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Desk Study and Ground Investigation at Royal Victoria Hospital, Folkestone, Kent.

Final Report

Prepared by

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For

East Kent Hospitals NHS Trust

Hydrock Ref: R/07060/001

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EXECUTIVE SUMMARY AND CONCEPTUAL SITE MODEL

SITE INFORMATION & SETTING	**Client**	East Kent Hospitals NHS Trust.
	Site	Royal Victoria Hospital.
	Site Location	Royal Victoria Hospital, Radnor Park Avenue, Folkestone.
	Current Land Use & Description	The site is currently in partial use as a hospital. The site includes the main hospital building in the south of the site with associated car park, gardens and out-building in the middle of the site including: chapel; hall; mortuary; storage building and dilapidated tennis court. In the north there is an east west trending slope which was the former face of quarry workings in this area. The northern lower lying part of the site is unmade ground and is used unofficially as a pick up point/car park for the school to the north.
	Development	The proposed development is likely to comprise a mix of houses and apartments with buildings up to 5-6 storeys, along with associated infrastructure, gardens and public open spaces.
CONCEPTUAL SITE MODEL	**Geology**	The British Geological Survey 1:50,000 geological map of Folkestone and Dover A (Sheet 305 & 306) indicates the underlying geology to consist of Alluvium in the far north and the Cretaceous Lower Greensand Formation throughout.
	Hydrogeology	The Environment Agency indicates the Lower Greensand Formation to be a major aquifer. It is expected that the Lower Greensand Formation will be permeable with hydraulic continuity between itself and the stream in the north. The site is not within a source protection zone. There is 1 licensed groundwater abstraction 763m to the east.
	Hydrology	Pent stream is situated 4 meters to the north of the site and is flowing towards the east. Two ponds, noted as a boating pond and fishing pond, are situated to the east, 75m and 80m away respectively. There is 1 licensed surface water abstraction within 1000m of the site. It is 111m west and is abstracted from Pent Stream, however the location of this abstraction means there is no pathway for surface water flow from the site to the abstraction.
	Stability	There has previously been a quarry at the north of the site and the slope from the former face of the quarry is still present on site. If development is proposed in close proximity to the slope additional detailed slope stability assessments will be required.
	Historic Site Use	The site has been used as a hospital since 1898 and in the north of the site a quarry was present from prior to 1873 until 1937. There is a potential for elevated hydrocarbons, VOCs, SVOCs, PAH and metals to impact the soils, groundwater and surface water due to the sites past uses.
	Regulatory Enquiries	Nil to date.
	Ground Investigation	The ground investigation works undertaken by Hydrock in March 2007 comprised dynamic sample boreholes and pioneer type boreholes with 4 exploratory boreholes being fitted with standpipes for long term gas and groundwater monitoring. In situ testing included Standard Penetration Tests in 9 exploratory boreholes and falling head permeability tests in 4 exploratory boreholes. Geotechnical testing included: moisture contents; Atterberg tests; particle size distribution tests; and SD1 tests. Chemical testing comprised analysis of soils, waters and leachates. The ground investigation confirms that the site is in general accordance with the conceptual site model, with the Lower Greensand Formation located across the entire site however no alluvium was encountered in the north of the site. Made Ground is encountered throughout the site above the Lower Greensand and was encountered to depths of between 0.60m bgl and 3.65m bgl.

		An employee of the hospital estates department has indicated buried concrete from the retaining wall structure on the eastern site boundary is present at approx 3.50m bgl. This concrete was confirmed during the site investigation.	
	Plausible Pollution Linkages from Desk Study & Ground Investigation	The conceptual risk model is based on the source, pathway, receptor approach. Linkages for which the receptors are (re)development workers are excluded from the assessment and should be covered by method statements under the relevant health and safety legislation. The Plausible Pollutant Linkages on an un-remediated site determined by desk study and ground investigation works are summarised according to the contaminant sources and impacts to possible receptors (see Table 6.1 for the full pathways).	
		Source(s)	◄ potential Impact on ► Receptor(s)
		Free product or dissolved phase hydrocarbons.	Ground and surface water.
		TPH, PAH, VOCs, SVOCs metals and metalloids in the Made Ground.	Ground and surface water. Buildings. Plants. End users.
ASSESSMENT & CONSIDERATIONS	**Flooding**	The Environment Agency flood potential map of the area indicates the northern extent of the site to be partially within an area of Extreme Flooding from Rivers and Sea without Defences (Zone 2) as well as Flooding from Rivers and Sea without Defences (Zone 3).	
	Site Preparation, Earthworks & Landscaping	It is envisaged that removal of some or all existing site buildings will be undertaken along with removal of underground services ahead of development. Large tracked 360º type excavators and breaking equipment will be required to remove obstructions, buried concrete and former foundations. Excavations are likely to be unstable due to the nature of the Made Ground and natural sand. It is recommended that no personnel enter unsupported excavations and for deep excavations shoring should be considered. Groundwater was only encountered in the north of the site on the lower level of the site by Pent Stream therefore it is recommended that an allowance be made for dewatering of any excavations that are undertaken in this area of the site. There is a significant amount of concrete on the site and there may be unknown obstructions left on the site following demolition. Provision should be made for the breaking out and excavation of these as the need arises. If managed correctly with an appropriate demolition method statement, the demolition of the site will produce significant volumes of recycled aggregate (Type 1 and 6F2) and other higher value aggregates could be produced with additional spend on processing for which there would be a positive business case.	
	Mine Workings	There are no underground mine workings in the vicinity of the site; however there was open cast quarrying in the north of the site which have not been backfilled and the former face of the quarry is still present as a steep slope.	
	Foundations	Based on the findings of the current investigation, it is anticipated that two foundation solutions will be applicable for the site. • Shallow strip/trench fill foundations at a minimum depth of 0.90m bgl (low to medium volume change potential) within the natural sand and clay of the Lower Greensand Formation, with an allowable bearing pressure of 125kN/m^2. • Piles foundations where buildings are in excess of 3 stories high and in the area of deep Made Ground in the east, extending through the Made Ground and embedding in the clay, sand and sandstone bands. **Trench fill** Foundations will need to extend through the Made Ground and embedded at least 300mm into the clay or sand. Due to the presence of low to medium shrinkability clays near the surface foundations will require deepening due to the presence of existing or removed trees. Foundations will need to be deepened where the proposed planting of shrubs is indicated	

		within 3m of the face of foundations. Where foundations are within the influence of trees and deeper than 1.5m bgl, a suitable compressible material or void former will be required. This includes piled foundations, if used. Where foundations require deepening to greater than 2.5m below ground level, they will require design by an engineer in accordance with Technical Requirement R5. Foundations which span differing founding materials should have mesh reinforcement placed top and bottom of the foundation. **Piles** Based on the proven ground conditions, a number of piled solutions could be given consideration e.g. driven steel, driven concrete piles, Continuous Flight Auger (CFA) piles or Continuous Helical Displacement (CHD) piles. It should be noted that the presence of obstructions in the Made Ground and the presence of previous foundations may impact the installation of piles and a methodology for this will need to be accounted for in the design of piles.
	Floor Slabs	As plastic soils are present on site and Made Ground is present at depths greater than 0.60m bgl, it is recommended that suspended floor slabs are used, constructed in accordance with NHBC Standards. Ground-bearing slabs may be possible but a plot-by-plot investigation would be required to confirm the absence of desiccation.
	Roads	As construction will be predominantly from a Made Ground horizon a CBR value of <2% should be allowed for design purposes subject to confirmatory CBR testing and proof rolling.
	Soakaways & Drainage	Falling head permeability tests in accordance with BS5930 were conducted and the results ranged from 5.60 x 10^{-04} to 8.23 x 10^{-06}. Soakaways will be technically possible in the main section of the site but this should be re-assessed once the proposed development and proposed soakaways design has be finalised. However, due to the high groundwater table no soakaway are recommended for the former quarry area in the north of the site.
	Buried Concrete	Buried concrete classification is based on guidelines provided in BRE Special Digest 1, the Design Sulfate Class for the site is DS-1 and the Aggressive Chemical Environment for Concrete is AC-1s.
	Retaining Wall	The toe of the retaining wall along the eastern boundary extends beneath the site and was encountered in RA1 between 3.45m bgl to 3.65m bgl. It is recommended that no construction is undertaken within the influence of the retaining wall.
	Slope Stability	Slope stability works were beyond the scope of works for this commission. If any development is to be undertaken in close proximity to the slope on the northern boundary or the retaining wall on the eastern boundary additional works will be required.
	Unacceptable Geochemical Risks following Generic Risk Assessment	**human health:** • possible pervasive PAH concentrations have been recorded in the area of WS6 and WS7; • hotspot of TPH has been recorded above generic criterion in WS3 @ 0.40m bgl; and • hotspot of SVOCs has also been detected in WS3 @ 0.80m bgl. **controlled waters:** • Groundwater exceedances have been seen for lead when compared to the UK/EU drinking water standard and for lead and PAH when compared to the EQS freshwater standard, however Hydrock do not consider the site to present a risk to controlled waters. This will require confirmation by the Environment Agency.
	Construction Materials & Water Supply Pipework	The presence of concentrations of TPH in excess of the respective trigger values warrant the use of Protectaline or similar proprietary barrier pipework for all water supplies at the site. It is recommended that the Water Supply Company is consulted with the chemical results for the site. All building products used within the vicinity of WS3 should be able to resist the impact of hydrocarbons.

	Ground Gases	**Radon** The British Geological Survey report states that no radon protection is required for new dwellings at this location, in accordance with BR211, 1999. **Ground Gas** The ground gas readings and gas regime conceptual model derived from the current works indicate Characteristic Situation 1 and no special precautions are required. This will need to be confirmed with the NHBC and Building Control Officer.
	Contamination Remediation Strategy	A preferred remedial strategy for the site will have to be developed in consultation with the design team and the regulatory authorities. Liaison should be continued during implementation and subsequent validation. Remediation works are to be carried out under the supervision of a suitably qualified Environmental Engineer. With the information available from the current investigation the following approach is suggested. • Undertake additional works in the vicinity of WS6 and WS7 following demolition, in consultation with the regulatory authorities. • Implement risk control measures to reduce the identified risks to acceptable values. This will involve remediation of the site as detailed below. The most appropriate remediation option for the site depending upon the perceived risk of groundwater contamination is removal of the TPH and SVOC Hotspot (WS3) If PAH is found to be pervasive in the front of the site, installation of an imported clean cover system designed according to the BRE guidance (Hollingsworth 2004) for garden areas will be required. The design requires chemical analysis of the proposed cover material but, assuming the worst case example of the cover being at the generic criteria for PAH (BaP), a thickness of 600 mm would be required.
	Limitations & Uncertainties	The analytical results for PAH from WS6 @ 0.40m bgl and WS7 @ 0.40m bgl are extremely different from the remainder of the analytical results. Detailed examination of the borehole logs does not provide a possible cause for this elevated PAH. Hydrock have queried the elevated PAH with the laboratory and while the laboratory states there are no analytical concerns, Hydrock consider these results spurious. Additional works will be required in this area following demolition.
	Further Work	Further works required are: • Slope stability assessment will be required if any development is to be undertaken in close proximity to the slope on the northern boundary or the retaining wall on the eastern boundary. • Foundation design will need to be undertaken once the development layout has been finalised and additional works may be required to provide information on shallow founding conditions following demolition. • Additional works in the area where possibly spurious elevated PAH levels were recorded (WS6 and WS7) following demolition.

This Executive Summary forms part of Hydrock Consultants Limited report number R/07060/001 and should not be used as a separate document.

Hydrock Consultants Limited

1.0 INTRODUCTION

1.1 Terms of Reference

In March 2007, Hydrock Consultants Limited (Hydrock) was commissioned by Atisreal Limited on behalf of East Kent Hospitals NHS Trust (reference NGD/HRW/061608) to undertake a desk study and geo-environmental ground investigation at Royal Victoria Hospital, Radnor Park Avenue, Folkestone.

