Geotechnical & Geo-environmental Site Investigation Report:
Proposed Residential Development
Herbert Road
Newport

Phase 1

Prepared For:
Keepmoat

February 2017

Job No: 12032P1

terrafirma

REPORT TITLE	:	**Geotechnical and Geoenvironmental Report Site Investigation Report:** Proposed Residential Development, Herbert Road, Newport Phase 1
REPORT STATUS	:	**Final**
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PREPARED BY	:	R. Howells. …….. **Mrs Ruth Howells**
REVIEWED BY	:	M. Lake …….. **Mathew Lake**
APPROVED BY	:	Gwyn Lake …….. **Dr Gwyn C Lake**

Executive Summary

Site Location	*The site is situated along the River Usk, Newport. It primarily comprises rough grassland along the River Usk intersected by a tarmac footpath, but part extends onto the main area of the development site, alongside the drainage reen.*
Site History	*The site in 1883 comprised field land alongside the River Usk. By 1937 a collection of small buildings had been erected alongside the river part way up the site, accessed via a trackway along the river's edge. Between 1937 and 1955 these buildings were replaced by a single house and an adjacent rectangular building of unspecified use, which were later demolished, and the trackway was constructed upon a raised embankment, as is seen presently.*
Ground Conditions	*The ground conditions were found to comprise made ground of variable granular and clay deposits with waste content including brick and concrete to a confirmed depth of between 5.2m and 5.4m depth, underlain by soft to very soft alluvial clay with bands of peat to depths of between 15.9m and 16.3m. Below the clay gravel is present to 16.8m/19.0m, being between 0.2m and 2.7m in thickness. St Maughans' Formation mudstone or sandstone bedrock underlies the superficial cover.*
Radon	*Basic radon protection is required for new development.*
Ground Gas/Landfill Gas	*In-situ gas monitoring has confirmed that gas protection measures will be required for the new apartments.*
Laboratory Chemical Testing and Proposed Remediation	*Laboratory analysis of site soils was undertaken. Lead was found to be present at a concentration of 470mg/kg in made ground in TP2 (0.6m), exceeding the residential threshold level of 200mg/kg. Chrysotile asbestos fibres were identified in made ground in TP06 (0.4m). Fragments of asbestos containing material were also visually identified in this location.* *Upon development the area of TP2 and TP6 will be capped with the new road, which will act as a physical barrier between the made ground and human receptors. No remedial measures are required for the any garden or landscaped areas adjacent to the new Phase 1 apartments.* *Any 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.*
Foundation Solution	*Due to the presence of made ground and soft alluvial clays beneath the site traditional shallow foundations are not recommended. Such foundations will lead to high total and differential settlements.* *A piled foundation is advised for the proposed apartment blocks. Precast concrete driven piles founded within the underlying weathered red mudstone and/or sandstone is recommended. For a 275mm square precast concrete pile driven to an appropriate set within the underlying competent mudstone a safe working load of typically 500kN should be achieved. Based upon the site investigation data, pile lengths should vary between 20m and 22m beneath current ground levels.* *Measurements should be kept on pile vibrations during driving. Measures should also be taken to dampen such vibrations. If, however, vibrations exceed permissible values then consideration should be given to using a contiguous flight auger (cfa)/bored pile solution.* *Floor slabs should be designed as suspended.*

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SECTION 1 Introduction and Proposed Development

1.1 Introduction

Keepmoat is proposing the residential development of an area of land off Herbert Street, Newport.

This development is to be constructed in four phases. This report applies to the Phase 1 development only (henceforth referred to as 'the site'). Phase 1 extends northwards from Courtney Street along the River Usk and includes an area alongside the drainage reen and a new road on the main body of the site. Three apartment blocks are to be constructed on the Phase 1 site.

