FORMER HADDEN HALL HOTEL
BUXTON, DERBYSHIRE

CASTLEMEAD GROUP

GEO-ENVIRONMENTAL ASSESSMENT

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1.0 INTRODUCTION AND OBJECTIVES

The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by Castlemead Group Ltd (hereafter known as 'the Client'), to undertake a Geoenvironmental Investigation for a proposed care facility in Buxton, Derbyshire.

We understand that the scheme comprises the construction of a two storey 64 bedroom care home facility with associated areas of hardstanding, access roads and landscaping.

The assessment was conducted to obtain geotechnical and geo-environmental information with regard to the nature and thickness of the underlying strata in order to provide engineering data to assist in the design of the proposed development. Part of this assessment includes the formulation of an opinion as to the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use.

The contract was awarded on the basis of a competitive tender quote. The terms of reference for the assessment were provided by the Client within the agreed budget and are as laid down in the Earth Science Partnership proposal of the 23rd February 2012 (Ref: 4994e.lt1). The assessment involved a desk study of available historical Ordnance Survey maps, geological maps and memoirs, desk study information, a site reconnaissance walkover, supervision and direction of, trial pits, soakaway tests, geotechnical and geo-environmental laboratory sampling and testing, assessment and reporting.

This report represents the findings of the brief relating to the proposed end use as detailed in the text. The brief did not require an assessment of the implications for any other end use, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use be considered, the findings of the assessment should be re-examined relating to this use.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

2.0 DESK STUDY, WALKOVER SURVEY AND PRELIMINARY RISK ASSESSMENT

The information presented in this section comprises a Preliminary Risk Assessment which presents information obtained from desk based research that was used to inform decisions made in scoping the physical works.

2.1 Site Location and Description

The site is located on the site of the former Hadden Hall Hotel, London Road, Buxton. The National Grid Reference is SK061725 and a Site Location Plan is presented as Figure 1.

The site is roughly 'L Shaped' covering an area of 0.48Ha and is situated at an approximate elevation of approximately 320mAOD. The site is located to west of the River Wye and the general topography in the vicinity slopes towards the river. Additionally a small stream is noted approximately 200m to the south.

The site is bordered by:

- To the east: immediately by residential areas, associated with Buxton. The A6 (road) is located approximately 1km to the north east. The River Wye is located approximately 800m to the north east.
- To the south: immediately by residential areas associated with Buxton followed by the A515 (London Road) approximately 100m to the south.
- To the west: immediately by the A515 (London Road) followed by residential housing associated with Buxton.
- To the north: immediately by a Public House followed by a fuel filling station approximately 100m to the north. Beyond this residential areas are indicated and associated with Buxton.

At present the majority of the site is vacant, with the former Hadden Hall Hotel having been demolished and the demolition materials crushed. The arisings from this operation have been retained on site and form a stockpile bund around the west and south boundaries. Additionally some minor fly tipping is noted in the east portion of the site.

A concrete base is present in the north portion of the site and a caravan associated with the demolition works is also present in this area.

It is understood from anecdotal evidence that the former hotel had a large basement along the frontage of the building and also contained a swimming pool, although the exact locations are unknown.

2.2 Site History

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. Relevant extracts of the maps are presented in Appendix A. Relevant information from other sources, such as the Local Authority and the Sitecheck report, has also been incorporated, where appropriate.

Table 1: Review of Historical Plans

Date	On-Site	In Vicinity of Site
1879	A building is indicated in the west portion. The remainder is indicated to be vacant.	London Road is indicated at the west boundary, followed by woodland which extends to the west. Residential buildings associated with Buxton are indicated immediately to the north and extending northward to the main town of Buxton indicated approximately 800m to the north. Open ground is indicated to the south and east with an Old Limekiln indicated approximately 200m to the east. Old Limekilns and a quarry are indicated approximately 700m to the east, south and west. A stream is indicated approximately 200m to the south. The river Wye is indicated approximately 800m to the north east. A small feature indicated approximately 5m to the north west likely to be a pond.
1898	Buildings are now indicated in the east and are annotated as "Hadden Grove Hydro".	The Buxton and High Peak Line Railway is indicated approximately 600m to the east. A cemetery is indicated approximately 600m to the south east.
1922	Additional buildings are indicated and the site is now annotated as "Oliver's Hydro".	A quarry is indicated approximately 400m to the south. No other significant changes are indicated.
1938	No significant changes are indicated.	Residential buildings are now indicated to the east and south west of the site.
1954-1955	No significant changes are indicated.	No significant changes are indicated.
1967	The buildings on site are now annotated as "Electricity Hall". This is understood to be the offices of the local Electricity Board. No other significant changes are indicated.	The feature to the north west is now annotated as a "Pond". No other significant changes are indicated.
1973-1989	The buildings in the west of the site are annotated as "Hadden Hall Hotel". The buildings in the east are indicated to remain as an "Electricity Hall".	The pond to the north west is no longer indicated. No other significant changes are indicated.
1990 (Partial)	All buildings on site are now annotated as "Hadden Hall Hotel" and a small substation is indicated in the central portion.	No significant changes are indicated.
1993	The hotel on site is indicated to have been extended, occupying all of the central, west and south portions of the site. A separate building is indicated in the east portion.	No significant changes are indicated.
1996	No significant changes are indicated.	No significant changes are indicated.
1999-2011	No significant changes are indicated.	No significant changes are indicated.

Anecdotal evidence from local residents during site works indicates that the hotel that previously existed on site had a large basement and a swimming pool.

Additional research has indicated that Hadden Hall Hydro (Oliver's Hydro) was a natural spring water, hydrotherapy centre and positioned in the east portion. It is possible that this site use accounts for the anecdotal reference to a swimming pool. It is unknown if the pool was fed by natural spring water. The site was at one time used as the offices of the local Electricity Board, hence the references to 'Electricity Hall' on the historical maps.

