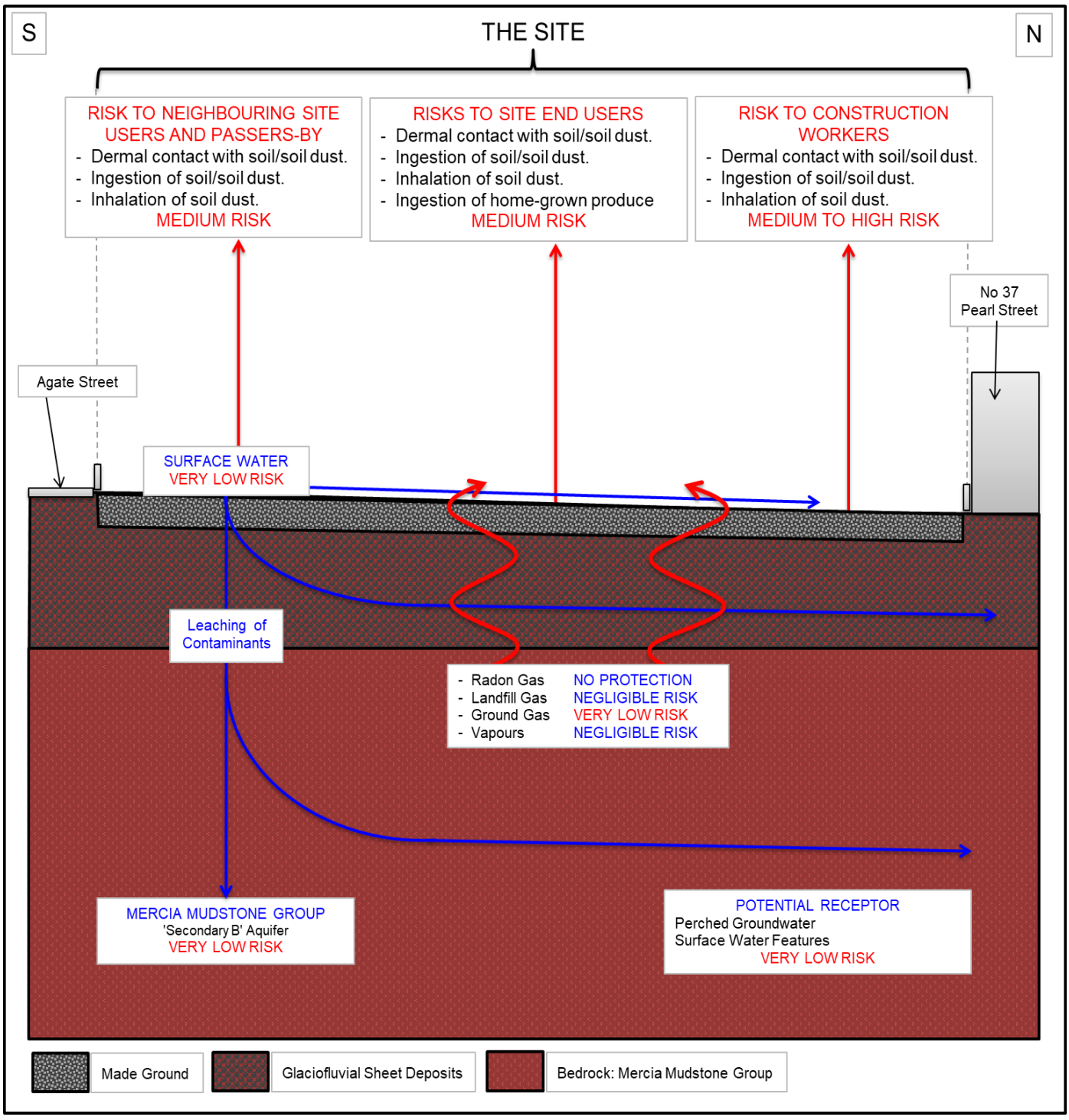


Figure 3.1 *Preliminary Illustrative Site Conceptual Model (not to scale)*

SECTION 4 Field Investigation

4.1 Site Works

A geotechnical and geoenvironmental site investigation was carried out on 5th October 2017. This comprised 10 machine excavated trial pits (TP01 to TP10). The trial pits were dug with a JCB 3CX backhoe excavator. One soakaway test was also undertaken in TP02.

The fieldworks were supervised by Terra Firma (Wales) Limited and the trial pits were logged to the requirements of BS5930:2015.

The trial pit logs may be found in **Annex E** and their locations are given on **Drawings 02** and **03.**

4.2 Ground Conditions

A summary of the ground conditions identified in the boreholes is given in **Table 4.1**.

Table 4.1 Summary of Ground Conditions

Depth (m)	Thickness (m)	Stratum
GL - 0.30/2.20	0.30/2.20	**MADE GROUND:** (Loose), grey brown, very clayey **SAND** and **GRAVEL** with cobbles and boulders. Contains brick, concrete, ceramic, timber, slate (Demolition Rubble).
0.30/2.20 - >2.00/3.30	-	**VARAIBLE NATURAL**: (Loose), brown, clayey **SAND** and **GRAVEL** / (Medium dense becoming dense), brown, slightly clayey very sandy **GRAVEL** / Soft to firm, brown, slightly sandy gravelly CLAY with common cobbles (Medium dense), brown, slightly clayey very sandy **GRAVEL** with common cobbles / (Medium dense to dense), brown, sandy **GRAVEL** with common cobbles and boulders / (Medium dense to dense), brown, gravelly **SAND** with common cobbles and boulders

4.3 Water Strikes

No groundwater was encountered in the boreholes.

