GEOTECHNICAL & GEO-ENVIRONMENTAL REPORT
PROPOSED DEVELOPMENT
SITE OFF FLORAL MILE,
HARE HATCH, READING

Prepared for:
GTO Engineering

July 2012

Job No: 11839

REPORT TITLE	**:**	**Geotechnical and Geo-environmental Report: Proposed Development, Site off Floral Mile, Hare Hatch, Reading**
REPORT STATUS	**:**	**Final**
JOB NUMBER	**:**	**11839**
DATE	**:**	**July 2012**
PREPARED BY	**:**	**……..** **(Mr D. Emanuel)**
REVIEWED BY	**:**	**……..** **(Mr M. Watkins)**
APPROVED BY	**:**	**……..** **(Dr G. C. Lake)**

REPORT TITLE	:	**Geotechnical and Geo-environmental Report: Proposed Care Home Development, Site off Floral Mile, Hare Hatch, Reading**
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Executive Summary

The current report was initially performed for Castleoak Care Developments. Reliance on this report has been transferred to GTO Engineering (DE 11/12/2014)

There is a proposal to develop the site off Floral Mile, Bath Road, Twyford.

Historically the site was undeveloped until c. 1930 when the site was developed for agricultural purposes. The site was visited in July 2012 and was seen to contain a large house in the east surrounded by gardens, and an active building yard located in the north of the site.

The Geological Map shows the site to be underlain by the Upper Chalk Formation (Undifferentiated). The site is located close to the receding margin of the Lambeth Group and the geological setting is conducive to solution feature formation. Records reveal that two solution features have been recorded within 1 km of the site.

The British Geological Survey confirms that no radon protection is required.

A ground investigation was performed in July 2012 comprising 8 Mini-Percussive Windowless Sampler Boreholes. A supplementary investigation was performed in July to assess the footprint of the building for solution features. Soakage tests were performed in selected boreholes and four gas wells were installed. Initial gas monitoring places the site in Gas Characteristic Situation (GCS) 1.

Chemical testing revealed that all determinants tested were at concentrations below the published Soil Guideline Values for a residential setting with plant uptake with the exception of a single incident of elevated lead and benzo(a)pyrene within made ground.

Beneath a mantle of made ground and natural superficial deposits chalk was encountered at between 1.20m and 2.15m depth. Chalk was typically Grade B4/C4/C5. Mass concrete strip foundations excavated into the structured chalk as graded above should perform satisfactorily with loads up to 200 kN/m^2.

The site investigation and additional probing near the corners of the proposed development did not encounter evidence of solution features.

Soakaways performed within the chalk recorded soil infiltration rates of 5.63 x 10^{-6} to 7.09 x 10^{-6} ms^{-1}. Permission to discharge should be sought from the Environment Agency.

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SECTION 1 Introduction and Proposed Development

Castle Oak Care Development are proposing to construct a Care Home on a site at Mabey Holding Limited, Floral Mile, Hare Hatch, Reading, RG10 9SQ.

Terra Firma (Wales) Limited has been commissioned to carry out a geo-technical and geo-environmental investigation of the above site.

The main objectives of the geo-environmental assessment programme were to:

- Identify the potential environmental liabilities at the site associated with any soil and groundwater contamination from past site uses.
- Provide a summary of the environmental conditions at the site, together with any necessary remediation works to render the site fit for its intended use.
- Provide recommendations with regard to any other geo-environmental aspects pertaining to the development such as radon gas emissions.

The main objectives of the geotechnical site investigation were to:

- Determine the type, strength and bearing characteristics of the shallow superficial deposits and underlying solid geology.
- Provide a Natural Cavity Risk Assessment
- Provide recommendations for a suitable and economic foundation/floor slab solution 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 determine the prevailing ground conditions and also to collect and analyse soil samples from selected locations around the site.

1.1 Limitations and Exceptions of Investigation

Castleoak Care Development have requested that a Geo-environmental Site Assessment (GSA) and Geo-technical Investigation (GI) be performed in order to determine if contamination is present beneath the site, the affect of radon gas, and to determine an appropriate foundation solution for the proposed development.

The GSA and GI were conducted and this report has been prepared for the sole internal reliance of Castleoak Care Development and their 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 geo-technical consultants. Terra Firma (Wales) Limited does not provide legal advice and the advice of lawyers may also 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 the presence of buried services and existing buildings and hard-standing on the site.

SECTION 2 Review of Existing Data

2.1 Physical Setting, Current Use and Site Conditions

The site locates on the northern side of Floral Mile, Hare Hatch, Reading at a National Grid Reference 479920, 177980, see **Figure 01**.

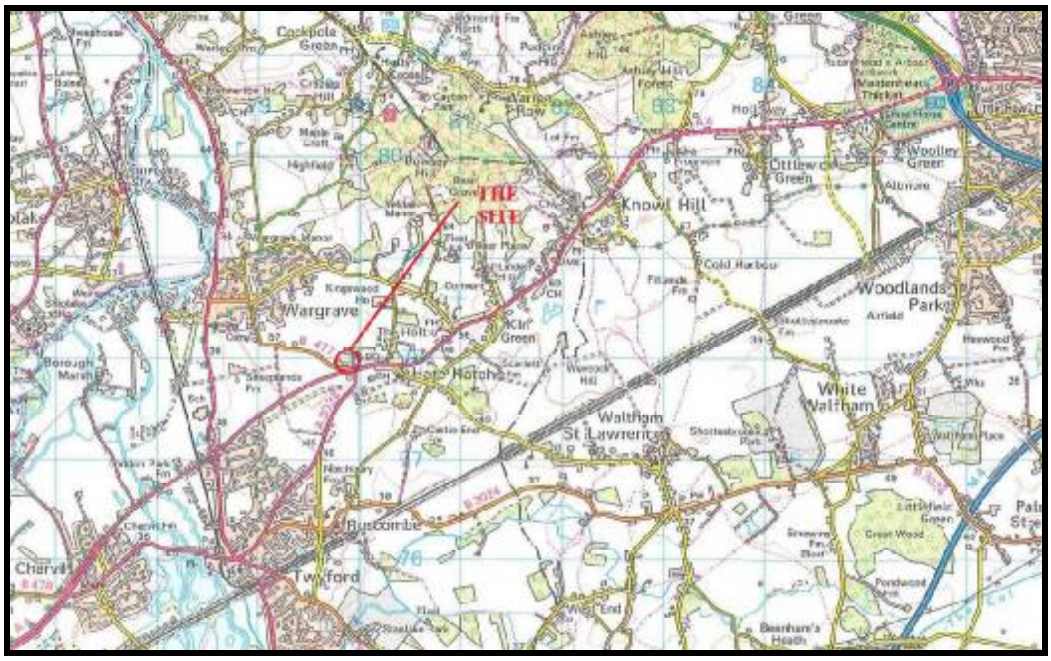


Figure 01. Site Location.