2.3 Geology, Hydrology and Hydrogeology

2.3.1 Geology

The published geological map for the area of the site (1:50,000 scale, Sheet 111) indicates the site to be underlain by Bee Low Limestone (Lower Carboniferous) which are thickly bedded Limestone dipping north at an approximate angle of 12 degrees. The Limestone beds in the area are recorded on historical mapping and geological plans to have been quarried with Limekilns also identified in the surrounding area.

The Limestone bedrock can also be susceptible to the development of solution features in the horizontal and vertical direction as a result of rock solution and flushing of fine materials. This will have an impact on the design of potential drainage at the as sustainable drainage could potentially accelerate the development of solution features or exacerbate any already underlying features.

Immediately south of the site is a geological boundary with the Lower Miller's Dale Lava which comprises extrusive volcanic strata.

No superficial deposits are indicated on mapping for the site, however the bedrock is likely to contain weathered upper horizons. A cover of Made Ground is also expected due to the historical development of the site.

2.3.2 Hydrology

The nearest major surface water feature to the site is the River Wye approximately 800m to the north east. Additionally, a stream is recorded approximately 200m to the south and the surrounding area is also indicated to contain a number of small surface water features.

2.3.3 Hydrogeology

The Environment Agency have recently updated their aquifer classification system (Groundwater Protection Policy – April 2010) and have now separated all potential aquifers into three major groups, Principal Aquifers, Secondary Aquifers and Unproductive Strata, with Secondary Aquifers sub divided into an additional three groups. The new groups are described as follows:

Principal Aquifers (generally corresponding with previously classified "Major Aquifers") are described as "rock or drift deposits that have high intergranular and/or fracture permeability. They may support water supply and/or river base flow on a strategic scale.

Secondary Aquifers are split into three classifications:

- Secondary A (generally corresponding with previously classified "Minor Aquifers") – permeable layers capable of supporting water at a local rather than strategic scale and in some cases form an important base flow to rivers;
- Secondary B (generally corresponding with previously classified water bearing parts of "Non Aquifers") – lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.
- Secondary Undifferentiated – assigned where it has not been possible to categorise an aquifer in either Secondary Group A or B. In most cases this is attributable to a unit being classified as both minor and non-aquifers in different locations due to the variable characteristics of the rock type.

Unproductive Strata are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Review of the Environment Agency Aquifer maps indicates that the Carbonierfous Limestone comprises the main aquifer in the vicinity; classified by the Environment Agency as a Principal Aquifer. Groundwater movement will be controlled by fracture by intergranular and fracture flow.

Additionally the underlying aquifer is also designated as a Source Protection Zone 1 (SPZ1) this is the highest ranked SPZ and indicates the presence of groundwater of high vulnerability and is of strategic regional importance.

2.4 Contact with Regulatory Bodies & Local Information Sources

A request for information was made to South Derbyshire Council on the 13th April 2012. At the time of writing a response is yet to be received. Any pertinent information received will be forward under separate cover upon receipt.

2.5 Environmental Setting

The site exists in a historically rural and now an urban setting.

Table 2: Summary of Envirocheck Data

Item	On the Site	In the Immediate Vicinity
Discharge Consents	None recorded.	None recorded within 250m.
Pollution Incidents	None recorded.	None recorded within 250m.
Contemporary Trade Directory Entries	None recorded.	Eight recorded within approximately 250m of the site, comprising fuel filing station and local hospitals.
Water Abstractions/Protection Zones	Source protection zone – Underlying Principal Aquifer and Source Protection Zone.	
Landfill Sites & Waste Management Facilities	None recorded.	None recorded.
Recorded Mineral Sites	None recorded.	One recorded within 250m of the site – Ceased activity.
Fuel Filling Stations	None recorded.	One recorded 100m to the north.
Radon	The site is in an area affected by Radon and full Radon protection measures will be required.	

2.6 Anticipated Site Hazards

2.6.1 Flooding

From a review of topographical plans and data presented on the EA Website, the site is not indicated to be at risk from flooding from rivers, seas or reservoirs.

Evidence indicates that the site may contain a buried basement the construction of the basement is unknown. It is possible that groundwater may lead to flooding of these type of structures, particularly during high precipitation events or during periods of high groundwater levels.

2.6.2 Limestone Solution Features

The limestone bedrock underlying the site is susceptible to chemical weathering, producing solution cavities in both and horizontal and vertical direction. Such features can cause uncontrolled subsidence at the surface in the right conditions.

No evidence of solution features were observed during the walkover and reference to historical maps and aerial photographs has not identified any features that could be the surface expressions of solution features. In addition, Peter Brett Associates LLP was commissioned to undertake a Natural Cavities Database Search.

The report indicates that the nearest recorded natural cavities are as follows:

- 910m east north east – 1 Vadose Cave.
- 1100m west – 1 Vadose Cave.
- 1220m west north west – 1 Spring Outlet Cave.
- 1250m south west – 1 Vadose Cave.
- 1370m south – 1 Spring Outlet Cave.

The full report is included in Appendix C.

The report states that while no natural cavities are recorded on site, geological conditions at the site are such that it is possible that previously unrecorded gulls / fissures could be present and additional consideration may be needed in regard to this and to the positioning of any soakaway drainage.

2.6.3 Geomorphology

The existing topography and geomorphology at the site has evolved over a period of many, perhaps sixty to seventy millions of years under a number of different erosional regimes. However, the original geomorphology of the area has been altered by man's activities, in particular:

- The development of the site as a hotel and other buildings;
- The development of Buxton and surrounding areas;
- Local infrastructure comprising road and railways;
- Infrastructure associated with mineral extraction and processing;
- Karst landforms and Limestone Solution Features.

