YELLOWAYS DEVELOPMENT

(ROCHDALE OFFICE)

Geo-Environmental Interpretative Report

760140/R/02C

August 2006

Produced for
Rochdale Development Agency

Prepared by
Melanie Wrigley – Assistant Hydrogeologist
Jeremy Jones – Senior Geotechnical Engineer

Parkman House
Lloyd Drive
Ellesmere Port
South Wirral
CH65 9HQ

T 0151 356 5555
F 0151 356 4225
E melanie.wrigley@mouchelparkman.com

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EXECUTIVE SUMMARY

Introduction	Mouchel Parkman was appointed by Rochdale Development Agency to design and supervise a geo-environmental ground investigation at the Yelloways car park, Rochdale. The aim of the work is to identify potential environmental and geotechnical abnormals that may impact the viability of the site for proposed redevelopment as offices with car parking and landscaping.
Site Location	The 0.46 hectare site is located south east of Rochdale town centre, off Slack Street and beside the River Roch (Figure 1). The site is centred at National Grid Reference (NGR) SD 899 133 (389960E, 413360N) and comprises a rough surfaced carpark for season ticket holders (Figure 2 and Figure 3). The site has a significant infestation of Japanese Knotweed (*Fallopia Japonica*) present along the southern river wall. The growth is also spreading up the east and western boundaries of the site and there is one, small area of growth on the northern boundary as well. This plant was viewed as posing a significant risk to the proposed redevelopment timescales and therefore, on consultation with the client, eradication treatment was commissioned through a specialised contractor.
Site History	The site was occupied by open fields until circa 1831 when two mills and a tobacco works were built. The mills and tobacco works remained until circa 1958/59 when a bus station was built, occupying the whole of the site. The bus station was demolished in c1992. From historical research it appears that the bus station also had its own facilities for maintenance, bodywork and refuelling of the buses. The surrounding land has been occupied by housing, works, mills and more recently, a large bus station to the north of the site.
Environmental Data	There are no landfills registered within 250m of the site. There is one former landfill between 251m-500m of the site and two more within 1km of the site. In addition, there are no IPC/IPPC authorisations within 250m of the site; however there is an APC permit 227m to the east of the site. There have been 4 pollution incidents to the River Roch within 250m of the site but all occurred in 1995 and were classed as Minor Incidents.
Geology, Hydrology and Hydrogeology	The geological plans indicate that the site is underlain by Alluvium with the solid geology shown as Lower Coal Measures (Geological Survey Map Sheet 76 (S&D), Rochdale). A Coal Authority Report was obtained and no potential risks to the development were highlighted. The nearest watercourse to the site is the River Roch that flows from east to west past the south of the site and along the western boundary. The site is located within an area of extreme fluvial flooding from the River. The Lower Coal Measures are considered to be a minor aquifer and the site is not within a source protection zone. There are no abstraction points within 1km of the site.
Conceptual Site Model	The initial conceptual site model identified contaminated soil and dust, underground storage tanks, service pits, groundwater and contaminant vapours as potential sources of contamination. Possible receptors included current and future site users, surrounding users, perched groundwater, the minor aquifer, the River Roch and infrastructure.
Site Investigation	This investigation comprised the excavation of 9 trial pits to depths between 1.5m-3.8m and 4 cable percussion boreholes, two of which were extended to 16.5m and 19.5m by rotary coring (BH2B and BH3). Standpipes for gas and groundwater monitoring were installed in BH1 and BH4. Soil and groundwater samples were taken and submitted for contaminant analysis and gas and groundwater monitoring post works was undertaken. Geotechnical samples were also taken and tested. Exploratory hole locations are shown in Figure 2.
Physical Ground Conditions	The made ground thickness ranged between 0.4m-2.9m and comprised bricks, tarmac, wood, slag, ash, clinker, sandstone setts and concrete with a thin layer of black hardcore gravel on the surface. The made ground is underlain by alluvial drift deposits with a 4m band of clay at the base. The clay overlies the Coal Measures' strata of mudstones, sandstones and siltstones. The weathered surface of the Coal Measures was encountered at 11.5-12.2mbgl. The investigation also encountered subsurface structures such as infilled basements and service pits that were filled with perched water. Shallow groundwater was encountered in all of the exploratory holes except for TP4 in the east of the site and deeper groundwater in the Coal Measures was encountered in BH2B and BH3 and found to be artesian. The shallow groundwater levels in the alluvium indicate that groundwater beneath the site is in continuity with the River Roch and that a proportion of the baseflow of the river flows under the site. Hydrocarbon contamination of the shallow groundwater across the site was noted in the investigation.
Geotechnical Assessment	The variable nature of the made ground means that it does not represent a suitable founding stratum for structures with significant imposed loads or those sensitive to settlement. Deeper foundations are required such as basement rafts with thickened beams between columns founded on the deeper soils, or piled foundations.

	The construction of undercroft car parks in unsupported excavations with sloping sides is not considered appropriate due to the shallow groundwater present at the site. Dewatering or water exclusion techniques would be required to allow the work to proceed. The findings of the ground investigation will require further review to enable detailed design once the proposed construction details are known. However, the subsurface structures (former basements, foundations and service pits), the possibility of opening up pathways into the aquifer and the artesian groundwater should also be considered.
Risk Assessment	Site wide contamination within the made ground exists as diesel range organics, benzo-a-pyrene and total petroleum hydrocarbon with additional hotspots of alkaline pH, lead, sulphide, boron and copper. TP4 in particular was noted as a hotspot of significant hydrocarbon contamination. Site wide contamination of the shallow groundwater with hydrocarbons (gasoline range organics, benzo-a-pyrene) and copper was also noted but is not thought to be as a result of leaching from the made ground, but from an unidentified, subsurface contamination source located in the vicinity of TP2, TP5 and BH2B. The shallow groundwater poses an unacceptable risk to the adjacent controlled water, the River Roch.
Conceptual Model	The conceptual model drawing can be seen in Figure 5. *Source*: Contamination has been identified in the made ground across the site and around TP4. The risk assessment has also predicted the presence of a subsurface source of hydrocarbon contamination in the shallow groundwater. *Receptors post redevelopment with no remediation*: Controlled waters, plant life, infrastructure and site workers during redevelopment *Pathways:* Controlled waters – direct contact of uncontaminated shallow groundwater with subsurface source and offsite migration of contaminated shallow groundwater into the River Roch; (contamination of deeper groundwater is considered a lower risk due to the artesian pressures in the aquifer and the confining clay layer); Plant life – direct contact and uptake; Infrastructure – direct contact with contaminated made ground and groundwater; Site Workers – direct contact and inhalation. The risk assessment and revised conceptual model for the site assuming commercial end use with no remedial work indicates a high risk to controlled waters. The risk to plant life and infrastructure is assumed to be addressed indirectly as a result of importation of clean fill material for landscaping and service trench backfill. The risk to site workers will be addressed through the CDM regulations. However, as a result of the contamination identified in the made ground, several of the samples are determined as hazardous based on the 'Hazardous Waste Assessment Criteria'. This therefore presents an important consideration for the development itself which should be designed to minimise excavation and disposal.
Further Characterisation Works and Remediation	Further work is recommended to address the two remaining issues; *(Cost estimates have been undertaken using professional judgement and without consultation with the appropriate regulatory bodies)* 1. The uncertainty with regards to the extent of contamination identified at TP4 and following characterisation, the cost implications of the potential remedial works: - *Characterisation works recommended*: A second phase of 4-5 trial pits in the vicinity of TP4 with associated chemical testing. - *Estimated characterisation costs:* £4,125 - *Estimated remedial costs:* £91,000 **Total cost estimated £95,125** 2. The location and nature of the subsurface source of the groundwater hydrocarbon contamination and following location and characterisation, the extent and cost implications of the potential remedial works involved: - *Characterisation works recommended:* A series of investigative 'trenches' in the vicinity of TP2, TP5 and BH2 and associated chemical testing. - *Estimated characterisation costs:* £11,250 (consultation with specialist contractors would provide a more accurate estimate for the cost of obtaining pumping facilities and an operative (*See Section 13.6.2*))). - *Estimated remedial costs* (hypothetical localised source, say 10m^3 of contamination)*:* £1,600 **Total cost estimated £12,850** ***N.B This estimate does not make allowance for any additional costs relating to the potential sludgy nature of the source or any additional works that the Environment Agency may specify. It is also highly sensitive to the actual volume of the source which is currently unknown – hence the need for the characterisation.***

1 INTRODUCTION

1.1 Introduction

1.1.1 Terms of Reference

Mouchel Parkman was appointed by Rochdale Development Agency to undertake a geo-environmental investigation in order to identify potential environmental and geotechnical abnormalities that may impact the viability of the site for proposed redevelopment as an office scheme.

The site reviewed in this report is based on the boundaries as defined by Rochdale Development Agency. Mouchel Parkman prepared this report based on the available information received during the study period. Although every reasonable effort has been made to obtain all of the relevant information available, all potential contamination, environmental constraints or liabilities regarding the site may not necessarily have been revealed.

Mouchel Parkman has also used reasonable skill, care and diligence in the design of the investigation of the site. The inherent infinite variation of ground condition allows only definition of the actual conditions at the location and depths of exploratory holes, while at intermediate locations conditions can only be inferred.

This report has been prepared for the benefit of Rochdale Development Agency and written for the purpose of providing geo-environmental information relevant to the current potential environmental liabilities and the potential liabilities associated with developing the site for a commercial end use. The report contents should not be used out of that context. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

1.1.2 Report Format

The report gives a summary desk study including a description of the site and its surrounding area, geology, hydrology and hydrogeology, site history, identification of the potential contamination sources, their potential receptors and possible pollutant linkages. The details of the ground investigation are reported along with a summary of the physical and chemical ground conditions identified. Recommendations with regard to any necessary further works or remedial measures based upon the proposed commercial end use of the site are also presented.

1.1.3 Methodology

In carrying out the desk study section of this report, a number of statutory consultees were contacted prior to the design and completion of the ground investigation. A list of the consultees is given below:

- Landmark
- Environment Agency (website only)
- Service Companies

- Local Authority
- The Coal Authority

In reviewing information from the ground investigation, reference has been made to current legislation and best practice guidance.

1.2 Basis of Conceptual Ground Model

The Conceptual Ground Model for this site has been designed and assessed according to best practice and the following legislation and the associated guidelines, given the proposal to redevelop the site for a commercial end use. It should be noted that any redevelopment of a site could actually create new pathways that could increase the liabilities associated with the site.

Section 57 of the *Environment Act 1995,* adds Part IIA (ss.78A-78YC) to the *Environmental Protection Act 1990* and contains the legislative framework for identifying and dealing with contaminated land. The regulations cover the following:

- Land to be designated as special sites
- Pollution of controlled waters
- Content of remedial notices, and persons to whom they should be copied
- Compensation for rights of entry etc
- Grounds of appeal against a remediation notice

In addition, section 86 of the Water Act 2003 contains amendments to Part IIA relating to controlled waters that causes Part IIA only to apply where "significant " pollution of controlled waters is being caused from within the soil, or there is a "significant" possibility of such pollution being caused.

Local authorities (district councils and unitary authorities) are the enforcing authority for contaminated land and the Environment Agency for any land designated as a special site due to the nature of its contamination.

In identifying contaminated land, local authorities will be required to act in accordance with guidance from the Secretary of State. Contaminated Land is defined as:

"land, which appears …..to be in such a condition, by reason of substances in, on or under the land that-

significant harm is being caused or there is a significant possibility of such harm being caused; or

significant pollution of controlled waters is being caused or there is a significant possibility of such pollution being caused"

The Statutory Guidance defines what "harm" is to be regarded as "significant" to:

Human beings: death, disease, serious injury, genetic mutation, birth defects, or the impairment of reproductive functions. Disease is to be taken to mean an unhealthy condition of the body or some part thereof.

Living organisms: or ecological systems: an irreversible or other substantial adverse change in the functioning of the habitat or site;

Property (buildings): structural failure or substantial damage making them unfit for their intended purpose.

The site is to be redeveloped and this report is to be used to support a planning application. As such, contamination issues will be addressed through the planning process, rather than Part IIA. However, the determination of appropriate mitigation identified as part of the planning process is based on a similar assessment to that described above.

The results of this assessment are presented in Section 5 and 12.

2 SITE AREA

2.1 Site Location and Description

The site is located in Rochdale, south east of the town centre as shown in Figure 1. The site is centred at National Grid Reference SD 899 133 (389960E, 413360N) and occupies an area of approximately 0.46 hectares. The majority of the site comprises a rough surfaced area that is used as a season ticket holder's car park. In addition, the north western corner of the site is occupied by an access slipway, owned and maintained by the Environment Agency and at the time of the site works (May 2006), the eastern portion of the site was in use as a contractor's storage compound. The contractor's enclosure was due to be vacated by late June 2006. The site is roughly level with a slight slope down towards the west. Specific site levels can be obtained from the topographical survey that was commissioned by Mouchel Parkman (drawing number 2620/01 by RFP Surveys). Access to the site is off Slack Street via a 4m wide gateway at the western end of the northern boundary.

The site is bounded on two sides by the River Roch that flows westwards, passing over a weir beside the site. The river boundaries on the site comprise a sandstone wall along the southern edge and a rough, mounded earth and wooded fence boundary along the western edge, which meets the stone wall of the Environment Agency slipway. The eastern boundary of the site is a brick wall (within the contractor's enclosure) and the northern boundary is a wire mesh fence. There is also an earth mound boundary running from north to south within the site in the eastern portion that serves to delineate the contractor's area.

The car park area of the site comprises gravel/tarmac scalpings with areas of concrete showing through from below and there are also two areas covered by concrete slabs. One of the slabs lies in the southeastern corner, beside the river wall and one at the northern end of the earth mound that delineates the contractor's enclosure. There are no drains on the site and following heavy rain encountered during the site works, several large puddles developed in the south of the site. The contractor's enclosure is surfaced with larger gravel and sandstone chippings and the service road leading to the enclosure from Slack Street is surfaced with sandstone setts.

Being a car park, there are currently no major services to the site but there is a solar powered parking ticket machine beside the entrance to the site and a line of 5 lighting posts in the western portion of the site running approximately north to south. The lighting posts are supplied from the nearest off site streetlight.

The site layout can be seen in Figure 2.

A separate Extended Phase 1 Habitat Survey and Ecological Assessment Report (760140/R/01) was carried out by Mouchel Parkman (June 2006) and identified that the vegetation at the site generally consists of trees and scrub around the periphery of the car park. However, significant infestations of Japanese Knotweed (*Fallopia japonica*) are also present on the site, growing out of the river wall along the south of the site and spreading up the east and western boundary in smaller growth patches.

There is also one small area of growth on the northern boundary. The Japanese Knotweed infestation of the site would have posed a significant risk to the viability of the proposed redevelopment however, eradication treatment has been commissioned (July 2006) following consultation with a specialised contractor.

2.2 Surrounding Land Use

The surrounding land use is comprised primarily of commercial properties and car parking, though there is also a Christian Science Church off Slack Street on Ink Street that runs northwards away from the site entrance. The northern boundary of the site is formed by Slack Street that runs east-west. To the south of the river are more commercial and industrial buildings and to the west of the river is a second season ticket holder's car park.

Notable industries within the immediate vicinity of the site include several car dealers 20m south east and 102m east, a Blinds, Awnings and Canopy works and a Ventilator manufacturer 78m south and an unidentified works 30m west, the Bus Station 80m north and a Youth Centre and Church 100m north east.

2.3 Land Ownership

The site is currently owned and operated as a season ticket holder's car park by Rochdale Metropolitan Borough Council (RMBC).