4.4 Stability and Obstructions

The trial pits remained stable in the short term.

In TP06 a brick column was encountered in the side wall of the trial pit. In TP10 which was located on the top of the stockpile, an obstruction was encountered at 2.10m and appeared to be a concrete floor slab.

4.5 Laboratory Chemical Testing

4.5.1 Exploratory Strategy and Sampling Regime

During the intrusive investigation 10 small disturbed soil samples were collected. The sampling regime was conducted in accordance with BS5930: 1999 in order to satisfy the following criteria:

- Identify and confirm suspected sources of contamination
- Determine type and concentration of contamination
- Determine lateral and vertical spread of contaminants
- Ensure representation of the entire site
- Provide sufficient data to determine suitable remedial measures if necessary

The sample locations and depths are listed in the following table.

Table 4.2 Sample Locations and Depths

Sample	Depth (m)	MCerts Sample Matrix Description
TP01	0.20	Brown slightly clayey, gravelly SAND (Possible made ground: brick)
TP01	0.80	Brown clayey, gravelly SAND
TP02	0.20	Dark brown slightly clayey gravelly SAND including odd rootlets (Made ground: ceramic)
TP02	0.60	Brown clayey, very gravelly SAND
TP03 (Stockpile)	N/A	Brown, slightly clayey, Gravelly SAND including odd rootlets (Possible made ground: brick)
TP04 (Stockpile)	N/A	Brown, slightly clayey gravelly SAND (Made ground: brick, ceramic)
TP05	0.70	Dark brown, clayey, gravelly SAND (Possible made ground: brick)
TP06	1.00	Dark brown, slightly clayey, gravelly SAND (Made ground: brick)
TP07	0.40	Brown grey slightly clayey gravelly SAND (made ground: concrete)
TP08	0.70	Brown clayey, gravelly SAND including odd rootlets

4.5.2 Laboratory Soil Analysis

The soil samples taken were despatched to the laboratories of Derwentside Environmental Testing Services Limited (DETS) of Consett, County Durham.

The following chemical tests were undertaken:

Metals and Metalloids
Lead
Arsenic
Mercury
Chromium
Copper
Nickel
Zinc

In-Organics
Cyanide
Sulphate

Others
pH (acidity)
Organic Matter
Asbestos Screen
Asbestos Quantification

Organic Chemicals
Phenol
Polycyclic Aromatic Hydrocarbons (PAHs)
Petroleum Hydrocarbons (TPH CWG)

The laboratory soil chemical test results are presented in **Annex F**.

4.5.3 Laboratory Leachate Analysis

Laboratory leachate testing was undertaken on a number of determinants listed below:

Metals	In-Organics	Organic Chemicals
Lead	Sulphate	Dibenzo(ah)anthracene

The testing was undertaken by DETS and the test results are presented in **Annex F**.

4.6 Soil Property Testing

4.6.1 In-situ Permeability Testing

During the site investigation one falling head permeability test was undertaken in TP02 at as close to the proposed location of the soakaway as possible.

Three fills were achieved in the trial pit.

The test was undertaken to the requirements of BRE:365 and the test results are discussed in **Section 7.6**. The calculation sheets can be found in **Annex G**.

SECTION 5 Soil Analytical Results

5.1 Soil Assessment Methodology

Comparison of the analytical results has been made with Soil Guideline Values (SGVs) for a residential scenario (without plant uptake), sourced from the Land Quality and Management Limited and the Chartered Institute of Environmental Health Suitable 4 Use Levels (S4ULs) for Human Health Risk Assessment. Where S4ULs are not available reference has been made to the Category 4 Screening Levels (C4SLs) and in the absences of this for Cyanide, the Environment Agency Contaminated Land Exposure Assessment (CLEA).

Sulphate results have been compared to British Research Establishment (BRE) guidelines as sulphate levels need only be considered for buried concrete risk assessment only, not human health related.

5.2 Soil Test Results

A summary of the chemical test results which include the regulatory soil guideline values used in the Tier 1 assessment are given in **Tables 5.1** to **5.4**.