2.7 Previous Investigations and Assessments

We are not aware of any previous investigation works undertaken at the site.

2.8 Anticipated Site Contamination & Migration Pathways

The site has historically been developed and a range of contaminants relating to this use may be present such as a range of metals, semimetals and hydrocarbons.

A historic building has been identified as "Hadden Hall (Oliver's) Hydro and is anticipated to be hydrotherapy building.

A small electricity substation has been identified which presents the potential for contamination.

The site and surrounding areas are affected by Radon with 30% of homes at risk. Full Radon protection measures are required.

2.9 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified a number of potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

2.9.1 Introduction to Risk Evaluation Methodology

The methodology set out in CIRIA C552 (2001), *Contaminated Land Risk Assessment – A guide to Good Practice*, has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk. The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (defined below);
- The magnitude of the probability (likelihood) of risk occurring (defined below).

Classification of Consequence

Classification	Definition	Examples
Severe	• Short-term (acute) risk to human health likely to result in *Significant Harm*. • Short-term risk of pollution to a sensitive water resource. • Catastrophic damage to buildings/property. • Short-term risk to ecosystem, or organism forming part of that ecosystem.	• High concentrations of Cyanide at surface of informal recreation area. • Major spillage of contaminants from site into controlled water. • Explosion causing building collapse.
Medium	• Chronic damage to human health. • Pollution of sensitive water resource. • A significant change to ecosystem, or organism forming part of that ecosystem.	• Contaminant concentrations exceed assessment criteria. • Leaching of contaminants to Principal or Secondary aquifer. • Death of species within nature reserve.
Mild	• Pollution of non-sensitive water resources. • Significant damage to crops, buildings, structures. • Damage to sensitive buildings, structures or the environment.	• Pollution of Secondary Undifferentiated groundwater sources. • Damage to building rendering it unsafe to occupy.
Minor	• Harm, although not necessarily significant harm, which may result in financial loss, or expenditure to resolve. • Non permanent risks to human health (easily prevented by means of PPE). • Easily repairable effects of damage to buildings and structures.	• The presence of contaminants at such concentrations that PPE is required during site works. • The loss of plants in a landscaping scheme. • Discoloration of concrete.

Classification of Probability

Classification	Definition
High Likelihood	There is a pollutant linkage and an event that either appears very likely in the short term and almost inevitable over the longer term. Or, there is already evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the longer term.
Low Likelihood	There is a pollutant linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such an event would take place, and is less likely in the shorter term.
Unlikely	There is a pollutant linkage, but circumstances are such that it is improbable that an event would occur, even in the very long term.

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category.

Risk Categories – Comparison of consequence against probability

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability	**High Likelihood**	Very High Risk	High Risk	Moderate Risk	Moderate / Low Risk
	Likely	High Risk	Moderate Risk	Moderate / Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate / Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate / Low Risk	Low Risk	Very Low Risk	Very Low Risk

Description of Risk Categories

Classification	Description
Very High Risk	• There is a probability that severe harm could arise to a designated receptor from an identified hazard. Or, there is evidence that severe harm to a designated receptor is currently happening. • The risk, if realised, is likely to result in a substantial liability. • Urgent investigation (if not already undertaken) and remedial action are likely to be required.
High Risk	• Harm is likely to arise to a designated receptor from an identified hazard. • Realisation of the risk is likely to present a substantial liability. • Urgent investigation (if not already undertaken) is required, and remedial action may be necessary in the short term and are likely over the longer term.
Moderate Risk	• It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur, it is more likely that the harm would be mild. • Investigation (if not already undertaken) is normally required to clarify the risk and to determine potential liability. Some remedial action may be required in the longer term.
Low Risk	• It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very Low Risk	• There is a very low possibility that harm could arise at a receptor. In the event of such harm being realised, it is not likely to be severe.

The methodology described above has been used to establish Plausible Pollutant Linkages and to evaluate the risks posed by those linkages, using information known about the site, at this stage.

2.9.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 3: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL).

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
General Made Ground with potential contaminants. Substation identified on site. Potential presence for asbestos in crushed demolition materials.	Direct contact/ Inhalation/ Ingestion of contaminated soil or dusts.	Site users/visitors.	Medium – potential for chronic levels.	Likely – Evidence of contamination source	Moderate Risk	Discussed further in Section 6.
	Direct contact/ Inhalation/ Ingestion of contaminated soil or dusts.	Construction and Maintenance workers.	Medium – potential for chronic levels – may easily be prevented with PPE.	Likely – Evidence of contamination source	Moderate Risk	
	Leaching of soil contaminants.	Impact on Groundwater	Severe – Principal Aquifer.	Low likelihood – No evidence of contamination source	Moderate Risk	
	Leaching of soil contaminants.	Impact on surface waters	Medium – nearest major surface water feature is 800m to the north east. Minor stream 200m to the south.	Likely – Substation identified on site.	Moderate / Low Risk	
	Damage to building materials by aggressive ground.	Building/property	Mild – Owing to potential aggressive ground.	Likely.	Moderate / Low Risk	
Ground gas (methane / carbon dioxide) from Made Ground, demolition materials and risk from Radon.	Asphyxiation/poisoning. Injury due to explosion.	Site users/visitors.	Severe	Likely –Made Ground anticipated and in a Radon affected area.	High Risk	
	Damage through explosion.	Building/property	Severe			
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance workers.	Severe			

3.0 EXPLORATORY INVESTIGATION

3.1 Field Investigations

3.1.1 Trial Pits

7no. trial pits (TP1 to TP7) were excavated across the site on the 29th March 2012 using a wheeled, backacting, hydraulic excavator. The trial pits were excavated to a maximum depth of 3.3m. The tarmacadam surface was broken out prior to the excavation of the pits using a hydraulic breaker. Disturbed samples were collected from the trial pits for laboratory testing. The trial pit records are presented in Appendix D.