2.4 Site History

The history of the site and the surrounding area has been determined by the use of historical Ordnance Survey maps of the site obtained from Landmark. The historical maps are presented as part of the Landmark Report in Appendix A.

The site comprised open land and fields from c1851 until c1893 when mills and a tobacco works are shown on the site. In c1910 one of the mills became a warehouse but by 1930 the warehouse had gone and the mill was no longer labelled. There were also chimneys on the site from 1910. By 1956 the site appears to have been cleared and in 1959 a Bus Station is located on the site and the tobacco works is no longer labelled.

The Bus Station was demolished some time between 1988 and 1992 and the site has remained unoccupied since then. Historical research indicates that the bus station was known as Weir Street Bus Station, however Weir Street (northwest of the site leading off Smith Street towards Slack Street, running beside the river) was built over at the same time as the bus station was demolished. Historical research also describes the site as 'a large coach station and vehicle maintenance garage'.

The area surrounding the site comprised open fields from c1951 and the River Roch followed the same course that it does today. By 1893 there had been significant development in the area with the site being surrounded by housing to the north east, a mill and a timber yard to the south, works to the west and further mills to the north. On the opposing side of the river, 80m south of the site there was also an Iron Foundry. Slack Street forms the northern boundary of the site from c1893. The surrounding land use remained as housing, mills, warehouses and works (including iron works) until the late 1970's when the mills and works began to be replaced. The housing to the north east of the site was completely demolished by 1986. The large Bus Station situated 80m north of the site was constructed c1978

The history of the site is detailed in Table 1.

Table 1. Site history

Year	Site Land Use	Surrounding Land Use	Scale of Source Map
1851	Open land/fields	The surrounding land in the immediate vicinity is open land with buildings further to the north and to the south of the river. The River Roch runs along the southern and western boundaries of the site.	1:10,560
1854	No map coverage	No map coverage	
1893	Two mills; Weir Mill and a Corn Mill occupy the site. A Tobacco Works occupies the east of the site.	Slack Street runs along the north of the site. 150m north there is a public baths, a school, a Woollen Mill and Bowling Green mill. To the east of the site (opposing side of the river) there is a timber yard and housing. To the south there is an Iron Foundry and an Iron Works and to the southwest there is a Glove Works. To the west there is another Iron Works and to the northwest a Butt Factory. There is also a weir by the western boundary of the site. The surrounding area also comprises a significant amount of housing.	1:2,500
1894	No significant change.	No changes visible due to the map scale.	1:10,560
1910	The Corn Mill appears to have been demolished and replaced by a Warehouse. There are also chimneys shown on the site. To the north west of the site is Weir Street running towards the site from Smith Street alongside the river.	The surrounding area is still largely industrial with a machinery works now located immediately west of the site, on the opposite side of the river. There are also now two warehouses approximately 50m north of the site. The Iron Foundry has been replaced by a Print Works (90m south) and there is a Spring Works 50m northeast. The Timber Yard to the south of the river is no longer labelled.	1:2,500
1910/ 1911	No significant change.	No changes visible due to the map scale.	1:10,560

1930	The Weir Mill is no longer labelled and the warehouse has been demolished.	The Print Works is now a warehouse and the Machinery Works to the west is no longer labelled. There is a Tarpaulin Works 220m north east and a Paper and Tube Works 180m south east.	1:2,500
1931/ 1932	No significant change.	No changes visible due to the map scale.	1:10,560
1956	The buildings on the site appear to have been demolished.	No changes visible due to the map scale.	1:10,560
1958/ 1959	There is now a bus station covering most of the site.	The woollen mill has been demolished and the school and public baths are now Lea Hall Youth Club. There are a number of mills and warehouses approximately 200m southeast of the site. The Iron Works to the east of the site is now an electric works and the Iron Works to the south of the site have also been replaced. The surrounding area still largely comprises mills, works and warehouses. There is an abattoir 40m north east of the site, off Morton Street and immediately south of the river is Central Garage.	1:1,250
1959/ 1960	No significant change.	No significant change.	1:2,500
1967/ 1968	No significant change.	No changes visible due to the map scale. There is an area of landfill shown 600m east of the site.	1:10,560
1974/ 1975	No significant change.	The abattoir is no longer labelled. There is a scrap metal works 90m to the southeast and three further garages in the area.	1:1,250
1975	No significant change.	No significant change.	1:1,250
1977/ 1979	No significant change.	No significant change. The area of landfill has spread and is now within 450m of the site.	1:10,000
1977/ 1983	No significant change.	A large bus station has now been built on the old Woollen Mill and Bowling Green Mill site, 80m to the north. There is also a large health centre to the north. Overall the number of works, mills and warehouses in the surrounding area has reduced.	1:1,250
1981/ 1986	No significant change.	There is now a large supermarket to the north-east of the site and the number of industrial buildings in the surrounding area has reduced again, due to demolition.	1:1,250
1992	Bus station has been demolished and the site is now unoccupied. Weir Street is no longer labelled.	The Wheatsheaf Shopping Centre is located 160m to the northwest.	1:1,250

1989/ 1993/	No significant change.	No significant change.	1:10,000
1993/ 1995	No significant change.	No significant change.	1:1,250
1999	No significant change.	No significant change.	1:10,000

3 ENVIRONMENTAL INFORMATION

3.1 Environmental Searches/Landmark Report

Environmental data has been obtained in the form of a Landmark Report. This information is included in Appendix A. A summary of the information received is included below.

3.1.1 Sensitivity Analysis

There are no environmentally sensitive areas within 500m of the site. However, Rochdale Canal is designated as a Site of Special Scientific Interest and a Special Area of Conservation and is located 971m south of the site.

3.1.2 Landfills

There are no registered landfill sites within 250m of the site.

There is a registered landfill site 478m east of the site, on the southern bank of the River Roch. The landfill was formerly operated by G.M.W.D.A. but the licence has now lapsed (Ref R/045). The site was a very large landfill (>250,000 tonnes per year) accepting construction, demolition, household and commercial wastes.

There are also records of two further landfills (Licence references 00544/89 and 00324/M03) within 1km of the east of the site at 893m and 943m, only one of which is active. Both were licensed to accept inert/non-hazardous wastes only.

3.1.3 Licensed Waste Management Facilities

There are 2 Licensed Waste Management Facilities within 500m of the site;

- Old Rochdale Incinerator Entwistle Road, Rochdale (Licence number 53780, 351m east); Special waste transfer station, operated by G M Waste Ltd.
- T A Motors, Trafalgar Street (Off Entwistle Road, Rochdale (Licence number 50346, 489m north east); End of life vehicle station (scrapyard), operated by Mahmood Tahir.

3.1.4 Registered Waste Treatment, Transfer and/or Disposal Sites

There are no registered waste treatment or disposal sites within 250m of the site.

There is one Registered Waste Transfer Site located within 500m of the site;

- Rochdale Incinerator, Entwistle Road, Rochdale (Licence reference 01009, 322m east); Transfer site, operated by G M Waste Ltd.

3.1.5 Integrated Pollution Control (IPC) / Integrated Pollution Prevention and Control (IPPC)

There is one IPPC permit (permit reference Bp0628iw) within 500m of the site (approximately 358m west) registered to;

- PW Greenhalgh And Co Ltd, Newhey Bleachworks
  Activity code 6.4 A(1)(B) Coating, printing and textiles.

3.1.6 Air Pollution Control Authorisations

There is one Local Authority Pollution Prevention Control permit within 250m of the site held by;

- Taylor Engineering & Plastics Ltd (NGR 390220 413280, 227m east of the site).

There are a further 8 permits within 500m of the site with the following descriptions:

- Approximately 268m south east – Taylor Engineering & Plastics Ltd
  PG6/29 Di-isocyanate processes

- Approximately 299m south east – Molesworth Street Service Station
  PG1/14 Petrol filling station

- Approximately 383m east – Isaac Butterworth Iron Founders
  PG2/4 Iron, steel and non-ferrous metal foundry processes
  PG2/3 Electrical and rotary furnaces

- Approximately 413m east – Readymix Concrete (NW)
  PG3/1 Blending, packing, loading and use of bulk cement

- Approximately 427m southeast – Timbmet Northern Ltd.
  PG6/2 Manufacture of timber and wood based products

- Approximately 435m east – Thomas Sandiford (Rochdale) Ltd
  PG2/4 Iron, steel and non-ferrous metal foundry processes

- Approximately 481m south – Henly Ford
  PG6/34 Respraying of road vehicles

3.1.7 Registered Hazardous Substances

There are no registered hazardous substances within 500m of the site.

3.1.8 Pollution Incidents

There have been four pollution incidents (dated 1995) to controlled waters (the River Roch) within 250m of the site, all of which have been classed as Category 3 (Minor) incidents and where identified the pollutant was rubble/litter or crude sewage.

There have also been a further ten pollution incidents to controlled waters (the River Roch) recorded between 251m and 500m of the site, one of which was classed as Category 2 (significant) incident and related to oils/diesel entering the River Rock/Moss Brook. The remainder were classed as Category 3 (minor) incidents.

3.2 Site Geology

3.2.1 Drift and Solid Geology

The 1:50 000 geological maps (Geological sheet 76 solid and sheet 76 drift) indicate that the site is underlain by Alluvium drift deposits overlying the Carboniferous Lower Coal Measures.

3.2.2 Coal Authority Records

The site is located within an area that may be affected by coal mining activity. A Coal Authority Report was obtained for the site but no potential risks to the development were highlighted. The Coal Authority Report is included in Appendix B.

3.2.3 National Geoscience Information Service & British Geological Survey

Ground condition data is included in the Landmark Report. This information is included in Appendix A. A summary of the information received is included below;

- Potential for Compressible Ground Stability Hazards;
  Onsite and 26m north east – Moderate

- Potential for Landslide Ground Stability Hazards;
  Onsite – Very Low
  142m east – Low

- Potential for Running Sand Ground Stability Hazards;
  Onsite – Low to Very Low
  26m northeast – Low
  64m & 110m north - Low

- Potential for Shrinking or Swelling Clay Ground Stability Hazards;
  Onsite and 18m northeast – Very Low

3.2.4 Radon

BR211 Radon: Guidance on Protective Measures for New Dwellings (1999) indicates that the site lies within an area where less than 1% of homes are above the Radon Action Level, and as such indicates that no radon protection measures within buildings are required.

3.3 Hydrogeology

The Lower Coal Measures underlying the site are a minor aquifer (variably permeable). These can be fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability including unconsolidated deposits. Although not producing large quantities of water for abstraction, they are important for local supplies and in supplying base flow to rivers.

The alluvial deposits that the site is located on are classed as a soil of high leaching potential (U). This classification is given to restored mineral workings and urban areas and is based on fewer observations than elsewhere. A worst case vulnerability classification H is assumed until proved otherwise.

3.3.1 *Groundwater*

The site is not within a source protection zone. There are no groundwater abstractions within 250m of the site. The nearest abstraction is 1220m to the west at a Textiles and Leather works. The water is abstracted to use as process water.

3.4 Hydrology

The nearest surface watercourse to the site is the River Roch that flows westwards along the southern boundary of the site, bending around to flow northwards along the western boundary as well. To the north east of the site (approximately 800m) there are also two tributaries to the River Roch, Hey Brook and Stanney Brook.

3.4.1 *River Quality*

General Quality Assessment (GQA) Classifications have been recorded for the River Roch along the reach that flows past the site (from Stanney Brook to Rochdale Sewage treatment works) as Class C (fairly good) for the year 2000.

The same reach was also graded as Grade E (poor) with respect to River Quality Biology GQA. A grade E means the river biology is 'restricted to pollution tolerant species'.

The Environment Agency monitoring data for 2002-2004 along the same reach of the River Roch record the water hardness as 89mg/l$CaCO_3$.

3.4.2 *Flooding*

The site is located within a fluvial floodplain at extreme risk of flooding, associated with the River Roch. A separate report has been compiled by Mouchel Parkman in relation to the flooding risks at the site.

3.4.3 *Discharge consents*

There are 4 discharge consents within 250m of the site boundary. All allowances relate to discharge of storm sewage overflow from United Utilities Sewage Disposal Works into unspecified receiving waters.

- Consent reference 01ROC0097, approximately 63m north east of the site
- Consent reference 01ROC0039 , approximately 126m north east of the site
- Consent reference 01ROC0078, approximately 155m west of the site
- Consent reference 01ROC0079, approximately 156m west of the site

There are a further 4 consents between 251m and 500m of the site. These also related to United Utilities Sewage Disposal Works discharging into unspecified receiving streams.

4 STATUTORY AUTHORITY ENQUIRIES

4.1 Service Companies

The following service companies were contacted to determine the presence of any services currently on the site, and therefore to allow the planning of the intrusive investigation;

- United Utilities
- National Grid Gas/Transco
- BT
- National Grid
- ntl Telewest
- Cable & Wireless

The service plans obtained are included in the Services section of Appendix B.

4.2 Local Authorities

Rochdale Metropolitan Borough Council was contacted with regards to information relating to the site. The council responses are included in the Local

4.2.1 Planning

The following information has been provided by the Planning Department of Rochdale MBC and is included in the Local Authority section of Appendix B:

- The site falls within Policy TC/16 'Development Sites, Riverside, Rochdale' under the current Unitary Development Plan (adopted 1999). It also falls within Policy S/1 – Rochdale Town Centre. A Replacement Development Plan is currently under review and details of this and current plan can be accessed though the council web site or the Strategic Planning Manager.

- There are no tree preservation orders on the site.

- No confirmation was given relating to any site of archaeological interest on the site or in the vicinity

- No confirmation was given regarding any history of mining or mineral extraction that may have taken place within 1km of the site (however, Mouchel Parkman has also obtained a Coal Authority Report (included in Appendix B) and no risk to the development was highlighted)

The planning department also supplied a list that documents planning applications relating to this site since 1984 and gives the reason for refusal if this was the case. It also lists planning applications since 1984 that are within 50m of the site.

4.2.2 *Environmental Protection*

Information provided by the Environmental Protection Team of Rochdale MBC is summarised below and included in the Local Authority section of Appendix B.

One landfill is identified within 500m of the site;

- Waithlands (Rochdale MBC reference LF24): This landfill was initially filled pre-licensing and accepted incinerator waste. Tipping is believed to have ceased in 1978. The site was also licensed under the Control of Pollution Act 1974 (RD/RES/045/80) as a waste transfer, landfill and civic amenity site.

  Subsoil Surveys Ltd carried out a ground investigation at the site in 1986 for a proposed sports development. Methane levels up to 57% (vol) were measured and subsequently GMWDA installed four long-term gas-monitoring wells. The most recent round of data available (February 2000 – June 2003) records methane levels regularly above 25% and carbon dioxide regularly over 10%.

No sites within 500m of the site have been designated as ‘contaminated land’ under Part IIA of the Environmental Protection Act 1990.

There are four Part B or A2 processes within 500m of the site (also recorded by Landmark):

- RMC Nile Street, 410m to the east – concrete batcher
- Isaac Butterworth, 360m to the east – ferrous foundry
- Taylor Engineering and Plastics, 400m to the southeast–di-isocyanate/ spraying (plastic components)
- Timbmet Northern Ltd., 410m southeast – timber yard

Seven site investigation reports have been identified relating to land within 500m of the site. A plan indicating the location of these investigations is presented in Appendix B. These investigations may be consulted if required. Two of the reports related to the land immediately west of the site, on the opposing side of the river.

No private water supplies are known to be present within 500m of the site.

There are no Statutory Nuisance notices still in force for properties within the site area.