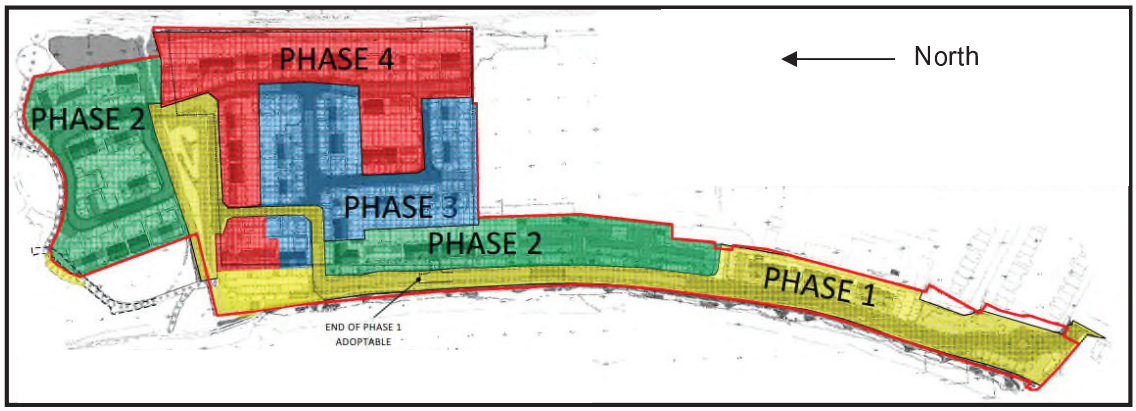

Figure 1.1: Phase 1 Layout

The section of new road and area alongside the drainage reen on the main body of the site was previously included in an investigation by Terra Firma in 2013, as reported in Geotechnical and Geo-environmental Report No. 12032. This area has been excluded from this report as ground conditions have been proved and all soil chemical data has already been assessed and approved.

Terra Firma (Wales) Limited has been commissioned to undertake a geo-environmental 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

Keepmoat has requested that a Geoenvironmental 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 Keepmoat and its 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.

SECTION 2 Review of Existing Data

2.1 Physical Setting and Current Site Use

The site is situated along the River Usk, Newport, and is centred on an approximate National Grid Reference of 331621 189115. It occupies a plan area of approximately 1.5 hectares.