Table 5.1 Summary of Soil Chemical Test Results: Standard Suite

Substance	SGV/GAC (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedences
			Minimum	Maximum	
Arsenic	40	CIEH	5.5	24	0
Cadmium	85	CIEH	<0.1	0.8	0
Chromium III	910	CIEH	9.8	30	0
Chromium VI	6	CIEH	<1.0	<1.0	0
Copper	7100	CIEH	12	200	0
Lead	310	C4SL	8.8	590	**2**
Mercury	56	CIEH	<0.05	5.8	0
Nickel	180	CIEH	11	25	0
Selenium	430	CIEH	<0.5	<0.5	0
Zinc	40000	CIEH	44	500	0
Cyanide	8	CLEA	<0.1	3.91	0
Phenols	440	CIEH	<0.3	2.3	0
Sulphate	2400	BRE	200	12000	**6**
Organic Matter	-	-	0.1	12	0
pH	-	-	8.1	11	0
Total PAH	-	-	<0.1	9.6	See Table 5.2

Notes:

- CLEA - Soil guideline values for a residential development without plant uptake
- CIEH - Generic Assessment Criteria for a residential development without plant uptake
- C4SL - Category four screening level for a residential development without plant uptake
- BRE - British Research Establishment
- A total of 10 samples were tested
- - no available guideline

5.2 Soil Test Results (Continued)

All samples were tested for speciated PAH.

Table 5.2 Summary of Soil Chemical Test Results: Speciated PAH

Substance	GAC (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedences
			Minimum	Maximum	
Naphthalene	2.3	CIEH	<0.03	0.11	0
Acenaphthylene	2900	CIEH	<0.03	0.2	0
Acenaphthene	3000	CIEH	<0.03	<0.03	0
Fluorene	2800	CIEH	<0.03	0.04	0
Phenanthrene	1300	CIEH	<0.03	0.84	0
Anthracene	31000	CIEH	<0.03	0.23	0
Fluoranthene	1500	CIEH	<0.03	1.8	0
Pyrene	3700	CIEH	<0.03	1.4	0
Benzo(a)anthracene	11	CIEH	<0.03	0.78	0
Chrysene	30	CIEH	<0.03	0.89	0
Benzo(b)fluoranthene	3.9	CIEH	<0.03	1.2	0
Benzo(k)fluoranthene	110	CIEH	<0.03	0.37	0
Benzo(a)pyrene	3.2	CIEH	<0.03	0.75	0
Indeno(123cd)pyrene	45	CIEH	<0.03	0.42	0
Dibenzo(ah)anthracene	0.31	CIEH	<0.03	0.49	**1**
Benzo(ghi)perylene	360	CIEH	<0.03	0.52	0

Notes:

- LQM/CIEH - Generic Assessment Criteria for a residential development without plant uptake.
- Guidelines for a residential land use without plant uptake.
- Thresholds based on 1.0% SOM
- 10 samples were tested for Speciated PAH

5.2 Soil Test Results (Continued)

The samples were tested for petroleum hydrocarbons. The results are summarised below in **Table 5.3**.

Table 5.3 Summary of Soil Chemical Test Results: Petroleum Hydrocarbons

Substance	SGV/GAC (mg/kg)	Source	Measured Concentrations (mg/kg)		Number of Exceedences
			Minimum	Maximum	
Aliphatic					
PH C5 – C6 Ali	42	LQM/CEIH	<0.01	<0.10	0
PH C6 – C8 Ali	100	LQM/CEIH	<0.01	<0.10	0
PH C8 – C10 Ali	27	LQM/CEIH	<0.01	<0.10	0
PH C10 – C12 Ali	130	LQM/CEIH	<1.5	4.50	0
PH C12 – C16 Ali	1100	LQM/CEIH	<1.2	2.70	0
PH C16 – C21 Ali	65000#	LQM/CEIH	<1.5	4.60	0
PH C21 – C35 Ali	65000#	LQM/CEIH	<1.5	61.00	0
Aromatic					
PH C5 – C7 Arom	370	LQM/CEIH	<0.10	<0.10	0
PH C7 – C8 Arom	860	LQM/CEIH	<0.10	<0.10	0
PH C8 – C10 Arom	47	LQM/CEIH	<0.10	<0.10	0
PH C10 – C12 Arom	250	LQM/CEIH	<0.9	3.50	0
PH C12 – C16 Arom	1800	LQM/CEIH	<0.5	4.70	0
PH C16 – C21 Arom	1900	LQM/CEIH	<0.6	9.50	0
PH C21 – C35 Arom	1900	LQM/CEIH	<1.4	100.00	0

Notes:

- LQM/CIEH - Generic Assessment Criteria for a residential development without plant uptake
- CLEA - Soil guideline values for a residential development without plant uptake
- A total of 10 soil samples were tested for Petroleum Hydrocarbons
- Ali - Aliphatic Hydrocarbon
- Arom - Aromatic Hydrocarbon
- LQM/CEIH Based on 1.0% SOM
- # - LQM for Ali C16 - 21 and C21 - C35 based on LQM for EC >16 - 35

5.3 Asbestos Test Results

Asbestos testing was undertaken on all four sample. **Table 5.4** below summarises the findings:

Table 5.4 Summary of Soil Test Results: Asbestos Screen

Location	Depth (m)	Result	Comment
TP01	0.20	No Asbestos Detected	-
TP01	0.80	No Asbestos Detected	-
TP02	0.20	Chrysotile	Chrysotile present in bundles
TP02	0.60	No Asbestos Detected	-
TP03	(Stockpile)	No Asbestos Detected	-
TP04	(Stockpile)	Chrysotile	Chrysotile present in bundles
TP05	0.70	Chrysotile	Chrysotile present in bundles
TP06	1.00	No Asbestos Detected	-
TP07	0.40	No Asbestos Detected	-
TP08	0.70	No Asbestos Detected	-