There are no deemed / express hazardous substances within 500m of the site.

4.2.3 *Building Control*

The Building Control Department of Rochdale MBC had no information to supply.

5 INITIAL CONCEPTUAL SITE MODEL

5.1 Introduction

The conceptual site model has been designed and assessed according to best practice and in accordance with PPS23 as part of the planning regime. Contaminated land relates to the significant possibility of a significant risk within a planning context. This approach requires remedial action to be undertaken where it can be shown that, at a particular site, contamination is causing (or has the potential to cause) unacceptable risks in relation to the current or intended use of the site. The suitable for use approach involves managing the risks posed by contaminated land by making risk-based decisions. The risk-based approach is founded on the source-pathway-receptor relationship, using the following definitions:

Source (or contaminant):	the hazardous substance / agent
Receptor:	the entity that is vulnerable to the adverse effects of the hazardous substance or agent
Pathway:	the means by which the hazardous substance / agent comes into contact with, or otherwise affects the target

For a risk to exist there must be a source capable of causing harm, a receptor sensitive to that source and a pathway linking them. If one of these elements is missing, there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the pathway.

The contaminant-pathway-receptor relationship is referred to as the pollutant linkage. On each individual site, there may be more than one pollutant linkage and each of these requires individual assessment.

The conceptual model considers the major environmental factors such as geology, water bodies, location of potential sources of contamination, how the contaminant moves (pathway) and receptors likely to be affected by the contamination.

The conceptual model outlined below assesses the risks at the site based on desk study information. It is based on the proposed redevelopment of commercial offices with landscaping, assuming no remediation.

5.2 Pollutant Linkages

5.2.1 Source

Historically, the site was used as a bus station (and vehicle maintenance garage) and prior to that was occupied by mills, a warehouse (with chimneys) and a tobacco works.

Potential facilities that may have been on-site at the time of the bus station include diesel and petrol storage tanks, collection pits and workshop facilities for maintenance of the buses. The various mills along with the warehouse and tobacco works could also have had fuel tanks associated with them as well as lubricating oils. Site contamination could arise from the leaks and spillages of fuels and oils and the remains of any processes involving the chimneys on the site.

Possible contaminants associated with these uses includes - acetone, aromatic and polyaromatic hydrocarbons, chlorinated aliphatic hydrocarbons, organolead compounds, heavy metals, ash (from the chimneys) and asbestos as identified by 'The Contaminated Land Exposure Assessment (CLEA) Model: Potential Contaminants for the Assessment of Land. R&D Publication CLR 8 – 2002' published by DEFRA.

Historically the site was surrounded by mills, works and warehouses that could have contributed to contamination of groundwater beneath the site due to leaching of contaminants from potentially contaminated ground.

It is also likely that a layer of fill material was brought in prior to the construction of the bus station in order to level off the site. Based on the surrounding industries (including iron works) it is possible that the imported fill could have contained ash and even iron foundry slag. These would present a possible contamination issue with regards to heavy metals, PAH's and free cyanide.

Organic material within fill materials and within the underlying drift deposits may degrade to form hazardous gases such as methane and carbon dioxide.

Contaminated soils may leach contaminants into perched water, which could in turn contaminate deeper groundwater or the adjacent surface water.

5.2.2 Receptors

The main receptors at risk from contamination at the site following redevelopment with no remediation are as follows:

- Site occupants and neighbouring sites;
- Controlled waters including River Roch and the groundwater in the area.
- Infrastructure and buildings – particularly buried services and foundations.
- Vegetation

5.2.3 Pathways

The potential pathways through which contamination could impact on the identified receptors are:

- Site occupants and adjacent sites – direct contact, ingestion and inhalation. Direct contact refers to skin contact with contaminated material. Ingestion refers to oral intake of contaminants. Inhalation refers to both the direct inhalation of dust as well as inhalation of vapours or soil gas.
- Controlled waters – leaching of contaminants from the soil offers a pathway to controlled waters. Permeable made ground and the possible presence of preferential flow pathways within the Alluvium drift can allow migration of contaminated liquids. Mobile contaminants, including fluids can migrate through the ground or via groundwater. Surface run-off/overland flow directly from the site into the adjacent River Roch could also cause contamination of controlled waters. The presence of preferable flow pathways beneath the site i.e. disused storm drains/surface water drains could also provide a direct pathway into the River Roch.
- Infrastructure and buildings – direct contact with contaminated material or through migration of gas or vapours along service culverts and accumulation in living space. Concrete present as part of the development e.g. foundations, may be at risk from sulphate attack.
- Plants are at risk from contact with phytotoxic contaminants present within the growing medium.

5.2.4 Summary of pollutant linkages

A number of pollutant linkages can be identified from the information detailed so far.

Table 2 below summarises the pollutant linkages identified above based on the site's proposed use as commercial offices with landscaping. The risk is assessed using the three categories listed below:-

- High – Action must be taken to reduce the risk that is judged to be too high.
- Medium – There is sufficient evidence to suggest that there may be an unacceptable risk. Further work is needed before this can be rejected or accepted.
- Low – There is a low risk to the identified receptors, which should still be addressed with the aim of reducing the risk to a minimal acceptable level.

Table 2. Summary of pollutant linkages and potential risk

Source	Pathway	Receptor	Risk
Contaminated made ground	Direct contact	Site occupants	Medium
		Infrastructure	Medium
		Plant life	Low
	Inhalation / ingestion	Site occupants and adjacent site users	Medium
	Leaching/migration of contaminants	Controlled waters	High
		Perched water and shallow groundwater	High
		Infrastructure	Medium
Soil gas / vapours	Migration of gas / vapour	Site occupants and infrastructure	High
	Inhalation	Site occupants	High
		Adjacent site users	High
Contaminated groundwater	Direct contact	Site occupants and adjacent site users	Medium
		Infrastructure	High
	Ingestion	Site occupants and adjacent site users	Medium
	Migration	Uncontaminated perched water and shallow groundwater	High
		Controlled waters	High

6 GROUND INVESTIGATION

6.1 Rationale

The rationale behind the investigation was to obtain data on the physical and chemical ground conditions at the site. This was done in order to assess any potential risks to human health, controlled waters and infrastructure in view of the proposed redevelopment as well as gaining geotechnical data to assess the viability of the site and allow the potential founding options to be explored.

6.2 Site Works

The intrusive investigation was undertaken by Geotechnics Ltd between the 22nd and 26th May 2006 and was designed and monitored by Mouchel Parkman. Soil and groundwater samples were taken from the exploratory holes for chemical analysis and geotechnical samples were also taken. Selected soil and groundwater samples were scheduled by Mouchel Parkman for chemical analysis at ALcontrol Geochem, Chester. Mouchel Parkman scheduled the geotechnical samples and the testing carried out by Geotechnics Ltd. at their laboratory in Coventry. In-situ geotechnical testing was also carried out during the intrusive investigation.

Following the intrusive investigation, Geotechnics Ltd also carried out 4 monitoring trips to the site during June 2006 to undertake gas and groundwater monitoring. Samples of groundwater were retrieved from selected installations and sent for analysis.

The investigation comprised 9 machine dug trial pits excavated to depths of between 1.5m and 3.8m (TP1-TP9), 2 cable percussion boreholes drilled to between 8.5m and 9.2m depth (BH1 and BH4) and a further 2 cable percussion boreholes to 12.90m and 14.05m with rotary follow-on with coring to 16.5m and 19.50m respectively (BH2B and BH3). BH3 only reached 16.5m during the rotary coring phase as the borehole collapsed and the drilling therefore had to be abandoned. The exploratory hole locations are shown in Figure 2.

The exploratory hole logs together with the geotechnical testing results and the gas and water level monitoring data are included in Geotechnics' Factual Report, presented in Appendix C of this report.

Installations to facilitate gas and groundwater monitoring were located in the two cable percussion boreholes (BH1 and BH4). The initial plan to put installations in all 4 of the boreholes had to be re-assessed following the discovery of artesian groundwater conditions in the Coal Measures at BH2B and BH3. These boreholes were subsequently sealed to the surface in order to stop the artesian flow. Table 3 below summarises the installation details within the holes.

Table 3. Installation Details

Exploratory Hole ID	Response Zone (mbgl) & Type of Installation	Strata Covered by Response Zone
BH1	0.60-3.60 Standpipe (and flush, lockable cover)	Made Ground and silty/gravelly Sands
BH2B	Sealed to surface due to artesian groundwater	N/A
BH3	Sealed to surface due to artesian groundwater	N/A
BH4	1.00 – 4.00 Standpipe (and flush, lockable cover)	Made Ground, silty Gravel and gravelly Sands

7 PHYSICAL GROUND CONDITIONS

7.1 Ground Conditions

Observations from the exploratory holes excavated indicate the ground conditions to generally comprise a sequence of made ground of variable thickness overlying drift deposits that in turn overlie bedrock. The ground level of the exploratory holes ranges between 119.46mAOD and 120.48mAOD.

The following generalised sequence of strata was encountered by the exploratory holes on the site (with the exception of TP4 in the east of the site);

- Made ground; bricks, concrete, tarmac, rubble, slag, ash and clinker
- Alluvial deposits; silts, sands, gravels and clays
- Coal Measures; sandstone, mudstone and siltstone

The general strata sequence at TP4 comprised a 1.8m thickness of made ground that included: 0.25m of sandstone hardcore gravel; 0.95m of brown silty medium to coarse sand with ash, cobbles, brick, sandstone, shale, tarmac and slate; soft brown sandy, gravelly silt with ash, slag and clinker and a creosote odour. The made ground overlay 0.9m of sandy silt with a natural organic odour directly on top of a full 1.1m of stiff, slightly gravelly/sandy clay. The gravel within the clay was sub-rounded, fine to medium.

The generalised strata for the rest of the site, as encountered in the exploratory holes are summarised in Table 4 with typical depths and general descriptions.

Table 4. Summary of strata encountered (excluding TP4)

Stratum	Range of strata thickness (m)	Strata base level range mAOD	General Description
Made Ground	0.4 to 2.9	119.12 to 116.74	Comprises several distinct types; Present across the whole site: 0.05m-0.5m surface layer of dense black and pale grey sandy, silty angular gravel of limestone hardcore, tarmac, bricks, ash, slag and clinker (in places)
			Present in 5 out of the 13 exploratory holes: 0.2m-2.1m thickness of brown slightly gravelly, silty medium and coarse sand with brick, stone and ash. This also gave off a hydrocarbon odour in several encounters.

			Present in 6 out of the 13 exploratory holes: 0.1m to 1.3m thickness of black silty, gravelly fine, medium and coarse sand of ash, slag and clinker. This stratum also gave off a hydrocarbon odour in some encounters.
			Other constituents of the made ground include sandstone and cobble setts (in bitumen matrix), sandstone paving slabs, wood and timber, reinforced concrete, brickwork and tarmac.
Alluvial deposits	Proved thickness in BH3 & BH2B; 10.7 to 11.75 *Elsewhere base not proven*	108.74 to 107.57 *Elsewhere base not proven*	Interbedded combination of; - brown/grey gravelly, silty fine and medium SAND - grey silty fine and medium SAND/sandy SILT with a natural organic odour - grey silty, sandy medium and coarse GRAVEL - grey/brown sandy, gravelly CLAY - dark brown firm laminated CLAY - brown silty fine, medium and coarse SAND *N.B All four boreholes encountered approximately 4m of firm, brown clay at ~6mbgl with the base of the strata at 10mbgl. This could be Boulder Clay.* (with rapid inflow of water noted)
Lower Coal Measures	5.0 to 7.0 *Full thickness not proven*	103.74 to 100.27 *Full thickness not proven*	Comprises bands of; - highly/completely weathered brown/yellow fine, SANDSTONE recovered as a very silty sand - moderately strong yellow/brown, fine to medium grained SANDSTONE - weak/very weak black/grey highly weathered MUDSTONE/SILTSTONE - moderately strong/strong grey fine to medium laminated SANDSTONE - weak/very weak weathered micaceous MUDSTONE

Apart from the ground conditions summarised above, the made ground also comprised subsurface structures such as the remains of basements and foundations, likely to have been associated with the site's historic use. TP5 in the centre of the site encountered what appeared to be a backfilled service pit, probably related to the historic bus station and BH2 dug into an old basement. TP2 encountered a wall running parallel to the river, cutting the trial pit in two across the centre.

During the investigation hydrocarbon and oily odours were noted in a number of the exploratory holes. In several instances black staining and mottling was also noted;

- BH2B at 0.9m-1.1m depth: Oily odour noted in the silty sand below the made ground. The made ground at this location contained sandstone setts and tarmac.

- BH3 at 0.3.-0.8m: Slight hydrocarbon odour noted in the gravelly, silty brown sand of the made ground. The made ground at this location also contained tarmac and sandstone setts.

- BH4 at 0m-2.9m: Slight hydrocarbon odour noted in the black silty gravel made ground. There was also an oily odour noted in the dark grey silty gravel below this. The made ground at this location contained cobbles, bricks, ash and clinker.

- TP2 at 1.3m-1.4m: Hydrocarbon odour noted in the black silty gravelly sand. The made ground above this included tarmac, wood and ash.

- TP3 at 0.55m-0.9m: Strong hydrocarbon odour noted in the black silty gravel of the made ground. A strong hydrocarbon odour was also noted at 1.1m-2.3m in the grey silty sand. The made ground at this location comprised a 0.15m layer of tarmac as well as cobble setts, ash and clinker.

- TP5 at 1.2m-1.5m: Hydrocarbon odour noted in the brown silty sand. The made ground above this geology included tarmac and rotting timber with a black, sticky, sickly smelling coating.

- TP7 at 2.2m-3.0m: Strong hydrocarbon odour noted in the dark grey sand silt. The made ground above this included tarmac, ash, brick, clinker and slag.

In addition to the oily and hydrocarbon odours already mentioned, the following were also noted;

- BH1 at 1.8m: Slight fishy odour noted in the gravelly clay of the made ground. The made ground above this included tarmac.

- BH1 at 2.6m-3.6m: Slight natural organic odour noted in the grey/brown very silty sand.

- TP4 at 1.2m-1.8m: Creosote odour noted within the brown sandy gravelly made ground. The made ground at this location included large lumps of slag and clinker along with coarse ash, cobbles and tarmac. A natural organic odour was also noted in the sandy silt below.

- TP5 at 0.65m-1.2m: A sickly odour was noted coming from a black, sticky coating on timber found in the brown gravelly sand of the made ground. The made ground also contained tarmac and weathered concrete. The excavation at TP5 also revealed a subsurface structure that could have been an old service pit from the former bus station.

- TP8 at 1.4m-2.2: A natural organic odour was noted in the grey sandy silt. The made ground above this included ash and sandstone slabs.

- TP9 at 2.2m-2.6m: A slight natural organic odour was noted in the grey sandy silt.

7.2 Groundwater

Perched water was encountered at one definite location within the made ground (BH1) and potentially at several other locations across the site as subsurface structures were encountered and found to contain water (i.e. TP5 and TP2). The high levels of water collected in the structures could be attributed in part to the heavy rain experienced leading up to the week of site works.

Shallow groundwater was encountered within the natural alluvium and deeper, artesian groundwater was encountered in the Coal Measures and the sandy, silty layer immediately overlying the Coal Measures.

The following table (Table 5a) gives details of water strikes during the excavation of the exploratory holes.