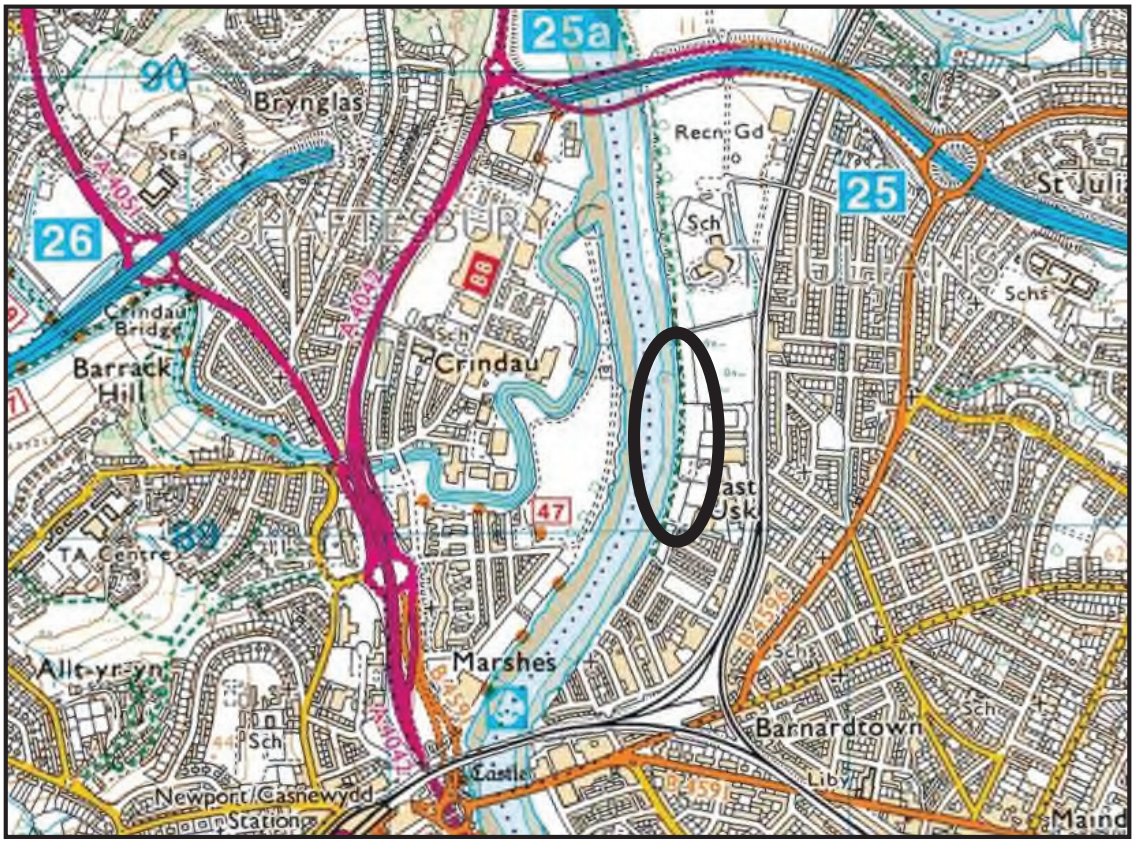

Figure 2.1: Site Location – OS Map 152 Newport and Pontypool

The site primarily comprises rough grassland along the River Usk intersected by a tarmac footpath. The footpath is frequented by dog walkers and those accessing the river.

The area of Phase 1 that extends on to the main body of the Herbert Road development site will comprise a road and a section alongside the drainage reen.

2.2 Site History

The history of the site has been traced using historical Ordnance Survey maps from Landmark Information Group. The maps may be found in **Annex A.** Please note that the boundary of Phase 1 is not specified on these plans, and the southern extent of the site denoted is incorrect. The Phase 1 site extends further south than shown. A summary of the history of the site is given below. Distances, where quoted, are approximate.

The site in 1883 is seen to comprise field land alongside the River Usk, intersected by east-west aligned drainage reens. A brick works (Brick Field) occupies land to the south, which by 1902 includes a large excavated area directly adjacent to the site's southern tip. This is likely to have been used to access clay for the brick works, known in 1902 as Newport Patent Brick Works. By 1920 the brick works is no longer present and housing is seen to have extended up to the far southern site boundary along Collier Street. Courtney Street also exists at this time across the former excavated depression, although no terraced housing has yet been established. By 1937 the Courtney Street terraces have been built and a collection of small buildings have been erected alongside the river part way up the site, accessed via a trackway along the river's edge. Their use is not documented. Between 1937 and 1955 the track along the river has been constructed upon a raised embankment, as is seen presently. The collection of small buildings has been removed and a single property, Glen Usk, takes their place along with a rectangular building of unspecified use. Both of these structures situate in the Phase 2 site area but may slightly overlap on to the Phase 1 site. A field now appointed as allotment gardens overlaps on the southern section of site. A clothing factory has been established on the main part of the Herbert Road development site (Phases 3 & 4). Very little change has occurred to the site since 1955, although the allotment gardens and Glan Usk were absent by 1978.

2.3 Geological Setting

2.3.1 Geology

The 1:50,000 scale geological map of the area (Sheet 249) was consulted. This shows the site to be underlain by rocks of the by the St Maughan's Formation, belonging to the Devonian Period. These rocks comprise interbedded argillaceous rocks with subordinated sandstone.

The solid geology is shown to be overlain by estuarine alluvium.

Made ground is anticipated to be present across the section of site alongside the River Usk in connection with raising of the footpath route between 1937 and 1955.

2.3.2 Coal Mining

The site lies outside the South Wales Coalfield. The site will not be affected by past mining.