The site was visited on 3rd and 4th July 2012 by a Terra Firma Wales Ltd Engineer. The south of the site comprised a series of garden areas separated by hedge lines. A tennis court was also located in this area. In the east of the site stood Maybey House, a three storey masonry construction with surrounding hard standing.

A yard locates in the north of the site with a large metal shed located in the east of this site, another shed in the west of this area and a two storey masonry building in the centre. The site was used for storing sheet piles and trench props.

A series of small brick buildings was positioned in the west of the site on the north side of an open field. A road located to the south of the site. Agricultural land locates to the north of the site and a Garden Centre lies to the east of the site. Residential land locates to the west of the site.

2.2 Site History

Historical maps of the site have been obtained from the Landmark Information Group. These are supplied in **Annex A** with the most relevant history maps summarised below.

1872/1876 (Scale 1:2,500)
The 1872/1876 edition shows the site and its immediate surroundings to be undeveloped. A lane runs along the south side of the site, along the present day route of Mulberry Hill/A4 and A3032. A quarry locates approximately 180m south of the study site.

1882 (Scale 1:10,560)
The 1882 edition shows the study site to remain undeveloped. The site is surrounded by fields and the town of Hare Hatch is shown approximately 250m east of the site. A quarry is indicated approximately 180m south of the site and further quarries are indicated approximately 500m south and 1 km west-northwest of the site and 400m north of the site. A railway line passes approximately 1.3km southeast of the site.

1899 (Scale 1:2,500)
The 1899 edition shows the site to remain undeveloped. The northern boundary of the site is defined by a hedge-line/small woods. The quarry is still indicated 180m south of the site.

1900/1901 (Scale 1:10,560)
The 1900/1901 editions show the study site to remain undeveloped. A lime kiln is indicated in the quarry located near Wargrave, 1 km west-northwest of the site. A waterworks is identified approximately 700m north of the study site.

1912/1913 (Scale 1:10,560)
The 1912/1913 edition shows the study site and its immediate surroundings to remain undeveloped. As previously the northern boundary of the site is defined by a hedge-line/small woods.

1932/1933 (Scale 1:2,500)
The 1932/1933 edition shows the study site to contain green-houses and several other buildings of unspecified purpose. A house called Bycroft has been constructed immediately west of the site. The A4 has been constructed to the south of the site. The quarry located approximately 180m south of the site appears to have been partially backfilled with trees indicated in the east of the quarry.

1948/1949 (Scale 1:10,560)
The 1948/1949 edition (aerial photo) shows the study site to contain a series of large buildings, presumably green-houses. The photo shows a building to the west of the study site and a road to the south of the site. The site is otherwise surrounded by fields.

2.2 Site History (Continued)

1960 (Scale 1:10,000)
The 1960 edition shows the site to contain a series of large buildings including green-houses. The immediate surroundings are as previous editions. The land to the south of the quarry has been developed as orchard.

1968/1972 (Scale 1:2,500)
The 1968/1972 edition shows the site to contain a series of large greenhouses with several other buildings. The site is identified as The Floral Mile Nursery and Garden Centre. The centre continues to the east. A tank of unspecified content is identified in the northwest of the site. The land to the north of the site remains undeveloped. A building immediately south of the site is identified as a garage.

1975/1976 (Scale 1:10,000)
The 1975/1976 edition shows the site to contain a garden centre with greenhouses located within the site.

1987/1992 (Scale 1:2,500)
The 1987/1992 shows the site to contain a Tennis Court and Depot. The garage formerly located to the south of the site is identified as Festival House although its purpose is not disclosed.

1993 (Scale 1:2,500)
The 1993 edition shows the study site to contain a water tower in its north western corner. A depot and tennis court is shown as previously.

2006 and 2012 (Scale 1:10,000)
The 2006 and 2012 editions show the site to contain a depot. A garden centre locates immediately east of the site and buildings locate immediately south and west of the site. The land to the north of the site is undeveloped and a road junction locates to the south of the site.

2.3 Geology

A 1:50,000 Scale Geology Map (BGS Sheet 268, Solid and Drift Edition, 2000) shows the site to locate on rocks of the Upper Chalk Formation (Undifferentiated). Superficial cover is not indicated at the site. Given the sites known history areas of made ground are likely to be present.

There are records of solution features having been recorded 430m east and 980m northeast of the site. The site geology is shown to comprise the Upper Chalk Formation located close to the receding margin of the Lambeth Group. The site locates on the gently sloping valley on the east of the Thames. The site has a similar elevation to the known solution features. We would consider that the site locates within a setting prone to solution feature formation.

In view of the identified risk supplementary probing was performed after the initial site investigation. These are detailed within this report.

2.4 Hydrogeology

The Environment Agency website was consulted. The bedrock beneath the site is classified as a Principal Aquifer. A principal aquifer is defined as "Layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer".

The superficial deposits beneath the site are not classified on the EA plan.

The site is shown to locate on the boundary of Zone 2/Zone 3 of a Source Protection Zone for an abstraction located in Wargrave.

2.5 Hydrology

The nearest surface water features identified on the 1:10,000 Scale Historical Map Edition, provided by Landmark Information Group comprises a pond and drain located approximately 500m east of the site.

2.6 Radon

A radon report was purchased from the British Geological Survey. The report stated that **no** radon protection measures are required for a new development at the site. A copy of this report is presented in **Annex B**.

2.7 Envirocheck Report Data

An Envirocheck Report was purchased from Landmark Information Group. Key issues are detailed below;

2.7.1 Industrial Usage

During the site walkover the north of the site was seen to comprise a yard storing sheet-piling. A garden centre was located immediately east of the site.

The Envirocheck Report records Countrywide Store (Agricultural Merchants) trading 82m south of the site. Berkshire Garden Machinery are recorded as formerly trading 219m south of the site and an Awning Distributer is recorded as formerly trading 224m east of the site. Further trades are presented in the Envirocheck Report.

2.7.2 Landfill Records

The Envirocheck Report records one historical landfill within 1km of the study site. The landfill is referred to as 'Old Chalk Pit' located 191m south of the study site. The site is recorded as being active between 1980 and 1984 and authorised wastes included ash, excavated natural material, glass, hardcore and rubble, inert industrial waste, metal, minerals, paper/cardboard, plastic, polythene, textiles, rag, wool, cloth, hessian, wood and timber.

2.7.3 Flooding

The Environment Agency website reveals that the study site does not locate within an area affected by river flooding from 1% (1 in 100 year) and 0.1% (1 in 1000 year) events.