Table 5a. Water strikes

Exploratory Hole	Ground level (mAOD)	Depth of strike (m bgl)	Level of water strike (mAOD)	Level after 20mins (mAOD)	Comments
BH1	119.6	0.3	119.30	-	No rise
BH1	119.6	3.2	116.40	117.2	
BH1	119.6	9.2	110.40	112.1	
BH2B	119.77	1.1	118.67	118.67	
BH2B	119.77	11	108.77	109.07	
BH2B	119.77	13.6	106.17	-	Artesian
BH3	120.24	1.2	119.04	119.04	
BH3	120.24	9.2	111.04	114.44	
BH3	120.24	12.9	107.34	-	Artesian
BH4	119.64	1.7	117.94	118.14	Slight inflow
BH4	119.64	2.9	116.74	117.64	Fast inflow
BH4	119.64	8.5	111.14	118.94	Fast inflow
TP1	119.71	1.6	118.11	-	Oily sheen, no odour
TP2	120.24	1.4	118.84	-	Oily sheen, hydrocarbon odour

Table 5a. Water strikes continued…

Exploratory Hole	Ground level (mAOD)	Depth of strike (m bgl)	Level of water strike (mAOD)	Level after 20mins (mAOD)	Comments
TP3	119.74	1.2	118.54	-	Oily sheen, hydrocarbon odour
TP4	120.48	No water encountered within this exploratory hole			
TP5	119.72	1.2	118.52	--	Oily sheen with a green scum on the surface, hydrocarbon odour
TP6	119.52	2.8	116.72	-	Slight sheen on water
TP7	120.29	2.9	117.39	-	Oily sheen, strong hydrocarbon odour
TP8	119.46	2.2	117.26	-	Rapid upwelling through the base of the pit, oily sheen on water. Still rising after 2mins, at which point the trial pit was infilled
TP9	120.04	2.8	117.24	-	Inflow from the corner of the trial pit nearest the centre of the site (south west). Slight sheen on water

Details of the post site works monitoring the boreholes BH1 and BH4 are given as part of the Factual Report in Appendix C and are summarised in Table 5b.

Table 5b. Water level data from site monitoring rounds

	Monitoring round no.	Date	Depth to water (m)	Water level (mAOD)	Average water level (mAOD)
BH1	1	01-06-06	2.14	117.46	117.46
	2	09-06-06	2.14	117.46	
	3	22-06-06	2.13	117.47	
	4	29-06-06	2.14	117.46	
BH4	1	01-06-06	1.70	117.94	117.84
	2	09-06-06	1.83	117.81	
	3	22-06-06	1.84	117.80	
	4	29-06-06	1.83	117.81	

Details or the river levels recorded during the full topographic survey of the site are detailed in Table 5c.

Table 5c. River water level data obtained from the site topographic surveyors

	Grid reference	Location on site boundary, relative to site centre	Water level (mAOD)
R1	389982, 413329	South east	118.03
R2	389932, 413337	South west/west (Immediately upstream of the weir)	116.07
R3	389914, 413383	North west	116.16

Using the shallow groundwater levels obtained during the site works, the post works monitoring data and the river water level data obtained by the surveyors conducting the topographic survey, two attempts were made to contour the shallow water table within the natural alluvium below the site. This contouring was done using the computer package SURFER v.8 with kriging as the gridding method. The two plots can be seen in Figure 4a and 4b.

Both figures include the following exploratory hole water levels:

TP1 – 118.1 mAOD	TP8 – 117.26 mAOD
BH1 – 117.6 mAOD	TP9 – 117.24 mAOD
TP3 – 118.54 mAOD	R1 – 118.03 mAOD
BH4 – 117.84 mAOD	R2 – 118.07mAOD
TP7 – 118.11 mAOD	R3 – 116.16 mAOD

In addition to these water levels, Figure 4b also includes an assumed maximum water level for TP4 of 116.68mAOD that corresponds to the deepest point excavated to during the site investigation and the point at which water had still not been encountered in the trial pit.

Other exploratory holes were not included in the contouring exercise because it could not be ensured that they were natural groundwater levels and were likely to be perched levels resulting from subsurface structures. The shallow groundwater level at BH3 was also removed from the data set as it was unusually high and could indicate a degree of influence of the upwards hydraulic gradient from the artesian groundwater at depth or conversely, could be as a result of the leakages emanating from the temporary pipework supplying the porta-cabins that were present in the contractors enclosure in the east of the site, adjacent to BH3. These leaks were clearly visible during the site works and were causing water to pond on the surface of the site within the compound.

Both Figure 4a and 4b show that the shallow groundwater appears to be flowing towards the north, away from the river running along the south of the site and towards the stretch of the river that passes the north west of the site. This is indicated particularly clearly in Figure 4b and with the water level dropping towards the east of the site. This would also account for why no water was encountered in TP4 during the site works.

The observed flow pattern would suggest that the natural alluvium (sands and silts) below the site are in hydraulic continuity with the River Roch and that a proportion of the baseflow from the river is cutting off the corner and instead of flowing around the site and over the weir, is flowing under the site. Assuming this to be the case, the baseflow water from the river appears to be crossing into the site boundary from the river at approximately the eastern side of TP1 and flowing towards TP8, from the south towards the north/northwest. This would also correlate with the observations in TP9 that the inflowing water was entering the trial pit only from the southwestern corner.

To further support the integrity of the groundwater plots, the water level drop over the weir can be seen around BH1 as the 117.5mAOD contour line is pulled back and lies perpendicular to the location of the weir indicating that the flow in the area of the weir is towards the north, as is the case in reality.

7.3 Ground Gas

Gas monitoring was carried out by Geotechnics' Ltd. following the site investigation. A summary of the monitoring results is presented in Appendix C as part of the factual report.

Two locations were fitted with monitoring installations (BH1 and BH4) and flush, lockable covers. All have response zones targeting the made ground as this was considered to be the most likely source of soil gas.

7.3.1 Methane

No concentrations of methane have been recorded to date with the results showing methane concentrations of 0% by volume.

7.3.2 Carbon Dioxide

The concentrations of carbon dioxide observed to date are 0% by volume in BH1 and in BH4 0.1% and 1.0% by volume.

7.3.3 Oxygen

Oxygen concentrations recorded to date have ranged from 19.8% to 20.1% by volume.

7.3.4 Assessment for development

Following the withdrawal of CIRIA149 for the interpretation of gas data, the method proposed in the Wilson & Card paper - Reliability and risk in gas protection design – published in Ground Engineering, February 1999 has been widely employed.

The paper proposes a combination of measured concentrations together with flow rates to identify the potential risk to any development and subsequently the type of protection measures that would be required in order to address any identified risk. The worst-case scenario for each location has been identified and the "characteristic situation" for that scenario has been determined.

Therefore, considering that the results of the gas monitoring on the site show no concentrations of ground gases have been recorded to date, it is considered that Characteristic Situation 1 is appropriate. As such there is no need for special protective measures against ground gases to be built into the design of the new building.

Mouchel Parkman is aware that the following footnote was omitted from the bottom of Table 5 in the Wilson and Card paper.

"*Site characterisation should be based on gas monitoring of gas concentrations and borehole flow rates for a minimum period of one year and covering a range of atmospheric conditions. For readings covering six months increase Characteristic Situation by 1. For readings covering less than six months but over three months, increase Characteristic Situation by 2."*

Since monitoring readings have been obtained for less than six months, the Characteristic Situation should in theory be increased to Characteristic Situation 3. We consider that results obtained to date are realistic and that Characteristic Situation 1 is appropriate. However, this would need to be agreed with the Building Control Department of RMBC. For information, the typical measures required for Characteristic Situation 3 for commercial end use are:

- Reinforced concrete cast insitu ground slab;
- All joints and penetrations sealed
- Waterproof/gas resistant membrane
- Passively ventilated underfloor sub-space.

8 CHEMICAL GROUND CONDITIONS

8.1 Introduction

The chemical testing was scheduled by Mouchel Parkman. In total, 14 samples of made ground and 12 samples of natural ground were sent for analysis for the following determinands:

- Standard (metals and non-metals) suite including: Arsenic, cadmium, chromium, copper, nickel, zinc, lead, mercury, selenium, water soluble boron, hexavalent chromium, total cyanide, free cyanide, total sulphate, sulphide, total sulphur, pH, speciated polyaromatic hydrocarbons (19 species), phenols, thiocyanate, fraction of organic carbon and soil organic matter.

In addition a selected number of samples were also scheduled for TPH (Criteria Working Group method), water-soluble sulphate, asbestos, soil organic matter and loss on ignition.

A total of 5 out of the 14 made ground samples were also selected for leachability testing, along with 2 of the 12 natural ground samples. The leachate was then tested for approximately the same contaminants as the corresponding soil samples.

For the purposes of buried concrete design, a total of 9 selected soil samples were also scheduled for BRE (Building Research Establishment) testing to allow assessment in accordance with the BRE Special Digest 1:2005 (SD1) 'Concrete in Aggressive Ground Part C: Assessing the aggressive chemical environment'.

Water samples were taken from the trial pits during the site works where it was encountered in a sufficient quantity to sample. Additional samples were also taken from the monitoring wells during the post-investigation monitoring period. In total 3 groundwater samples from the intrusive investigation were recovered and 2 of these were selected for testing. 2 further samples were recovered from the monitoring boreholes and sent for testing along with surface water samples from the River Roch, taken at points located up and downstream from the site.

The analytical results from the investigation are included in Appendix D of this report.

8.2 Hazardous Waste Assessment

Wastes are classified in accordance with the Environment Agency's Technical Guidance WM2 Hazardous Waste: Interpretation and classification of hazardous waste, 2005. Some hazardous properties are determined from the concentration of the individual substance having a particular risk phrase, while others are determined from the concentration of ALL substances within the soil having that particular risk phrase (cumulative).

Four areas of the Yelloways site contain soil that is considered to be hazardous:

- TP 4 – the material sampled at 1.6m depth is hazardous due to mineral oil and DRO content (Hazard H7). It was also calculated as hazardous based on a cumulative effect of all the substances detected in the soil (Hazard H14). A creosote odour was noted during the excavation of this exploratory hole and tarmac, ash, slag and clinker was found within the made ground at 0.25m-1.8m depth.
- TP9 – the material sampled at 0.5m depth is hazardous due to the mineral oil content (Hazard H7). Tarmac was noted within the made ground during the excavation of this exploratory hole.
- TP2 – the material sampled at 0.4m depth is hazardous due to the mineral oil content (Hazard H7). Tarmac was noted within the made ground during the excavation of this exploratory hole as well as a hydrocarbon odour. This material also registered as hazardous due to the levels of chromium detected (Hazard H7).
- BH3 – the material sampled at 0.5m depth is hazardous due to the mineral oil content (Hazard H7). Tarmac was noted within the made ground during the excavation of this exploratory hole as well as a hydrocarbon odour.

The hazards highlighted in the assessment have the following properties as defined by the Hazardous Waste Directive Annex III:

- H7 - Carcinogenic: substances and preparations which if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence
- H14 - Ecotoxic: substances and preparations which present or may present immediate or delayed risks for one or more sector of the environment

It is recommended that material is stockpiled and re-tested should it be excavated in order to ensure correct disposal. Made ground should be stockpiled separately from natural materials.

9 RISK ASSESSMENT METHODOLOGY

9.1.1 *Introduction*

The method by which soils are assessed with respect to contamination has changed from the ICRCL 59/83 'Guidance on the Assessment and Redevelopment of Contaminated Land, used for some 20 years, to the Contaminated Land Exposure Assessment (CLEA) guidance. With the introduction of CLEA, it is now necessary to consider chemical soil concentrations with respect to CLEA Soil Guideline Values. SGVs are nationally relevant and are only available for a limited number of determinants. Of particular note is that few SGVs have yet been provided for hydrocarbons.

The site is proposed for commercial redevelopment (offices) and therefore the soil results have been screened against the published SGV's and BP-Risc derived site threshold values (STV's) for a commercial with landscaping end use.

When there are no SGVs or BP-Risc derived STV's available for a contaminant, STVs are determined based on professional judgement. These professional judgement derived STVs are considered to be health conservative and have been derived for use as screening values only. They have not been derived to form remediation criteria values.

The CLEA model assesses risks presented by material within the upper 1m of the soil, therefore only soil samples from depths shallower than 1m are usually assessed. However, it is possible that extensive excavation may be required at the Yelloways site to remove underground structures and as such there is the potential for material deeper than 1m to be transferred to the surface; in this instance all made ground soil results have been assessed together.

9.1.2 *Statistical Analysis*

The level of confidence that can be assigned to contaminant measurements depends on sampling and analytical errors and the extent to which these can be successfully controlled. The statistical approach as detailed in CLR 7 (2002) has been followed. This involved the designation of averaging areas, the identification of outliers and the screening of contaminant results to determine the contaminant status of each averaging area within the estate.

Where one or more areas of a site appear to have different characteristics from the remainder of the site, an assessor may divide the site into zones of similar character that can be considered independently of each other. These zones are called averaging areas and are defined in CLR 7 (2002) as that area of soil to which a receptor is exposed or which otherwise contributes to the creation of hazardous conditions. Zoning may take into account such characteristics as variations in soil properties or historical, existing or proposed new land uses (CLR 7, 2002). The soil within the averaging area will contain variable concentrations of contaminants, which, when averaged across the area, will provide a representative indication of how much of the contaminant the receptor within that averaging area is exposed to.

9.1.3 Assessment of Polycyclic Aromatic Hydrocarbons (PAHs)

Advice from the Chemical Hazards and Poisons Unit of the Health Protection Agency indicates that the CLEA Project Board is considering possible Health Criteria Values for 10 PAHs, 7 of which are considered to be non-threshold and 3 of which are considered to be threshold PAHs. It is these 10 PAHs in addition to benzo(a)pyrene and naphthalene which have been assessed.

To derive an STV for the non-threshold PAHs (benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, benzo(ghi)perylene and indeno(123cd)pyrene), the individual results have been used to determine a non-threshold PAH equivalent of benzo (a) pyrene (BaP), the most carcinogenic PAH. This method is based on the ratios of the non-threshold PAHs within the soil and toxic equivalency factors (TEFs), which are detailed in Table 6. TEFs are weighting factors which are used to compare the toxicity of structurally related compounds with similar toxicological effects to the best characterised of the group, in this case BaP. Multiplication of the concentration of each PAH by its TEF and summing the results gives the toxic equivalent concentration of the group. This BaP equivalence value together with the STV for BaP is then used to derive a STV for the total of the PAHs. As this value is dependent on the ratio of the individual PAHs within the sample and as this varies between each sample, the lowest STV for all samples within an averaging area has been chosen as the STV that will be protective of human health, for all soil samples irrespective of the ratio of PAHs within the sample, within that averaging area.

An STV has been derived for the non-threshold PAH BaP using the model BP-RISC and DEFRA published toxicity data (R&D Tox 2 Publication, 2002). It is this STV that has been used to derive a STV for the other non-threshold PAHs, as per the methodology above.

Four PAHs have been classified as threshold substances: phenanthrene, naphthalene, pyrene and fluoranthene. These have all been modelled in BP-RISC except for naphthalene which where use was made of DEFRA published toxicity data (R&D Tox 20 Publication, 2003) as detailed in Table 7.

To account for the more volatile PAHs i.e. those with a dimensionless Henrys Law Constant greater than 10^{-3}, inhalation of vapours has been included as an exposure pathway. Use has been made of the Dermal Check in SNIFFER II to ascertain whether dermal exposure is an important pathway. Exposure by ingestion has been included as a pathway for all PAHs.

Table 6. Toxic Equivalence Factor for selected PAHs in relation to BaP.