2.3.3 Radon

A radon report acquired from the British geological Survey (**Annex B**) details that basic radon protection will be required for new buildings on site.

2.4 Hydrogeology and Hydrology

The bedrock beneath the site is detailed to be a Secondary A aquifer. These aquifers 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. These are generally aquifers formerly classified as minor aquifers.

The estuarine alluvium is classified as unproductive strata.

Any surface or shallow groundwater flows along the river will either be towards the River Usk, adjacent land to the east, or the main body of the Herbert Road development site. Part of the Phase 1 site lies directly alongside a drainage reen.

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

2.5 Environmental Setting

Relevant data sourced from the Environment Agency online 'What's in Your Back Yard' database in 2013 is summarised in the following sections.

2.5.1 Industrial Operator Scores

There are no sites within a 1km radius of the site where pollution is regulated.

2.5.2 Industrial Pollution

There are no industrial pollution scores within a 1km radius of the site where pollution is regulated.

2.5.3 Pollution Incidents

There is one pollution incident within close proximity of the site. The incident took place in February 2004 approximately 200 metres south of the site. The incident caused a significant impact to land and involved 'specific waste materials'.

2.5.4 Landfills

One historical landfill facilities is located within influencing distance of the part of the site to be residentially developed.

Shaftsbury Park historic landfill is located approximately 120 metres west of the site. No information is provided regarding the date at which the landfill was active. Shaftsbury Park received industrial and household waste.

2.5.5 Groundwater Source Protection Zones

The site does not locate within a groundwater protection zone.

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 C** 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 site past use and the history of the surrounding area.

Fill is expected to be present for the majority of the site, alongside the River Usk, which appears to have been historically raised. The source or type of fill is unknown. This could comprise waste materials from local industry. Any fill is considered to be a potential source of contamination.

Previous exploratory holes excavated on the section of Phase 1 that extends on to the main part of the Herbert Road development site did not identify made ground. However, current filling has raised levels with imported material, but all imported soils have been pre-tested and approved for use by the NRW and Newport City Council.

Any fill and underlying bands of peat known to exist within the alluvium are known to present a risk from ground 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 dust and inhalation of soil dust or vapours. Workers may also be exposed to asbestos fibres, if present in fill soils.

A residential end use is proposed on part of the Phase 1 site, comprising three apartment blocks. Once developed, future site residents will potentially be at risk from any contamination from the same pathways as well as through intake of potable water and inhalation of ground gas.

Future site residents are at risk from ground gas. The risk from landfill gas is negligible given that the historical landfill identified within influencing distance of the site lies on the opposing side of the River Usk.

Any future maintenance contractors could be at risk from dermal contact with soils and dust, ingestion of soil dust and inhalation of soil dust/asbestos fibres/vapours.

Passers-by and neighbouring site users are similarly at risk from site soils via soil dust and asbestos fibre inhalation.

If any contamination is identified this may be leachable, enabling it to mobilise through perched groundwater within site soils and impact the river 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.

Table 3.1 - Qualitative Preliminary Human Health Risk Assessment					
Potential Source	**Pathway**	**Receptor During Construction**	**Level of Risk**	**Receptor Post Construction**	**Level of Risk**
Made ground	**Ingestion, inhalation and dermal contact with soil and soil dust**	Construction Workers	Medium Risk	Future residents Maintenance Contractors	Medium Risk
Made ground	**Inhalation of soil dust**	Neighbouring site users and passers-by	Low Risk	Neighbouring site users and passers-by	Low Risk
Made ground	**Inhalation of asbestos fibres**	Construction Workers Neighbouring site users and passers-by	Medium Risk	Future residents Maintenance Contractors Neighbouring site users and passers-by	Medium Risk
Made ground	**Inhalation of Vapours**	Construction Workers	Low Risk	Future residents Maintenance Contractors	Low Risk
Radon Gas	**Inhalation** *Accumulation of gas indoors in confined spaces- asphyxiation and explosion*	N/A	N/A	Future residents	Unacceptable Risk *BGS confirm BASIC Radon Protection required for new buildings*
Landfill Gas	**Inhalation** *Accumulation of gas indoors in confined spaces- asphyxiation and explosion*	N/A	N/A	Future residents	No Risk *Landfill lies on opposing side of River Usk*
Ground Gas	**Inhalation** *Accumulation of gas indoors in confined spaces- asphyxiation and explosion*	N/A	N/A	Future residents	High Risk *Potential gas where made ground and peat present.*
Made Ground	**Ingestion of potable water** *Absorption of contamination from made ground into potable water pipes*	N/A	N/A	Future Residents	Medium Risk