3.1.2 BRE Soakaway Testing

During the trial pit investigation, full size soakaway tests (in general accordance with BRE:365 – 2009) were undertaken within TP2 and TP3. The tests were undertaken in order to establish the infiltration capacity of the near surface ground conditions to allow potential use of soakaway drainage. The results of soakaway testing are presented in Appendix E.

The suitability of soakaway drainage has been further discussed in Section 7.0.

3.1.3 Asbestos Screening

At the request of the client, 6no. near surface were collected from the demolition stockpiles on site and scheduled for Asbestos screening to define the potential for the presence of asbestos fibres.

3.2 Evidence of Site Hazards Found During Site Works

3.2.1 Site Evidence of Contamination

During exploratory works, a large amount of demolition rubble is noted on the site however, no obvious sources of contamination were identified.

It is anticipated that the basement associated with the former Hadden Hall Hotel was identified in TP4 and TP7 and the basement is indicated to have been backfilled with demolition materials to a minimum proven depth of 3.3m. This basement feature is indicated to extend along the length of the former hotel frontage, adjacent to London Road. A cross section of this feature is presented in Appendix D.

The demolition materials were noted to contain, brick, concrete, glass, ceramic, metal, slate, carpet, wiring and pipework. We understand that this basement is to be excavated and replaced as part of the works, removing the volume of Made Ground.

The electrical substation identified on historical mapping is no longer indicated on site and is anticpated to have been removed as part of the demolition works.

3.2.2 Site Stability

Outside the footprint of the former hotel, bedrock was encountered at shallow depths with a limited cover of Made Ground. No obvious evidence for general instability was noted across the site, however, whilst undertaking TP4 and TP7 within the anticipated basement, heavy spalling of the Made Ground was noted below 1.5m.

3.3 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples recovered from the trial pits. The following tests were undertaken in accordance with BS1377:1990 and the results are presented in Appendix G:

- Natural moisture content.
- Atterberg limits.
- Soil and groundwater sulphate content.
- pH value.

3.4 Geoenvironmental Laboratory Testing

3.4.1 Soil Samples

In order to provide further information on the potential for contamination within the near surface soils, a suite of geo-environmental laboratory testing was undertaken on samples recovered from the exploratory holes. A strictly statistically valid regime was not implemented, however samples were tested from across the site to provide a general coverage of the site.

All testing was undertaken at an established testing laboratory with details of appropriate test accreditation including UKAS and MCERTS provided on the individual test certificates.

The suite of geo-environmental laboratory testing undertaken on 6no. samples is based on the guidelines provided in the Environment Agency CLR publications as part of the CLEA Model, and other contaminants typical on brownfield sites.

- Arsenic, cadmium, total chromium, chromium III, chromium VI, lead, mercury, nickel, selenium, Total cyanide, pH value, total polyaromatic hydrocarbons (PAH), B(a)P, phenols, Asbestos screen.

At the request of the client series of samples (6no.) were taken from the demolition materials in order to screen for potential asbestos contamination.

The results of geoenvironmental testing are presented in Appendix F.

4.0 DEVELOPMENT OF THE CONCEPTUAL MODEL

4.1 Geology

The main features of the geological environment are limited/no drift over a broad outcrop of Bee Low Limestone Formation. A cover of Made Ground is also present as a result of the historical development of the site. The following ground conditions were encountered in the exploratory holes:

Made Ground: Generally Made Ground was encountered to a maximum depth of 0.9m as a loose, dark red to brown, fine to coarse, sandy, cobbly gravel, comprising brick, concrete, slate, wood.

In the area of the anticipated historical basement (TP4 and TP7), Made Ground was encountered to a maximum depth of 3.3m as a dark red to brown, fine to coarse, sandy, cobbly gravel, comprising brick, concrete, glass, ceramic, metal, slate, carpet, wiring and pipework, carpet, insulation materials and plastic.

A concrete obstruction was identified within both TP4 and TP7 and halted progression of the trial pits, believed to be the floor of the historical basement.

Bee Low Limestone Formation: proven to a depth of 3m and encountered in TP1 to TP3 and TP5 to TP6. Bedrock was initially encountered as a firm, red brown, sandy Clay, GRADE V : Completely Weathered and the trial pits typically reached refusal in hard Limestone recovered as a GRADE II, slightly weathered rock.

Within TP5 the bedrock was recovered as a white, coarse Lime gravel which was generally difficult to excavate and halted progression of this trial pit.

As previously discussed, the Limestone bedrock can also be susceptible to the development of solution features in the horizontal and vertical direction as a result of rock solution and flushing of fine materials. This will have an impact on the design of potential drainage at the as sustainable drainage could potentially accelerate the development of solution features or exacerbate any already underlying features.

4.2 Hydrogeology

The main features of the hydrogeological environment are a Principal Aquifer overlain by limited unclassified drift deposits.

No groundwater was encountered in the investigation. However, for reasons of health and safety the trial pits needed to be backfilled on completion and it is possible that owing to the permeability of the soils, seepage may have resulted in the occurrence of shallow groundwater in time.

4.3 Geotechnical Stability

No major natural geotechnical hazards were identified during the site works. The site is generally flat with shallow bunds around the west and south boundaries.

Outside the footprint of the former hotel, bedrock was encountered at shallow depths with a limited cover of Made Ground and no obvious evidence for general instability was noted. Heavy spalling of the Made Ground was noted within the former basement due to loose highly variable demolition materials.

During the Desk Study phase and the preliminary fieldworks, no obvious evidence of Limestone Solution Features have been identified at the site. This aspect will require further consideration during the design and construction stage (See Section 7.0).