The site covers approximately 0.96 ha and is currently still partly in use as a hospital. Whilst Hydrock have not reviewed the proposed development it is proposed to comprise a mix of houses and apartments with buildings up to 5-6 storeys, along with associated infrastructure, gardens and public open spaces.

A site location plan (Drawing 07060/D001) is presented in Appendix A and a current site layout plan is presented in Appendix B.

1.2 Objectives

The objectives of this investigation are to assess the ground conditions to provide initial geotechnical design recommendations and to carry out a risk assessment of potential chemical contaminants to establish 'suitability of use' under the current planning regime.

1.3 Scope

The scope of work for this commission comprises:

- a desk study to determine the nature of the site and its surroundings including current and former land uses, geology, hydrogeology, hydrology, and geo-environmental data;
- an intrusive ground investigation including dynamic sampling boreholes, pioneer type boreholes, gas and water monitoring installations, chemical testing and geotechnical testing; and
- provision of a report detailing findings of the investigation, the risk assessment and recommendations for development.

This report details the findings of work carried out in March 2006. The report has been prepared by Hydrock Consultants Limited on the basis of available information received during the study period. Although every reasonable effort has been made to obtain all relevant information, all potential environmental constraints or liabilities associated with the site may not have been revealed.

The report has been prepared for the exclusive benefit of East Kent Hospitals NHS Trust and those parties designated by them for the purpose of providing geotechnical and

environmental recommendations for the site. The report contents should only be used in that context. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

Hydrock Consultants Limited has used reasonable skill, care and diligence in the design of the investigation of the site. The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes. At intermediate locations, conditions can only be inferred.

The work has been carried out in general accordance with recognised best practice as detailed in guidance documents such as in the CLR 11 Model Procedures (Environment Agency 2004), BS5930:1999 and BS10175:2001. Important aspects of the risk assessment process are transparency and justification. The rationale behind the assessments carried out for this report are given in Appendix H.

The chemical analyses reported were scheduled for the purposes of risk assessment with respect to human health, plant life, ecosystems and controlled waters as discussed in the report. Whilst the results may be useful in applying the Hazardous Waste Assessment Methodology given in Environment Agency Technical Guidance WM2, they are not primarily intended for that purpose and additional analysis may be required should waste classification be required for consideration of off-site disposal of contaminated soils. Separate analyses will be required to meet the Waste Acceptance Criteria for specific landfill sites.

The preliminary risk assessment process may identify potential risks to site demolition and redevelopment workers (see Table 3.2). However, consideration of occupational health and safety issues is beyond the scope of this report.

1.4 Report Structure

This report describes a two-staged investigation and assessment of the site. Throughout the report the term ‘geotechnical’ is used to describe aspects relating to the physical nature of the site (such as foundation requirements) and the term ‘geo-environmental’ is used to describe aspects relating to ground-related environmental issues (such as potential contamination). However, it should be appreciated that this is a composite investigation and these two main aspects are inter-related.

The **first stage** is the Phase 1 Investigation, comprising desk study and walk-over survey, and the Preliminary Risk Assessment. An outline conceptual model of the site is developed and from this are identified any geotechnical and geo-environmental hazards. The Hazard Identification evaluates all the **possible** pollution linkages in tabular form. Professional judgement is then used to evaluate which of these pollution linkages may be considered as **plausible**. Plausible pollution linkages are unacceptable risks in terms of the current contaminated land regime legal framework and require either remediation or further assessment. These are normally addressed via intrusive ground investigation.

The **second stage** is the Ground Investigation and Generic Risk Assessment. This represents the further assessment mentioned above. The Ground Investigation comprises

field work and laboratory testing based on the findings of the Phase 1 investigation, to reduce uncertainty in the geotechnical and geo-environmental hazard identification. Geotechnical data are gathered to provide design recommendations and chemical and physical data are gathered to generate inputs to the Generic Risk Assessment. The ground model and exposure model are refined and the plausible pollution linkages evaluated against generic criteria in line with the CLR 11 Model Procedures. Linkages which fail the generic assessment are unacceptable risks in terms of the current contaminated land regime legal framework and require either remediation or further assessment.

2.0 PHASE 1 INVESTIGATION

A number of desk study sources have been used to assemble the following information, including a Landmark Information Group Envirocheck report which has been obtained for the site (dated 9th March 2007) and is presented in Appendix D. The Envirocheck report is the result of searches of a number of regularly updated authoritative databases and is presented as a series of tables and accompanying maps. In particular, two site sensitivity maps showing items within 250m and 1000m, respectively, of the site boundary.

2.1 Site Referencing

The site is referenced in Table 2.1.

Table 2.1:Site Referencing Information

Item	Brief Description
Site name	Royal Victoria Hospital.
Site address	Radnor Park Avenue, Folkestone.
Site location	Folkestone.
Grid reference	622310, 136670.

A site location plan is provided in Appendix A (Drawing 07060/D001).

2.2 Site Description and Walkover

The description of the current site conditions is summarised in Table 2.2.

Table 2.2: Site Description

Item	Brief Description
Site access	Via Radnor Park Avenue.
Land area	Approximately 0.96 ha.
Elevation and topography	The ground slopes moderately to the north for much of the site from approximately 31.00m AOD to 20m AOD, with a steep slope towards Pent Stream in the far north of the site. A retaining wall with a significant drop in height is located on the eastern side of the site.
Site boundaries	Much of the east of the site is bound by a retaining wall with an approximate 3.50m drop on the other side. To the east and west of the main hospital building there was no defined site boundary and the site is connected with additional hospital buildings to the west and the estates department to the east. To the south the site boundary is Radnor Park Avenue, separated by a wall. In the north west, the site is bound with a chain link fence. The northern section of the site that is lower than the rest of the site and is bound by a small access road and beyond this is Pent Stream.
Geomorphic features	There is a steep slope in the north of the site which formed the face of a former quarry in this area. A drop in elevation of around 6 metres is noted from south to north. In addition there is a significant level change on the eastern boundary of the site associated with a retaining wall.

Present land use and existing structures, industrial processes etc.	The site is currently still partly used as a hospital with most of the southern half of the site being made up of the main hospital buildings. To the north east of the site there are a number of buildings including a Chapel and Wakefield Hall. The north west of the site is covered in grass and a dilapidated tennis court. In the far north of the site there is woodland and a change in level associated with a former quarry.
Services	There are a number of known services associated with the hospital building and out buildings. Each position was cleared by a service engineer prior to commencement of drilling. There is no service plans associated with these works.
Way leaves	None known to Hydrock.
Vegetation	There is woodland in the far north and much of the rest of the northern half of the site is covered in grass and occasional bushes. Around the main hospital buildings there are occasional bushes and shrubs.
Surrounding land	To the north of the site there is dense woodland, a river and beyond this there are school buildings. To the south there Radnor Park Avenue, with bushes and trees beyond, and beyond this is a park with a lawn bowls green. To the east there are residential houses and storage buildings for the estates department. To the west there are additional hospital buildings and two ponds beyond.

A walk-over reconnaissance survey was undertaken to confirm the findings of the desk study and assess visually any potential hazards and receptors. Photographs are presented in Appendix B and the main observations are summarised on the Site Zonation Plan in Appendix E.

The walkover has identified two possible sources of contamination present on site and one off site source that may impact the site. These include:

- an area towards the middle of the site identified as a storage room used to store supplies for the kitchen including cooking fats (on site);
- a building described as a store for cleaning products and other solvents towards the north of the site (on site) and is of particular interest due to its close proximity to the river to the north of the site; and
- an area just to the east of the site identified as a storage area for the estates department that had stored fuel in the past.

Please note that whilst the presence of asbestos or asbestos-containing materials were not identified during our walk-over survey, that survey does not constitute a formal asbestos survey and Hydrock does not have any duty of care to the duty holder in that regard. It is recommended that a Type 3 asbestos survey be undertaken.

2.3 Summary of Proposed Development

It is proposed that the development is likely to comprise a mix of houses and apartments with buildings up to 5-6 storeys, associated infrastructure, gardens and public open spaces.

2.4 Geology

The general geology of the site area is shown on the 1:50,000 geological map of Folkestone and in Table 2.3.

Table 2.3: Geology

Age	Stratigraphic Name		Description
Recent	Alluvium		Grey and dark grey thin interbedded deposits of clay, sand and flint gravel with occasional shell deposits.
Cretaceous	Folkestone Beds	Lower Greensand Formation	Sands and sandstone (varying from well-sorted fine-grained to poorly sorted medium- to coarse-grained with silts and clays in some intervals.
Cretaceous	Sandgate Beds		

2.5 Hydrogeology

2.5.1 Hydrogeological Conditions

From the above-mentioned geological units, it is likely that the hydrogeological conditions beneath the site are as follows. The hydraulic characteristics of individual units are summarised in Table 2.4. Information has been abstracted from Allen *et al* (1997), with respect to major aquifers.

Table 2.4: Hydraulic Characteristics of Strata

Stratum	Hydraulic Characteristics
Made Ground (Imported Fill)	Moderate to high porosity because of unconsolidated nature, but permeability likely to be constrained to low or low to moderate because of poor sorting and clay content.
Lower Greensand	Dominated by high permeability sands and sandstone which are interbedded with moderate to low permeability layers of clay with occasional gravel; overall, this unit is likely to be anisotropic in nature with horizontal permeability greater than vertical permeability (i.e. kh>kv).

2.5.2 Groundwater Vulnerability

The Environment Agency Groundwater Vulnerability Map and Regional Appendices, which make up part of the published Policy and Practice for the protection of groundwater, divide the underlying strata in England and Wales into major, minor and non aquifers, dependent upon their potential for potable water supply. The Environment Agency classification of the hydrogeology of the area is summarised in Table 2.5. An extract from the groundwater vulnerability map is given in the Envirocheck report (Appendix D).

Table 2.5: Groundwater Vulnerability

Stratum	Vulnerability Class
Lower Greensand	Major Aquifer

The Envirocheck report refers to the site as having soils of a high leaching potential (U). A worst case vulnerability classification (H) is assumed, until proved otherwise.

In addition, the Agency has defined Source Protection Zones (SPZs) for 2000 groundwater sources such as wells, boreholes and springs used for public drinking water supply. These zones show the risk of contamination from any activities that might cause pollution in the area. The closer the activity, the greater the risk. The maps show three main zones (inner, outer and total catchment).

The zones are used in conjunction with the Groundwater Protection Policy to set up pollution prevention measures in areas which are at a higher risk, and to monitor the activities of potential polluters nearby. The site is not within a source protection zone.

There is 1 licensed groundwater abstraction within 1000 m of the site which is 763m east and is described as being used for Machinery and Electronics: General Use (Medium Loss).

2.6 Hydrology

The surface water features in the vicinity of the site are listed in Table 2.6 and, where appropriate, are marked on the Site Zonation Plan in Appendix E.

Table 2.6: Surface Water Features

Feature	Location Relative to Site
Pent Stream	4m north
Boating pond	Approx 75m west
Fishing Pond	Approx 80m southwest

The Envirocheck report (Appendix D) contains an extract from the Environment Agency flood potential map of the area indicates the northern extent of the site to be partially within an area of Extreme Flooding from Rivers and Sea without Defences (Zone 2) as well as Flooding from Rivers and Sea without Defences (Zone 3).

There is 1 licensed surface water abstraction within 1000 m of the site. It is 111m west and is abstracted from Pent Stream and is described as being used for Municipal Grounds: Make up or top up water.

2.7 Site Stability

The Envirocheck report (Appendix D) lists incidences of mining hazards plus natural hazards resulting from cavities, compressible ground, dissolution of soluble strata, superficial structures, landslip and swelling clays. The report indicates the presence of moderate potential for shrinking or shallow clay ground stability hazards.

The Envirocheck report shows the presence of a quarry at the north of the site (Envirocheck historical map 1873, 1:2500) and the slope from the former face of the quarry is still present on site. If development is proposed in the areas close to the slope additional detailed slope stability assessments will be required.

2.8 Historical Land Use

A study of historical Ordnance Survey maps has been undertaken to identify any former potentially contaminative land uses at the site and surrounding areas. Extracts from the maps are provided in Appendix C. Information obtained from the maps and other sources is summarised in the Envirocheck report (Appendix D) Historical Land Use section in tabular form with an accompanying map.