Table 3.2 – Qualitative Preliminary Environmental Risk Assessment					
Potential Source	**Pathway**	**Receptor During Construction**	**Level of Risk**	**Receptor Post Construction**	**Level of Risk**
Surface Water	**Run-off**	Site and Adjacent Sites Shallow/Perched Groundwater	Low	Site and Adjacent Sites Shallow/Perched Groundwater	Low
Accidental spillage	**Run-off , digging foundations, moving contaminated soil, drainage misconnections, discharges to local surface waters or the ground, construction materials and/or exposed ground, wheel washings, oil or chemical spills**	Site and Adjacent Sites	Low *On site proceedures will ensure that all efforts are made to prevent accidental spillage*	N/A	N/A
Made Ground	**Leaching of contamination**	Shallow/Perched Groundwater	Medium Risk	Shallow/Perched Groundwater	Medium Risk
Contaminated Groundwater	**Direct migration and Perched Groundwater migration**	Secondary A Aquifer	Low Risk *Superficial alluvium acts to confine perched groundwater above underlying bedrock*	Secondary A Aquifer	Low Risk *Superficial alluvium acts to confine perched groundwater above underlying bedrock*
Contaminated Groundwater	**Groundwater Migration**	River Usk	Medium Risk	River Usk	Medium Risk

SECTION 4 Field Investigation

4.1 Site Works

A geo-technical and geo-environmental site investigation was carried out during January and February 2017. This comprised twelve machine excavated trial holes and four cable percussive boreholes.

The trial pits were excavated by JCB.

The boreholes were sunk using a Shell and Auger drilling rig. Standard penetration tests were undertaken at regular depths in the boreholes. The boreholes were terminated within the Mercia Mudstone after one hour of chiselling.

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

The trial pit logs may be found in **Annex D** and the borehole logs are available in **Annex E**. Exploratory locations are given on **Drawing 01.**

4.2 Ground Conditions

Trial pits excavated along the length of the river encountered made ground to the maximum excavation depth, which ranged from 1.1m and 3.0m. This generally comprises sand and gravel or gravelly clay deposits with variable competency and content of waste materials, particularly brick and concrete. Fragments of corrugated cement sheeting containing asbestos were also noted in made ground in TP6.

A summary of the ground conditions identified in the trial pits and boreholes beneath the area of the proposed apartment blocks is given in **Table 4.1**.

Table 4.1 Summary of Ground Conditions
Area of Proposed Apartment Blocks

Depth (m)	Thickness (m)	Stratum
0.0 - 5.2/5.4	5.2/5.4	**MADE GROUND:** Soft to firm grey **CLAY** / Loose red and grey very **clayey SAND and GRAVEL and COBBLE** with brick / Medium dense to dense **GRAVEL** of mudstone / Very loose **ASH**
5.2/5.4 - 15.9/16.3	10.6/11.1	Soft to very soft grey silty **CLAY ALLUVIUM** with **PEAT and PEATY** bands
15.9/16.3 - 16.8/19.0	0.2/1.7	Dense red **GRAVEL and COBBLE** of mudstone
>16.8/19.0	-	Weathered red **MUDSTONE or SANDSTONE (St Maughan's Formation)**

The depth to the top of the mudstone/sandstone bedrock generally increases towards the south.