SECTION 3 Preliminary Risk Assessment

The following sub-sections detail a preliminary risk assessment, based upon the desk study information.

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**'. A pollutant linkage requires three essential elements:

(1) A **CONTAMINANT** (hazard) - a substance that is in, on or under the land and has the potential to cause harm or to cause pollution of **controlled waters**

(2) A **RECEPTOR** (target) - something which could be adversely affected by a contaminant

(3) A **PATHWAY** - a route or means which either allows the contaminant to cause significant harm to that receptor, or that there is a significant possibility of such harm being caused to the receptor, or that pollution of controlled waters is being or likely to be caused.

The term 'Risk' is widely used in different contexts and situations, but a prescriptive definition is given by the Guidelines for Environmental Risk Assessment and Management (DEFRA *et al*, 2000):

'Risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence'.

A 'Hazard' is defined as '*a property or situation that in particular circumstances could lead to harm'.*

The classification of consequences and probability and determining the risk category are defined in the following sections.

3.2 Classification of Consequence

Table 3.1 Classification of Consequence

Classification	Definition
Severe	• Short term (acute) risk to human health likely to result in significant harm • Short term risk to controlled waters • Catastrophic damage to buildings/structures • Short term risk to an ecosystem or organism within the particular ecosystem
Medium	• Chronic damage to human health (long term risk) • Pollution of a sensitive water resource • A significant change in an ecosystem or organism within the ecosystem
Mild	• Pollution of non-sensitive water resources • Significant damage to buildings/structures
Negligible	• Harm (not necessarily significant) which may result in financial loss • Non permanent health effects to humans (easily prevented by PPE for example) • Easily repairable effects of structural (building) damage

3.3 Classification of Probability

Table 3.2 Classification of Probability

Classification	Definition
High	• There is a complete pollution linkage and an event appears very likely to occur in the short term and is inevitable in the long term. • Evidence of harm to the receptor
Medium	• There is a complete pollution linkage which means that is it probable that an event will occur • The event is not inevitable but possible in short term and likely in the long term
Low	• There is a complete pollution linkage and circumstances are possible under which an event could occur • It is not certain that an event will occur in the long term, and it is less likely to occur in the short term
Negligible	• There is a complete pollution linkage but circumstances are such that it is improbable that an event would occur even in the long term

3.4 Risk Assessment Matrix

By comparing the consequences of a risk and the probability of the risk of a pollution linkage, the likely risk category can be determined as shown in **Table 3.3** below.

Table 3.3 Risk Assessment Matrix

Increasing acceptability →		Consequence			
		Severe	**Medium**	**Mild**	**Negligible**
Probability	**High**	High	High	Medium / Low	Near zero
	Medium	High	Medium	Low	Near zero
	Low	High / medium	Medium / Low	Low	Near zero
	Negligible	High / medium / Low	Medium / Low	Low	Near zero

High Risk
There is a high probability that severe harm could risk a receptor, or there is evidence that a receptor is being harmed. The risk if realised is likely to result in liability, and urgent investigation or remediation will be required.

Medium Risk
It is probable that harm will arise to a receptor. However it is relatively unlikely that such harm would be severe, or if harm does occur the harm is likely to be relatively mild. Investigation will be required to determine the liability, and some remedial works may be required in the long term.

Low Risk
It is possible that harm may arise to a receptor, but it is likely that the harm would be mild.

Near Zero Risk
There is a very low risk of harm to the receptor. In the event of harm being realised the harm is not likely to be severe.

3.5 Potential Sources of Contamination

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

Historical maps have revealed that the site has been used for agricultural purposes. A storage yard for sheet piles locates in the north of the site.

3.6 Potential Receptors

The potential receptors of any contamination and gas/vapours are considered to be:

During Construction

- Construction workers
- Neighbouring site users
- Passers-by
- The aquatic environment - Surface waters, perched groundwater within made ground and groundwater within the superficial deposits and secondary aquifers beneath the site.

Following Construction

- Site End Users - Residents and visitors
- Site End Users - Maintenance contractors
- The aquatic environment - Surface waters, ground waters
- Building Materials - Sulphates in the ground can damage building materials.

3.7 Potential Pollution Pathways

The following potential pollution pathways require consideration:

- Soil/soil dust ingestion
- Soil dust inhalation
- Dermal contact with soil/soil dust
- Vapour inhalation
- Inhalation of radon gas
- Permeation of drinking water pipes
- Migration of surface water into underlying soils and perched groundwater
- Leaching of contaminants from soil into perched groundwater
- Contaminant migration via groundwater transport
- Corrosion of building materials

3.8 Qualitative Preliminary Human Health and Environmental Risk Assessment

Ingestion of Soil/Soil Dust and Dermal Contact with Soils/Soil Dust

The construction workers are potentially at risk from ingestion, inhalation and dermal contact with soil/soil dust. The anticipated risk to construction workers is considered to be **medium**.

Neighbouring site users and passers-by are considered to be at **low** risk from ingestion and dermal contact with soil dust and at **low** risk of dermal contact or ingestion of soil.

Future Residents and visitors to the development are considered to be at **low** risk from ingestion of soil/soil dust following development.

Inhalation of Vapours

Neighbouring site users and passers-by are considered to be at **near zero** risk. Construction workers and site end users are considered to be at **low** risk.

3.8 Qualitative Preliminary Human Health and Environmental Risk Assessment (Continued)

Inhalation of Radon Gas

There is an **acceptable** risk to site end users from radon gas.

No radon protection measures are required at the site.

Ground Gas and Landfill Gas

Indoor migration of gas generated from degradation of organic/waste materials in fill presents a risk from inhalation and explosion.

The Envirocheck Report identified an historical landfill site located 191m south of the site.

Future residents/visitors of the development are considered to be at **low/medium** risk from gas ingress.

Ingestion of drinking water

Organic contaminants have the potential to be absorbed into plastic water pipes which may be used for drinking water supply. Toxic and corrosive contaminants may also enter the potable water source.

Contaminants entering potable water supply pipes therefore provide a direct pathway for human consumption. Future residents/visitors are considered to be at **low** risk.

Surface Water Run-off

Receptors such as adjacent sites are potentially at risk from surface runoff of water or materials during the site construction period. The risk is considered to be **low**.

There is also a **low** risk from accidental spillage of materials during construction earthmoving activities.

Leaching and Groundwater transport

Leaching of contaminants from the soil into the groundwater is a potential pathway into the aquatic environment. The local aquatic system is also at risk from the migration of dissolved contaminants through groundwater flow.

Given the sites history the risk is considered to be **low**.

Vegetation

Vegetation upon the site is potentially at risk from phytotoxic contaminants. Only landscaped areas are planned for the development, and this area of the site has low sensitivity. The risk is considered to be **low**.