The historical development of the site and its surroundings is summarised in Table 2.7.

Table 2.7: Historical Development from Map Information

Map Edition and Scale	Key Features on Site	Key Features off Site
1873: 1:2,500	The site is shown to lie within a field with the northern extent of the site being noted as a quarry.	A stream is shown just to the north of the site running from the west and meets another stream to the east of the site. This second stream runs from north to south. To the east of the site are Pavilion Gardens and a gravel pit and to the south east are numerous residential dwellings. To the south there are a number of brick fields, a brick pit, a brick and tile works, a gas works and a railway. To the north there is a cutting possibly from a quarry. The remaining north and east of the site is occupied by fields.
1877: 1:10,560	No significant changes have been made to the site.	No significant changes have been made to the surrounding areas.
1898: 1:2,500	The site now shows a building in the south, surrounded by gardens and is noted as Victoria Hospital. There is a building noted as a Mortuary in the north and a number of unnamed buildings in the quarry area in the far north of the site.	To the north there is a building noted as a Laundry, a football and cricket ground and the cutting noted in the 1873 map is noted as a Sand Pit. In the east and south the land has become increasingly residential with associated roads, and the gardens, gravel pit, brick fields, brick pits, and brick and tile works are now absent. A church is also present in the east. The gas works is still present in the south east. To the south east there is now a large park named Radnor Park with more residential houses to the west. To the east of the site there are two ponds separated by Radnor Park Avenue which runs along the bottom of the site. In the far north there are still fields present. The stream to the north of the site and the stream to the east of the site terminate at

Map Edition and Scale	Key Features on Site	Key Features off Site
		the new residential buildings but reappear as one stream again to the south east.
1899: 1:10,560	No significant changes have been made to the site.	A reservoir can be seen to the north of the Laundry and beyond this is a brick yard.
1907: 1:2,500	An additional building has been added to the east of the existing Victoria Hospital building.	Residential dwellings have appeared to the north east of the site.
1908: 1:10,560	No significant changes have been made to the site.	No significant changes have been made to the surrounding areas.
1937: 1:2,500	There is no mention of the northern most section of the site being a quarry and the building associated with this part of the site are absent. There have been more buildings added to the main hospital building to the north, east and west. A patch of land, later noted as a tennis court had appeared in the north east of the site with another building to the south of this.	To the north is a school and a beyond the Laundry are residential dwellings. There is now a small building within the north east corner of Radnor Park which is later described as a pavilion associated with lawn bowls. The sand pits to the north west are noted as absent.
1938: 1:10,560	No significant changes have been made to the site.	The surrounding land is getting continuously more built up with residential dwellings in the north east, south west and west.
1957: 1:1,250/ 1:2,500	The site is now named Royal Victoria Hospital. There are a number of additional buildings associated with the main hospital building as well as two separate building to the north one of which is a chapel. A number of trees are noted on the area that was previously noted as a quarry face. The area of the site to the north of this is noted as Allotment Gardens.	The laundry building to the north has now been replaced by a fire station. Beyond the houses to the north is Holywell County Secondary School for Girls. The school just to the north of the site is noted as Stella Maris R C School. The sand pits to the north west are now noted as cuttings.
1962: 1:10,560	No significant changes have been made to the site.	There are more residential buildings in the north east. The Brick Yard area is now noted as a factory and has an associated building.
1972: 1:1,250	The area in the far north of the site is no longer noted as being Allotment Gardens.	A school has appeared to the north of the site between Stella Maris R C School and the fire station and is noted as Parkfield Special School.
1975: 1:10,000	No significant changes have been made to the site.	The stream running just to the north of the site is noted as Pent Stream. There are more residential dwellings in the north and north west. The factory in the north has many additional buildings.
1978: 1:1,250	No significant changes have been made to the site.	The school beyond the fire station is now noted as Wyndgate Lower School.
1987: 1:1,250	No significant changes have been made to the site.	No significant changes have been made to the surrounding areas.
1992: 1:1,250	The building south of the tennis courts is now absent.	The main hospital building has been extended west up to the northernmost of the two ponds. The school beyond the fire station is now noted as The Channel High School Annexe.
1994: 1:10,000	No significant changes have been made to the site.	The factory buildings in the north have become more numerous and have extended west. Additional residential dwellings are noted in the north west.
1999: 1:10,000	No significant changes have been made to the site.	The factory buildings in the north have become more numerous.
2003: 1:10,000	No significant changes have been made to the site.	No significant changes have been made to the surrounding areas.

The long historical use as a hospital is likely to present the most significant contaminative risks to this site. Contamination issues are considered in more detail later in this report.

The use of the site as a quarry in its northern most part presents a geotechnical risk to future development due to the quarry face/slope left behind. Geotechnical issues are considered in more detail later in the report.

2.9 Present Industrial Land Uses

The site is still partially in use as a hospital. Within 250m of the site there are 8 Contemporary Trade Directory Entries. These include garage services that are both active and inactive all greater than 150m east and south east of the site. None of the other Contemporary Trade Directory Entries are active and are not considered to be a significant risk to the site.

2.10 Waste Management and Hazardous Substances

There is a Licensed Waste Management Facility 786m north of the site and a Registered Waste Transfer Site 817m north of the site. These are both still currently operational; however due to the distances from the site they are not considered to be a significant risk to the subject site.

2.11 Local Knowledge

Personnel from the estates department associated with the hospital indicated areas on-site and just off-site that may pose potential contamination risk. The on-site sources include an area near the middle of the site which stored materials for the hospital kitchens including cooking fats and an area in the north of the site which stored cleaning products and other solvents. The off-site source is an area just to the east of the site was noted as storing fuels up until very recently and could well have an impact on the site.

A section beyond the eastern boundary of the site is a lot lower than the site itself and as a result a retaining wall has been built to support the near vertical drop. Personnel from the estates department have indicated buried concrete approximately 3-4m into the site along the length of this retaining wall (toe of retaining wall).

2.12 Previous Evidence of Contamination

The Envirocheck report indicated 1 minor Pollution Incident to Controlled Waters present on site which refers to Crude Sewage in Pent Stream to the north. This is not considered to be significant as it is a one off incident and has not been repeated.

There are three other minor incidents noted off site. These are 101m south, 232m east and 325m east.

2.13 BGS Radon Report

Reference to the BRE 211 (Building Research Establishment 1999) indicates that no radon protection is required for new dwellings at this location.

2.14 Environmental Sensitivity

The sensitive land use map given in the Envirocheck report (Appendix D) indicates the site to be within a Nitrate Vulnerable Zone. In general, the site is within a built up setting with residential dwellings, commercial and industrial buildings and public open spaces (gardens and parks).

3.0 PRELIMINARY RISK ASSESSMENT

The findings of the Phase 1 investigation have been used to develop an outline conceptual ground model of the site and an outline exposure model of possible pollution linkages. The scope of the exposure model is intended primarily to identify potential impacts to human health and construction materials from on-site contaminants, in order to establish suitability of use for the proposed development in terms of the planning control framework. More generalised comments are included with respect to potential impacts to controlled waters and the wider ecosystem, where appropriate to the development. Risks to the development from flooding, landslip, former mine working etc. are also discussed, where applicable.

3.1 Outline Conceptual Site Model

The findings of the Phase 1 investigation indicate the site to be sloping to the north with a very steep slope down to Pent Stream in the far north of the site.

The geology is likely to consist of Made Ground above Cretaceous Lower Greensand Formation, and possible Alluvium in the far north of the site.

Groundwater is likely to be very close to the surface in the far north of the site due to the close proximity of Pent Stream, with deeper groundwater anticipated over the rest of the site. Due to the nature of the geology and the close proximity of Pent Stream the groundwater is likely to be in hydraulic continuity with Pent Stream.

The main details of the site and potential hazards are summarised on the Site Zonation Plan (Appendix E).

3.1.1 Geotechnical Hazard Identification

Potential geotechnical hazards have been assessed during the Phase 1 assessment and are summarised on the Site Zonation Plan (Appendix E) and in Table 3.1 on the following pages.

These form the basis of the ground investigation specified in Section 4.0, together with the gathering of general design parameters. Design recommendations are given in Section 7.0.

Table 3.1 Geotechnical hazard risk assessment

Hazard Description	Probability	Potential Impact	Assessed Risk	Actions required
Made Ground (Variable strength and compressibility)	High	Bearing capacity failure, excessive total/differential settlement, degradation, chemical attack.	High	Investigate fully, deepen foundations or improve ground/remove.
Soft ground (Low strength and high settlement potential)	High	Bearing capacity failure, settlement (total and differential) Floor slab failure, creep.	High	
Cavities (Previous mineral workings, backfilled ground, solution features)	High	Foundation/slab/road failure (now or later) differential settlement	High	
Slope instability (Existing)	High	Potential for future movements/collapse, serviceability issues, retaining walls, reduced bearing capacity/strength parameters	High	Investigate fully if buildings are in close proximity to slopes, stabilise/remove slopes.
Slope instability (Potential due to development)	High	Potential for future movements/collapse, serviceability issues	High	Investigate fully if buildings are in close proximity to slopes and ensure all slopes are safely designed.
Insufficient information on shallow ground conditions to provide adequate design information for shallow foundations.	Moderate	Foundation failure/excessive settlement	Moderate	Investigate the site fully laterally and vertically.
Insufficient information of deep ground conditions to provide adequate design information for deep foundations/excavations	Moderate	Foundation failure/excessive settlement	Moderate	
Potential for shallow groundwater/dewatering issues due to expected shallow groundwater in the north by Pent Stream.	High	Flooding of excavations/foundation failure, groundwater ingress into substructures.	High	Investigate site fully, install and monitor groundwater wells and ensure adequate on site pumping facilities if perched water is encountered during construction.
Potential for shrinkage swelling of clays.	Moderate	Excessive settlement or building distress	Moderate	Investigate site fully, conduct appropriate laboratory analysis.
Potential for impact on existing and adjacent structures/land	Negligible	Building damage, foundation failure	Negligible	No existing structures within influencing distance (all buildings on neighbouring site located away from site boundary).
Underground services	Moderate	Death of workers, loss of supplies to surrounding areas.	Moderate	Construction activities to be undertaken only when all services are traced and disconnected.

3.1.2 Geo-Environmental Hazard Identification

With reference to the Phase 1 investigation results reported above, Table 3.2 lists the possible contaminant sources, receptors and pathways identified, i.e. the possible pollution linkages. The plausibility of each of these linkages has been assessed by professional judgement and the justification for the decision recorded in the table. Linkages which are deemed plausible are labelled 'Y', those deemed implausible are labelled 'N' and where judgement is not clear-cut, the linkage is labelled 'Y/N' and, under the precautionary principle, must be considered as plausible in the first instance.

Table 3.2: Outline Exposure Model - Plausibility of Source-Pathway-Receptor Pollution Linkages from Desk Study

Source(s)	Possible Pathway(s)	Receptor(s)	Plausibility Y, N, Y/N	Justification
Inorganic chemicals				
Metals and metalloids, **Cyanide and Acids and bases** – In Made Ground.	Direct contact. Ingestion of soils. Inhalation of fugitive dust.	End users.	Y	The proposed redevelopment of the area is residential housing with gardens. The future land use increases the risk of contact with any elevated metals if present.
	Root uptake.	Existing planting.	Y	
	Root uptake (plants). Direct contact (plants & animals). Ingestion of soils and water (animals). Transport in surface water drainage.	Terrestrial Ecosystem.	Y	
	Run-off and infiltration through geology from contaminated soils.	Surface water and aquatic ecosystem.	Y	The stream in the north could be of risk from run-off from contaminated soils.
	Infiltration.	Groundwater.	Y	The Lower Greensand Formation is likely to be permeable. The Lower Greensand Formation is a major aquifer, so the risk of infiltration of contamination needs to be considered.
	Direct contact.	Buried concrete and services.	Y	There is no direct evidence of past use of acids / bases but the past uses of the site indicate these may be present.
Sulfates – In Made Ground or Natural Soils.	Direct contact with dissolved sulfates.	Buried concrete.	Y	Sulfates may be present. Standard concrete mix designs are available to counter deleterious effects. May also exist naturally in natural clays.