4.4 Soil Contamination

The long term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting Toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

Publication of additional SGV and TOX reports by the Environment Agency depends on factors including the availability of good scientific data, timely agreement on data interpretation, reaching cross government consensus and interaction with other on-going work with other national and international authorities. Further future reports are expected as part of the ongoing research and development by the Environment Agency.

The Chartered Institute of Environmental Health (CIEH) Generic Assessment Criteria for Human Health Risk Assessment have been used to supplement the CLEA SGVs where applicable in order to provide additional confidence in assessing the risk to human health at the site. The CIEH GAC's have been developed using the CLEA UK software for the standard land use scenarios outlined in the CLR documents with the exception of Allotments.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate guidance levels, determined by assessment of exposure frequency/duration and the *Critical Receptor*.

We understand that the scheme comprises the construction of a two storey care home facility with associated areas of hardstanding, access roads and landscaping.

The CLR SGVs for 'residential' are considered appropriate for this assessment and as summarised on the table below, the levels of the determinands were all below all the respective, stringent, guideline values. Additionally Asbestos has only been identified in 1no. sample as indicated below.

Table 4: Summary of Geoenvironmental Soil Results

Compound	Maximum Recorded	Guideline Value	Source of Guideline Value
Arsenic	12mg/kg	32mg/kg	CLR SGV
Cadmium	10mg/kg	10mg/kg	CLR SGV
Chromium III	47mg/kg	3,000mg/kg	LQM/CIEH
Hexavalent Chromium	<0.1mg/kg	4.3mg/kg	LQM/CIEH
Copper	67mg/kg	2330mg/kg	LQM/CIEH
Lead	290mg/kg	450mg/kg	CLR SGV
Mercury	0.29mg/kg	170mg/kg	CLR SGV
Nickel	70mg/kg	130mg/kg	CLR SGV
Selenium	0.8mg/kg	350mg/kg	CLR SGV
Phenol	110mg/kg	420mg/kg	CLR SGV
Polyaromatic Hydrocarbons (PAH)			
Acenaphthene	<0.1mg/kg	210mg/kg	CIEH GAC (Dependant on SOM %) Lowest Value Used Unless Stated Otherwise
Acenaphthylene	<0.1mg/kg	170mg/kg	
Anthracene	0.8mg/kg	2300mg/kg	
Benzo(a)anthracene	0.3mg/kg	3.1mg/kg	
Benzo(a)Pyrene	<0.1mg/kg	0.83mg/kg	
Benzo(b)Fluoranthene	<0.1mg/kg	5.6mg/kg	
Benzo(k)Fluoranthene	<0.1mg/kg	8.5mg/kg	
Benzo(g,h,i)perylene	<0.1mg/kg	44mg/kg	
Chrysene	0.6mg/kg	6.0mg/kg	
Dibenzo(a,h)anthracene	<0.1mg/kg	0.76mg/kg	
Fluoranthene	1.8mg/kg	260mg/kg	
Fluorene	<0.1mg/kg	160mg/kg	
Indeno(1,2,3-c,d)pyrene	<0.1mg/kg	3.2mg/kg	
Naphthalene	<0.1mg/kg	1.5mg/kg	
Phenanthrene	0.9mg/kg	92mg/kg	
Pyrene	1.4mg/kg	560mg/kg	
Occurrence of Asbestos			
No bulk fibres of Asbestos were noted within the samples collected from the trial pits including the infilled basement. Surface sampling from the demolition rubble has indicated Chrysotile Asbestos to be present in sample A2.			

4.5 Ground Gas

4.5.1 Degradation of Organic Materials

No monitoring for ground gas was undertaken as no potential gassing sources were identified by the desk study. During site works, Made Ground (proven to a minimum depth of 3.3m) has been recorded in the west portion and is indicative of an infilled basement. The fill comprised putrescible/potentially gassing materials.

It is therefore considered that there is a risk from combustible or noxious gas at the site. We understand that as part of the development this basement will be excavated and any organic or putrescible material will be removed from site, which will remove the ground gas risk associated with these materials.

4.5.2 Radon

The BRE Report BR211 (2007) classifies the risk from radon, based on the underlying geology. Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates where uranium and radium are naturally present in the bedrock and can move through fractures in the bedrock and overlying superficial deposits to collect in spaces in structures.

The site lies in an area identified by the BRE where it may be at risk from radon. Full Radon protection measures are required.

5.0 CONTAMINATION RISK EVALUATION & RELEVANT POLLUTANT LINKAGES

5.1 Discussion on Occurrence of Contamination and Distribution

Although Made Ground has been encountered across the site, no obvious visual or olfactory evidence for significant contamination was detected during the ground investigation. During construction works it may be necessary to confirm the lack of contaminants in the area of the former substation due to the potential for migrating contaminants.

Laboratory testing has recorded generally low contaminant levels across the site, with the levels of all determinands below the stringent CLR SGV guideline values for 'residential'.

Asbestos has been identified in the demolition stockpiles on site and is further discussed in Section 6.0.

5.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 2.0, the methodology set out in CIRIA C552 (2001), *Contaminated Land Risk Assessment – A guide to Good Practice*, has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Section 2.0) have been updated and revised following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 5: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL).