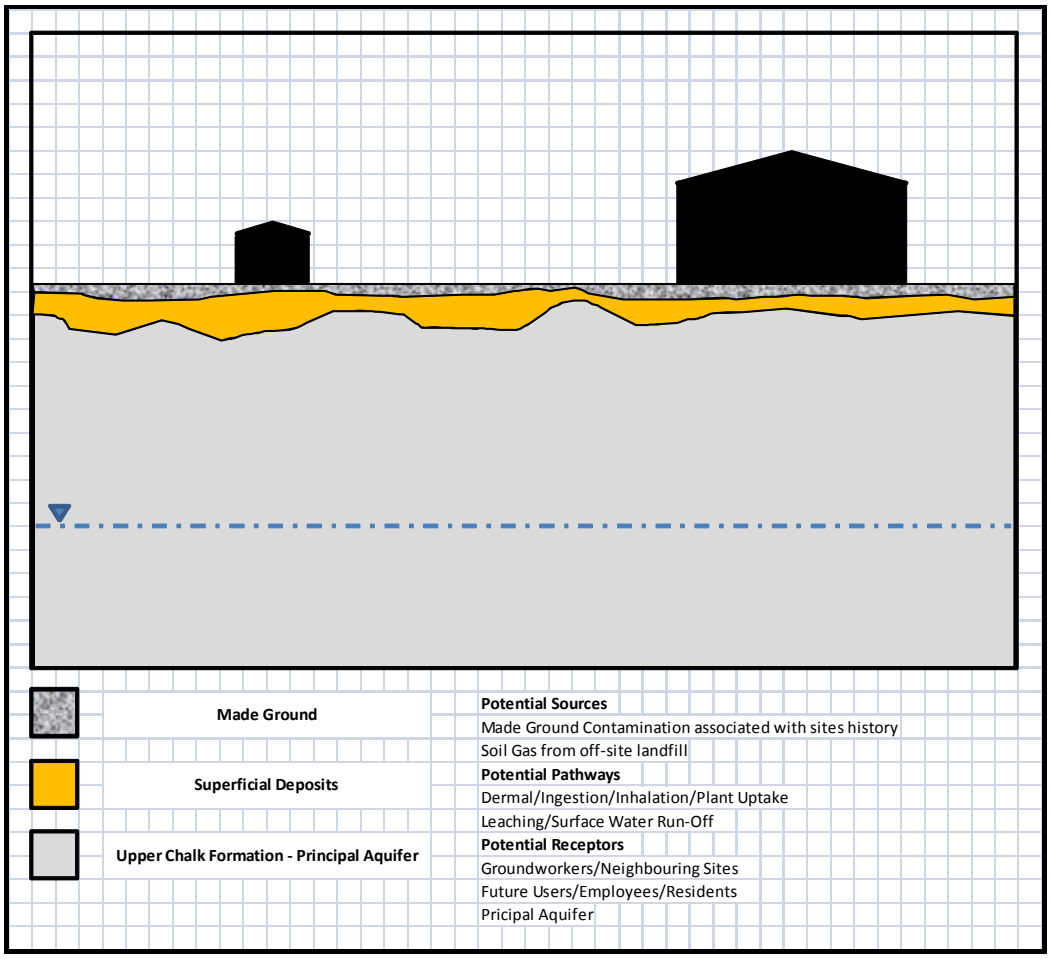
3.8 Qualitative Preliminary Human Health and Environmental Risk Assessment (Continued)

Building Materials

Building materials are potentially at risk from aggressive ground conditions involving sulphates. The risk is considered to be **low**.

3.9 Preliminary Site Conceptual Model

The results of the preliminary risk assessment are summarised in the preliminary Site Conceptual Model presented below;



SECTION 4 Field Investigation

4.1 Site Works

A geo-technical and geo-environmental site investigation was carried out by Terra Firma Wales Limited on the 3rd and 4th July 2012 comprising 8 No. Windowless Sampler Boreholes. Following a consideration of the solution feature risk at the site, supplementary probing was performed at the site on 24th July.

The boreholes and probes were performed using a Terrier Mini-Percussive Rig.

The fieldworks were supervised by Terra Firma (Wales) Limited and the boreholes were logged to the requirements of BS5930:1999. Chalk was logged in accordance in Ciria C574 when sample quality permitted.

The borehole logs are presented in **Annex C.** The additional probing is detailed in Annex H. The positions of the Boreholes (WS) and Probes (DP) are shown on **Figure 02.**