Organic Chemicals				
Volatile and semi volatile organic compounds (VOC & SVOC) – existing fuel tanks and previous chemical usage on and off site. **Petroleum hydrocarbons** – fuel, lubricants, hydraulic fluids, heating oil tanks and kilns. **Polynuclear aromatic hydrocarbons (PAH)** – from used engine oil, creosote and fires on site. **Phenols** – from burning tyres.	Direct contact. Ingestion of soils. Inhalation of fugitive dust and indoor and outdoor vapours. Ingestion of tainted water from compromised buried water pipes (end users).	End users.	Y	Observations of current practices include storage of cleaning products and other solvents, cooking fats and other kitchen waste as well as hydrocarbons storage just off site.
	Direct contact. Ingestion of soils and water. Transport in surface water drainage.	Terrestrial ecosystem (animal life the critical receptor).	Y	
	Run-off or seepage of free phase and dissolved phase from contaminated soils.	Surface water and aquatic ecosystem.	Y	The stream to the north could be at risk from run-off from contaminated soils.
	Infiltration of free phase and dissolved phase from contaminated soils.	Groundwater.	Y	The Lower Greensand Formation is likely to be permeable. The Lower Greensand Formation is a major aquifer, so the risk of infiltration of contamination needs to be considered.
	Direct contact with free phase or dissolved phase.	Buried services.	Y/N	Hydrocarbons are stored just off site and leaks or spills can not be ruled out .
Other substances				
Asbestos fibres – from asbestos cement products used in old buildings and as insulation in buildings.	Inhalation of fugitive dust.	End users. Neighbours.	Y	There are possibly asbestos containing materials present on site within the building fabric. It is recommended that a full asbestos survey is undertaken prior to demolition.
Ground gases	Migration through soils or groundwater to indoor air.	End users of new buildings.	Y	There are 2 registered landfill sites within 1000m of the site 786m and 817m to the north.
Radon	Migration through soils or groundwater to indoor air.	End users of new buildings.	N	BGS radon report indicates no precautions required.

3.2 Future Considerations

The findings of the risk assessments presented in Table 3.1 and Table 3.2 have allowed key issues at the site to be identified.

The issues raised will need to addressed, either by additional investigation and assessment works or by accommodating the risks within the design of the development. In most cases it is not possible to overcome all risk solely through design as the uncertainties that apply render any design based solution uneconomic. Therefore additional Site Investigation work should be undertaken to better quantify the risks present and to allow appropriate and economic design solutions to be formulated.

The plausible pollution linkages in Table 3.2 are defined as unacceptable risks in line with guidelines published in CLR 11. These require further consideration, either in the further tiers of risk assessment against generic or site-specific criteria, or by proceeding directly to some form of risk management strategy (including possible remedial actions).

The geotechnical risks that have been identified, which require further investigation are summarised below:

- density of the sands;
- soft compressible ground;
- stability of the existing slope to the north of the site; and
- retaining wall along the eastern boundary of the site.

The geo-environmental risks that have been identified, which require further investigation are summarised below:

- potential imported Made Ground;
- area where cleaning products and other solvents have been stored in the north west of the site;
- area towards centre of site used to store cooking fats and kitchen waste; and
- former area of fuel storage just off site to the east.

These form the basis for the ground investigation and generic risk assessment in Sections 5.0 and 6.0. Geotechnical considerations for the site are presented discussed in Section 7.0, whilst geo-environmental considerations for the site are discussed in Section 8.0.

Should existing structures be present on the site and these are required to be demolished, consideration should be given also to a pre-demolition asbestos survey.

4.0 GROUND INVESTIGATION

4.1 Investigation Rationale

The ground investigation comprised the following:

- 8 dynamic sample boreholes to a maximum depth of 4.00m to confirm the deeper geology, to identify competent bearing strata, to allow samples to be taken for geotechnical and geo-environmental assessment purposes and to allow ongoing groundwater and gas monitoring;
- 2 pioneer type boreholes to a maximum depth of 9.00m to confirm the deeper geology, to identify competent bearing strata, to allow samples to be taken for geotechnical and geo-environmental assessment purposes and to allow ongoing groundwater and gas monitoring;
- 4 falling head permeability tests, undertaken in boreholes with long term monitoring well installed in them were completed for the purpose of calculating permeability rates of the underlying ground;
- chemical testing including: soil; leachate; and water analysis; and
- geotechnical testing.

4.2 Boreholes

Eight dynamic sampling percussive boreholes were drilled on the 20th and 21st of March 2007 using a Terrier 2000 drill rig to a maximum depth of 4.00 m bgl (Boreholes WS1 to WS8).

Two pioneer type boreholes were drilled on the 21st and 22nd of March 2007 to a maximum depth of 9.00m bgl (Boreholes RA1 to RA2).

SPT tests were carried out in 7 of the dynamic sample boreholes at 1.00m intervals and in the pioneer type boreholes at 1.50m intervals.

Borehole RA1 was completed with standard (63 mm slotted HDPE) gas and water monitoring installation.

Boreholes WS2A, WS4 and WS6 were completed with standard (35 mm slotted UPVC) gas and water monitoring installations.

The approximate borehole locations (surveyed in using a 50m tape measure from landmarks) are shown on the Ground Investigation Plan in Appendix F. Co-ordinates and levels noted on the boreholes are based on CD Surveys Limited, Drawing Number ATIS/61149. The borehole logs are also presented in Appendix F.

4.3 Geotechnical Testing

Geotechnical testing has been carried out to provide design parameters for construction, and is in line with recommendations given in the NHBC Standards, Chapter 4, Ground Conditions.

4.3.1 In Situ Testing

SPT results were performed in the boreholes and the (un-adjusted) plots against depth are given in Appendix G.

4.3.2 Falling Head Permeability Testing

Falling head permeability tests in accordance with BS5930 were performed in boreholes RA1, WS2A, WS4 and WS6 and the logs are provided in Appendix F.

4.3.3 Laboratory Testing

A series of geotechnical testing was scheduled on samples retrieved from the trial pits. The testing was undertaken to enable the general geotechnical characteristics of the ground at the site to be determined.

The testing was undertaken by a UKAS accredited laboratory and comprised the following:

- 8 natural moisture contents;
- 5 Atterberg limits;
- 3 BRE SD1 (Building Research Establishment 2001) suite analyses for sulfate classification for buried concrete (total: - SO4, S, pH; water extract: - SO4 and the dependent options of ammoniacal N as NH4, Cl, NO3 & Mg); and
- 3 particle size distribution analyses;

The geotechnical test results are provided in Appendix G.

4.4 Geo-Environmental Testing

4.4.1 Sampling Strategy and Protocols

The locations of the investigatory holes were determined by reference to the conditions identified in the Phase 1 investigation. Certain specific targets were identified (for example: buried concrete associated with retaining wall; kitchen supply room; storage room associated with cleaning products; off-site fuel store room; and lower elevated section near Pent

Stream) but a random spacing was used for the remainder of the site. No specific sampling statistics or grid were utilised in this instance.

Soils for inorganic analysis were sealed in air-tight polythene tubs. Soils for organic analysis were sealed in amber glass jars with the minimal practicable headspace. Groundwater samples were collected in suitable containers, and with the correct preservatives, as provided by the laboratory. All samples were scheduled on chain of custody forms prior to being dispatched to the UKAS accredited laboratory for analysis. Samples requiring analysis of certain determinands, such as volatiles (VOC) were shipped in cool boxes with ice packs at the end of each day's sampling.

4.4.2 Monitoring

Gas monitoring boreholes were monitored on 2 occasions. The results are tabulated Table 5.4. Further monitoring visits will be reported in the form of an addendum letter

4.4.3 Laboratory Analyses

The findings of the Phase 1 investigation have been used to scope the analyses of chemicals of potential concern as follows.

The following were performed on samples of **soil or other solids**:

- 7 Hydrock default suite of determinands for solids comprising: As, B (water soluble), Be, Cd, Cr (total), Cu, Hg, Ni, Pb, S (elemental), Se, V, Zn, cyanide (total), sulfide, pH, asbestos fibres, speciated polycyclic aromatic hydrocarbons (PAH, by GC-FID), total phenols and fraction of organic carbon. If high total cyanide is detected, this may be re-analysed for 'free' and 'complex' species if appropriate. Note: SO_4 is included within the geotechnical testing schedule. See Appendix H for details;
- 1 volatile organic compounds (VOC general scan by GC-MS);
- 1 semivolatile organic compounds (SVOC general scan by GC-MS);
- 5 total petroleum hydrocarbons by GC-FID (Hydrock Level 2 suite comprising aliphatic / aromatic split and the following carbon banding: aliphatic - C5-C6, >C6-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C35, aromatic - C5-C7, >C7-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C21, >C21-C35 plus BTEX and MTBE); and
- 3 Hydrock default leachate suite of determinands, following NRA leaching method, comprising: As, B, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Se, V, Zn, cyanide (total), phenols (speciated), sulfide, SO_4, NO_3, PAH (speciated) & pH. If high total cyanide is detected, this may be re-analysed for 'free' and 'complex' species if appropriate.

The following were performed on samples of **water or other liquids**:

- 1 Hydrock default suite of determinands for water comprising: As, B (water soluble), Be, Cd, Cr (total), Cu, Hg, Ni, Pb, S (elemental), Se, V, Zn, cyanide (total), sulfide, pH, asbestos fibres, speciated polycyclic aromatic hydrocarbons (PAH, by GC-FID), total phenols and fraction of organic carbon. If high total cyanide is detected, this may be re-analysed for 'free' and 'complex' species if appropriate. Note: SO_4 is included within the geotechnical testing schedule. See Appendix H for details;

- 1 volatile organic compounds (VOC general scan by GC-MS);

- 1 semivolatile organic compounds (SVOC general scan by GC-MS); and

- 1 total petroleum hydrocarbons by GC-FID (Hydrock Level 2 suite comprising aliphatic / aromatic split and the following carbon banding: aliphatic - C5-C6, >C6-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C35, aromatic - C5-C7, >C7-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C21, >C21-C35 plus BTEX and MTBE).

The chemical test results are provided in Appendix I.

5.0 CONCEPTUAL GROUND MODEL

The findings of the ground investigation are presented in the following sections.

5.1 Physical Ground Conditions

The ground conditions over the entire site as proven during the current works were in general accordance with the published geological literature and expectations from the desk study.

The general geological sequence is listed in Table 5.1. Geotechnical test data are presented in Appendix G together with SPT depth profiles, and are discussed under the relevant stratum below.

Table 5.1: Geology Encountered

Stratum Description	Depth to Top (m bgl)	Thickness (m)
Made Ground: located across the whole site and can be split into 2 general types including: • soft to firm clay with varying percentages of silt, sand and gravel; and • sands with varying percentages of clay and gravel with minor constituents of brick and concrete.	0.00	0.60 - 3.65
Lower Greensand Formation: located across the whole site and can be split into 3 general types including: • soft to firm very sandy clays with sand pockets; • medium dense sands; and • moderately strong yellow brown sandstone.	0.6 - 3.65	Not proven >5.35

Made Ground was encountered across the whole site. The depth of the Made Ground was similar across the majority of the site, apart from on the eastern boundary due to the concrete platform associated with the retaining wall. The Made Ground is shallowest in the south, and is reduced in the north of the site at the lower elevation area near Pent Stream (former quarry).

5.1.1 Made Ground

Made Ground was encountered in all boreholes across the site to varying degrees of thickness. In general, there are 2 general types of Made Ground:

- soft to firm clay with varying percentages of silt, sand and gravel located across the majority of the site at shallow depths; and
- sands with varying percentages of clay and gravel with minor constituents of brick and concrete.

Clay Dominated Made Ground

The majority of the site is underlain by clay dominated Made Ground and was encountered in all exploratory holes with the exception of RA1 in the east and WS3 in the northwest. This Made Ground generally consisted of soft to firm brown or dark grey clay with varying constituents of sand and gravel. The gravel is generally subrounded to subangular, fine to coarse in size and is made up of brick, concrete, flint, quartzite and sandstone.