5.3 Asbestos Testing (Continued)

It can be seen from **Table 5.4** that asbestos has been encountered in three samples collected from the site. The asbestos has been identified as chrysotile. Further quantification of these materials was subsequently undertaken to establish the percentage of asbestos fibres within the samples. The gravimetric testing has also identified asbestos containing materials (ACMs) in two samples. The results are summarise below:

Table 5.5 Summary of Soil Test Results: Asbestos Quantification

	TP02 at 0.20m	**TP04 (Stockpile)**	**TP05 at 0.70**
Asbestos Type	Chrysotile	Chrysotile	Chrysotile
Comment	Chrysotile present in bundles	Chrysotile present in bundles	Chrysotile present in bundles
ACMs	N/A	N/A	Loose Fibrous Asbestos Debris
Mass of ACM (g)	-	-	0.08
Mass of ACM (%)	-	-	0.01
Asbestos in ACM (%)	-	-	85
Asbestos in Sample (%)	-	-	0.008
Chrysotile Bundles in Sample (%)	0.002	0.001	0.013
Total Mass of Asbestos (%)	**0.002**	**0.001**	**0.021**

5.4 Leachate Test Results

Leachate testing for lead has been undertaken on two samples and dibenzo(ah)anthracene which were found to exceed the soil guideline values. The results are summarise below in **Table 5.6**.

Table 5.6 Summary of Leachate Chemical Test Results

Substance	**GAC** (ug/l)	**Source**	**Measured Concentrations** (ug/l)		**Number of Exceedences**
			TP01 at 0.20m	**TP02 at 0.60m**	
Lead	1.2	WFD	<0.09	0.14	0
Dibenzo(ah)anthracene	0.01	LDL	0.02	-	**1**

Notes:

- WFD - Water Framework Directive (Fresh Water: Long Term Mean)
- LDL - Laboratory Detection Limit

SECTION 6 Quantitative Risk Assessment

6.1 Contaminants of Concern

Soil

Contaminants of concern are those that were found to exceed their residential threshold level. All determinants with the exception of lead in TP01 at 0.20m and TP02 at 0.60m and dibenzo(ah)anthracene in TP01 at 0.20m were found to be below their respective guideline values. Asbestos in the form of Chrysotile has also been found in three samples from TP02 at 0.20m, TP04 (Stockpile) and TP05 at 0.70m.

Lead was found to be at concentrations of 450mg/kg and 590mg/kg above the guideline value for a residential development without plant uptake of 310mg/kg.

Dibenzo(ah)anthracene was found to be at concentrations of 0.49mg/kg above the guideline value for a residential development without plant uptake of 0.31mg/kg

Sulphate was also found to be above guideline values however this poses a risk to buried concrete and not to human health.

Leachate

Leachate testing has found the lead to be below guideline values.

There are no guideline values available for dibenzo(ah)anthracene and the laboratory detection limit of 0.01ug/l has therefore been used. A concentration of 0.02ug/l was detected in the sample from TP01 at 0.20m.

6.2 Potential Receptors and Pathways

6.2.1 Human Receptors

Receptors are considered to be at risk from dermal contact with soils/soil dust, ingestion of soil/soil dust and inhalation of soil dust and asbestos fibres.

Future site residents may also be at risk from contamination in site soils through the potable water supply. The asbestos has been identified as chrysotile fibre bundles and loose fibrous asbestos debris.

6.2 2 Aquatic Environment

The underlying Mercia Mudstone Group has been classed by the Environment Agency as a Secondary B Aquifer and the superficial glaciofluvial sheet deposits are classed as a Secondary A aquifer.

The site does not situate within a groundwater source protection zone and there are no groundwater abstraction points within 250m of the site.

The nearest surface water feature is a small stream located 977m north of the site and the Severn Estuary locates 1.7km to the south east of the site. Shallow groundwater flow in the area will be towards the Severn Estuary.

6.3 Asbestos Risk Assessment

The chemical testing of the soils on site has identified asbestos to be present in the made ground materials.

Exposure to airborne asbestos fibres is known to cause lung cancer and mesothelioma. Paragraph 4.5 of the Welsh Government guidance document 'Contaminated Land Statutory Guidance - 2012' states that death, life threatening diseases (e.g. cancers), other diseases likely to have serious impacts on health, serious injury, birth defects and the impairment of reproductive functions constitute 'significant harm' to human health.

A potentially significant contaminant linkage has therefore been identified at the site, as summarised in **Table 6.1**.

Table 6.1 Contaminant Linkage for Assessment

Source	Pathway	Receptors
Loose bundles of asbestos fibres within made ground on site	Inhalation of asbestos fibres	Construction workers, maintenance workers, neighbouring site users and future site users

6.4 Risk Assessment Methodology

6.4.1 General

A quantitative risk assessment has been carried out for the site in accordance with CIRIA C733 - Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks. In the assessment, site investigation data along with published soil to air relationships have been used to calculate airborne fibre concentrations.

Overall excess lifetime cancer risks for a critical human health receptor have been calculated based upon exposure levels calculated using the airborne fibre concentrations.