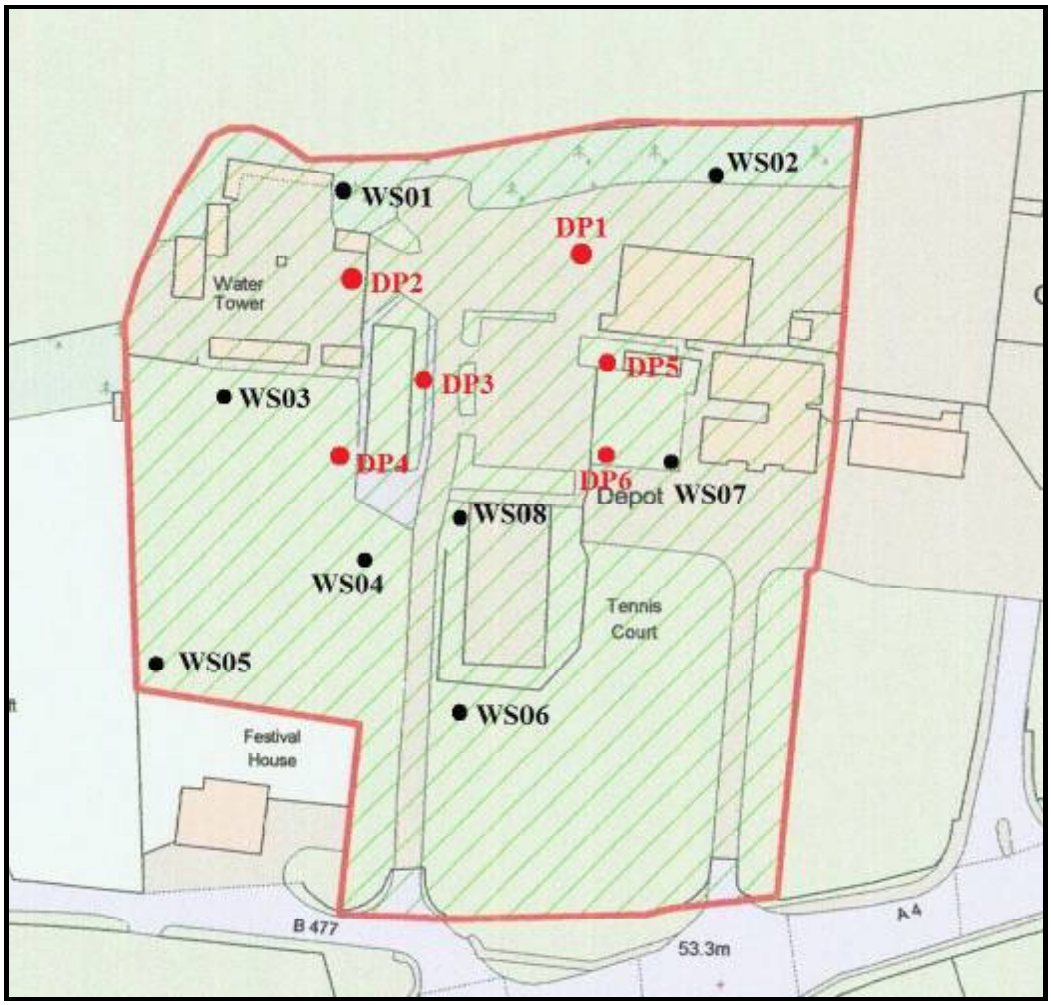


Figure 02. Site Layout and Borehole Locations

4.2 Ground Conditions

The ground conditions encountered can in general be summarised as shown in **Table 4.1.**

Table 4.1 Summary of Ground Conditions

Depth (m)	Thickness (m)	Stratum
GL - 0.00/0.90	0.00/0.90	**MADE GROUND:** Generally soft to firm, variably sandy, variably gravelly CLAY with inclusions of brick, chalk and flint.
GL/0.90 - 1.15/2.15	0.60/1.97	Typically firm to stiff, variably sandy and gravelly CLAY. Gravel comprises chalk and flint fragments.
1.55/2.15 - >4.00	>1.80	**UPPER CHALK FORMATION:** Typically Weak, medium density, Grade B4/C4/C5.

The two phases of investigation did not encounter evidence of solution features.

4.3 Water Strikes

Boreholes remained dry during drilling.

4.4 Laboratory Soil Chemical Testing

4.4.1 Exploratory Strategy and Sampling Regime

During the intrusive investigation, small disturbed soil samples were collected. The samples were collected from across the site to provide representative examples of the ground and chemical conditions.

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

Table 4.2 Sample Locations and Depths

Sample	Depth (m)	MCerts Sample Description
WS01	0.20m	Brown, slightly gravelly sandy CLAY with rootlets
WS02	0.50m	Dark white sandy CLAY
WS03	0.10m	Dark brown gravelly sandy CLAY
WS04	0.40m	Brown slightly gravelly sandy CLAY
WS05	0.40m	Brown gravelly sandy CLAY
WS06	0.30m	Dark brown sandy CLAY
WS07	0.20m	Dark brown sandy CLAY
WS08	0.10m	Brown gravelly sandy CLAY

4.4.2 Laboratory Analysis

Selected soil samples were despatched to the laboratories of Derwentside Environmental Testing Services Limited for laboratory chemical testing. The following soil chemical tests were undertaken:

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

Organic Chemicals

Phenols	Polyaromatic Hydrocarbons	
Petroleum Hydrocarbons	Pesticides	Soil VOCs

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

Soil gas monitoring was performed at the site following the site investigation.

SECTION 5 Soil Analytical Results

5.1 Methodology

Environmental risk assessment evaluates the risk to receptors via an analysis of the 'source-pathway-receptor' linkage. In order for a risk to be present, there must be a contaminant source capable of causing a health risk, a vulnerable receptor, and a pathway linking the two.

This sort of risk assessment is usually conducted using a tiered approach. Tier 1 consists of a comparison of the analytical results obtained from the site investigation with Soil Guideline Values (SGV's) specific to the type of development obtained from The Environment Agency Contaminated Land Exposure Assessment (CLEA) Guidelines.

Where SGV values are not available reference has been made to Generic Assessment Criteria (GAC) provided by Land Quality Management Limited (LQM) and the Chartered Institute of Environmental Health (CIEH). Groundwater samples have been assessed against data on the Environment Agency Environmental Quality Standards website.

At each tier, the amount and detail of investigation work increases as more site-specific data are needed to refine the characterisation of the site. Conversely, as site conditions are better understood, a more site-specific remediation strategy can be determined.

Should Tier 1 levels be exceeded, a choice is made either to remediate the site to conservative Tier 1 levels, or proceed to Tier 2. Tier 2 makes use of site-specific data to evaluate acceptable concentrations of chemicals for the particular conditions present at the site.

For Tier 1, the site itself is considered to be the receptor. Therefore, attenuation of contaminants between the source and receptor is not considered.

The proposed development is to comprise a residential care home. Therefore, the Soil Guideline Values for a residential setting with plant uptake have been employed.

A summary of the soil chemical test results which include the regulatory guidelines used in the Tier 1 assessment are given in the tables on the following pages.

5.2 Soil Test Results

Table 5.1 SUMMARY OF CHEMICAL TEST RESULTS SOILS – GENERAL DETERMINANTS

Substance	SGV/ GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		95% UCL	Number of exceedences
			Minimum	Maximum		
Arsenic	32	CLEA	12	23	17.906	0
Cadmium	10	CLEA	0.7	1.0	0.9629	0
Chromium III	-	CIEH	18	29	23.831	0
Chromium VI	130	CIEH	<1	<1	1	0
Copper	2330	CIEH	9.2	28	20.463	0
Lead	450	CLEA	14	630	265.57	1
Mercury	170	CLEA	<0.05	0.08	0.0642	0
Nickel	130	CLEA	17	39	32.576	0
Selenium	350	CLEA	<0.5	<0.5	0.5	0
Zinc	3750	CIEH	45	190	119.54	0
Cyanide	8	CLEA	<0.1	0.4	0.2086	0
Sulphate	2400	BRE	200	400	330	-
pH	-	-	8.1	8.9	8.7826	-
PAH	*	-	<1.6	16	*	-
Phenol	420	CLEA	<0.3	<0.3	0.3	0

Notes:

- CLEA - Soil Guideline Values for residential setting with plant uptake.
- CIEH - Generic Assessment Criteria for a residential setting, developed by Land Quality Management by the Chartered Institute of Environmental Health
- BRE - British Research Establishment (buried concrete risk assessment only, not human health related)
- A total of 8 samples were tested
- * See speciated PAH results.

5.2 Soil Test Results (Continued)

One sample exhibited detectable levels of Total PAH. This sample was thus subject to analysis for speciated PAH.