The clay dominated Made Ground was in direct contact with the natural Lower Greensand Formation in Exploratory holes RA2, WS1, WS4, WS5, WS6, WS7 and WS8. In WS2A the clay dominated Made Ground was underlain by sand dominated Made Ground.

No visual or olfactory evidence of hydrocarbons or other contamination was observed in this Made Ground, apart from WS6, which gave off an earthy organic odour.

Sand Dominated Made Ground

Sand dominated Made Ground was encountered in RA1, WS3 and WS2A, and this generally consisted of medium dense brown sands with varying constituents of clay and minor constituents of gravel. The sand is fine to coarse and the gravel is dominantly subangular brick but also includes concrete, quartzite, sandstone, flint, granite and chalk.

The sand dominated Made Ground overlies the natural Lower Greensand Formation in WS3 but is underlain by concrete in RA1 and WS2A. In WS2A the base of the Made Ground is at a fairly shallow depth of 1.30m bgl, but in RA1 concrete is encountered much deeper at 3.65m bgl. This is due to a concrete toe associated with a retaining wall along the eastern boundary of the site. The sand dominated Made Ground in RA1 becomes green brown with depth and includes minor amounts of angular granite and subrounded to rounded quartzite.

No visual or olfactory evidence of hydrocarbons or other contamination was observed in this sand dominated Made Ground.

Classification Tests

A single plasticity and moisture content result from Made Ground sample indicate the clay can be classified as moderate volume change potential in terms of NHBC Standards (Chapter 4.2) with respect to building near trees, and the moisture content for the sand dominated Made Ground was 9.2%.

In Situ Test Results

Standard Penetration Tests

Standard Penetration Tests were undertaken in the boreholes at frequent regular intervals. The 'N' values that have been derived from those SPT results are included on the borehole logs included in Appendix F. A plot of the measured SPT 'N' value against depth is included in Appendix G and shows the Made Ground to have a range of SPT "N" values from 12 to 32 and generally increase with depth.

Sulfates

Sulfate analyses were carried out on 1 sample in the Made Ground. Reference to BRE SD 1 indicates a Design Sulfate classification of **DS-1** and an Aggressive Chemical Environment for Concrete (ACEC) classification of **AC-1s**.

5.1.2 Lower Greensand Formation

The Lower Greensand Formation was encountered across the whole site at varying depths and generally consisted of medium dense, green brown, brown and yellow brown sands with varying degrees of clay, very sandy clays and sandstone. In places the Lower Greensand was recovered as, or included very weakly cemented sandstone.

The upper most section of the Lower Greensand Formation was recovered as brown, very sandy clays in WS4, WS5 and WS8 and was between 0.40m and 0.50m thick. In all instances this clay was overlain by clay dominated Made Ground and underlain by sands of the Lower Greensand.

The Lower Greensand Formation was encountered as sand in all exploratory holes with the exception of WS2 which terminated in the Made Ground due to an obstruction. With depth the sand changed from fine to coarse to medium to coarse and the clay content decreased. Gravel content was generally minor and included sandstone, very weakly cemented sandstone, chert and quartzite.

Solid sandstone was only observed in RA2 and consisted of a very thin band (0.05m) of moderately strong yellow brown sandstone. It is likely that solid sandstone is present across the whole site and was the cause of SPT and dynamic sample refusals.

No visual or olfactory evidence of hydrocarbons or other contamination was observed in this strata. The Lower Greensand from WS3 gave off an earthy organic odour.

Classification Tests

Plasticity and moisture content results from natural samples indicate the clay of the Lower Greensand can be classified as low volume change potential in terms of NHBC Standards (Chapter 4.2) with respect to building near trees. This may effect foundation depths.

The particle size distribution test results were in general accordance with the field descriptions and classified the Lower Greensand Formation as generally medium to coarse sands with minimal gravel, clay and silt.

The geotechnical test results are provided in Appendix G.

In Situ Test Results

Standard Penetration Tests

Standard Penetration Tests were undertaken in the boreholes at frequent regular intervals. The 'N' values that have been derived from those SPT results are included on the borehole logs included in Appendix F. A plot of the measured SPT 'N' value against depth is included in Appendix G and shows the Lower Greensand Formation to have a range of SPT "N" values from 5 to 69 and generally increase with depth.

Sulfates

Sulfate analyses were carried out on 2 sample in the Lower Greensand Formation. Reference to BRE SD 1 indicates a Design Sulfate classification of **DS-1** and an Aggressive Chemical Environment for Concrete (ACEC) classification of **AC-1s**.

5.2 Groundwater and Hydrogeology

Groundwater strikes during drilling are summarised in Table 5.2. Groundwater records from piezometers or wells obtained during subsequent monitoring visits are summarised in

Table 5.3.

Table 5.2: Groundwater Strikes

Borehole	Date	Depth to Groundwater (m bgl)	Ground Level (mOD)	Groundwater Elevation (mOD)
WS4	20/03/07	1.10m	19.90	18.80
WS5	20/03/07	1.80m	19.95	18.15

Table 5.3: Groundwater Monitoring Elevations

Borehole	Date	Depth to Groundwater (m bgl)	Ground Level (mOD)	Groundwater Elevation (mOD)
RA1	22/03/07	Dry	28.86	-
WS2A	22/03/07	Dry	26.42	-
WS4	22/03/07	0.73m	19.90	19.17
WS6	22/03/07	Dry	30.80	-
RA1	19/04/07	Dry	28.86	
WS2A	19/04/07	Dry	26.42	
WS4	19/04/07	0.73m	19.90	19.17
WS6	19/04/07	Dry	30.80	
RA1	03/05/07	Dry	28.86	-
WS2A	03/05/07	Dry	26.42	-
WS4	03/05/07	0.85m	19.90	19.05
WS6	03/05/07	Dry	30.80	-

It should be noted the groundwater encountered in WS4 is approximately coincident with the level of Pent Stream.

5.3 Soil Chemistry

The findings of the geo-environmental analyses for chemicals of potential concern are described in the following sections.

The analytical results for PAH from WS6 @ 0.40m bgl and WS7 @ 0.40m bgl are extremely different from the remainder of the analytical results. Detailed examination of the borehole logs does not provide a possible cause for this elevated PAH. Hydrock have queried the elevated PAH with the laboratory and while the laboratory states there are no analytical concerns.

5.3.1 Inorganic

Made Ground

The following were detected in the samples analysed from the Made Ground: As, B (water soluble), Be, Cr (total), Cu, Hg, Ni, Pb, V, Zn and cyanide (total).

Natural Ground

The following were detected in the sample analysed from the natural ground: As, B (water soluble), Be, Cr (total), Ni, V and Zn. Organic

Made Ground

PAHs were recorded in 6 samples with the higher concentrations being from WS6 @ 0.40m bgl with a concentration of 200mg/kg (total PAH) and WS7 @ 0.40m bgl with a concentration of 210mg/kg (total PAH).

TPH was recorded in 3 samples in the Made Ground with the higher concentrations being from WS3 @ 0.40m bgl (total TPH, 820mg/kg). The other two samples are WS1 @ 0.80m bgl (110mg/kg) and RA1 @ 1.50m bgl (67mg/kg). TPH concentrations are assessed in further detail in the following sections.

SVOCs were recorded in the sample for Made Ground from WS3 @ 0.80m bgl.

No Phenols, VOCs or BTEX were recorded above the detection level of the analytical apparatus in samples from Made Ground. No additional consideration is required for these chemicals of concern.

Natural Ground

PAHs were recorded in the sample for natural ground from WS3 @ 1.40m bgl with a concentration of 0.61mg/kg (total PAH) with the highest concentration being from naphthalene with a concentration of 0.41mg/kg.

TPH was recorded in the sample for natural ground from WS4 @ 0.80m bgl with a concentration of 160mg/kg (total TPH). TPH concentrations are assessed in further detail in the following sections.

No Phenols or BTEX were recorded above the detection level of the analytical apparatus in samples from natural ground. No additional consideration is required for these chemicals of concern.

5.3.2 Asbestos

The presence of asbestos was not detected during laboratory analysis on the soil samples. Therefore no further consideration of asbestos in soils is considered necessary.

5.4 Leaching Tests

Leachate testing was undertaken to assess the risk to controlled waters from soil contaminants in line with good practice defined in ISO 15175:2004.

5.4.1 Inorganic

Made Ground

Concentrations above the detection limit for the methods used have been recorded for As and Se.

Natural Ground

Concentrations above the detection limit for the methods used have been recorded for Cu.

5.4.2 Organic

Made Ground

PAHs were recorded in 2 samples of leachate with the highest concentrations being from WS04 @ 0.40m bgl (4μg/l total PAH).

No phenols were recorded above the detection level of the analytical apparatus in samples of leachate from Made Ground. No additional consideration is required for phenols in Made Ground.

Natural Ground

PAHs were recorded in the leachate sample for natural ground from WS5 @ 1.30m bgl with a concentration of 3.2μg/l (total PAH) with the highest concentration being from naphthalene with a concentration of 2.2μg/l.

No phenols were recorded above the detection level of the analytical apparatus in the sample of leachate from natural ground. No additional consideration is required for phenols in natural ground.

5.5 Groundwater Chemistry

5.5.1 Inorganic

The following were detected in the sample of water analysed: As, B, Ba, Cr, Cu, Pb, Se, Zn, SO_4, and NO_3.

5.5.2 Organic

PAHs were recorded in the sample of groundwater from WS4 with a concentration of 2.4μg/l (total PAH) with the highest concentration being from naphthalene with a concentration of 1.2μg/l.

No TPH, phenols, VOCs, SVOCs or BTEX were recorded above the detection level of the analytical apparatus in samples of water. No additional consideration is required for these chemicals of concern in groundwater.

5.6 Ground Gases

Records from the gas monitoring boreholes are summarised in Table 5.4.

Table 5.4: Gas Monitoring Results

Borehole	Date	CH_4 (%)	CO_2 (%)	O_2 (%)	Atmos-pheric Pressure (mb)	BH Gas Flow Volume – Total (l/hr)	BH Gas Flow Volume – CH_4 (l/hr)	BH Gas Flow Volume – CO_2 (l/hr)	BH Gas Flow Volume – CH_4 + CO_2 (l/hr)
RA1	19/04/2007	0.2	0.4	20.9	1013	-0.1	0.00	0.00	0.00
WS2A	19/04/2007	0.2	0.4	21.3	1013	-0.1	0.00	0.00	0.00
WS4	19/04/2007	0.1	0	21.2	1013	-0.7	0.00	0.00	0.00
WS6	19/04/2007	0.2	0.5	21.2	1013	0.1	0.00	0.00	0.00
RA1	03/05/2007	0.0	0.7	20.5	1011	0.1	0.00	0.00	0.00
WS2A	03/05/2007	0.0	0.0	20.9	1012	0.0	0.00	0.00	0.00
WS4	03/05/2007	0.0	0.9	19.8	1010	0.6	0.00	0.00	0.00
WS6	03/05/2007	0.1	0.6	20.4	1010	0.4	0.00	0.00	0.00

There are a number of potential ground gas sources within 1000m of the site. These include:

- a registered waste transfer station approximately 800m north of the site;
- a number of quarries and brick pits; and
- possible Alluvium along Pent Stream.

The sand will have a high porosity to allow migration of any potential ground gas and the information available suggests that there is only low volumes of $C0_2$ and CH_4, and no flow rates. CS1 gas protection measures should be adequate for the proposed development.

5.7 Summary of Ground Model and Hazard Identification

The conceptual site model initially developed from the desk study and walk-over survey (Section 3.1) has been updated using the findings of the ground investigation. This model forms the basis of the generic risk assessment described in the next section and the geotechnical recommendations made in Section 7.0.

The site is generally sloping north with a steep slope in the north associated with the former quarry face. Beyond the former quarry face there is a flat area of land, then beyond the site boundary there is a narrow road/access route and Pent Stream.