4.3 Water Strikes

Groundwater inflow was not encountered in the trial pits.

Water strikes were made in the boreholes, at 3.0m in BH1, 16.3m in BH2, 3.2m and 16.3m in BH3 and at 3.0m in BH4.

4.4 Stability and Obstructions

Trial holes were unstable in places where granular made ground was noted.

4.5 Soil Laboratory Chemical Testing

4.5.1 Exploratory Strategy and Sampling Regime

During the intrusive investigation, 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
TP1	0.3	Brown gravelly, sandy CLAY
TP2	0.6	Dark brown gravelly, sandy CLAY (Made ground - brick)
TP3	0.2	Brown gravelly, sandy CLAY including odd rootlets
TP4	0.5	Brown gravelly, sandy CLAY
TP5	0.3	Dark brown gravelly, sandy CLAY (Made ground - brick, glass)
TP6	0.4	Brown gravelly, sandy CLAY
TP7	0.2	Brown gravelly, sandy CLAY including numerous rootlets
TP8	0.6	Dark brown gravelly, sandy CLAY
TP9	0.4	Brown gravelly, sandy CLAY (Made ground - brick)
TP10	0.2	Brown gravelly, sandy CLAY including odd rootlets
TP11	0.5	Dark grey gravelly, sandy CLAY including odd rootlets (Possible made ground - brick)
TP12	0.3	Brown gravelly, sandy CLAY (Possible made ground - brick)

4.5.2 Laboratory Analysis

The soil samples taken were despatched to the laboratories of Derwentside Environmental Testing Services Limited.

4.5.2.1 Soils

The following chemical tests were undertaken:

Metals and Metalloids	In-Organics	Others
Lead	Cyanide	pH (acidity)
Arsenic	Sulphate	Organic Matter
Mercury		Asbestos
Chromium		
Copper		
Nickel		
Zinc		

Organic Chemicals
Phenol
Polycyclic Aromatic Hydrocarbons (PAHs)

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

4.5.2.2 Leachate

The following leachate tests were undertaken on one or more samples:

Lead
Sulphate

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

SECTION 5 Soil and Leachate Analytical Results

5.1 Soil Assessment Methodology

Comparison of the analytical results has been made with Soil Guideline Values (SGVs) for a residential scenario (including plant uptake), sourced from The Environment Agency Contaminated Land Exposure Assessment (CLEA). Where SGV values are not available reference has been made to the 2015 residential (including plant uptake) Suitable 4 Use Levels (S4ULs) provided by Land Quality Management Limited and the Chartered Institute of Environmental Health (CIEH) or Category 4 Screening Levels (C4SLs).

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 **5.3**.

Table 5.1 Summary of Soil Chemical Test Results Standard Suite

Substance	SGV/GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Number of Exceedences
			Minimum	Maximum	
Arsenic	32	CLEA	9.6	32	**0**
Cadmium	10	CLEA	0.1	3.2	0
Chromium III	910	CIEH	8.4	40	0
Chromium VI	6	CIEH	<1.0	<1.0	0
Copper	2400	CIEH	22	110	0
Lead	200	C4SL	27	470	1
Mercury	170	CLEA	0.05	0.66	0
Nickel	180	CIEH	5.6	39	0
Selenium	350	CLEA	<0.5	0.8	0
Zinc	3700	CIEH	46	250	0
Cyanide	8	CLEA	<0.1	0.5	0
Phenols	420	CLEA	<0.3	0.8	0
Sulphate	2400	BRE	400	2700	1
Organic Matter	-	-	1.0	6.8	-
pH	-	-	8.2	10.2	-
Total PAH	-	-	1.3	7.6	See Table 5.2

Notes:

- - no available guideline

5.2 Soil Test Results (Continued)

All samples were tested for speciated PAH testing.