PAH	Toxic Equivalent Factor	Reference
Benzo(a)anthracene	0.1	WHO, 1998
Chrysene	0.1	DETR, 1998
Benzo(b)fluoranthene	0.1	WHO, 1998
Benzo(k)fluoranthene	0.1	WHO, 1998
Dibenzo(ah)anthracene	1.0	WHO, 1998
Benzo(ghi)perylene	0.1	DETR, 1998
Indeno(123cd)pyrene	0.1	WHO, 1998

The results for BaP have been included with the spreadsheets for the threshold PAHs purely for reporting purposes.

Table 7. Tolerable Daily Intakes (TDI's) for threshold PAHs used in model

Threshold PAH	Oral Health Criteria Value (mg.kg.day^{-1})	Inhalation Health Criteria Value (mg.kg.day^{-1})
Fluoranthene	0.04	nd
Phenanthrene	0.02	7E-05
Pyrene	0.03	nd

9.1.4 *Assessment of Petroleum Hydrocarbons*

The approach for modelling petroleum hydrocarbons has been based on the "UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils" (Environment Agency Science Report P5-080/TR3, 2005). This approach involves the concurrent use of indicator compounds and petroleum fractions and assumes additivity of toxicological effects across all fractions. The indicator species used are detailed in Table 8 below and the petroleum fractions in Table 9. STVs for the carbon fractions were derived using published toxicity data (TPHCWG) and BP-Risc.

Table 8. Non-threshold and threshold indicator species

Non-threshold indicators	Threshold indicators
Benzene, Benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k) fluoranthene, chrysene, dibenz(a,h) anthracene, indeno(1,2,3-c,dpyrene)	Toluene, ethylbenzene, xylene, naphthalene, fluoranthene, phenanthrene, pyrene.

Table 9. Petroleum Fractions based on Equivalent Carbon (EC number).

Aliphatic Fraction	Aromatic Fraction
>5-6	>5-7
>6-8	>7-8
>8-10	>8-10
>10-12	>10-12
>12-16	>12-16
>16-21	>16-21
>21-35	>21-35

Where a screening value for an indicator compound or fraction is exceeded, a site specific assessment is undertaken. However, even when screening values for individual fractions are not exceeded, the potential additivity of toxicological effects between the petroleum fractions needs to be taken into account. This is addressed by deriving a hazard quotient (HQ) for each fraction. The HQs are then summed to form a hazard index (HI) as per equation 1 below. Where the HI exceeds unity, a potentially significant risk to human health may exist and further assessment is required.

$$HI = \sum_{F_i=1}^{16} HQF_i = \frac{MeasuredConcentrationf_i}{SVf_i}$$

Where:

HI=Hazard Index f_i=Fraction $_i$

HQ=Hazard Quotient SV=screening value

A remediation target value (RTV) for Total Petroleum Hydrocarbons (TPH) is derived according to the Total Petroleum Hydrocarbon Working Group approach (1999), using the following equation:

$$HI = \sum_{i=1}^{16} HQ_i = \sum f_i * RTV / SV_i$$

Where:

HI=Hazard Index RTV=remediation target value (mg/kg)

HQ_i=Hazard Quotient for fraction $_i$ SV_i=screening value for fraction $_i$

9.1.5 *Commercial with Landscaping Screening Values – proposed site use*

The screening values used in the Tier 1 assessment for the site in its proposed use are detailed below in Table 10. These screening values are very conservative, and assume an 'at risk' age group of 0 to 6 years, with exposure for 24 hours per day, 365 days per year.

Table 10. Summary of Contaminants and Associated Tier 1 Screening Values for Human Health – Commercial with landscaping end use.

Soil determinant	Site Threshold Value (STV) mg/kg	Basis of STV
Arsenic (Total)	500	SGV commercial/ industrial
Cadmium (Total)	1400	SGV commercial/ industrial pH6-8
Chromium (Total)	5000	SGV commercial/ industrial (assumes Cr VI)
Copper	100000	BP RISC derived GAC
Lead	750	SGV commercial/ industial
Mercury (Total)	480	SGV commercial/ industrial
Nickel (Total)	5000	SGV commercial/ industrial
Selenium (Total)	8000	SGV commercial/ industrial
Zinc	780000	BP RISC derived GAC
Cyanide (Total)	250	prof judge - screen
Phenols (Total) 1% SOM	21900	SGV commercial/industrial
Sulphide as S	250	Prof-judge - screen
Alkaline pH	9	screen - looking at alkalinity
Acid pH	5.5	screen - looking at acidity
PRO	82	Professional Judgement
DRO	1000	Professional Judgement
Benzo(a)pyrene	35	BP RISC derived GAC
TPH	1000	Professional Judgement - initial screen
Benzene 1% SOM	1.66	DRAFT SGV Commercial / industrial
Toluene 1% SOM	150	SGV commercial/industrial
Ethylbenzene	48000	SGV commercial/industrial
Naphthalene 1% SOM	290	DRAFT SGV Commercial / industrial
Xylene 1% SOM	340	DRAFT SGV Commercial / industrial
Fluoranthene	50000	BP-Risc derived GAC
Phenanthrene	520000	BP-Risc derived GAC

Pyrene	4900	BP-Risc derived GAC
TPH - Aliphatic C5-C6	1000000	BP-Risc derived GAC
TPH - Aliphatic C6-C8	1000000	BP-Risc derived GAC
TPH - Aliphatic C8-C10	190000	BP-Risc derived GAC
TPH - Aliphatic C10-C12	190000	BP-Risc derived GAC
TPH - Aliphatic C12-C16	190000	BP-Risc derived GAC
TPH - Aliphatic C16-C35	1000000	BP-Risc derived GAC
TPH - Aromatic C5-C7	818.23	BP-Risc derived GAC
TPH - Aromatic C7-C8	2088.46	BP-Risc derived GAC
TPH - Aromatic C8-C10	76000.00	BP-Risc derived GAC
TPH - Aromatic C10-C12	76000.00	BP-Risc derived GAC
TPH - Aromatic C12-C16	76000.00	BP-Risc derived GAC
TPH - Aromatic C16-C21	57000.00	BP-Risc derived GAC
TPH - Aromatic C21-C35	1000000.00	BP-Risc derived GAC

9.2 Phytotoxic Contaminants Screening

In order to assess the potential effect of boron, copper and zinc on plant growth, professional screening values, based on values from ICRCL Guidance values have been utilised.

As with the screening of soils, all samples have been assessed against the phytotoxic screening values.

Table 11. Summary of Phytotoxic Contaminants and Associated Screening Values

Soil Determinant	Site Threshold Value (STV mg/kg)	Basis of STV
Boron	3	ICRCL - Table 3, Group B
Copper	130	
Zinc	300	
Nickel	70	ICRCL 59/86

9.3 Water and Leachate Screening

The nearest surface watercourse is the River Roch that lies immediately south and west of the site. The site is not located within a Source Protection Zone and the solid geology beneath is Lower Coal Measures, classed as a minor aquifer. In addition, the intrusive investigation encountered 4m of firm clay beneath the natural alluvium in all four of the boreholes that were drilled on site and also identified artesian groundwater within the coal measures, resulting in an upwards hydraulic gradient in the deeper groundwater.

All of these factors combined, mean that the risk of contamination entering the Lower Coal Measures aquifer is likely to be less than the risk of impaction on the River Roch and therefore it is considered that the adjacent surface water is the most significant and vulnerable receptor with regards to controlled waters.

As such, chemical test results for waters and leachate have been compared against the Environment Agency Environmental Quality Standard (EQS) values and where no EQS exists, UK Drinking Water Standards (DWS) are used instead. The screening values employed are summarised in Table 12. Where the screening value requires a hardness value for the water, the Environment Agency value of 89mg/l $CaCO_3$ (as supplied by their website) was used. The EQS hardness dependant screening values also require that you specify they water type, i.e. Freshwaters suitable for all fish life; for Salmonid (game) fish or for Cyprinid (coarse) fish. Based on biological monitoring data from the Environment Agency website the River Roch is assumed to be suitable for cyprinid (coarse) fish only.

Table 12. Summary of Contaminants and Associated Screening Values for Water and Leachate Samples

Determinant	Screening Value (µg/l)	Source of screening value
Arsenic Dissolved	50	EQS freshwater - Stat List II
Boron Dissolved	2000	EQS freshwater - Stat List II
Cadmium Dissolved	5	EQS freshwater - Stat List I
Chromium Dissolved	175	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Copper Dissolved	6	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Lead Dissolved	125	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Nickel Dissolved	100	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Selenium Dissolved	10	UK Drinking Water Standards
Zinc Dissolved	175	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Mercury Dissolved	1	EQS freshwater - Stat List I
Sulphate (soluble)	400000	EQS freshwater - Non Stat
Hexavalent Chromium	175	EQS freshwater - Stat List II (hardness related - 89mg/l CaCO3)
Phenols Total	0.5	UK Drinking Water Standards (Stat Inst. 1989 No.1147 Schedule 2)
Total Cyanide	50	UK Drinking Water Standards
pH acid	6	EQS freshwater - Stat List II
pH alkali	9	EQS freshwater - Stat List II
Benzene	30	EQS freshwater - Stat List II
Toluene	50	EQS freshwater - Stat List II
Ethyl benzene	20	Environment Agency/SNIFFER value (2001)

Determinant	Screening Value (µg/l)	Source of screening value
Xylene (Total)	30	EQS freshwater - Stat List II
TPH (Aliphatics and Aromatics C5-C35) [Hydrocarbons (dissolved/emulsions)]	10	UK Drinking Water Standards (Stat Inst. 1989 No.1147 Schedule 2)
Naphthalene	10	EQS freshwater - Stat List II
Benzo(a)pyrene	0.01	UK Drinking Water Standards
Speciated PAH (total of 4#)	10	UK Drinking Water Standards

Benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene

10 RISK ASSESSMENT

In order to assess the significance of contaminants found within the site, the results have been compared against the guidance levels outlined in Section 9. All laboratory test results associated with the investigation are included in the Geotechnics' Factual Report presented as Appendix C of this report.

As part of this investigation, a total of 14 made ground soil samples and 12 natural ground samples were analysed for the range of determinants listed in Section 9.1.

The CLEA analysis has identified a number of outliers for both made ground and natural ground that are listed in the tables below. Outliers that exceed the STV are highlighted in **bold** and *italics* as these results are most likely to require further investigation / treatment. Where results are indicated as outliers the results are removed from the subsequent statistical analysis. Removal of the initial outliers may cause further outliers to become highlighted and these too are removed until no more are highlighted.

As discussed in section 9.1.1 all results have been included in the CLEA analysis.

10.1 Human Health Screening of Made Ground

10.1.1 Outlier test for site post redevelopment

The maximum value test when applied to the results has indicated the presence of 30 determinants (seven samples) which are statistically classified as outliers and may represent hotspots of elevated concentration. However, of these 30 determinants only 2 exceed the STV and the other 28 are potential outliers that do not exceed the STV. Details of these samples are provided in Table 12 below.

Table 12. Samples identified as outliers in the Made Ground

Exploratory Hole	Depth (mbgl)	Contaminant	Concentration (mg/kg)	STV (mg/kg)	Does concentration exceed the STV?
BH1	0.5	Total Phenols	0.02	21900	No
BH3	0.5	Aliphatic C5-C6	0.05	1000000	No
		Aliphatic C6-C8	0.02	1000000	No
BH4	2.0	***Sulphide***	***445***	***250***	***Yes***
		pH - alkalinity	***10.85***	***9***	***Yes***
TP1	0.5	Cyanide	4.00	250	No
TP2	0.4	Chromium	612.00	5000	No
TP2	1.6	Ethyl Benzene	0.08	48000	No
		Xylene	0.32	340	No
		Aliphatic C6-C8	0.05	1000000	No

Exploratory Hole	Depth (mbgl)	Contaminant	Concentration (mg/kg)	STV (mg/kg)	Does concentration exceed the STV?
		Aliphatic C10-C12	3.70	190000	No
		Aromatic C10-C12	5.56	76000	No
TP3	0.7	Total Phenols	0.02	21900	No
		Sulphide	117.0	250	No
		Benzene	0.09	1.66	No
		Toluene	0.14	150	No
		Ethyl Benzene	0.06	48000	No
		Xylene	0.09	340	No
		Aliphatics C5-C6	0.38	1000000	No
		Aliphatics C6-C8	1.93	1000000	No
		Aliphatic C10-C12	0.22	190000	No
		Aromatics C5-C7	0.09	818.23	No
		Aromatics C7-C8	0.14	2088.46	No
		Aromatics C10-C12	0.34	76000	No
TP4	1.6	Naphthalene	50.19	290	No
		Xylene	0.03	340	No
		Phenanthrene	470.96	520000	No
		Aliphatics C10-C12	0.66	190000	No
		Aromatics C10-C12	0.99	76000	No
		Benzo(a)pyrene*	***145.38***	***35***	***Yes****

* The concentrations of Benzo(a)pyrene detected at 1.6mbgl in TP4 is statistically not classed as an outlier by the CLEA calculations. However, on closer examination of the calculations it has been concluded that the BaP level at TP4 *should* be classed as an outlier associated with a local hotspot and is not a site-wide problem as the statistics suggest.

10.1.2 *Mean value test for the site post redevelopment*

The information in Table 13 below provides a summary of the results of the mean tests for all the made ground soil samples taken across the site following removal of the outliers identified above. The CLEA assessment spreadsheets are found in Appendix E of this report.

Table 13. Summary of Human Health Screening for the Made Ground – post redevelopment as a commercial site (offices)

Determinant	Range detected (mg/kg)	95% upper bound (mg/kg)	STV (mg/kg)	95% UB>STV	Comment
Lead	33.0-796.0	218.03	750	No	Average concentration less than STV
pH - alkalinity	7.71-9.05	8.62	9	No	Average concentration less than STV
DRO (Diesel Range organics)	***6.81-11414.34***	***3709.08***	***1000***	***Yes***	***Average concentration greater than STV – site wide contamination***
Total Petroleum Hydrocarbons	***6.41-11406.38***	***3711.21***	***1000***	***Yes***	***Average concentration greater than STV – site wide contamination***

The 95% Upper Bound exceeds the STV for diesel range organics (DRO) and total TPH. This indicates that a site wide problem exists for these determinands in the made ground.

10.1.3 Non-threshold Polycyclic Aromatic Hydrocarbons

An assessment of non-threshold PAH's, presented in Appendix F, indicates that one of the twelve samples contains concentrations greater than the STV for both total PAH and BaP equivalence (TP4 at 1.6m), thus indicating that there is not a site wide problem with regard to PAH's in the made ground, but instead as already suspected (Table 12) there appears to be a localised hotspot problem at TP4. There is also an exceedance at TP6 (1.6mbgl) for total PAH, but not BaP equivalence.

10.1.4 Total Petroleum Hydrocarbons

When screening values for individual fractions are not exceeded (as is the case here), the potential additivity of toxicological effects between the petroleum fractions needs to be taken into account. This is addressed by deriving a hazard quotient (HQ) for each fraction. The HQs are then summed to form a hazard index (HI). Where the HI exceeds unity, a potentially significant risk to human health may exist requiring further assessment.

An assessment of TPH as described above and presented in Appendix F, indicates that the individual concentrations of TPH fractions do not exceed the relevant assessment values. In addition, the assessment of risk to human health from cumulative toxicity of the TPH fractions indicates that no further assessment is required.

10.1.5 Asbestos

No asbestos fibres were detected in any of the eight made ground samples tested for asbestos.