6.4.2 Local Climate

Asbestos fibres within asbestos containing soils (ACS's) are only likely to be released when the soil surface is dry and dusty. The local temperature and rainfall has a significant influence over the period of time soils remain dry and dusty.

The number of days with an average daily rainfall of over 1mm has been obtained for the period of 1981-2010 at the Bute Park, Cardiff climate station. The data shows that the Cardiff area has 148.6 days a year where the average rainfall exceeded 1mm or conversely 216.4 dry days.

6.4.3 Calculation of Airborne Respirable Fibre Concentrations

Addison *et al* (1988) has been used to calculate airborne respirable fibre concentrations based upon bulk soil asbestos concentrations obtained through sample quantification.

This approach is considered acceptable on the basis that:

- The site soil is similar to the 'clay', 'sandy' or 'intermediate' soils prepared by Addison et al;
- Measured soil concentrations of asbestos fibres (per cent) are available; and
- The likely soil dust in air concentrations (mg/m^3) can be estimated or measured.

6.4.4 Calculation of Exposure

The exposure of an event is the product of the airborne concentration of asbestos during the event and the period of time that the exposure lasts. The annual exposure (Ei) from each event, i, can be expressed in fibre/ml.hours as:

$Ei = Ci \times Fi \times Ti$

Where:
Ci = the estimated concentration (f/ml) for the event
Fi = the frequency of the event per year
Ti = the period of time that the event lasts in hours

Cumulative exposure for each event is the sum of the relevant annual exposures. So, the cumulative exposure for event i, CEi, is the annual exposure for the event multiplied by the number of years that the event is predicted to occur.

$CEi = Ei \times Yi$

Where:
Yi = the number of years that exposure event i will occur.

6.5 Risk Assessment

Overall excess lifetime cancer risks have been estimated in accordance with the guidance published in CIRIA C733. For the assessment, the worst case of asbestos contamination was used to produce two models with varying exposure times. A summary of the models is presented on the following page in **Table 6.2**.

6.5 Risk Assessment (Continued)

Table 6.2 Model Data: Chrysotile					
Parameter	Units	Model Run 1		Model Run 2	
		Model Data	Justification	Model Data	Justification
Soil Type	-	Sand	As defined in laboratory matrix description	Sand	As defined in laboratory matrix description
Appropriate test soil prepared by Addison *et al*	-	Sand	As defined in Addison et al	Sand	As defined in Addison et al
Highest measured chrysotile concentration	Mass %	0.021	Laboratory gravimetric analysis	0.021	Laboratory gravimetric analysis
Predicted normalised fibre concentration	fibres/ml per mg/m^3	0.1	As per Graph a, Figure 6 of Addison *et al*	0.1	As per Graph a, Figure 6 of Addison *et al*
The concentration of soil dust during gardening activities in dry and dusty conditions	mg/m^3	0.1	Based on ambient urban dust levels and ART modelling of shovelling dry powders	0.1	based on ambient urban dust levels and ART modelling of shovelling dry powders
Airborne fibre concentration due to garden activities	f/ml	0.01	The product of the predicted normalised fibre concentration and concentration of soil dust during activities	0.01	The product of the predicted normalised fibre concentration and concentration of soil dust during activities
How long are residents/visitors assumed to be outside in dry and dusty conditions	h/yr	136.3	216.4 dry days per year based on Met office data. 230 days per year exposure based upon C4SL	165.9	280 days considered a reasonable worst case. 230 days per year exposure based upon C4SL
Annual exposure	f/ml.hours/ year	1.363	Product of airborne fibre concentration due to activities and child exposure time	1.659	Product of airborne fibre concentration due to activities and child exposure time
Cumulative exposure	f/ml.hours	8.178	6 years based on assumptions in C4SL final report	9.954	6 years based on assumptions in C4SL final report
Unit converted cumulative exposure	fibre/ ml.years	0.0041	assuming an occupational year is 2,000 hours (CIRIA C733)	0.0050	assuming an occupational year is 2,000 hours (CIRIA C733)

6.6 Risk Assessment Results

The quantitative risk assessment results based upon information published by Hodgson and Darnton (2000) are presented in **Table 6.4** below:

Table 6.3 Quantitative Risk Assessment Results		
Health Risk	Lifetime Risk (per 100,000 exposed)	
	Chrysotile Model 1	Chrysotile Model 2
Age adjusted mesothelioma risk (2.8 adjustment factor taking into account exposure from birth to 60 years)	Falls between insignificant and highest 4	Falls between insignificant and highest 4
Lung Cancer Risk	Insignificant	Insignificant

6.6.1 Acceptable Levels of Risk

At present there is a lack of UK guidance as to what acceptable levels of lifetime cancer risk posed by ACS's are. The HSE (2001) categorise levels of risk as shown below:

- Unacceptable
- Tolerable
- Broadly Acceptable

For occupational activities, the HSE (2001) suggest that "an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions". Assuming a 70 year lifetime, this equates to a risk of death of 7 in 100 000 over a lifetime (CIRIA C733).

The quantitative risk assessment revealed the level of risk falls between insignificant and 4 (highest). The worst case cumulative exposure of 0.005 fibre/ml.years falls below the acceptable and tolerable boundary suggested by the HSE (2001).