The site is underlain by Made Ground, extensively clay, which is occasionally underlain by sand dominated Made Ground. Below the Made Ground is the Lower Greensand Formation which consists of clay and sand with sandstone bands. In the north of the site the Lower Greensand is seen as very sandy clays to a depth of 1.80m bgl before transitioning into sands and sandstone bands. There is a retaining wall on the eastern boundary of the site and the Made Ground was found to be relatively deep above the buried concrete support structure. Hard strata was noted by the drillers from between 3.45m and 3.65m bgl and concrete rock chips were noted.

Groundwater was only encountered in exploratory holes near Pent Stream within the lower elevation in the north of the site. Water was struck at 1.10m bgl in WS4 and 1.80m bgl in WS5. Groundwater monitoring from WS4 shows groundwater level between 0.73m bgl and 0.85m bgl which is roughly co-incident with the level of Pent Stream. Groundwater was not encountered elsewhere on site although the natural sand of the Lower Greensand Formation was noted as becoming moist at 5m bgl in RA1.

Due to the unconsolidated nature of the clay dominated Made Ground, the presence of sand dominated Made Ground in some areas and the permeable nature of the Lower Greensand there is a high possibility that these units could provide a pathway for groundwater contamination.

The Site Zonation Plan (Appendix E) includes any new information relating to the conceptual ground model.

5.7.1 Limitations of the Conceptual Model

The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes. At intermediate locations, conditions can only be inferred.

6.0 GENERIC QUANTITATIVE RISK ASSESSMENT

6.1 Context and Objectives

The purpose of this risk assessment is to determine the suitability of the site for the proposed development. Whilst Hydrock have not reviewed the proposed development it is likely to comprise a mix of houses and apartments with buildings up to 5-6 storeys, along with associated infrastructure, gardens and public open spaces.

This is a Tier 2 assessment using soil screening values and involves generic human health risk assessment for the following standard land use scenario:

- residential with plant uptake; and
- a check on levels of priority phytotoxic chemicals to determine the likely risk to plant growth.

The soil chemical analysis results have been screened against guideline soil concentrations to provide an assessment of potential risks associated with contamination at the site. Justification for the criteria adopted for this risk assessment are given in Appendix H. It has been assumed in this report that the exposure conditions are within the generic conditions used to derive Soil Guideline Values (SGVs). Where no SGVs are published, a number of Site Specific Assessment Criteria (SSAC) have been developed for certain chemicals of potential concern. These SSAC have been developed using largely generic assumptions about the characteristics and behaviour of sources, pathways and receptors, i.e. similar to those used by the Environment Agency in the derivation of SGVs. Although strictly a site-specific risk assessment, these derived generic criteria are used alongside the SGVs and the process is referred to in this report as a Generic Quantitative Risk Assessment. (Note: a Detailed Quantitative Risk Assessment is herein considered to be one in which the generic assumptions have been modified in the light of site-specific findings.)

In the following assessment it should be noted that the term “failure” is used to denote soil concentrations that exceed a generic assessment criterion (GAC). This does not automatically mean that the soil is “contaminated”. The derivation of GACs includes a number of precautionary assumptions such that non-exceedance will indicate that risk to human health is acceptable and that the land is suitable for use, with regard to the contaminant in question.

However, the legal test for land contamination under the statutory guidance of Part IIA of the Environmental Protection Act 1990 (i.e. “significant possibility of significant harm”) is **unacceptable** intake or direct bodily contact. The details are given in Annex 3 of DEFRA Circular 01/2006 (DEFRA September 2006). PPS23 (DCLG November 2004) confirms that the standard of remediation to be achieved under the planning regime is also the removal of unacceptable risk. DEFRA (2005) has made it clear that exceedance of a GAC does not necessarily meet this legal test, i.e. exceedance of a GAC does not necessarily equate to

unacceptable risk. Consequently, the GACs must be considered as screening values only, and further consideration and judgement is required in setting any remedial targets.

The risks to groundwater from contaminants on site have been assessed according to the remedial targets methodology prescribed by the Environment Agency (2006). Depending on the available data, groundwater quality data are compared directly with the generic criteria for the quality of Controlled Waters; or a Level 1 soil assessment of risk to controlled waters has been undertaken by comparing soil leaching test results with accepted indicators of water quality. No further, more detailed, assessment has been made at this stage.

The plausible pollution linkages initially identified in Table 3.2 have been re-assessed in the light of the ground investigation and have been updated in Table 6.1.

The pH data obtained during site works indicates no acids and bases are present on sites. SD1 tests confirm concrete classification as DS-1, AC-1s;

Volatile organic compounds (VOC) and BTEX from existing fuel tanks and previous chemical usage on site can be discounted as none were detected during site works;

Phenols can be discounted as no phenol was detected above the detection limit of the laboratory analytical apparatus;

No asbestos in soils was detected during the laboratory screening. It is recommended to conduct a full asbestos survey prior to demolition.

The BGS radon report indicates no precautions for radon are required for this site.

Those linkages for which the receptors are demolition and site redevelopment workers are specifically excluded from the following assessment since this should be covered by method statements required under the relevant health and safety regulations. The remaining linkages of potential concern form the basis of this generic risk assessment for the standard land use scenarios of human health with plant uptake, plant growth and risk to groundwater.

The conceptual ground and exposure model is summarised in table form in the Executive Summary of this report.

Table 6.1: Outline Exposure Model - Plausibility of Source-Pathway-Receptor Pollution Linkages Following Ground Investigation

Source(s)	Possible Pathway(s)	Receptor(s)	Plausibility Y, N, Y/N	Justification
Inorganic chemicals				
Metals and metalloids – In Made Ground.	Direct contact. Ingestion of soils. Inhalation of fugitive dust.	End users.	Y	The proposed redevelopment of the area is residential housing with gardens. The future land use increases the risk of contact with any elevated metals if present. The ground investigation has indicated elevated concentrations of metals above the detection level of the analytical apparatus.
	Root uptake.	Existing planting.	Y	
	Root uptake (plants). Direct contact (plants & animals). Ingestion of soils and water (animals). Transport in surface water drainage.	Terrestrial Ecosystem.	Y	
	Run-off and infiltration through geology from contaminated soils.	Surface water and aquatic ecosystem.	Y	The stream in the north could be of risk from run-off from contaminated soils. The ground investigation has indicated elevated concentrations of leachates above the detection level of the analytical apparatus.
	Infiltration.	Groundwater.	Y	The Lower Greensand Formation is likely to be permeable. The Lower Greensand Formation is a major aquifer. The ground investigation has indicated elevated concentrations of leachates above the detection level of the analytical apparatus.

Organic Chemicals				
Semi volatile organic compounds (SVOC) – existing fuel tanks and previous chemical usage on and off site. **Petroleum hydrocarbons** – fuel, lubricants, hydraulic fluids, heating oil tanks and kilns. **Polynuclear aromatic hydrocarbons (PAH)** – from used engine oil, creosote and fires on site. .	Direct contact. Ingestion of soils. Inhalation of fugitive dust and indoor and outdoor vapours. Ingestion of tainted water from compromised buried water pipes (end users).	End users.	Y	Observations of current practices include storage of cleaning products and other solvents, cooking fats and other kitchen waste as well as hydrocarbons storage just off site.
	Direct contact. Ingestion of soils and water. Transport in surface water drainage.	Terrestrial ecosystem (animal life the critical receptor).	Y	
	Run-off or seepage of free phase and dissolved phase from contaminated soils.	Surface water and aquatic ecosystem.	Y	The stream to the north could be at risk from run-off from contaminated soils.
	Infiltration of free phase and dissolved phase from contaminated soils.	Groundwater.	Y	The Lower Greensand Formation is likely to be permeable. The Lower Greensand Formation is a major aquifer, so the risk of infiltration of contamination needs to be considered.
	Direct contact with free phase or dissolved phase.	Buried services.	Y	Hydrocarbons are stored just off site and leaks or spills can not be ruled out.
Other substances				
Ground gases	Migration through soils or groundwater to indoor air.	End users of new buildings.	Y	There are 2 registered landfill sites within 1000m of the site 786m and 817m to the north.

6.2 Estimation and Evaluation of Risks

Generic risk assessment is a two stage process. Firstly, the measured contaminant concentrations are compared to the relevant GACs. This is the Risk Estimation stage. Where there is a suitable dataset, this is done after carrying out the statistical tests in accordance with CLR 7 (Environment Agency 2002a). Otherwise, maximum or specific data points are compared directly.

The second stage, Risk Evaluation, comprises an authoritative review of the findings with other pertinent information, in cases where the GACs are exceeded, in order to consider if exceedance may be acceptable in the particular circumstances.

6.2.1 CLR 7 Statistical Tests

The 'averaging area' used in this report is the area of the site represented by the conceptual model, and in this case has been chosen to characterise materials that are likely to form the ground cover in critical receptor areas (e.g. gardens). This is discussed in more detail in Appendix H.

The analytical results for PAH from WS6 @ 0.40m bgl and WS7 @ 0.40m bgl are extremely different from the remainder of the analytical results. Detailed examination of the borehole logs does not provide a possible cause for this elevated PAH. Hydrock have queried the elevated PAH with the laboratory and while the laboratory states there are no analytical concerns, Hydrock have removed this PAH data from the statistical analysis. Additional works will be required in this area following demolition to prove there is no risk to site users.

Maximum Value Test

The results of the iterations of the Maximum Value Test (with PAH data from WS6 @ 0.40m bgl and WS7 @ 0.40m bgl removed from the data set), show no statistical outliers where the values exceed the appropriate generic criterion. It can be considered there are no statistical contamination hotspots. Additional work will be required in the vicinity of WS6 and WS7 following demolition.

Mean Value Test

The results of the Mean Value Test (with outliers removed) indicate there are no chemicals of potential concern failing the final Mean Value Test for human health or plant growth. This indicates there is no pervasive contamination present on site.

Additional works will be required in the area of WS6 and WS7 following demolition to prove there is no risk to site users.

6.2.2 Risk Evaluation of Other Substances

Petroleum Hydrocarbons

Petroleum hydrocarbon contamination is complex. The type of crude oil, its distillation, processing and blending, and the subsequent weathering in the environment all result in the development of petroleum residues of extreme chemical complexity (Environment Agency, 2003). The laboratory analysis of petroleum hydrocarbons is highly method dependent. In addition to contaminants such as fuels and lubricating oils, the analyses also pick up a range of other chemicals such as PAHs and phenols, together with naturally occurring substances like humic and fulvic matter in organic soils. For example, TPH determination on dried oak leaves can give a result of 18,000 mg/kg of TPH.

Generic assessment criteria can be developed for each TPH fraction in the same way as they can be for named substances, providing certain assumptions are made regarding the applicability of the data to all the compounds in each fraction. A significant part of the TPHCWG activity has been in determining fraction boundaries to maximize confidence in the eventual criteria.

A modified TPHCWG approach has been adopted in a framework developed by the Environment Agency (2005) for use within the UK. The 13 original TPHCWG fractions have been adopted, with the addition of >C35-C44.

The UK suggested approach to petroleum hydrocarbon risk assessment is summarised as follows:

- measure indicator chemicals and compare with their GAC – these are chemicals which are considered as key risk drivers at petroleum hydrocarbon contaminated sites. The chemicals of potential concern depend on the type of hydrocarbon product, but a (non-exhaustive) list has been suggested by the Environment Agency (2005):

  Non-threshold: benzene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3,cd)pyrene.

  Threshold: toluene, ethylbenzene, xylene, naphthalene, fluoranthene, phenanthrene, pyrene.

- measure TPH fractions and compare with their GAC, based on threshold toxicity only.

  Aliphatic fractions: >C5-C6, >C6-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C35, >C35-44.

  Undifferentiated: >C4`4-C77 (subject to review and confirmation by Agency. Currently, laboratories are unable to analyse for this fraction.).

  Aromatic fractions: >C5-C7, >C7-C8, >C8-C10, >C10-C12, >C12-C16, >C16-C21, >C21-C35, >C35-C44.

- consider additivity of the TPH fractions if none of the individual fractions exceed their GAC.