Table 5.2 Summary of Soil Chemical Test Results Speciated PAH

Substance	GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		Number of Exceedences
			Minimum	Maximum	
Naphthalene	2.3	CIEH	<0.03	0.06	0
Acenaphthylene	170	CIEH	<0.03	0.04	0
Acenaphthene	210	CIEH	<0.03	0.13	0
Fluorene	170	CIEH	<0.03	0.01	0
Phenanthrene	95	CIEH	<0.03	0.7	0
Anthracene	2400	CIEH	<0.03	0.16	0
Fluoranthene	280	CIEH	<0.03	2.9	0
Pyrene	620	CIEH	<0.03	1.8	0
Benzo(a)anthracene	7.2	CIEH	<0.03	0.68	0
Chrysene	15	CIEH	<0.03	0.55	0
Benzo(b)fluoranthene	2.6	CIEH	<0.03	0.79	0
Benzo(k)fluoranthene	77	CIEH	<0.03	0.26	0
Benzo(a)pyrene	2.2	CIEH	<0.03	0.56	0
Indeno(123cd)pyrene	27	CIEH	<0.03	0.3	0
Dibenzo(ah)anthracene	0.24	CIEH	<0.03	0.09	0
Benzo(ghi)perylene	320	CIEH	<0.03	0.33	0

Notes:

- Thresholds based on 1.0% SOM

Asbestos testing was undertaken on samples of made ground. **Table 5.3** below summarises the findings:

Table 5.3 Summary of Soil Test Results Asbestos

Location	Depth (m)	Result
TP1	0.3	No Asbestos Detected
TP2	0.6	
TP3	0.2	
TP4	0.5	
TP5	0.3	
TP6	0.4	Small bundle of chrysotile fibres
TP7	0.2	No Asbestos Detected
TP8	0.6	
TP9	0.4	
TP10	0.2	
TP11	0.5	
TP12	0.3	

5.3 Leachate Assessment Methodology

Substances found to be present above their respective soil guideline value have been subject to leachate analysis.

Leachate test results have been compared to thresholds for inland freshwater environments (annual average) provided by the 2009 and 2015 UK Water Framework Directive (WFD).

Sulphate has been compared to BRE criteria for assessment in relation to construction concrete (see **Section 8.5**).

5.4 Leachate Test Results

The leachate test results are detailed in **Table 5.4.**

Table 5.4 Summary of Leachate Test Results

Substance	Threshold (ug/l)	Source	Measured Concentrations of Tested Substances (ug/l)	Number of Exceedences
			TP2 (0.3m)	
Lead	1.2	WFD	0.27	0

SECTION 6 Gas Monitoring

Three gas wells were installed to assess if there are any risks from ground gas/landfill gas on site, in BH1, BH2 and BH4.

One round of gas monitoring has been carried out to date.

Methane concentrations were found to be undetectable in all boreholes.

Carbon dioxide levels varied between being 0.4% to 6.7% V/V.

Oxygen concentrations varied between 9.6% and 19.9% V/V.

The gas flow rate from the boreholes was also assessed. No flow was recorded.

Based on the gas monitor flow rate detection limit of 0.1l/hr and the highest recorded carbon dioxide concentration of 6.7%, a gas screening value of 0.0067l/hr is calculated, as follows:

(6.7/100) x 0.1 = 0.0067l/hr

When this result is compared with Table 8.5 of CIRIA report C665, the site is classified as 'gas characteristic situation 1'.

No gas protection measures are required for 'gas characteristic situation 1' sites.

However, given that the maximum carbon dioxide level exceeds 5% it is considered that gas protection should be incorporated into the development in accordance with **'gas characteristic situation 2'.**

Table 8.6 of the above publication confirms that for residential gas characteristic 2 sites, the following precautions are required:

- For a reinforced concrete cast in-situ floor slab (suspended, non-suspended or raft) - at least 1200g DPM and underfloor venting. All joints taped and sealed.
- For a beam and block or pre-cast concrete floor - 2000g DPM/reinforced gas membrane and underfloor venting.
- All joints taped and sealed.