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
General Made Ground with potential contaminants. Substation identified on site. Potential presence for asbestos in crushed demolition materials.	Direct contact/ Inhalation/ Ingestion of contaminated soil or dusts.	Site users/visitors.	Medium – potential for chronic levels.	Likely – Evidence of contamination source	Moderate Risk	Risk posed by Asbestos recorded in demolition materials. Discussed further in Section 6.0..
	Direct contact/ Inhalation/ Ingestion of contaminated soil or dusts.	Construction and Maintenance workers.	Medium – potential for chronic levels – may easily be prevented with PPE.	Likely – Evidence of contamination source	Moderate Risk	
	Leaching of soil contaminants.	Impact on Groundwater	Severe – Principal Aquifer.	Unlikely – low levels identified. Former substation previously removed from site.	Moderate / Low Risk	Risk posed by historical substation may need to be confirmed during site development works.
	Leaching of soil contaminants.	Impact on surface waters	Medium – nearest surface water feature is 800m to the north east and a minor stream 200m to the south.		Moderate / Low Risk	
	Damage to building materials by aggressive ground.	Building/property	Mild – Owing to potential aggressive ground.	Likely.	Moderate / Low Risk	
Ground gas (methane / carbon dioxide) from Made Ground, demolition materials and Radon.	Asphyxiation/poisoning. Injury due to explosion.	Site users/visitors.	Severe	Unlikely – gassing sources identified, but are to be removed as part of site development works.	Moderate / Low Risk	Discussed further in Section 6.0. However, risk considered low due to excavation and replacement of demolition materials.
	Damage through explosion.	Building/property	Severe			
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance workers.	Severe			

6.0 REMEDIAL STRATEGY FOR CONTAMINATION RISKS

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a Geoenvironmental Specialist sought immediately.

6.1 Risks to Health

6.1.1 Site End Users

Low contaminant levels have been encountered with the levels of all determinands below the stringent CLR SGV guideline values for 'residential'. Assuming an end use of a care facility, the levels of contamination at the site are not considered to pose a risk to future site users. Therefore, no specific remedial measures are considered necessary. We do not consider a Tier Two site specific risk assessment is necessary.

Asbestos has been identified in the demolition stockpiles on site and this aspect will need to be addressed further to ensure, that the site development does not introduce this asbestos into the ground, posing a risk to site end users. This will require the attention of an appropriately qualified asbestos specialist.

6.1.2 New Service Connections

Previous guidance relating to appropriate materials for water supply pipework provided by WRAS No 9-04-03-October 2002 has been withdrawn and is superseded by UKWIR document No 10/WM/03/21. The new guidance does not appear to hold the same concern over heavy metals, with risks attributed to organic contaminants. Low levels of organic contaminants were confirmed at the site and there is no former potentially contaminative use, thus it is likely that plastic water supply pipework will be acceptable. However, it is emphasised that the final design and selection of the pipe and associated backfill should be agreed with the appropriate regulator, prior to installation.

6.1.3 Risk to Construction and Maintenance Workers

The levels of general contamination at the site are not considered to pose a risk to construction workers or future maintenance workers. However, asbestos has been identified in the demolition stockpiles on site and this aspect will need to be addressed further to ensure, that workers are not at risk during the site development. This will require the attention of an appropriately qualified asbestos specialist.

Notwithstanding the above, we recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation (Health and Safety Executive – 1991 – Protection of Workers and the General Public During the Development of Contaminated Land).

6.1.4 General Public

As identified in Table 5, any remnant fragments of Asbestos at the site will pose a serious human health risk and must be removed from the site by an appropriately qualified asbestos specialist, whose advice should be sought immediately.

Careful dust control measures should be adopted during construction to minimise the risk to the general public.

6.2 Risks to Controlled Waters

Whilst no formal assessment of groundwater conditions has been carried out, a preliminary assessment of the risk to controlled waters has been made as part of this investigation. In summary:

- The site is underlain by a Principal Aquifer and Source Protection Zone 1;
- The nearest major surface water feature is approximately 800m away from the site. A minor steam is present 200m to the south;
- There is no current or planned potentially contaminative activity on the site;
- No potential point sources (e.g. fuel tanks) identified during exploratory site works however a historic substation has been recorded on historical mapping;
- No groundwater was encountered during the exploratory works;
- Low levels of organic and inorganic contaminants indicated by laboratory testing with all determinands below published guideline values.
- The infilled basement is to be excavated as part of the works, removing the Made Ground from site.

Given the site history and the information to date it is anticipated that the site presents a moderate to low risk to controlled waters. Based on the potential for unrecorded contamination in the area of the small substation it is likely that during site development works, it will be necessary to confirm the ground conditions and potential for contamination in this area.

6.3 Risks from Ground Gas

6.3.1 Risk to the Development – Degradation of Organic Material

No monitoring for ground gas was undertaken as no potential gassing sources were identified by the desk study. During site works, Made Ground (proven to a minimum depth of 3.3m) has been recorded in the west portion and is indicative of an infilled basement. The fill comprised putrescible/potentially gassing materials.

It is therefore considered that there is a risk from combustible or noxious gas at the site. We understand that as part of the development this basement will be excavated and any organic or putrescible material is removed from site, which will remove the ground gas risk associated with his aspect. This will require confirmation by the Engineer or suitably qualified specialist.

6.3.2 Risk to the Development – Radon

The site lies in an area identified by the BRE as of at risk from radon and full protection measures are required at the site.

It is also anticipated that the full Radon protection measures required will also provide additional protection from the risk of other ground gases.

6.3.3 Risk to Construction and Maintenance Workers from Ground Gas

Based on the above results we do not consider that there is a particular risk to construction and maintenance workers, and there is no requirement to define shallow excavations as confined spaces. However, we recommend good site practice and all excavations should be considered potentially confined spaces.

6.4 Risks to Property

6.4.1 Knotweed

No evidence of Japanese Knotweed was identified on the site during the site works.

6.4.2 Sulphate Attack on Buried Concrete

Laboratory test results indicate the levels of soil sulphate (as SO_4) to be between 20mg/l and 2480mg/l with an average of 791mg/l. pH values between 7.07 and 10.0 were recorded indicating near neutral to alkaline conditions to exist.

Based on the above results, and assuming a mobile groundwater table, based on Table C2 we consider that the site is classified as Design Class DS-3 and ACEC Class AC-3 (BRE, 2005).