Hydrock has adopted the first two points from above approach and has developed generic assessment criteria for the TPH fractions up to C35 (because it is beyond current laboratory capability to report beyond about C40, and there are no toxicological data available for these heavier fractions with which to calculate GACs). These are used for assessment where an appropriate level of sampling and laboratory analysis has been carried out, but cannot be used where more generalised TPH analysis has been scheduled (such as DRO/GRO only).

Based on the above WS3 @ 0.40m bgl exceeds the generic criterion and requires further consideration. TPH analysis is provided in Appendix I.

6.2.3 Contamination of Controlled Waters

Contamination of Controlled Waters is assessed using the Environment Agency (2006) Remedial Targets Methodology, as described in Appendix H. This was previously known as the "P20" methodology, after the now-withdrawn R&D Publication 20.

Where groundwater quality data have been obtained, a *Level 2 (groundwater below source) assessment* is made by comparing the results directly with the generic criteria for the quality of Controlled Waters. The compliance point is the groundwater below the site.

In cases where groundwater quality data have not been obtained directly, an indication of the potential for pollution resulting from soil contamination can be obtained by a *Level 1 (soil zone) assessment.* This considers whether the concentrations in the soil moisture are sufficient to impact the water receptor(s) without taking into account attenuation, dilution or dispersion. Pore water concentrations are determined by measurement of perched water quality or from soil leaching tests, and are compared with the generic criteria for the quality of Controlled Waters. The compliance point is the soil zone.

The results of the remedial targets methodology assessment are presented in

Table 6.2 and Table 6.3.

Where more than one criterion is given it is important to apply the one relevant to the critical receptor. The drinking water standards apply to groundwater or to surface water used for abstraction and the EQS apply to surface water where there is no abstraction. Where the relevance cannot be determined with certainty, the lower one is adopted.

Table 6.2: Summary of Remedial Targets Methodology Level 1 Soil Zone Assessment from SOIL Leaching Analyses

Chemical of Potential Concern (µg/l)	Generic Criterion (µg/l)	Basis of Criterion	No. Samples Tested	Range of Concentrations (µg/l)	Max. < Criterion
Hardness as mg/l $CaCO_3$	n/a	(used in some of following)	-	n/a	n/a
As	10	UK/EU drinking water	3	<1.0 – 1.3	PASS
	50	EQS freshwater			PASS
B	1000	UK/EU drinking water	3	<50	PASS
	2000	EQS freshwater			PASS
Ba	700	WHO drinking water	3	<10	PASS
Cd	5	UK/EU drinking water EQS freshwater	3	<0.05	PASS
Cr (total)	50	UK/EU drinking water	3	<2	PASS
	50*	EQS freshwater			PASS
Cu	2000	UK/EU drinking water	3	<5 – 5.3	PASS
	28*	EQS freshwater			PASS
Hg	1	UK/EU drinking water EQS freshwater	3	<0.2	PASS
Ni	20	EU drinking water	3	<2	PASS
	200*	EQS freshwater			PASS
Pb	25	UK/EU drinking water	3	<1.0	PASS
	20*	EQS freshwater			PASS
Se	10	UK/EU drinking water	3	<0.3 – 0.4	PASS
V	60*	EQS freshwater	3	<10	PASS
Zn	125*	EQS freshwater	3	<5	PASS
Cyanide (total)	50	UK/EU drinking water	3	<50	PASS
Phenols	30	EQS freshwater	3	<0.5	PASS
Nitrate (NO_3)	50,000	UK/EU drinking water	3	<2200	PASS
Sulfate (SO_4)	250,000	UK/EU drinking water	3	<2400	PASS
	400,000	EQS freshwater			PASS
Sulfide (S^{2-})	0.25	EQS freshwater	3	<10	PASS
PAH benzo(a)pyrene	0.01	UK/EU drinking water	3	<0.01	PASS
PAH naphthalene	10	EQS freshwater	3	0.32 – 2.8	PASS
PAH #	0.1	UK/EU drinking water	3	<0.04	PASS

From Environment Agency (2002c) Appendix A and Agency web site (annual average basis), Water Quality Regulations 2001 and WHO 2004.
*- depends on water hardness and fish type, the hardness has been measured at 700 mg/l as $CaCO_3$ and appropriate EQS have been used.
- sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene.

Table 6.3: Summary of Remedial Targets Methodology Level 2 Groundwater Assessment from Groundwater Analyses

Chemical of Potential Concern (µg/l)	Generic Criterion (µg/l)	Basis of Criterion	No. Samples Tested	Range of Concentrations (µg/l)	Max. < Criterion
Hardness as mg/l $CaCO_3$	n/a	(used in some of following)	1	700000	n/a
As	10	UK/EU drinking water	1	1.6	PASS
	50	EQS freshwater			PASS
B	1000	UK/EU drinking water	1	420	PASS
	2000	EQS freshwater			PASS
Ba	700	WHO drinking water	1	25	PASS
Cd	5	UK/EU drinking water EQS freshwater	1	<0.5	PASS
Cr (total)	50	UK/EU drinking water	1	21	PASS
	50*	EQS freshwater			PASS
Cu	2000	UK/EU drinking water	1	21	PASS
	28*	EQS freshwater			PASS
Hg	1	UK/EU drinking water EQS freshwater	1	<0.2	PASS
Ni	20	EU drinking water	1	<20	PASS
	200*	EQS freshwater			PASS
Pb	25	UK/EU drinking water	1	63	FAIL
	20*	EQS freshwater			FAIL
Se	10	UK/EU drinking water	1	8.8	PASS
V	60*	EQS freshwater	1	<10	PASS
Zn	125*	EQS freshwater	1	26	PASS
Cyanide (total)	50	UK/EU drinking water	1	<50	PASS
Phenols	30	EQS freshwater	1	<50	Standard lab reporting limit too high to determine but no elevated analysis from soil samples, so not considered significant.
Nitrate (NO_3)	50,000	UK/EU drinking water	1	6400	PASS
Sulfate (SO_4)	250,000	UK/EU drinking water	1	14400	PASS
	400,000	EQS freshwater			PASS
Sulfide (S^{2-})	0.25	EQS freshwater	1	<10	Standard lab reporting limit too high to determine but no elevated analysis from soil samples, so not considered significant.
PAH benzo(a)pyrene	0.01	UK/EU drinking water	1	0.072	FAIL
PAH naphthalene	10	EQS freshwater	1	1.2	PASS
PAH #	0.1	UK/EU drinking water	1	<0.282	FAIL

From Environment Agency (2002c) Appendix A and Agency web site (annual average basis), Water Quality Regulations 2001 and WHO 2004.
*- depends on water hardness and fish type, the hardness has been measured at 700 mg/l as $CaCO_3$ and appropriate EQS have been used.
- sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene.

As the site is situated within a major aquifer and the site is within close proximity of a stream it is required that both of these are considered when looking at failures above generic criterion.

There are no exceedances when comparing the leachate analysis against the corresponding criteria.

The groundwater comparison shows exceedances for lead when compared to the EQS freshwater, and lead, benzo(a)pyrene, and PAH# (benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene) when compared to the UK/EU drinking water.

There are no TPH concentrations above the detection limit for analytical apparatus for water samples.

The exceedances are not significant, there are no known sources on-site for the chemicals and as the chemicals are limited to groundwater from Pent Stream, Hydrock do not consider the site to be a significant risk to controlled waters.

6.2.4 Findings of the Generic Risk Assessment

The findings of the generic risk assessment are that the substances listed in Table 6.4 will require further consideration.

Table 6.4: Summary of Unacceptable Pollution Linkages

Receptor Group	Unacceptable Pollution Source	
	Hotspots	**Pervasive**
Human Health	TPH has been recorded above generic criterion in WS3 @ 0.40m bgl. SVOCs have also been detected in WS3 @ 0.80m bgl.	Additional works will be required in the area of WS6 and WS7 to prove there is no risk to site users from PAH.
Plant Life	Nil	Nil
Controlled Waters	No soil leachate samples exceed UK/EU drinking water standards or EQS freshwater standards.	
	The groundwater comparison shows exceedances for lead when compared to the EQS freshwater, and lead, benzo(a)pyrene, and PAH# (benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene) when compared to the UK/EU drinking water. However, Hydrock do not consider the site to present a risk to controlled waters. This will require confirmation by the Environment Agency.	

Particular areas of the site which are of potential concern are indicated on the Site Zonation Plan in Appendix E. Site-wide issues are not mapped on the plan, but are listed in the notes.

7.0 GEOTECHNICAL CONCLUSIONS AND RECOMMENDATIONS

Geotechnical aspects of the site are discussed in the following sections and where particular areas of the site which are of potential concern, these are indicated on the Site Zonation Plan in Appendix E. Site-wide issues are not mapped on the plan, but are listed in the notes.

7.1 Proposed Development

The proposed development is to comprise residential housing (5-6 storey houses), gardens, public open space and associated infrastructure.

7.2 Flooding

The Envirocheck report indicates the that the far north of the site is within an area at risk from Extreme Flooding from Rivers and Sea without Defences (Zone 2) as well as Flooding from Rivers and Sea without Defences (Zone 3).

The Envirocheck report indicates the rest of the site to be not at risk from flooding.

Comments on flooding in this report should not be taken to represent a comprehensive flood risk assessment. It is also of note that indicative floodplain maps are periodically updated and are therefore subject to change.

7.3 Site Preparation, Earthworks and Landscaping

It is not known if there will be removal of existing site buildings and underground services but it is envisaged there will be some scale of demolition needed on site. Large tracked 360^{o} type excavators and breaking equipment will be required to remove obstructions and former foundations. Whilst no *in situ* building foundations were encountered during the site investigation, areas associated with current and former buildings may have an increased incidence of bricks and general building rubble.

The toe of the retaining wall along the eastern boundary extends beneath the site and was encountered in RA1 between 3.45m bgl to 3.65m bgl. It is recommended that no construction is undertaken within 4m of the eastern site boundary.

Exploratory boreholes were unstable within the sand. It is recommended that no personnel enter unsupported excavations and for deep excavations shoring should be considered.

Groundwater was encountered in the northern section of the site in the area of the former quarry due to the close proximity of Pent Stream. It is recommended that an allowance be made for dewatering of any excavations that are undertaken in this northern section of the site.

Deep service runs will encounter sandstone bands at shallow depth. This was recovered as gravel from window samples and boreholes and should excavate to depths of approximately 3.0m bgl if large tracked 360^{o} type excavators are used.

There are unknown thickness's of concrete on the site and there may be unknown obstructions left on the site following demolition and provision should be made for the breaking out and excavation of these as the need arises.

If managed correctly with an appropriate demolition method statement, the demolition of the site will produce significant volumes of recycled aggregate (Type 1 and 6F2) and other higher value aggregates could be produced with additional spend on processing for which there would be a positive business case.

7.4 Foundations

Because of the ground conditions that have been identified at the site, it is considered that a combination of shallow trenchfill foundations and piled foundations will be appropriate.

7.4.1 Shallow and Trenchfill Foundations

Based on the findings of the current investigation, it is anticipated that trenchfill foundations will be possible across the majority of the site founding in either the clays or sands at an allowable bearing pressure of 125kN/m^2, at a minimum depth of 0.90m bgl.

Foundations will need to extend through the Made Ground and embedded at least 300mm into the clay or sand. Due to the presence of low to medium shrinkability clays near the surface foundations will require deepening due to the presence of existing or removed trees.

Foundations will need to be deepened where the proposed planting of shrubs is indicated within 3m of the face of foundations.

Where foundations are within the influence of trees and deeper than 1.5m bgl, a suitable compressible material or void former will be required. This includes piled foundations, if used.

Where foundations require deepening to greater than 2.5m below ground level, they will require design by an engineer in accordance with Technical Requirement R5.

Foundations which span differing founding materials should have mesh reinforcement placed top and bottom of the foundation.

7.4.2 Piled Foundations

Piles are recommended where:

- the proposed development is to be in excess of 3 stories; or
- on the eastern side of the site where the retaining wall is present and deep Made Ground has been encountered.

Piled foundations would need to extend through the Made Ground and embed in the underlying clay, sand and sandstone bands.

Based on the proven ground conditions, a number of piled solutions could be given consideration e.g. driven steel, driven concrete piles, Continuous Flight Auger (CFA) piles or Continuous Helical Displacement (CHD) piles.