Once the full 6 monitoring visits have been made, this classification will be reviewed and if necessary amended.

The gas monitoring results are presented in **Annex G.**

SECTION 7 Quantitative Risk Assessment

7.1 Contaminants of Concern

7.1.1 Contaminants of Concern in Soil

Contaminants of concern are those that were found to exceed their residential threshold level.

Only lead and asbestos were identified as contaminants of concern. Lead was found to be present at a concentration of 470mg/kg in made ground in TP2 (0.6m), exceeding the residential threshold level of 200mg/kg.

Chrysotile asbestos fibres were identified in made ground in TP06 (0.4m). Fragments of asbestos containing material were also visually identified in this location.

Sulphate was exceeded in one sample when compared to BRE concrete DS1 thresholds. This does not present a risk to human health.

7.1.2 Leachable Contaminants of Concern

No leachable contaminants of concern were identified.

7.2 Potential Receptors and Pathways

7.2.1 Human Receptors

Contamination has been identified in made ground on site in the form of lead in TP2 and asbestos in TP6.

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.

Radon presents a possible risk to human health.

In-situ gas monitoring has identified from carbon dioxide.

7.2 2 Aquatic Environment

The aquatic environment is not considered to be at risk.

7.3 Mitigation and Remedial Measures

7.3.1 Human Health

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. This should include protection from asbestos fibres if working in made ground identified in TP6.

Upon development the area of TP2 and TP6 will be capped with the new road, which will act as a physical barrier between the made ground and human receptors.

No remedial measures are required for the any garden or landscaped areas adjacent to the new Phase 1 apartments.

7.3.1 Human Health (Continued)

Any 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.

Gas protection measures should be installed as described in **Section 6**.

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. Terra Firma (Wales) Ltd offer this service if required.

7.3.2 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.

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

SECTION 8 Engineering Recommendations

8.1 Preparation of Site

All areas of hardstanding should also be excavated out and removed.

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

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. Terra Firma (Wales) Ltd offer this service if required.

8.2 Foundation and Floor Slab Solution

Due to the presence of made ground and soft alluvial clays beneath the site traditional shallow foundations are not recommended. Such foundations will lead to high total and differential settlements.

A piled foundation is advised for the proposed apartment blocks. Precast concrete driven piles founded within the underlying weathered red mudstone and/or sandstone is recommended.

For a 275mm square precast concrete pile driven to an appropriate set within the underlying competent mudstone a safe working load of typically 500kN should be achieved. Based upon the site investigation data, pile lengths should vary between 20m and 22m beneath current ground levels.

The estimated working loads, pile type and lengths should be confirmed by a specialist piling contractor. It may be prudent to test drive piles at select locations.

For the quoted pile size, founded within the competent bedrock, total settlements should not exceed 10mm with differential movements between adjacent piles being less than half this value.

Allowances should be made for re-driving piles should buried obstructions be encountered.

Floor slabs should be designed as suspended.

Measurements should be kept on pile vibrations during driving. Measures should also be taken to dampen such vibrations. If, however, vibrations exceed permissible values then consideration should be given to using a contiguous flight auger (cfa)/bored pile solution.

8.2 Foundation and Floor Slab Solution (Continued)

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

8.3 Excavations and Formations

Shallow excavations will be possible with normal soil excavating machinery.

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.

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.

8.4 Protection of Buried Concrete

Levels of total sulphate within the in-situ materials measured between 400mg/kg to 2700mg/kg and the pH varied between 8.2 and 10.2.

As a whole all buried concrete should most likely as a minimum conform to Class AC-1 (Table C2 of BRE Digest 1:2005). However, should any concrete structures be placed in the area of TP11 then consideration should be given to Class AC-2.

8.5 Access Roads and Car Parking Areas

For car parking and road areas, formations within the in-situ soils a CBR value of 1-3% may be used for design purposes.

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

Please note that the Local Council / Highways Authority may require in-situ CBR testing to be undertaken before a road is adopted.