7.0 GEOTECHNICAL COMMENTS

7.1 Foundation Design and Construction

It is understood that the site is to be developed as a care facility comprising a two storey, 64 bedroom care facility with parking areas and an access road. The comments and recommendations in this report assume that the development will involve the construction of typical two storey of conventional load bearing brickwork construction.

We understand that the existing basement and any other buried structures/features will be removed prior to construction.

It is considered that on the basis of the available investigation information mass concrete strip or trench fill foundations could be used at the site. The foundations should be placed at a minimum depth of 1.3m, placed on the natural weathered Limestone rock. For foundation sizing purposes, an allowable bearing pressure of 250kN/m^2 is considered appropriate within the limestone rock. Considering the location of the site in a limestone terrain, foundations should be designed to span a minimum distance of 3m.

For all spread foundation options, formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. Should any soft, compressible or otherwise unsuitable materials (e.g. buried structures) be encountered they should be removed and replaced by lean mix concrete or suitable compacted granular material. A blinding layer of concrete should be placed after excavation and inspection in order to protect the formation against softening and disturbance.

Additionally, where the footprint of the new structure crosses the buried basement or any other buried structure, foundations will need to be extended into the natural limestone strata, and possibly stepped to achieve the required depths. The presence and condition of the underlying materials should be considered and approved by an appropriately qualified specialist. The basement void will need to be replaced with a suitable granular engineering fill, or alternatively, the near surface Made Ground to be excavated in this treatment would be substantially suitable for re-use as compacted materials, following crushing of concrete, the removal of unsuitable materials such as putrescible and contaminated materials and always provided they are placed at a suitable Moisture Content and in line with the appropriate earthworks and engineering standards. The approximate anticipated location of the basement is shown on Figure 2.

Additionally, anecdotal evidence suggests the hotel housed a swimming pool which may be part of the basement. During construction works, the location and extent of the basement and swimming pool should be confirmed and when identified the advice of a specialist should be sought.

Laboratory testing has indicated the cohesive soils present at shallow depth to be of intermediate plasticity and therefore of moderate shrinkage potential.

Based on the existing information a suitable alternative foundation option would be either a reinforced ground beam or raft foundation constructed on compacted fill. The existing ground should be excavated to a minimum of depth of the order of 1.0m below the proposed formation level of the main structural foundations. The excavation should be replaced with suitable granular material (e.g. Department of Transport Type 1 Sub Base or similar approved) and compacted in layers in a controlled manner to a suitable specification.

This ground improvement should be carried out over an area extending to a minimum of 1.0m outside the footprint of each foundation. Thickening of the foundations is likely to be required beneath the columns and any load bearing walls.

Based on our investigation it is considered that the near surface Made Ground to be excavated in this treatment would be substantially suitable for re-use as compacted materials, following crushing of concrete, the removal of unsuitable materials such as putrescible and contaminated materials and always provided they are placed at a suitable Moisture Content.

If this type of foundation is preferred, an allowable bearing pressure for this design would need to be confirmed by us following review of the foundation design.

7.2 Limestone Solution Features

Considering the location of the site in a limestone terrain, foundations should be designed to span a minimum distance of 3m.

Should any solution features or faults be encountered in foundation trenches the following treatment should be appropriate.

- Where faults cross a trench they can be treated by removing the soft clay and fragmented rock infill to a depth of 500mm below formation level and then backfilling with concrete or designing the foundation to span such areas.
- Solution features such as natural cavities, natural pipes or natural channels should be treated by lining with a geotextile fabric and filling with free draining compacted suitable material.
- Ponds should be treated by excavating any unsuitable material and replacing with free draining compacted suitable material.

These recommendations should be approved by a geotechnical engineer before the foundations are constructed. The above measures would only be practicable provided the size of the features does not exceed 3 square metres. If an individual feature does exceed 3 square metres in size, then the most economical option may be to reposition the structure. However, due to limitations within the site boundary, repositioning is likely to be unsuitable and bridging of any identified features may present the most suitable solution, which would need to be confirmed based on emerging ground conditions.

Care should be taken in the design and maintenance of the proposed development drainage system to limit the potential for the creation and propagation of solution within the limestone strata.

7.3 Floor Slab Foundations

Due to the presence of over 600mm of Made Ground at the site/soft compressible soils at the site, it is considered that ground bearing floor slabs would not be suitable, and floor slabs should be suspended. In areas where Made Ground or compressible sols are identified shallower than 600mm, ground bearing floor slabs could be utilised dependant on a review of the materials encountered and improvement of the near surface materials.

7.4 Site Preparation and Earthworks

7.4.1 Existing Foundations and Services

Some old foundations and underground structures (infilled basement) have been identified at the site. These foundations should be grubbed up as part of the site preparation works.

Based on service plans provided by the client, there are no known live services present within the vicinity of the site. A network of land drains is likely to be present and may provide a seepage path into excavations. The land drains should be diverted where they enter foundation excavations.

7.4.2 New Services

For new services, flexible pipework and connections should be provided for all new services as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

Considering the location of the site in a limestone terrain, foundations should be designed to span a minimum of 3m.

7.4.3 Earthworks

Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site. Any proposed changes to the topography should reviewed by a geotechnical engineer.

7.5 Pavement Design

We understand that vehicle access roads/hardstanding are proposed at the site.

California Bearing Ratio (CBR) tests have not been carried out at the site, but based on experience and published guidelines, a CBR value of <2% is considered appropriate for preliminary design purposes, for the near surface Made Ground and 2% to 5% in areas where shallow weathered bedrock has been identified. Actual design values should be determined for designated areas as required.

The final sub-grade should be inspected by a qualified engineer, and any soft or loose material removed and replaced as necessary, to ensure that the design CBR value is achieved. It is further recommended that the sub-grade be proof rolled with a suitable roller prior to the placement of the sub-base materials. In order to improve the sub-base performance the use of a suitable geogrid may be considered.