It should be noted that the presence of obstructions in the Made Ground may impact the installation of piles. A methodology for this will need to be accounted for in the design of piles.

Driven Piles

There are some existing commercial buildings in the general site area and hence the use of driven piles may have restrictions due to noise and vibration constraints. However, the surrounding areas could not be considered as densely populated and it is considered that the use of driven piles is worth exploring.

The Local Authority would need to be contacted with the noise and vibration output to be expected from the works, such that they could determine if the method is suitable. In addition, it is noted that 'quiet' driven piling techniques are now available from some contractors. These have made driven piling allowable in cases where it would have been previously refused.

Continuous Flight Auger Piles (CFA)

CFA piling would provide a 'quiet' piling technique that is often used in residential areas. From the borehole information from the current works, preliminary pile safe working load calculations have been undertaken for CFA piles.

Indicative safe working loads for single 300mm and 450mm diameter bored piles at various depths are presented in the following tables. The assessment is based upon the data obtained from the boreholes and from field observations for CFA piles.

The working loads incorporate a factor of safety of 2.5 for both shaft friction and base resistance. An adhesion coefficient of 0.5 has been assumed, embedment in the Sand has been assumed and it has been assumed that an average 3m thickness of Made Ground will be encountered where piles are to be considered.

Pile Depth (m)	300m Diameter Pile SWL (kN)	450mm Diameter Pile SWL (kN)
6	250	500
8	450	900
10	900	1200

Continuous Helical Displacement Piles (CHD)

The technique comprises a steel, hollow stem boring head with helical flights that are screwed into the ground whilst displacing the soil laterally. When the founding depth is reached, the direction of rotation is reversed and the auger withdrawn. During withdrawal, concrete is pumped at high pressure through the hollow stem and tip, forming a pile with flanges that follow the path created by the helical flight.

If piles are considered as the preferred foundation solution, advice would need to be sought from a specialist contractor.

7.5 Floor Slabs

Plastic soils are present on site and Made Ground is present at depths greater than 0.60m bgl and so it is recommended that suspended floor slabs are used, constructed in accordance with NHBC Standards. Ground-bearing slabs may be possible but a plot-by-plot investigation would be required to confirm the absence of desiccation.

7.6 Roads

As construction will be predominantly from a Made Ground horizon a CBR value of <2% should be allowed for design purposes subject to confirmatory CBR testing and proof rolling.

7.7 Soakaways and Drainage

Falling head permeability tests in accordance with BS5930 were conducted and the results ranged from 5.60×10^{-04} to 8.23×10^{-06}. It was not possible to calculate a permeability rate for WS4 due to high groundwater level. Soakaways will be technically possible in the main section of the site but this should be re-assessed once the proposed development and proposed soakaways design has be finalised. However, due to the high groundwater no soakaway are recommended for the former quarry area in the north of the site.

7.8 Buried Concrete

Buried concrete classification is based on guidelines provided in BRE Special Digest 1, the Design Sulfate Class for the site is **DS-1** and the Aggressive Chemical Environment for Concrete is **AC-1s**.

7.9 Recommendations for further work

Slope stability works were beyond the scope of works for this commission. If any development is to be undertaken in close proximity to the slope on the northern boundary or the retaining wall on the eastern boundary additional works will be required.

Foundation design will need to be undertaken once the development layout has been finalised and additional works may be required to provide information on shallow founding conditions following demolition.

8.0 GEO-ENVIRONMENTAL CONCLUSIONS AND RECOMMENDATIONS

8.1 Human Health

There is no pervasive contamination present on site; although additional works will be required in the vicinity of WS6 and WS7 due to potentially spurious elevated PAH concentrations. Subject to these additional works provision should be allowed for a 600mm cover system.

8.2 Controlled Waters

The groundwater comparison shows exceedances for lead when compared to the EQS freshwater, and lead, benzo(a)pyrene, and PAH# (benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene) when compared to the UK/EU drinking water. It is recommended that discussions be held with Environment Agency with respect to the vulnerability of the aquifer. If the Agency is concerned about the continuing source of contaminants additional risk assessment may be necessary.

8.3 Plant Life

There are no chemicals of concerns with regards to plant life.

8.4 Construction Materials

8.4.1 Water Pipelines

The WRAS information and guidance note 9-04-03 sets out trigger concentrations for water supply pipes to be laid in contaminated land. This a general guidance note and more detailed design advice can be found in a report, five best practice manual booklets and the Contaminated Land Investigation for Pipe Selection (CLIPS) database available from UK Water Industry Research[1] (2004). Individual water companies may have their own trigger concentrations and advice should be sought.

Where soil concentrations exceed the trigger values, special consideration of material selection or pipeline construction will be required.

In the case of metals and other inorganic substances, the trigger concentrations do not consider the risk to potable water in the pipes because there should be no risk of contaminants entering through joints as the water is under pressure. The values are set to protect staff working in an excavation. Typical requirements are to line the trench with an impermeable membrane and use clean backfill.

[1] CLIPS database is available to subscribers only.

The values for organic substances are set to protect the water because they can permeate the plastic pipe walls. Note that in the more heavily contaminated sites, the water company may require site-specific consideration of the type of pipe and connections.

The presence of concentrations of TPH in excess of the respective trigger values warrant the use of Protectaline or similar proprietary barrier pipework for all water supplies at the site. It is recommended that the Water Supply Company is consulted with the chemical results for the site.

8.5 Precautions Against Ground Gases

8.5.1 Radon

The British Geological Survey report states that no radon protection is required for new dwellings at this location, in accordance with BR211, 1999.

8.5.2 Landfill Gases

The ground gas readings and gas regime conceptual model derived from the current works indicate Characteristic Situation 1 and no special precautions are required.

8.6 Waste Management

Any material excavated on site may be classified as waste and, as such, its handling, re-use or disposal is regulated by the Environment Agency. Generic advice is available from the Environment Agency (April 2006) in the form of a guidance note, but it is *recommended that site-specific advice be sought from the local Agency staff at the earliest opportunity*, particularly as the guide refers to work in progress and developing case law.

It is the responsibility of the holder of a substance or object to decide whether or not they are handling waste. The Agency guide gives examples of whether or not materials are likely to be considered as waste, having regard to the tests that the Courts have used and to the aims of the Waste Framework Directive.

Further details of the guidance and the classification of waste are presented in Appendix J.

8.7 Remedial Strategy

A preferred remedial strategy for the site will have to be developed in consultation with the design team and the regulatory authorities. Liaison should be continued during implementation and subsequent validation. With the information available from the current investigation the following approach is suggested.

1. Undertake additional works in the vicinity of WS6 and WS7 following, in consultation with the regulatory authorities.

2. Implement risk control measures to reduce the identified risks to acceptable values. This will involve remediation of the site as detailed below.

The most appropriate remediation option for the site depending upon the perceived risk of groundwater contamination is removal of the TPH and SVOC Hotspot (WS3) and if PAH is found to be pervasive in the front of the site, install an imported clean cover designed according to the BRE guidance (Hollingsworth 2004) for garden areas. The design requires chemical analysis of the proposed cover material but, assuming the worst case example of the cover being at the generic criteria for PAH (BaP), a thickness of 600 mm would be required

8.8 Uncertainties

Uncertainties or limitations associated with these conclusions are as follows:

- The analytical results for PAH from WS6 @ 0.40m bgl and WS7 @ 0.40m bgl are extremely different from the remainder of the analytical results. Detailed examination of the borehole logs does not provide a possible cause for this elevated PAH. Hydrock have queried the elevated PAH with the laboratory and while the laboratory states there are no analytical concerns.

8.9 Recommendations for Further Work

- Additional works in the vicinity of WS6 and WS7 following demolition.

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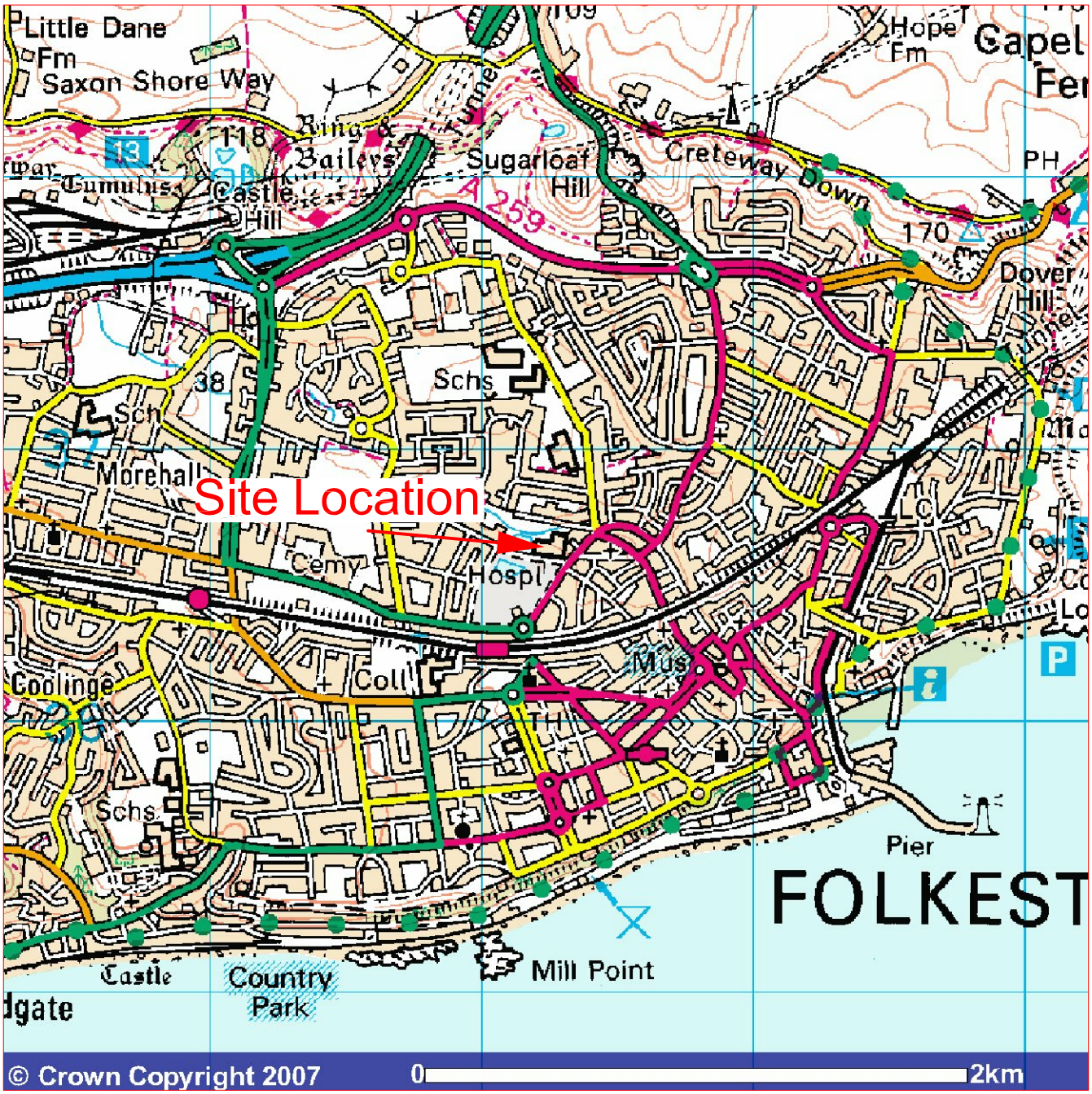
APPENDICES

Appendix A

SITE LOCATION PLAN



Rev	Date	Description	Drawn	Checked
A	26/04/07	First Issue	DM	AB
Rev	00/00/00	Description	ACS	ACS

Project: ROYAL VICTORIA HOSPITAL, FOLKESTONE

Title: Site Location Plan

Client: EAST KENT HOSPITALS NHS TRUST

Drawing Status: INFORMATION

Job No.: C/07060

Drawn	Checked	Scale at A4	Date	Issue Date
DM	AB	NTS	26/04/07	26/04/07

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