10.2 Phytotoxic Contaminant Screening of Made Ground

One outlier was detected at one location within the made ground with respect to boron in TP3 at 0.7mbgl (2mg/kg). Following the removal of this outlier, the exceedance information is summarised in Table 14 below. From Table 14 it can be seen that there is a localised hotspot of copper that is at a sufficient concentration to be phytotoxic in that area, but it does not represent a site wide problem.

Table 14. Summary of phytotoxic screening – Made Ground

Determinant	Range detected (mg/kg)	95% upper bound (mg/kg)	STV (mg/kg)	95% UB>STV	Comment
Copper	20.0-193.0	82.18	130	No	Average concentration less than STV

10.3 Human Health Screening of Natural Ground

10.3.1 Outlier test for the site post redevelopment

The maximum value test when applied to the results has indicated the presence of twenty four determinants (three samples) which are statistically classified as outliers and may represent hotspots of elevated concentration. Details of these samples are provided in Table 15.

Table 15. Samples identified as outliers in the Natural Ground

Exploratory Hole	Depth (mbgl)	Contaminant	Concentration (mg/kg)	STV (mg/kg)	Does concentration exceed the STV?
TP5	1.4	Cadmium	34.0	1400	No
		Copper	256.0	100000	No
		Lead	641.0	750	No
		Zinc	2427.0	780000	No
		Petroleum Range Organics (PRO)	5.47	82	No
		Benzo(a)pyrene	4.6	35	No
		Fluoranthene	16.68	50000	No
		Phenanthrene	5.60	520000	No
		Pyrene	15.11	4900	No
		Aliphatic C8-C10	0.23	190000	No
		Aliphatic C10-C12	1.96	190000	No
		Aromatic C8-C10	0.34	76000	No
		Aromatic C10-C12	2.94	76000	No
TP6	1.5	Total Phenols	0.05	21900	No
		Benzo(a)pyrene	9.11	35	No

Exploratory Hole	Depth (mbgl)	Contaminant	Concentration (mg/kg)	STV (mg/kg)	Does concentration exceed the STV?
		Naphthalene	4.6	290	No
		Fluoranthene	31.24	50000	No
		Phenanthrene	38.63	520000	No
		Pyrene	40.99	4900	No
		Aromatic C12-C16	7.47	76000	No
		Aromatic C16-C21	76.21	57000	No
		Aromatic C21-C35	359.29	1000000	No
TP8	1.5	***Sulphide***	***727.0***	***250***	***Yes***
		Benzo(a)pyrene	0.15	35	No

10.3.2 Mean value test for the site post redevelopment

Following the removal of the initial outliers identified above, there were no site-wide exceedances detected. The CLEA assessment spreadsheets are found in Appendix E of this report.

10.3.3 Non-threshold Polycyclic Aromatic Hydrocarbons

An assessment of non-threshold PAH's indicates that none of the 12 natural ground samples contain concentrations greater than the SSV for either total PAH or BaP equivalence.

10.3.4 Total Petroleum Hydrocarbons

As described in Section 10.1.4 and presented in Appendix F, the individual fraction hazard quotient (HQ) assessment indicates that the individual concentrations of TPH fractions detected in the natural ground do not exceed the relevant assessment values. In addition, the assessment of risk to human health from cumulative toxicity of the TPH fractions indicates that no further assessment is required.

10.4 Phytotoxic Contaminant Screening of Natural Ground

Four outliers were identified in the natural ground samples following the maximum value test, summarised in Table 16. Following removal of the outliers detailed below, no further exceedances were recorded.

Table 16. Summary of phytotoxic screening – Natural Ground

Exploratory Hole	Depth (mbgl)	Contaminant	Concentration (mg/kg)	STV (mg/kg)	Does concentration exceed the STV?
TP5	***1.4***	***Copper***	***256.00***	***130***	***Yes***
		Zinc	***2427.00***	***300***	***Yes***
TP6	***1.5***	***Boron***	***3.00***	***3***	***Yes***
TP9	2.5	Boron	2.00	3	No

No upper bound concentrations were exceeded and therefore the phytotoxic contaminants within the natural ground do not pose a site wide risk to plant life. However, the localised outlier exceedances may pose a threat to plant life within each specific area.

10.5 Risks to Controlled Waters

10.5.1 Leachate screening

The limit of detection for total phenol is above the screening value for the determinant and so is shown as possibly exceeding the screening value. However, it is generally acknowledged that unless the determinant is detected above the limit of detection, it is not considered to pose a risk to controlled waters.

A summary of leachate exceedances recorded from the 7 soil samples that had leachate extracted from is provided in Table 17 below. Results highlighted in **bold** and *italics* also exhibit elevated concentrations in the corresponding soil sample.

Table 17. Summary of leachate testing exceedances

Exploratory Hole	Made Ground (MG) or Natural Ground (NAT)	Depth (mbgl)	Determinant and screening value (µg/l)				
			Copper	Sulphate	Total Petroleum Hydrocarbons (TPH)		BaP
			6.0	400000	10		0.01
					Total Aliphatic	Total Aromatic	
TP1	MG	0.5	553		16	-	-
TP2	MG	1.6	7		-	***246***	-
TP3	MG	0.7	10		-	70	0.045
TP5	NAT	1.4	18		-	-	**0.016**
TP6	NAT	1.5	-	576000	-	-	0.019

- No exceedance recorded.

The results indicate a number of elevated results for copper, sulphate, TPH and Benzo(a)pyrene, indicating that the made ground and the natural ground poses a risk to controlled waters.

10.5.2 *Shallow groundwater screening*

As with the leachate screening, the detection limit for total phenols is above the screening value however the determinant is not considered to pose a threat to controlled waters.

A summary of shallow groundwater exceedances recorded in the 4 on site water samples are summarised below in Table 18.

Table 18. Summary of shallow groundwater exceedances

Expl. Hole	Made Ground (MG) or Natural Ground (NAT)	Depth (mbgl)	Determinand and screening value (µg/l)					
			Copper	Gasoline Range Organics (GRO)	Total Petroleum Hydrocarbons (TPH)		BaP	PAHs (total of 4#)
			6.0	10	10		0.01	10
					Total Aliphatic	Total Aromatic		
TP2	NAT	1.3	10	Not tested	Not tested	Not tested	0.371	-
TP5	NAT	1.2	-	2182	30521	12717	4.834	16.589
BH1	MG/ NAT	Screened 0.6-3.6mbgl	-	-	-	-	0.261	-
BH4	MG/ NAT	Screened 1.0-4.0mbgl	-	747	1345	479	0.074	**-**

Benzo(b)fluoranthene, benzo(k)fluoranthene benzo(ghi)fluoranthene and indeno(123cd)pyrene

The results indicate a number of elevated results for copper, GRO, TPH, Benzo(a)pyrene and PAHs, indicating that the shallow groundwater on the site poses a risk to the nearby controlled water.

Note: The UK DWS screening value for TPH (10 µg/l) is a screening value applicable to “total dissolved or emulsified hydrocarbons”, and is therefore usually applied to the Total TPH concentrations detected in the chemical analysis. However, the screening value has in this case been applied to the total Aliphatics and total Aromatics concentrations individually, as well as to GRO in order to illustrate that the levels of hydrocarbon at the site exceed on an individual fraction type basis as well as on an overall, total basis.

10.5.3 *Surface water screening*

Two samples from the adjacent surface water, the River Roch were taken during the monitoring round. The samples were taken up and downstream from the site and the results of the chemical analysis and screening are shown in Table 19.

Table 19. Summary of surface water exceedances

Exploratory Hole	Determinand and screening value (µg/l)	
	Copper	Benzo(a)pyrene
	6.0	0.01
WS1 - UPSTREAM	-	0.076
WS2 - DOWNSREAM	7.0	-

The results indicate minor exceedances of copper and benzo(a)pyrene in the River Roch up and downstream from the site.

11 GEOTECHNICAL ASSESSMENT

11.1 Geotechnical Testing

Selected samples from the ground investigation were used to provide geotechnical soil parameters for design purposes. Tests were carried out in accordance with the relevant parts of BS1377:1990 ‘Code of Practice for laboratory testing’, BSI London.

11.1.1 Made Ground

Made ground was encountered at the surface in all exploratory holes to depths of between 0.4m to 2.9m below ground level and comprised sandy, silty gravel and gravelly clay including limestone, sandstone, hardcore, cobbles, stone setts, tarmac, concrete, brick, timber, glass, metal, pottery, ash, slag and clinker, and was frequently oily.

Four standard penetration tests (SPT) recorded ‘N’ values from 19 to 50 blows for 300 mm penetration, with an average value of 42. The two tests recording blows of 50 reached refusal whereby the test was stopped before full penetration was achieved due to a high blow count. However, the unit is also described as soft / uncompacted in places.

11.1.2 Sand / Gravel

Sand/sandy gravel was generally encountered beneath the made ground across the site and also as a layer on top of the bedrock. This material was often silty and was shown to be sand/silt in BH3 at 9.20m depth.

Seven standard penetration tests (SPT) recorded SPT ‘N’ values from 2 to 21 blows for 300 mm penetration, with an average value of 15.

CBR tests carried out in the laboratory on seven samples of gravelly sand from depths of between 0.5m and 1.2m, gave results of between 0.24% (at 24% moisture content) and 44% (at 11% moisture content) with an average of 19.9%.

11.1.3 Clay

Clay was encountered within all boreholes at depths of between 2m and 4.1m below ground level and can generally be split into two layers. The upper layers of the clay stratum, between 1.9m and 3.6m thick, was slightly gravelly and the lower layers, between 0.8m and 4.4m thick, was laminated with no gravel.

Eight standard penetration tests (SPT) carried out in the clay recorded SPT ‘N’ values from 8 to 17 blows for 300 mm penetration, with an average value of 11. (Upper clay – min. 8, max. 17, ave. 12. Lower clay – min. 9, max. 12, ave. 10).

The following geotechnical laboratory tests were undertaken on samples of clay soils recovered from the exploratory holes;

Nine multistage undrained triaxial tests undertaken on samples of the clay gave average strengths of between 24 kN/m^2 and 98 kN/m^2 (average 57 kN/m^2). The material is generally described as soft, firm and stiff. (Upper clay – firm, 63 kN/m^2 to stiff, 98 kN/m^2, average 80 kN/m^2 . Lower clay – soft, 24 kN/m^2 to firm, 32 kN/m^2, average 28 kN/m^2.)

Twelve Atterberg Limit tests were undertaken on the clay. Three tests classified the clay as low plasticity clay, three classified as intermediate and four classified as high plasticity clay. (Upper clay – low, 16%, to intermediate, 24%, plasticity. Lower clay – high, 31% - 42%, plasticity). Liquid limit tests gave results of 30% to 38% (average 33% for the upper clay and 30% to 63% (average 52%) for the lower clay).

A summary of the maximum and minimum values for these tests are presented in the table below:

Table 20 : Clay Soils Geotechnical Laboratory Test Summary

Parameter	Minimum	Maximum	Average	Number of tests
SPT 'N' value	8	17	11	8
Undrained Triaxial test (kN/m^2)	24	98	57	9
Bulk density Mg/m^3	1.89	2.21	2.03	24
Plastic limit %	14	26	19	10
Liquid Limit %	31	63	44	10
Plasticity Index %	16	42	25	10
Moisture Content %	16	35	26	12

11.1.4 *Mudstone / Sandstone*

Bedrock comprising weathered sandstone or mudstone was encountered in BH2B and BH3 at 12.2m and 11.5m depth respectively (107.57 and 108.74 mOD). The material was highly to completely weathered at rock head. The sandstone is described as weak to strong and the mudstone weak to very weak. Three SPTs recorded values in excess 50 blows for less than 300 mm penetration. One SPT recorded a value of 40 blows.

11.1.5 *Buried Concrete*

Sulphate and pH testing was undertaken on seven soil samples recovered from the exploratory holes. For two samples of clay the pH range was from 8.24 to 8.29 with an average of 8.3. The Sulphate (2:1 water extract) was from 0.026 g/l to 0.030 g/l, with an average of 0.028 g/l. Five samples of sand/gravel occasionally with clay pockets were tested with pH results ranging from 6.94 to 8.30, average 7.36. Sulphate values (2:1 water extract) ranged from 0.023 g/l to 0.134 g/l, average 0.063g/l. Total sulphate values of between 0.186% and <0.005%, and total sulphur values of between 0.54% and 0.01% have also been obtained.

Considering the above and adopting conditions of a brownfield site with mobile groundwater, a Design Sulphate Class of DS-2 and an ACEC Class of AC-2 should be used in accordance with BRE Special Digest 1 ‘Concrete in Aggressive Ground’, 2005.

11.2 Geotechnical Design Parameters

Preliminary design parameters that could be adopted for the soils encountered at the site are given in Table 21. At the time of writing the ground investigation data was available as a draft factual report.

11.2.1 Made Ground

The Made Ground was found to be an extremely variable unit of both cohesive and granular material comprising demolition waste and reworked natural material. Also present within the deposit was deleterious and compressible material such as timber/wood, brickwork and possible foundations. The stratum is likely to be highly compressible, and have low bearing capacity.

11.2.2 Sand and Gravel

The granular sand and gravel encountered below the made ground was generally described as medium dense. However, SPT N-values of 2 were obtained in BH2B and BH3 at 1.4m depth.

The particle size distribution tests undertaken recorded variable grading classifications. In accordance with Table 3 of BS 8002:1994 ‘Code of Practice for Earth retaining structures’, BSI, London a critical state angle of shearing resistance of 32° (30°+0+2) is recommended. Based on this, an angle of shearing resistance of 32° should be adopted as an overall design value for this stratum.

11.2.3 Clay

The clay can generally be split into two layers.

Upper clay

The upper layer was generally described as firm to stiff. Undrained triaxial tests obtained shear strengths of between 63 kN/m^2 and 98 kN/m^2 with an average of 80 kN/m^2 and 5 SPT tests obtained ‘N’ values of between 8 and 17 with an average of 12. Adopting an f1 value of 5.5 (Stroud and Butler, 1975), the SPT range corresponds with shear strength from 44 kN/m^2 to 94 kN/m^2, with an average of 66 kN/m^2. Therefore, a moderately conservative design shear strength value of 70 kN/m^2 is recommended for preliminary design purposes.

Based on the plasticity range for the upper clay of between 16% and 24%, with an average of 19%, a design effective angle of shearing resistance of 27° is recommended for the upper clay.

Liquid limit results suggest the upper clay to be generally of low compressibility.

Lower clay

The lower layer was generally described as soft to firm. Undrained triaxial tests obtained shear strengths of between 24 kN/m^2 and 32 kN/m^2 with an average of 28 kN/m^2 and SPT tests obtained 'N' values of between 9 and 12 with an average of 10. Adopting an f1 value of 4.5 (Stroud and Butler, 1975), the SPT range corresponds with shear strength from 40 kN/m^2 to 54 kN/m^2, with an average of 45 kN/m^2. Therefore, a moderately conservative design shear strength value of 30 kN/m^2 is recommended for preliminary design purposes.

Based on the plasticity range for the lower clay of between 31% and 42%, with an average of 34%, a design effective angle of shearing resistance of 24° is recommended for the lower clay.

Liquid limit results suggest the upper clay to be generally of intermediate to high compressibility.

11.2.4 Mudstone / Sandstone

Interbedded moderately strong sandstone and weak to very weak mudstones was encountered in BH2B. In BH3 moderately weak to weak sandstone and weak to very weak mudstone was encountered.

The rock was cored to a maximum depth of 19.5m (100.27mOD) with solid core recovery of between 0% and 67%, and zero RQD (Rock Quality Designation) throughout.

No laboratory tests have been undertaken in the bedrock.