TABLE 5.2 SUMMARY OF CHEMICAL TEST RESULTS SOILS – POLYAROMATIC HYDROCARBONS

Substance	GAC (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)	95% UCL	Number of exceedences
Naphthalene	1.5	CIEH	<0.1		0
Acenaphthylene	170	CIEH	<0.1		0
Acenaphthene	210	CIEH	<0.1		0
Fluorene	160	CIEH	<0.1		0
Phenanthrene	92	CIEH	0.1		0
Anthracene	2300	CIEH	<0.1		0
Fluoranthene	260	CIEH	2.3		0
Pyrene	560	CIEH	2.4		0
Benzo(a)anthracene	3.1	CIEH	0.5		0
Chrysene	6	CIEH	0.3		0
Benzo(b)fluoranthene	5.6	CIEH	1.8		0
Benzo(k)fluoranthene	8.5	CIEH	0.8		0
Benzo(a)pyrene	0.83	CIEH	2.6		1
Dibenzo(ah)anthracene	0.76	CIEH	0.7		0
Benzo(ghi)perylene	44	CIEH	1.8		0
Indeno(123cd)pyrene	3.2	CIEH	2.1		0

Notes :

- 1 sample was tested for speciated PAH.
- Based upon 1% SOM
- CIEH – Chartered Institute of Environmental Health. Generic Assessment Criteria (GAC) for residential setting with plant uptake.

5.2 Soil Test Results (Continued)

TABLE 5.3 SUMMARY OF CHEMICAL TEST RESULTS SOILS - PETROLEUM HYDROCARBONS

Substance	LQM/SGV (mg/kg)	Source	Measured Concentrations of Tested Substances (mg/kg)		95% UCL	Number of exceedences
			Minimum	Maximum		
Aliphatic						
PH C5 – C6 Ali	30	CIEH	<0.01	<0.01	0.01	0
PH C6 – C8 Ali	73	CIEH	<0.01	<0.01	0.01	0
PH C8 – C10 Ali	19	CIEH	<0.01	<0.01	0.01	0
PH C10 – C12 Ali	93	CIEH	<1.5	<1.5	1.5	0
PH C12 – C16 Ali	740	CIEH	<1.2	<1.2	1.2	0
PH C16 – C21 Ali	45000**	CIEH	<1.5	<1.5	1.5	0
PH C21 – C35 Ali	45000**	CIEH	<3.4	<3.4	3.4	0
Aromatic						
PH C5 – C7 Arom	65	CIEH	<0.01	<0.01	0.01	0
PH C7 – C8 Arom	120	CIEH	<0.01	<0.01	0.01	0
PH C8 – C10 Arom	27	CIEH	<0.01	<0.01	0.01	0
PH C10 – C12 Arom	69	CIEH	<0.9	<0.9	0.9	0
PH C12 – C16 Arom	140	CIEH	<0.5	<0.5	0.5	0
PH C16 – C21 Arom	250	CIEH	<0.6	0.8	0.6551	0
PH C21 – C35 Arom	890	CIEH	<1.4	1.5	1.579	0

Notes :

- CIEH LQM – Chartered Institute of Environmental Health Land Quality Management Generic Assessment Criteria for Residential Setting with plant uptake.
- 8 samples were tested for Petroleum Hydrocarbons
- Ali - Aliphatic Hydrocarbon
- Arom - Aromatic Hydrocarbon
- CIEH LQM Based on 1% SOM

** - LQM for Ali C16 – 21 and C21 – C35 based on LQM for EC >16 - 35

5.2 Soil Test Results (Continued)

Four soil samples were subject to analysis for a suite comprising 39 common pesticides. The analysis did not detect any of the determinants above the detection limit of the analysis (<0.1 mg/kg).

Eight soil samples were subject to analysis for 52 Volatile Organic Compounds. The analysis did not detect any of the determinants tested above the detection limit of the analysis (0.01 mg/kg) with the exception of one incident of naphthalene being detected at 0.06 mg/kg in sample WS03 0.10m. This, however, is below the generic soil guideline value for this determinant in a domestic setting.

5.3 Contaminants of Concern in Soils

All substances tested were at concentrations below the corresponding guideline for a residential setting with plant uptake with the exception of one incident of elevated lead recorded in made ground at WS03 0.10m at a concentration of 630 mg/kg, against a guideline of 450 mg/kg and elevated benzo(a)pyrene in the same sample at a concentration of 2.6 mg/kg against a guideline of 0.83 mg/kg. Benzo(a)pyrene is not considered to pose a vapour risk on the basis of its Henrys' Law Constant.

During the construction phase ground workers will be in intimate contact with the ground. Likewise, future maintenance contractors engaged in groundwork's will also be in intimate contact with the ground. Precautions should, therefore, be taken by these groups.

If, during construction, soil are encountered which differ significantly from those described above the risk assessment should be re-evaluated.

5.4 Soil Gas Monitoring

During the site investigation four shallow gas monitoring wells were installed across the site. These were monitored on 25th July 2012. The results are summaries below and presented in **Annex E**.

Table 5.4. Summary of Soil Gas Monitoring

	Air Pressure (mB)	Flow (l/hr)	CH_4 (%)	CO_2 (%)	O_2 (%)	C0 (ppm)	H_2S (ppm)
Maximum	1011	0.0	0.0	1.1	20.2	0	0
Minimum	1011	0.0	0.0	0.0	19.1	0	0

Flow was not detected so Gas Screening Values were derived using the detection limit of the Gas Analyser (0.1 l/hr). Methane was not detected and the highest recorded concentration of Carbon Dioxide resulted in a GSV of 0.001%. In accordance with Table 8.5 of CIRIA C665 the site falls into Gas Characteristic Situation 1, requiring no specialist gas precautions.

Five further gas monitoring rounds are proposed at site. The above conclusions should be re-assessed on the basis of the results of the additional rounds.

SECTION 6 Quantitative Risk Assessment/Mitigation Measures

The following section presents a quantitative risk assessment and, where necessary, details mitigating measures required to deal with these risks.

6.1 Potential Receptors

During Construction

- Construction workers
- Neighbouring site users
- Passers-by
- The aquatic environment - Surface waters, perched groundwater, groundwater within the superficial deposits

Following Construction

- Site End Users - Employees and visitors
- Site End Users - Maintenance contractors
- The aquatic environment - Surface waters, perched groundwater, groundwater within the superficial deposits
- Building Materials - Sulphates in the ground can damage building materials.

6.2 Potential Contaminants

Chemical testing has revealed that all of the contaminants tested were present at concentrations below the corresponding human health guidelines for future site end users with the exception of one incident of elevated lead in WS03. In addition, ground workers will be in more intimate contact with the soil than future site users/visitors.