In addition the model has used an airborne fibre concentration due to garden activities however there are no private garden area proposed as part of the development. Instead outside spaces consist of paved areas with small borders / planters. This significantly reduces the potential cumulative exposure.

6.7 Mitigation and Remedial Measures

6.7.1 Human Health

Whilst the asbestos risk assessment would suggest the levels of chrysotile pose an acceptable risk, it is understood that the risk assessment is based on a number of uncertain assumptions such as the soil to air relationship set out by Addison *et al* (1988). In addition to this lead and dibenzo(ah)anthracene have been found above the guideline values.

Given the nature of the development a large amount of the impacted material will be removed with the excavation of the undercroft car park. To protect site end users the remaining area of the site will need to be capped. The capping should consist of the proposed building (where levels are not reduced) and hard standings. In soft landscaped areas the capping should consist of 600mm of suitable inert topsoil and subsoil over a no dig barrier.

It is considered that this would significantly reduce the calculated lifetime risk and negate the uncertainties in the assumptions made in the asbestos risk assessment.

Following the importation of topsoil and subsoil to all garden and landscaped areas, it is considered that no further remedial measures will not be required to render the site fit for its intended use.

Service runs on site through areas of demolition waste should be lined with clean inert material to prevent exposure to maintenance workers.

As the stockpiles stand they pose an acceptable risk to human health however to reduce the risk further it is recommended that the stockpiles are covered by sheeting or for the longer term they can be seeded.

6.7.1 Human Health (Continued)

If works are to be undertaken on the stockpiles precautions should be employed. The advice of an asbestos specialist will be required and as a minimum the following precautions should be employed:

- Dust suppression and measures to dampen the material
- Suitable PPE for site workers
- Air monitoring on the site boundary
- Personal air monitors (for a time to determine actual personnel / fibre interaction)

In addition to the above it is best practise to clean down plant and change air filters on any plant used in the works with asbestos contaminated material.

As good practice, construction workers should adhere to good site management, COSHH, good standards of hygiene and appropriate health & safety on site, with personal protection equipment (PPE) and dust suppression where appropriate.

The advice of an asbestos specialist should also be sought.

All imported soils should be validated as clean and suitable for use in accordance with 'Requirements for the Chemical Testing of Imported Soils for Various End Uses and Validation Cover Systems'.

For proposed new supply water pipes, the UK Water Industry Research publication 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites (Report 10/WM/03/21)' should be consulted.

In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM3 soils destined for off-site disposal should be classified on the basis of their hazard phrases prior to disposal. Soils are classified as a mirror entry waste and should be classified on the basis of their specific chemical properties.

6.7.2 Aquatic Environment

The dibenzo(ah)anthracene leachate is marginally above the laboratory detection limit and there is no guideline available. The aquatic environment is not considered to be a risk and any contaminants would soon be rendered insignificant through the effects of dilution and attenuation.

Once the site is capped with the proposed development the amount of surface water infiltration will be significantly reduced and there will be a negligible risk to the aquatic environment.

During the construction period, there is a risk to the environment/adjacent sites from de-watering, digging foundations, moving contaminated soil, drainage misconnections, discharges to local surface waters or the ground, runoff from construction materials and/or exposed ground, wheel washings and oil or chemical spills.

The risk is considered to be negligible as any adverse effects will be easily preventable by due diligence to good construction practise and housekeeping in preventing surface runoff and the spillage of materials.

6.7.2 **Aquatic Environment** (Continued)

The basic measures that should be taken are as follows:

- Prepare a drainage plan and mark the manholes to prevent pollutants accidently reaching the surface water sewers;
- Carry out any activities that could cause pollution in a designated, bunded area, away from rivers or boreholes. Where possible it should drain to the foul sewer;
- Use settlement ponds to remove silty water;
- Store all oils and chemicals in a fully bunded area to prevent leaks or spills;
- Get advice on whether you need an environmental permit and apply in good time