11.2.5 Groundwater

Perched groundwater was encountered at a number of locations within the made ground from 0.3m depth. Deeper groundwater was encountered within natural strata generally as slight to fast inflow, at depths of between 1.1m and 11.0m below ground level. The groundwater flow direction is generally from the south east to the north west across the site where groundwater in continuity with the river cross the site between the site boundaries adjacent to the river.

Artesian groundwater was encountered within the bedrock at rock head in boreholes BH2B and BH3. Boreholes BH1 and BH4 were terminated upon encountering a granular layer believed to be above the bedrock, in order to avoid the artesian groundwater.

Installations within boreholes BH1 (3.6m depth within made ground and gravelly sand) and BH4 (4.0m depth within made ground and gravel / sand) have recorded water levels of between 2.13m and 2.14m bgl (average 117.46mOD, BH1) and between 1.70m and 1.84m bgl (average 117.84mOD, BH4).

For preliminary design purposes a groundwater level of 1m bgl is recommended.

Table 21 Geotechnical Design Parameters

Stratum	Short term	Long term	Comments
Made Ground	γ_b = 18 kN/m^3 *	γ_b = 18 kN/m^3 *	Likely to be compressible. Unsuitable for spread foundations sensitive to settlement. Low bearing capacity.*
Sand / Gravel	γ_b = 19 kN/m^3 See long term	Φ´ = 32 º	
Upper clay	γ_b = 20 kN/m^3 c_u = 70 kN/m^2	γ_b = 20 kN/m^3 Φ´ = 27º	
Lower clay	γ_b = 20 kN/m^3 c_u = 30 kN/m^2	γ_b = 20 kN/m^3 Φ´ = 24º	Intermediate to high compressibility
Mudstone	γ_b = 20 kN/m^3 UCS = 1MPa	γ_b = 20 kN/m^3 UCS = 1MPa	
Sandstone	γ_b = 22 kN/m^3 UCS = 12.5MPa	γ_b = 22 kN/m^3 UCS = 12.5MPa	

* It is assumed that this stratum would not form part of the permanent works design and therefore no design parameters have been derived.

11.3 Foundation Solutions

It is understood that the proposed development comprises two 5 storey buildings with anticipated column loads in the order of 2250kN (internal) and 1750kN (external) assuming a typical 6m x 6m grid. The most recent set of design proposal drawings by Leach Rhodes Walker Architectcs (6462/L(00)04, 6462/L(00)05, 6462/L(00)06, June 2006), indicate the proposals to include ground level car parking and undercroft car parks below ground level beneath the buildings.

The findings of the ground investigation will require further review to enable detailed design once the proposed construction details are confirmed.

Due to the variable nature of the made ground, inclusion of deleterious matter, and variable consistency / degree of compaction this stratum is considered not to represent a suitable founding stratum for any structures with significant imposed loads or those sensitive to settlement. Therefore, the main structures proposed are likely to require deep foundations in the form of basement rafts with thickened beams between columns founded on the deeper soils or with piled foundations.

The construction of piles can create pathways for contamination migration from made ground in to the underlying bedrock. This is considered elsewhere in this report.

Lightly loaded structures with generous settlement tolerances such as small control rooms may be suitable for adoption of shallow spread foundations placed within the made ground.

The presence of former foundations, basements, or vehicle maintenance pits beneath the site should be considered when designing a suitable foundation technique.

11.3.1 Piled Foundations

Consideration could be given to utilising piled foundations to transfer the structural load down to the bedrock beneath the made ground and soft, compressible soils. Carrying capacity would be provided mainly by end bearing at the base of the pile in the bedrock.

Driven pre-cast piles are likely to be suitable dependant upon the sensitivity to vibration of adjacent structures such as neighbouring buildings and the river retaining walls.

Continuous flight auger piles are likely to be feasible however they may require casing during construction. Particular care would be required during construction of any cast in place piles (such as tremieing of concrete) to cater for the artesian groundwater conditions.

The effects of negative skin friction due to the made ground would have to be considered during pile design.

Design of the foundations could be undertaken once the details of the proposed structures and associated features have been confirmed and would require further examination of the ground investigation data. The advice of specialist contractors should be sought to formulate the most economic and satisfactory piling scheme.

11.3.2 Floor slab / Basement rafts

Conventional ground bearing floor slabs are likely to experience potentially significant total and differential settlement as a result of the variability in the near surface ground conditions. The inherent variability of settlement is difficult to predict and it would also be proportional to imposed floor slab loading.

Consideration could be given to the use of suitably reinforced basement rafts with thickened beams between columns, founded within the natural strata. However, such a raft may also require a piled foundation due to the soft compressible soils beneath.

Construction for the undercroft car parks in excavations with sloping sides is not considered appropriate due to the shallow groundwater present at the site. However, should a shallow excavation be required then this may be achievable depending upon the depth proposed, the proximity to the site boundary and the suitability of dewatering techniques. Otherwise temporary support such as sheet pile walls could be adopted.

Alternatively an embedded wall design using a reinforced concrete diaphragm wall or contiguous or secant bored pile walls should be considered. Permanent sheet pile walls may also be feasible and are likely to be less costly.

11.3.3 Other Engineering Considerations

The above assessment is to provide indicative information for estimating / feasibility evaluation. The advice of specialist contractors should be sought to formulate the most economic and satisfactory piling scheme.

Groundwater is likely to be present within the excavation depth range for the undercroft car park. Dewatering or water exclusion measures such as the piling techniques mentioned above may be required to ensure construction can be achieved in the dry.

It should be noted that the groundwater is likely to be in continuity with the river and therefore will be subject to variations with river level.

An appropriate California Bearing Ratio (CBR) value for pavement construction, which should be adopted for preliminary design purposes, would be 2% for the Made Ground.

Adopting conditions of a brownfield site with mobile groundwater, a Design Sulphate Class of DS-2 and an ACEC Class of AC-2 should be used in accordance with BRE Special Digest 1 ‘Concrete in Aggressive Ground’, 2005.

A Coal Authority Report was obtained for the site. It reported no significant related risks to the development and confirmed the following:

- the property is not within the zone of likely physical influence on the surface from past or present underground or opencast coal workings,
- Coal Authority has no knowledge of any mine entries within, or within 20 metres of, the boundary of the property,
- Records do not indicate any subsidence or damage claims for the property.

12 REVISED CONCEPTUAL SITE MODEL

12.1 Introduction

Section 5 summarises the potential sources, pathways and receptors identified from the desk study phase of the investigation.

For there to be a risk of harm occurring as a result of contamination, all of the following elements listed below must be present:

- Source
- Receptor
- Pathway

If one of these elements is missing then there can be no significant risk. If all are present, then the risk from the resulting pollutant linkage should be assessed and an appropriate remediation strategy developed to address the problems and remove the linkage.

The Conceptual Model (Figure 5) shows sources, pathways and receptors and has been determined for an end use as a commercial site with landscaping (and undercroft parking) assuming no remediation and with removal of above ground structures only.

12.2 Sources

12.2.1 *Risks to Human Health*

There is site wide contamination of the made ground soils with diesel range organics and TPH.

In addition, the levels of TPH and benzo(a)pyrene detected at TP4 were particularly high compared to the rest of the site. TP4 is therefore considered to be a hotspot in itself that will require further investigation.

The following hotspots of contamination within the made ground were also identified during the maximum value test (and therefore classed as outliers):

BH4 at 2.0mbgl	– alkaline pH (10.85)
	– sulphide (445mg/kg)
TP4 at 1.6mbgl	– benzo(a)pyrene (145.38mg/kg)

And the following were identified as localised exceedances in the made ground by the mean value test (and were not classed as outliers):

TP3 at 0.7mbgl	– lead (796.0mg/kg)
TP1 at 0.5mbgl	– alkaline pH (9.05)

There was no site wide contamination of the natural ground and just one localised hotspot detected (outlier):

TP8 at 1.5mbgl – sulphide (727mg/kg)

Gas monitoring did not highlight any abnormal ground gas conditions on the site that would warrant further investigation. A Characteristic Situation 1 has been determined for the site using Wilson and Card methodology, as discussed in Section 7.3.

No asbestos fibres were detected during the chemical analysis of the made ground.

The intrusive site investigation identified underground structures including what appear to be basements and possibly a service pit, all of which have been backfilled and contain perched water.

No underground storage tanks were encountered during the investigation but considering the previous use of the site as a bus station their presence beneath the site cannot be ruled out. The same applies for any sumps or interceptors.

12.2.2 Risks to Plant Life

One of the phytotoxic contaminants' 95% upper bound exceeded the screening values and that corresponded to Zinc at TP5 (1.4mbgl – 2427mg.kg), thus representing a risk to plant life on the site. There were also localised exceedances of the following that would pose a risk to plant life in each specific location;

Made ground:
TP3 at 0.7mbgl – Copper (193.0mg/kg)

Natural ground:
TP5 at 1.4mbgl – Copper (256.0mg/kg)
TP6 at 1.5mbgl – Boron (3.0mg/kg)

The exceedance of copper within the made ground was not classed as an outlier and was accompanied by other relatively high copper levels across the site (20.0-193.0mg/kg). The exceedances in the natural ground (excluding the zinc result) were statistical outliers representing localised hotspots but none of the 95% upper bounds exceeded the screening values.

However, it is usual on redevelopment sites to import topsoil for landscaping purposed and in doing so the contamination pathway will be broken.

12.2.3 Risks to Site Infrastructure

Plastic service pipes, such as water mains, are susceptible to permeation by organic contamination subsequently affecting both the mechanical properties of the pipe and the quality of the water supply. High lead levels detected would also affect the water supply quality. Pipework is also subject to corrosion by abnormal pH and high sulphide levels.

There would therefore be a site-wide risk posed to the service pipes by the hydrocarbon contamination and localised risks associated with the alkaline pH, lead and sulphide. However, this is likely to be addressed without specific remediation measures if the standard practice of importing clean service trench fill is employed.

Adopting conditions of a brownfield site with mobile groundwater, a Design Sulphate Class of DS-2 and an ACEC Class of AC-2 should be used in accordance with BRE Special Digest 1 'Concrete in Aggressive Ground', 2005. This would result in a low risk of sulphate attack to below ground concrete.

12.2.4 Risks to Controlled Waters

Soil leachate:

The leachate results indicate that copper, sulphate, TPH (Aliphatics and Aromatics) and benzo(a)pyrene have the potential to leach out of the soils in concentrations that will pose a risk to controlled waters.

However, considering the high concentrations of hydrocarbon encountered in the soil samples, the respective concentrations detected in the leachate testing are significantly lower. Therefore, although there is potential for hydrocarbon contamination to leach from the made ground material, this does not appear to be the source of the significant hydrocarbon contamination in the shallow groundwater. In addition, the copper contamination detected in the shallow groundwater does not correlate to the levels detected in the leachate analysis i.e. TP5 at 1.4mbgl leachate analysis detected 18µg/l copper whilst the water sample tested from 1.2mbgl showed only 3 µg/l of copper.

Leachate analysis on natural ground samples also indicated that some of the natural material has become contaminated with copper, sulphate and benzo(a)pyrene.

Shallow groundwater:

The chemical analysis also showed significant contamination within the shallow groundwater beneath the site associated with gasoline range organics (GRO) (C4-C12), TPH (Aliphatics and Aromatics) and benzo(a)pyrene. There were also exceedances recorded in the shallow groundwater for copper and PAH.

The contamination in the shallow groundwater is significant but as already discussed, it does not correlate with the high contaminant levels detected in the made ground. It therefore seems more likely that the source of the shallow groundwater contamination is deeper than the made ground and that the pathway from the potential source to the shallow groundwater does not incorporate the made ground tested here.

Considering the historic use of the site, possible explanations for such a source could be an underground storage tank or something smaller such as an interceptor within the old drainage system that was not cleared out when the bus station was demolished.

Another possible explanation of the shallow groundwater contamination could be a source located within one of the subsurface structures (such as a potential service pit noted on the site) that has gradually filled with water and is overtopping into the groundwater. Structures were noted at TP2 (a wall dividing the pit running from east to west), TP5 and BH2.

Based on the direction of groundwater flow as modelled in Figure 4b, the distribution of visible contaminated groundwater across the site (detailed earlier in Table 5b) and the chemical testing results, it is likely that the suspected source exists somewhere in the south of the site between TP2, TP3 and BH2B and that the contamination is being carried down the hydraulic gradient as a plume within the water towards the north of the site and TP8 and TP9. This prediction would also account for the observations in TP8 and TP9 of inflowing water contaminated with hydrocarbon sheen and the same in TP1 and TP6.

River Roch:
Chemical analysis of two samples of river water, from upstream and downstream of the site showed slightly elevated levels of copper and benzo(a)pyrene, but no other hydrocarbons were detected.

12.3 Receptors

The principal receptors for the site post redevelopment are:

- Site workers during redevelopment
- Site occupants
- Controlled waters (shallow groundwater and River Roch)
- Infrastructure i.e. services and foundations.

12.4 Pathways

12.4.1 Site workers and site occupants

Despite the site wide exceedance of hydrocarbons and the other contaminant hotspots highlighted above it is unlikely that a significant risk is posed to the future occupants of the site considering the end use of office buildings and significant proportions of hardstanding.

It may however be necessary to target the localised hotspots identified, particularly TP4 that has significantly higher levels of hydrocarbon and BaP contamination compared to the rest of the site and will require further delineation to determine the extent of this significant hotspot.

In addition although there is hydrocarbon contamination within the made ground across the main body of the site, this is not viewed as a risk in terms of a potential vapour source because the majority of the contamination comprises the heavier hydrocarbon fractions (C12-C35) and these are less volatile. The inclusion of an undercroft parking area in the proposed redevelopment plans will also help to minimise any vapour risk.

The contamination identified in the soil and the groundwater will pose a threat to the site workers during the redevelopment phase as they are likely to come into direct contact with it, however it is generally assumed that this receptor's risk will be controlled by appropriate health and safety measures for works that may come into contact with the contaminated material. This would be addressed through adherence to the CDM Regulations.

12.4.2 Plant life

The phytotoxic contamination identified will present a localised risk to vegetation in landscaped areas by direct contact and plant uptake.

12.4.3 Infrastructure and buildings

The site wide hydrocarbon contamination presents a risk to service pipe networks through direct contact, as do the localised hotspots of lead and alkaline pH.

Below ground concrete should be at low risk of sulphate attack if the appropriate concrete classes are adopted (Design Sulphate Class of DS-2, with an ACEC classification of AC-1s).

12.4.4 Controlled waters

The leachable compounds identified in the made ground pose a threat to the shallow groundwater but are not considered to be the primary source of the observed groundwater contamination.

The concentrations of hydrocarbon and other contaminants observed and the shallow groundwater on the site pose a risk to the nearest, most vulnerable controlled water receptor, the River Roch.

The risk to the River Roch is via lateral migration of shallow groundwater on the site, potential direct runoff from the surface of the site that may contain leachable contaminants and downwards migration of leaching water through the made ground followed by lateral migration into the river.

The lateral migration of shallow groundwater from the likely deeper source is thought to be the most significant risk that will need addressing.

Groundwater flow from the deeper Coal Measures minor aquifer is upwards. It is artesian at this location, confined by the clay layer. The clay layer and the upward gradient will therefore minimise the potential for contaminant migration from the site to the aquifer (see Section 9.3).

12.5 Pollutant Linkages

The following sections refine the initial conceptual model initially developed in Section 5, taking into account the findings of the ground investigation. Table 22 summarises the pollutant linkages at the site following redevelopment, assuming no remedial measures are taken. As in Section 5, the risks are assessed using the three categories listed below:-

- High – Action must be taken to reduce the risk that is judged to be too high.
- Medium – There is sufficient evidence to suggest that there may be an unacceptable risk. Further work is needed before this can be rejected or accepted.
- Low – There is a low risk to the identified receptors, which should still be addressed with the aim of reducing the risk to a minimal acceptable level.