6.3 Potential Pathways

6.3.1 Ingestion of Soil/Soil Dust, Dermal Contact with Soil, Inhalation of Soil Dust

A single incident of elevated lead, in excess of the guideline for a residential setting with plant uptake, was recorded in WS03 0.10m depth.

We would recommend that the soils in the vicinity of the identified hotspot be screened by chemical testing during the earthworks phase to identify the extent of the affected soils. Provision should then be made for the off-site disposal of these soils. Alternatively these soils could be subject to leachate analysis and, if found to be suitable, could be reused on-site beneath hard-standing cover or other locations where the soils will not be exposed to the future site users.

Any materials to be removed from the site should be classified in accordance with Environment Agency Document WM2 and allocated a waste code in accordance with the European Waste Catalogue. Once removed from site, the contaminant source will no longer be present and the future site users will no longer be at risk.

During earth works dust suppression measures may be implemented if necessary. Ground work contractors should perform their own risk assessment.

6.3.2 Inhalation of Radon Gas

The British Geological Survey has concluded that no radon protection measures are required for a new build at the site.

6.3.3 Inhalation of Vapours

The algorithms used to derive the Human Health Guidelines consider the inhalation of vapours. All potentially volatile determinants tested were below the corresponding guideline.

In accordance with the criteria of CIRIA C682 benzo(a)pyrene is not considered to pose a vapour risk.

We would therefore consider there to be no vapour risk at the site based on the site observations and chemical test results.

6.3.4 Permeation of Drinking Water Pipes

For any new water pipes reference should be made to the UKWIR Report Ref No 10/WM/03/21 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites'.

If these guidelines are exceeded along the route of the proposed pipe, specialist pipe materials should be employed.

6.3.5 Surface Water Run-Off/Leaching Into the Groundwater/ Groundwater Transport

Total chemical analysis has revealed that the determinants tested are not present at excessive concentrations and we do not, therefore, consider there to be a significant risk to surface and groundwater.

6.4 Summary of Human Health Risks

A Quantitative Risk Assessment on the potential human health effects is detailed below:

Table 6.1 - Human Health Risk Assessment

Source	Pathway	Target	Risk Assessment	Mitigation Measures
Made Ground	Dermal contact with soil/dust. Inhalation and ingestion of soil/soil dust	Construction workers	**Negligible Risk with mitigation measures**	COSHH assessment and good level of PPE/ hygiene by site workers/ staff; dust suppression measures if required
Made Ground	Inhalation and ingestion of soil dust, dermal contact with dust	Neighbouring site occupants, Passers-by	**Negligible Risk with mitigation**	Dust suppression where necessary
Made Ground	Dermal contact with soil/dust. Inhalation and ingestion of soil/soil dust	Future site employees/ residents and visitors	**Acceptable Risk**	Soils exceeding guidelines should be disposed off site or reused beneath hard-standing cover.
Landfill	Inhalation of landfill gas Risk of explosion	Future site employees and customers	**No Risk**	Soil Gas Testing places the site in Gas Characteristic Situation 1.
Bedrock	Inhalation of radon gas	Future site employees and customers	**Acceptable Risk**	BGS conclude that no radon protection measures are required
Made Ground	Inhalation of vapours	Future site employees and customers	**No Risk**	Soil testing reveals concentrations of volatile compounds are below corresponding guideline values
Made Ground	Permeation of water pipes	Future site employees and customers	-	UKWIR Report Ref No 10/WM/03/21 should be consulted.

6.4 Summary of Human Health Risks (Continued)

During the ground works, the contractor should comply with all current Health and Safety regulations.

Any made ground or natural soils to be excavated and removed from the site should be disposed of at a suitable landfill facility. We recommend that the soil exhibiting elevated lead and benzo(a)pyrene (WS03, 0.1m) be set aside for off-site disposal following excavation and screening of the surrounding soils to delimit the extent. The surrounding soils should be tested to confirm which impacted soils have been removed.

To determine the waste classification of the materials i.e. non-hazardous, hazardous or special waste, Waste Classification in accordance with WM2 should be undertaken.

Alternatively, affected soils could be subject to leachate analysis and, if found to be acceptable, may be suitable for re-use on site beneath areas of hard standing.

If during the development materials are encountered that are significantly different to those encountered in the investigation, the occurrence should be reported to the Engineer and appropriate action taken prior to continuing with the works.

6.5 Summary of Risks to the Aquatic Environment

A Quantitative Risk Assessment on the potential effects to the aquatic environment is detailed in **Table 7.2.**

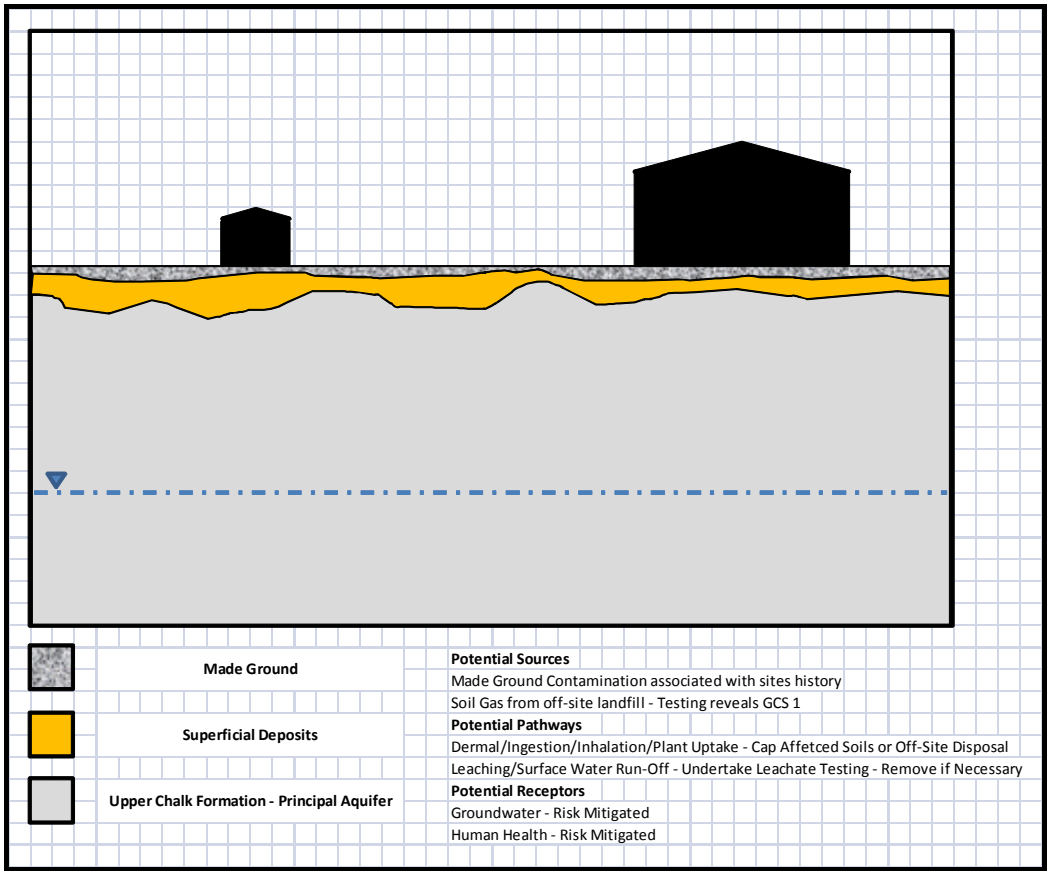
Table 6.2 Risks to the Aquatic Environment