The near surface cohesive/granular soils are considered to be frost susceptible. A total construction thickness of 450mm non-frost susceptible pavement construction will be required to avoid frost heave.

7.6 Excavation and Dewatering

It should be noted that due to the presence of rock at relatively shallow depths, higher capacity machines may be required whilst the excavation of old foundations or buried structures will also require higher capacity machines for their removal.

It is likely that shoring/supports will be required in the areas of deep Made Ground due to the spalling recorded during the trial pit investigation.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations should be adequate.

7.7 Comments with Respect to Soakaway Drainage

Soakaway testing was undertaken within the weathered Bee Low Limestone Formation at the locations indicated on Figure 2.

The soakaway test results are presented in Appendix E. The calculations are based on the observed reduction in water level over the test interval are presented for both tests.

The soakaway tests were undertaken in at the locations of excavated trial pits, SA1 within TP2 and SA2 within TP3. Results of $1.5x10^{-4}$ m/s and $2.8x10^{-4}$ m/s were recorded. Test pit fillings were limited to one occasion only (over one working day) due to the availability of large water quantities and the Health and Safety aspects of leaving open pits unattended.

Care should be taken in the design and maintenance of the drainage system to limit the potential for the creation and propagation of solution within the limestone strata. Limestone bedrock can be susceptible to the development of solution features in the horizontal and vertical direction as a result of rock solution and flushing of fine materials. This will have an impact on the design of potential drainage at the as sustainable drainage could potentially accelerate the development of solution features or exacerbate any unknown underlying features.

Careful consideration and liaison with the local Building Control officer will need to be given to the placement of soakaways due to the potential for the production of solution features in the bedrock due to the input of drainage water.

Additionally sustainable drainage has traditionally been unacceptable in Limestone areas and particularly in Source Protection Zones. However, we have approached the Environment Agency for some initial guidance on the use of soakaway drainage in a Source Protection Zone 1. Initial advice suggests the following:

- Soakaway drainage will be acceptable for roof water drainage as long as a sealed system is used to prevent ingress from car parks, gullies etc;
- Drainage of gullies and hardstanding areas may be acceptable but will require careful design to include interceptors and filtration;
- Sewage, foul or untreated surface drainage will be unsuitable for soakaway drainage and cannot be granted permission;

The above aspects should be discussed and agreed with the local Environment Agency officer as part of the scheme design to agree suitability and possible locations.

8.0 CONCLUSIONS

Soakaway testing indicates variable infiltration values (of the order of 10^{-4} m/s) for the site. in principle, soakaway drainage is possible it will be necessary to liaise with both the local Building Control officer and the Environment Agency in order to ensure the soakaways are placed appropriately and pose no risk to the underlying Principal Aquifer and Source Protection Zone.

Asbestos has been identified within the stockpiled demolition rubble on the site. This aspect will need to be addressed by an appropriately qualified Asbestos specialist. It is likely that further works will include, additional asbestos screening and specialist screening and removal of Asbestos containing materials.

Based on the potential for unrecorded contamination in the area of the small substation it is likely that during site development works, it will be necessary to confirm the ground conditions and potential for contamination in this area.

9.0 REFERENCES

BRITISH GEOLOGICAL SURVEY & ENVIRONMENT AGENCY. 2000. The Physical Properties of Major and Minor Aquifers in England and Wales. BGS Technical Report WD/97/34. EA R&D Publication 8.

BRITISH STANDARDS INSTITUTION (BSI). 1990. Methods of Test for soils for civil engineering purposes. BS1377, Parts 1 to 9, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 1999. Code of Practice for Site Investigations. BS5930 Incorporating Amendment No.1, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2001. Investigation of Potentially Contaminated Sites – Code of Practice. BS10175, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2007. Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments. BS8485, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2004. Eurocode 7: Geotechnical Design – Part 1: General Rules. BS EN 1997-1:2004, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2007. Eurocode 7: Geotechnical Design – Part 2: Ground Investigation and Testing. BS EN 1997-2:2007, HMSO, London.

BUILDING RESEARCH ESTABLISHMENT (BRE). 1987. The influence of trees on house foundations in clay soils. BRE Digest 298. BRE, Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 1996. Desiccation in clay soils. BRE Digest 412. BRE, Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2007. Radon: Guidance on Protective Measures for New Dwellings. BR211. BRE, Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2005. Concrete in Aggressive Ground. Third Edition. Special Digest 1. BRE, Garston.

CONSTRUCTION INDUSTRY RESEARCH & INFORMATION ASSOCIATION (CIRIA). 2001. Contaminated Land Risk Assessment – A Guide to Good Practice. CIRIA 552.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (DEFRA) AND THE ENVIRONMENT AGENCY. 2002a. Assessment of Risks to Human Health from Land Contamination – an Overview of the Development of Soil Guideline Values and Related Research. R&D Publication CLR7.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (DEFRA) AND THE ENVIRONMENT AGENCY. 2002b. Potential Contaminants for the Assessment of Land. R&D Publication CLR8.

ENVIRONMENT AGENCY. 2010. Groundwater Protection Policy (Aquifer Classification).

HEALTH & SAFETY EXECUTIVE. 1991. Protection of Workers and the General Public During the Development of Contaminated Land. HMSO, London.

LAND QUALITY PRESS. 2007. Generic Assessment Criteria for Human Health Risk Assessment. Land Quality Management (LQM) and Chartered Institute for Environmental Health (CIEH).

STROUD, M.A.1975, The standard penetration test in insensitive clays and soft rocks, Proceedings of the European Symposium on Penetration Testing, 2, 367 –375.

TOMLINSON, MJ. 2001. Foundation Design and Construction (7th edition). Prentice Hall.

WATER REGULATIONS ADVISORY SCHEME, 2002. The Selection of Materials for Water Supply Pipes to be laid in Contaminated Land.