6.8 Refined Illustrative Site Conceptual Model

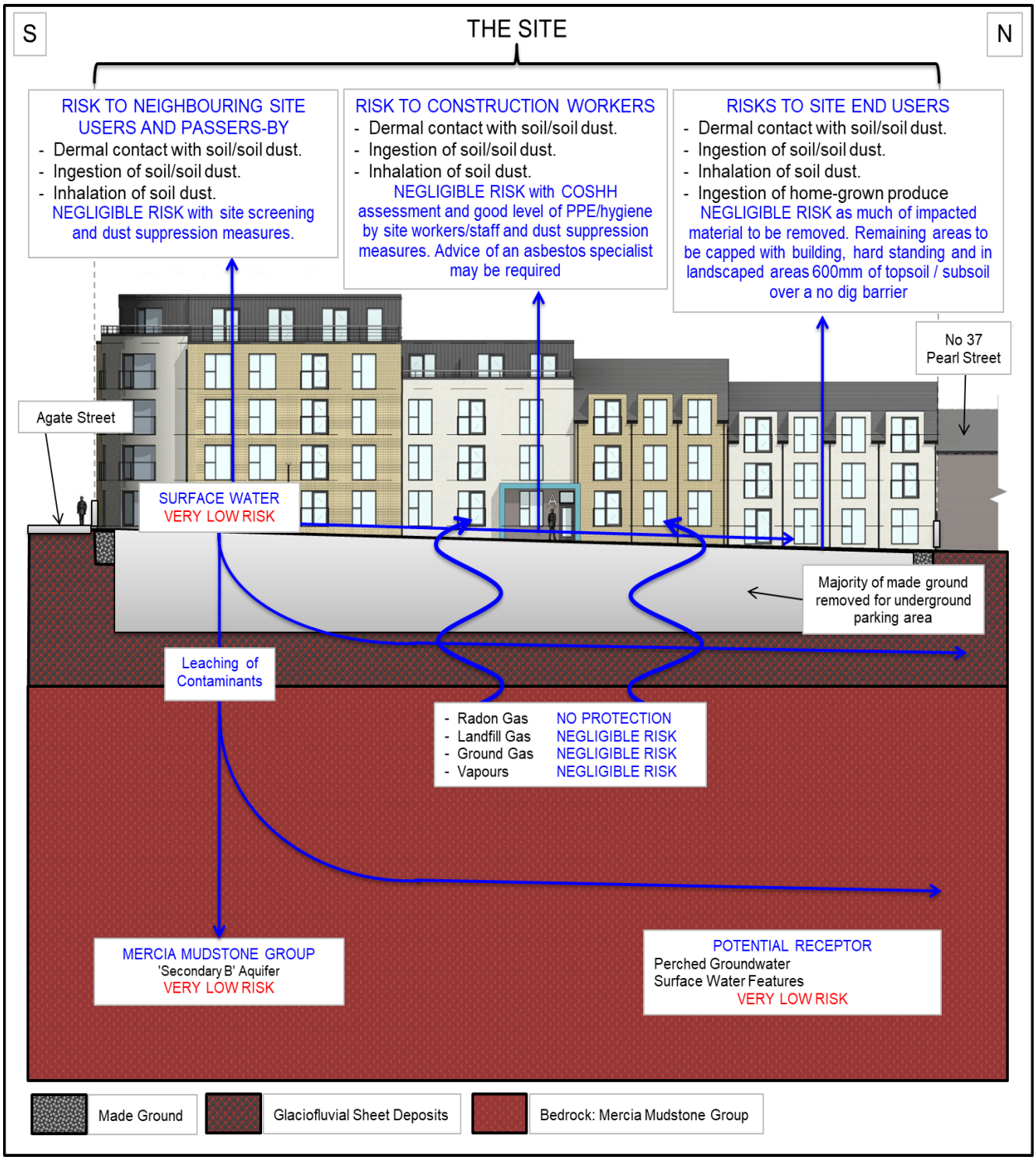


Figure 6.1: *Refined Illustrative Site Conceptual Model (not to scale)*

SECTION 7 Engineering Recommendations

7.1 Preparation of Site

Due to the significant cut required for the under croft car parking allowances should be made for temporary/permanent support works to adjacent structures made necessary as a result of the proposed works. A structural survey of the neighbouring properties / structures should be undertaken prior to the start of works.

Any vegetation including all roots should be stripped and removed from beneath the proposed building and areas of hard standing.

Allowances should be made for encountering, and the excavation of buried obstructions. A mechanical breaker attachment may need to be utilised.

Contingencies should be made for the protection/diversion any underground/overhead services present beneath the site brought about as a result of the proposed works.

Allowances should be made for the excavation of any soft spots/areas and their replacement with well compacted imported granular materials.

Any reduced levels should be brought up to the required levels with suitable inert mainly granular materials. Department of Transport (DoT) type 2 sub base or similar should be used and should be compacted in layers to the requirements of the Specification for Highway works.

In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM3 soils and other materials destined for off-site disposal should be classified on the basis of their hazard phrases prior to disposal. Soils are classified as a mirror entry waste and should be classified on the basis of their specific chemical properties

7.2 Foundation and Floor Slab Solution

The proposed building has an undercroft parking area and will effectively be a retaining structures. It is recommended that an integral reinforced concrete raft/retaining wall structure would be the most appropriate form of foundation for the proposed development.

The raft can be founded within the medium dense to dense, brown, SAND and GRAVEL.

For the above foundations within the given founding materials an allowable bearing pressure of 200kN/m^2 may be used for design purposes for a maximum total settlement of 30mm. Differential settlement of foundations should not lead to structural distortion of more than 1:750.

In order to prevent damage from frost heave and/or thermal shrinkage the raft edge beams should extend down to 900mm below the finished ground level, and foundations should penetrate at-least 200mm in to the founding horizon.

Allowances should be made for removing any ‘soft spots/areas’ and their replacement with well-compacted imported granular materials as previously described.

7.2 Foundation and Floor Slab Solution (Continued)

Allowances should be made for the removal of any 'soft spots' and their replacement with well-compacted granular materials. Department of Transport (DoT) Type 2 materials or similar could be used and should be compacted in layers to the specification for Highway Works. Allowances should also be made for buried obstructions, as previously described. It may be possible to reuse any site won granular material.

All foundation formations should be inspected by a suitably qualified Engineer before being concreted.