Source	Pathway	Target	Risk Assessment	Mitigation Measures
Site Soils	Surface water run-off	Perched Groundwater	**Low Risk during construction**	Measures to avoid accidental spillage of materials, and to control surface run off. Contingency for accidental spillages
Site Soils	Leaching	Perched Groundwater	**Low Risk**	No significant contaminants identified. The area of elevated lead and B(a)P should be removed from site during excavation or leachate tested to determine if they are suitable to remain on site.
Site Soils	Downward migration of perched groundwater	Secondary B Aquifer underlain by Principal Aquifer		
Site Soils	Groundwater migration	Nearby Surface Waters		

Development of the site should reduce soil infiltration by reducing the area of exposed soils by the creation of hard standing cover and the importation of clean topsoil.

6.6 Site Conceptual Model

A site conceptual model is presented below. The model is schematic and not to scale.



SECTION 7 Engineering Recommendations

7.1 Preparation of Site

All surface vegetation and topsoil beneath the proposed development area, including all roots should be grubbed up and removed from site. The existing buildings will require demolition. It is beyond the scope of this report to undertake a hazardous materials assessment of the buildings at the site.

Prior to construction the existing hard-standing cover and former foundations should be excavated out. The material may be suitable for recycling by crushing. Likewise, the mounds of rubble/soil should be screened and processed for re-use as a recycled aggregate or classified for off-site disposal.

Any reduced levels should be brought up to the required levels with well compacted imported granular materials. Department of Transport (DoT) Type 2 sub-base, recycled granular aggregate or similar may be used and should be compacted in layers, in accordance with Series 600 of the Specification for Highway Works.

Allowances should be made for removing any 'soft spots/area' and their replacement with suitable, well compacted granular materials.

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

All materials to be removed from site should be taken to an appropriately licensed landfill facility. In accordance with EC Regulation 1272/2008 and Environment Agency Guidance WM2 (v. 2.3/2011) 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.

7.2 Foundation and Floor Slab Solution

Chalk was encountered between 1.55m and 2.15 m. The chalk typically comprised Grade B to C of low to predominantly medium density. CIRIA C574 (Part 7, 2002) describes the applied stress/settlement characteristics of chalk as comprising a zone of minor settlement followed by a significant increase in settlement per unit of applied stress above a yield stress q_y which should not be exceeded. With reference to Figure 7.4 of CIRIA 574 (applied stress/settlement ratios for low density chalk of Grades B, C and D) the majority of results lie within a stress envelope with an upper-bound Yield Modulus (E_y) of 26 MN/m^2 and a lower-bound E_y value of 19 MN/m^2. With reference to Figure 7.5 of CIRIA 574 CIRIA and Part 7.8.1. a lower bound yield stress for low density Grade B and C chalk of 240 kN/m^2 is recommended. Mass concrete strip foundations, extended into structured chalk should, therefore, perform satisfactorily with foundation loads up to 200 kN/m^2, at which intensity total settlement should not exceed 30mm.

Ground-bearing floor slabs should be feasible provided they are sat upon natural stiff clay or a bed of <600 mm of compacted granular fill. If made ground horizons greater than 600mm are unavoidable we would recommend suspended floor slabs.

The two phases of ground investigation did not encounter indications of solution features. However, we would suggest that during excavation the engineer on site remains vigilant for sudden changes in the elevation of the chalk surface and indications of voids or clay intrusions into the chalk. If any anomalies are encountered a geotechnical engineer should be consulted immediately.

Given the shallow water table measures should be taken to seal the basement to groundwater and the issue of buoyancy should also be considered during the basement design.

To avoid the influences of thermal damage the foundations should, as a minimum, extend to a minimum depth of 900mm below the final surface.

7.3 Excavations and Formations

Most of the shallow excavations should be possible with normal soil excavating machinery, although allowances should be made for breaking out buried obstructions such as former foundations.

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

The sub-formations/formations will 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. Allowances should be made for special precautions to prevent formation deterioration in addition to the above. Chalk is especially susceptible to deterioration during excavation and exposure.

It is recommended that approval be gained from a qualified engineer of the formation condition before covering them with any subsequent construction.

7.4 Protection of Buried Concrete

The laboratory soil chemical tests revealed total sulphate content below 200mg/kg to 400 mg/kg and pH values of between 8.1 and 8.9. Groundwater was not encountered within founding depth and is thus considered as static.

Based on the above it is recommended that all buried concrete should as a minimum conform to Class AC-1s, DS-1 of BRE Digest 1:2005.

7.5 Sustainable Urban Drainage

Borehole Soakage Tests were performed in duplicate in Window Sampler Boreholes WS03 and WS06. The tests were performed on partially sunk boreholes and boreholes were cased to provide a defined soakage surface. The tests were performed under the following conditions;

Table 7.1. Borehole Soakage Test Conditions

	WS03	WS06
Borehole Depth During Test (m)	2.0 (Borehole Partially Sunk)	3.0 (Borehole Partially Sunk)
Casing Depth (m)	2.0	2.0
Casing Diameter, D (m)	0.116	0.116
Intake Factor from BS:5930:1999 (2.75D)	0.319	0.319

The soakage rates were calculated in accordance with BS:5930, 1999. The testing calculated soil infiltration rates of between 5.63×10^{-6} ms^{-1} and 7.09×10^{-6} ms^{-1} for the chalk. We would recommend that the lower bound value be employed for design purposes.

The site locates within a Source Protection Zone and the Environment Agency should be consulted about the feasibility of discharging directly into this strata.

The Soak Test calculations are presented in **Annex F**.

7.6 Geotechnical Engineering

Bulk and dry density analysis was performed on chalk samples. The chalks dry density ranged from 1.42 Mg/m^3 to 1.62 Mg/m^3 (low to medium density in accordance with CIRIA C574).

Plasticity analysis revealed that the superficial clay deposits had a modified plasticity index of 13.6% to 19.8%.

Geotechnical Test Results are presented in **Annex G**.