7.3 Excavations and Formations

Shallow excavations will be possible with normal soil excavating machinery. However allowances should be made for the use of a breaker attachment when encountering historic obstructions.

Shallow perched water flows are not expected. Any water inflows together with rainwater infiltration should be dealt with by conventional pumping techniques.

The sides of any excavations deeper than 1.0m, or shallower if unstable, should be supported by planking and strutting or other proprietary means.

Allowances should also be made for encountering running sand conditions.

The sub-formations/formations are likely to be susceptible to loosening, softening and deterioration by exposure to weather (rain, frost and drying conditions), the action of water (flood water or removal of groundwater) and site traffic.

Formations should never be left unprotected and continuously exposed to rain causing degradation, or left exposed/uncovered overnight, unless permitted by a qualified engineer.

Construction plant and other vehicular traffic should not be operated on unprotected formations.

As a minimum the formation/excavation surfaces must be protected by blinding concrete immediately after exposure.

Allowances should be made for the removal of soft spots/areas and their replacement with well compacted granular materials.

Allowances should also be made for special precautions to prevent formation deterioration in addition to the above.

7.4 Protection of Buried Concrete

Levels of total sulphate within the in-situ materials measured between 200mg/kg to 12000mg/kg and the pH varied between 8.1 and 11. Aqueous sulphate testing was undertaken on six samples which exceeded the Design Class 1 level. The aqueous sulphate levels were found to be between 1100mg/l and 1600mg/l.

When these results are compared with Table C2 of BRE Digest 1:2005, it indicates that all buried concrete should as a minimum conform Design Sulphate Class 3 and to Aggressive Chemical Environment for Concrete Class AC-3.

7.5 Car Parking Areas

For car parking and road areas, formations within the in-situ soils a CBR value of 1% may be used for design purposes. If the material is excavated and re-compacted an increased CBR value of 5% may be used.

Allowances should be made for the removal of any 'soft spots/areas' and their replacement with well-compacted granular materials as previously described.

7.6 Storm Drainage

During the site investigation one falling head permeability test was undertaken in TP02 in the proposed location of the soakaway in the natural sand and gravel deposits. The test was repeated three times and was undertaken to the requirements of BRE 365. The following infiltration rates were recorded:

1st Fill: 1.99×10^{-5} m/s
2nd Fill: 1.49×10^{-5} m/s
3rd Fill: 1.25×10^{-5} m/s

For design purposes the infiltration rate for the 3rd fill should be used.

Soakaways should be positioned outside of influencing distance (5m) of existing and proposed structures.

7.7 Retaining Walls

Due to the undercroft car parking retaining walls will be required. Any cuts should be undertaken in small sections and in such a way so as not to induce any instability to the ground.

The effective angles of shearing resistance of the encountered materials have been determined based upon past experience of the materials and are presented on the following page.

Table 7.1 Effective Shear Stress Parameters

Stratum Description	Bulk Unit Weight (γ) kN/m^3	Effective Cohesion (c') kN/m^2	Effective Angle of Shearing Resistance (ϕ') degrees
Soft to firm cohesive soils	18	0	20 – 25
Firm to stiff cohesive soils	18	0	30
Loose granular soils	18	0	22
Medium dense granular soils	18	0	25
Well compacted, granular materials, compacted as per Specification for Highway Works and other relevant guidance such as British Standards (BS) 6031: 1981. Code of Practise for Earthworks.	19 - 20	0	30 - 35
Fresh/slightly weathered mudstone/siltstone bedrock	19-24	5	35 - 40
Moderately / highly weathered Mudstone/siltstone bedrock	19-24	0	30 – 35

7.7 **Retaining Walls** (Continued)

The design and construction of the retaining walls should be in accordance with BS 6031: 1981 Code of Practise for Earthworks and other relevant guidance.

Allowances should also be made for the removal of soft spots and their replacement with imported suitable selected inert granular materials or suitable inert site won materials.

The cohesive deposits will have a tendency to flake and soften with weathering as they are less resistant. Measures should be put in place to prevent deterioration.

Measures should be in place to prevent de-stabilisation due to surface water ingress and groundwater emergence upon the cutting face which will ultimately reduce the effective stress of the soil, cause erosion and instability. The retaining walls should be appropriately tanked to prevent the ingress of water.

It is recommended that the construction of retaining walls be carried out in small sections.

During the site development/construction phases stability surveys should be undertaken at regular intervals, including pictorial records. Any evidence of cutting instability should be reported to a qualified engineer and appropriate remedial measure implemented.

If any future infrastructure developments become likely to impart a load upon the retaining walls/retained soils/slope crests or slope faces, appropriate slope face stability assessments should be undertaken to ensure their long term stability after such developments.

It is also recommended that periodic appraisal of the slope faces/retaining walls and drainage systems be undertaken by a qualified engineer to ensure their continued integrity.

ANNEX A
Envirocheck Historical Maps

ANNEX B
BGS Borehole Record

ANNEX C
Envirocheck Datasheet and Maps

ANNEX D
Risk Assessment Definitions

ANNEX E
Trial Pit Logs

ANNEX F
Laboratory Chemical Test Results

ANNEX G
Soakaway Calculation Sheets

DRAWINGS