Table 22. Summary of Pollutant Linkages for the Site (assuming no remediation)

Source	Pathway	Receptor	Risk	Justification
Contaminated made ground	Direct contact	Site occupants	Low	Hardstanding – hardstanding will prevent direct contact thus breaking the pathway
		Infrastructure	High	Potential for organic contamination to permeate and degrade pipework. Would be addressed by importing clean service trench fill.
		Site workers during redevelopment	High	Site workers will be exposed to the contaminated ground during the redevelopment phase
		Plant life	Medium	Plants in localised areas of contamination are at risk from direct uptake
	Inhalation of particles / ingestion	Site occupants and adjacent site users	Low	Hardstanding – hardstanding will impede the inhalation pathway
	Leaching/ migration of contaminants from made ground	Controlled surface waters	Medium	Hardstanding will reduce infiltration and thus limit future leachate generation
		Shallow groundwater	Medium	
		Infrastructure	Medium	Potential for contamination to permeate and degrade pipework but hardstanding will reduce future leachate generation

Source	Pathway	Receptor	Risk	Justification
Theoretical hydrocarbon source identified as the cause of the shallow groundwater contamination	Direct contact	Site workers during redevelopment	High	Site workers will be exposed to the source during site works
		Shallow groundwater	High	Shallow groundwater is at risk from direct contact with the buried source which is likely to be within the reach of the natural water levels
Soil gas / vapours	Migration of vapours/ soil gas	Site occupants and infrastructure	Low	No CH_4 or abnormal CO_2 was detected during monitoring – and the heavier range hydrocarbons detected have a low volatilisation.
	Inhalation	Site occupants	Low	
		Site workers during redevelopment	Medium	Site workers could be exposed to higher vapour levels as they disturb the contaminated made ground during redevelopment works
		Adjacent site users	Low	No CH_4 or abnormal CO_2 was detected during monitoring and the heavier range hydrocarbons detected have a low volatilisation.
Contaminated shallow groundwater	Direct contact	Site workers during redevelopment	High	Site workers are likely to come into direct contact with the shallow groundwater during redevelopment
		Site occupants and adjacent site users	Low	Unlikely to come into contact with the shallow groundwater following redevelopment
		Infrastructure	High	Potential for organic contamination to permeate and degrade pipework. Would be addressed by importing clean service trench fill.
	Ingestion	Site occupants and adjacent site users	Low	Unlikely to come into contact with the shallow groundwater following redevelopment
	Migration	Uncontaminated shallow groundwater	High	Contaminated shallow groundwater on the site poses a risk to any uncontaminated areas
		Controlled surface waters	High	Contaminated shallow groundwater poses a risk to the River Roch. This risk is increased if the ground is disturbed during the redevelopment

13 REMEDIAL MEASURES

13.1 Identified Risks

13.1.1 Pollutant Linkages

Pollutant linkages exist with regard to contaminated soils and shallow groundwater across the site. These materials pose a risk to controlled waters, human health, plant life and infrastructure on the site (as discussed in Table 22), and therefore require action. These risks are summarised below in Table 23;

Table 23. Summary of contaminants present on the site and the receptors at risk

Contaminant	Extent of the contamination	Contamination detected in soil (MG or NAT), leachate (L) or shallow groundwater (SGW) ?	Medium – High Risk Posed to Receptors			
			Human Health	Controlled Waters	Plant Life	Infrastructure
Hydrocarbons (TPH, DRO, Aliphatics, Aromatics and GRO)	Site wide	MG, L, SGW	✓	✓		✓
Benzo(a)pyrene	Localised hotspot in soils, widespread in waters	MG, L, SGW	✓	✓		✓
Lead	Localised hotspot	MG	✓			✓
Copper	Site wide	MG, NAT, L, SGW		✓	✓	
Boron	Localised hotspot	MG, NAT			✓	
PAH	Localised hotspot	SGW				✓

Overall the risk assessment has identified the significant pollutant linkages that require action are to;

1. *Site occupants*; from localised hotspots of contamination identified (particularly at TP4 and the uncertainty that surrounds the extent of the source).
2. *Site workers during the redevelopment phase*; from direct contact with contaminated made ground and theoretical groundwater contamination source, inhalation of vapours originating from hydrocarbon contamination in the made ground at a higher concentration due to disturbance of the ground during site works and direct contact with contaminated shallow groundwater.
3. *Shallow groundwater*; primarily from the theoretical deeper source that is thought to be present based on the risk assessment.
4. *River Roch*; from migration of contaminated shallow groundwater into the adjacent river. Direct surface run-off into the river may also pose a risk.
5. *Plant life;* from direct uptake of phytotoxic contaminants in localised areas on the site
6. *Infrastructure;* from direct contact with made ground contaminated with hydrocarbon, metals and alkaline pH and with shallow groundwater similarly contaminated.

13.2 Assumed Characterisation and Remedial Objectives

Note: The remedial options discussed in the following sections have been compiled without regulatory approval that would need to be sought prior to undertaking any remedial works.

There is some risk that the regulators may not agree with the assumptions made and therefore may require further testing/remedial works to be undertaken.

Human Health

The proposed redevelopment's end use of commercial with landscaping and significant proportions of hardstanding, means that the site wide made ground exceedances of heavy end hydrocarbons and metals will not pose an unacceptable risk to human health in terms of the future occupants of the site. This contamination will however mean that there will be a waste disposal issue associated with the excavation of any of the contaminated material.

It is assumed that the risk posed to site workers during the redevelopment works will be controlled by appropriate health and safety measures for works that may come into contact with the contaminated material. This would be addressed through adherence to the CDM Regulations.

The localised exceedances of alkaline pH and metals are likely to be addressed indirectly as a result of the resurfacing/levelling of the site that will occur during redevelopment.

However, the hotspot of significant hydrocarbon and benzo(a)pyrene contamination at TP4 does require further investigation and delineation in order to determine whether it is indeed a hotspot or whether the contamination is more wide spread. This may also be a waste issue for the site if it is necessary to excavate any of this material in the future.

<u>Controlled Waters</u>

When considering the remediation strategies for the site, the main driver behind the justification for remediation is the current state of the shallow groundwater and the potential impact that this could have on the nearby controlled water, the River Roch as a result of the source likely to be on the site. As already discussed, (Section 9.3) the risk posed to the minor Coal Measures aquifer is considered less significant due to the upwards (artesian) groundwater gradients within the aquifer that appears to be confined from the site by the layer of clay (4m proved) encountered during the site investigation.

<u>Plant Life</u>

The localised hotspots of phytotoxic contaminating metals will need addressing but considering the general practice of importing planting mediums/topsoil onto redevelopment sites and that a degree of excavation/site levelling will be undertaken as part of the redevelopment works, it is likely that this will remediate the phytotoxic contaminants via excavation or by burying them at a sufficient depth that the direct contact pathway is broken, within the root zone.

<u>Infrastructure</u>

The infrastructure (pipework) on the site is at risk from the localised hotspots of sulphide, alkaline pH, lead and site wide hydrocarbons as these are potentially corrosive and toxic and will affect material selection. The contaminated shallow groundwater will also pose a risk to the materials used.

Therefore to summarise overall, the characterisation and remedial objectives considered here are to reduce;

1. the risk posed to future site occupants by localised hotspots of contamination identified
2. **the uncertainty with regards to the relationship between the levels of contamination detected at TP4 and the main body of the site, i.e. determining whether TP4 is a localised hotspot of contamination or whether it represents a more wide spread area of contamination at particularly elevated concentrations**
3. **the risk posed to the River Roch by ensuring EQS standards are met at the site boundary (investigation of the presence of a source of groundwater contamination on the site)**
4. the risk to plant life from localised areas of phytotoxic contamination
5. the risk to infrastructure from contact with contamination in the made ground and shallow groundwater

However, points 1, 4 and 5 could be addressed during the redevelopment works and are unlikely to require additional, targeted work (as discussed in Section 13.2)

13.3 Principles of Remediation

Remediation can be used to remove significant pollutant linkages by one or more of three strategies;

- Removal of sources
- Breaking pathways
- Removal or receptor

13.3.1 Source Removal

Until recently, the strategy used in the UK for most remedial situations was source removal for both soil and waters remediation. Where it is not possible to directly remove the solid phase source by excavation, this is generally achieved by using air or water as a medium to either:

1. physically flush contaminants from the soil/rock, collect them and bring them to the surface, where they can be treated ex-situ; and/or
2. convey chemicals, oxygen or bacteria to the contaminants, where they can be broken down in situ by chemical or biological reactions

13.3.2 Breaking Pathways

Blocking or restricting pathways by physical/chemical containment, for example by grouting, hydraulic containment, cut-off walls, reactive barriers or capping can also reduce risks.

13.3.3 Removal of Receptors

In some circumstances, receptors can be removed. For example, by a change of site end-use or by preventing human/ecological receptors entering areas where sources exist. This is a less commonly used method of breaking pollutant linkages, as it is usually not possible or practical.

13.4 Site Specific Approach

As already discussed, there are two key issues to be addressed in relation to site-specific characterisation and remediation of this site;

1. The hydrocarbon contamination identified in the 1.2-1.8mbgl layer of made ground in TP4 *and* the uncertainty surrounding the lateral extent of this contamination in the eastern portion of the site.

2. The indicated source of the shallow groundwater hydrocarbon contamination *and* the uncertainty surrounding the location and size of this source within the southern portion of the site (hypothesised to be within the area of TP2, BH2 and TP5).

Considering these two issues and combined with the environmental situation of the site, the best approach would be further characterisation of the two contamination sources followed by source removal in order to break the source-pathway-receptor linkage described in Section 13.3.

Given the proposed end use of the site and the timescales involved with the proposed redevelopment, removal of the pathway from the linkage is not a realistic and viable option. The only way to do this would be to isolate the sources on the site from the River Roch receptor by either a permeable (reactive) barrier or an impermeable (cut-off wall) barrier. Both potential containment options would not be effective in the event of potential flooding on the site from rising groundwater (in continuity with the river) and invading river floodwaters, which could cause overtopping of the barriers. Individually they also have key weaknesses in their suitability to be applied to this site.

Receptor removal is also not a viable option as the receptor considered most at risk in this case is the River Roch.

13.5 Recommended Further Site Characterisation Works

In light of the two key site issues already discussed, the following further characterisation works are recommended as a second phase of targeted works in order to effectively quantify the contamination implications relating to the site that were highlighted in the first site investigation:-

13.5.1 Delineation and characterisation of the contamination hotspot identified at TP4

In order to determine the extent of the hydrocarbon (DRO) and benzo(a)pyrene contamination identified within a 0.6m layer of strata (1.3-1.8mbgl) at TP4 it is advised that a second phase of 4-5 machine excavated trial pits is carried out, targeting the area in the east of the site that was a contractors enclosure during the site works in May 2006.

This will allow further samples to be taken from across the area to assess the extent of contamination in this otherwise unknown area. In doing so, it will also be possible to make a more accurate determination of the potential waste issues relating to the hotspot, and the cost implications of potentially having to excavate it in order to allow the redevelopment to proceed.

13.5.2 Location and characterisation of the subsurface source of the shallow groundwater hydrocarbon contamination

Work to characterise the source of the groundwater contamination should only be undertaken following liaison with the Environment Agency to agree acceptable levels of action, however the following could be considered:-

Geophysical techniques present a non-intrusive way of locating subsurface structures and one technique in particular that is often used to locate subsurface cavities is the microgravity technique. The technique measures minute variations in the gravitational pull of the Earth and interprets the presence of voids and cavities from these readings. However, in order for the technique to be effective there needs to be a density contrast between the target (i.e. the cavity) and the surrounding material to create the gravitational anomaly that the instrument will detect. In the case of this specific site, the subsurface structures to be located are infilled with made ground material and in most cases perched groundwater as well. Therefore there is unlikely to be a sufficient density contrast between the infilled cavities/subsurface structures and the surrounding ground to create a gravity anomaly that can be detected. Such results can also be highly ambiguous.

Other popular geophysical techniques applied to contaminated land such as magnetic and electromagnetic surveying target buried metal objects, but the precise nature of the subsurface source in this case is unknown, thus choosing such a targeted method means that the subsurface source could easily be missed.

Another approach to investigate the subsurface structures on the site would be an intrusive investigation involving site-wide clearance of the surface material down to the depth of the subsurface structures (within 1mbgl where encountered). However once the material is excavated it would be classed as a ‘waste’. In light of the contamination detected in the made ground, and the ‘hazardous’ waste classification of the soil, it would then not be permissible to put the material back into the ground under a waste licence exemption. Instead it would be necessary to dispose of the material offsite and this would create a significant waste disposal cost. This is also an important consideration for the development itself which should be designed to minimise excavation and disposal.

Therefore the only approach available is a series of investigative ’trenches’ down to a depth of 1m originating from the structures identified in the south of the site around TP2, BH2 and TP5 and corresponding with the theoretical location of the subsurface source. This would be classed as an ‘investigative’ process.

Whilst carrying out the trenching, the contents of any subsurface structures encountered would be sampled and the material tested and characterised. This will also allow site characterisation for any eventual waste disposal. Care should be taken to avoid any spillages caused by breaking down any subsurface structures encountered, bearing in mind the proximity of the River Roch. In light of this, it may be necessary to have appropriate equipment on site to remove any liquid contamination encountered immediately to remove this risk to the River.

Any such intrusive investigation undertaken at the site must be agreed with the contractors dealing with the Japanese Knotweed treatment on the site, as excavation in the vicinity of the Knotweed stands could be detrimental to the effectiveness of the pre-arranged treatment process and could also spread the Knotweed further across the site.

13.6 Estimated 3rd Party Costs for Further Site Characterisation Works

The rates below are based on the rates charged for the first phase of site investigation undertaken in May 2006 (where available) and therefore would need to be confirmed by a competitive tender before the work is undertaken. The rates exclude VAT and Mouchel Parkman fees.

13.6.1 Delineation and characterisation of the contamination hotspot identified at TP4

1 day trial pitting (4-5 pits) with a JCB excavator to a maximum of 4.5m depth, mobilisation, site welfare and sampling: £2,000

Chemical Testing £1,500

Waste acceptance criteria (WAC) testing may also need to be undertaken on the material encountered to confirm which landfill it could be sent to if excavation was required as part of the redevelopment. The testing would cost an additional £125 per sample (if the material is categorised as WAC suite D).

Therefore, if 5 WAC tests were needed as part of the TP4 characterisation this would cost an additional £625. £625

Total Estimated 3rd Party Costs £4,125

13.6.2 *Location and characterisation of the subsurface source of the shallow groundwater hydrocarbon contamination*

1 week JCB hire with pitting crew and supervision in order to dig investigative trenches to an approximate maximum depth of 2m (~1m down to the subsurface structures and ~1m into the structures to excavate):

1 wk JCB hire (£600/day) £3,000

1wk contractor supervision and trench logging (£200/day) £1,000

It would also be necessary to undertake contamination testing of the strata encountered in order to effectively characterise the site. At this stage it is difficult to quantify what testing would be required but an allowance of £4,500 might be appropriate to allow for testing of ~30 samples. £4,500

Waste acceptance criteria (WAC) testing may also need to be undertaken on the material encountered to confirm which landfill it could be sent to if excavation was required as part of the redevelopment. The testing would cost an additional £125 per sample (if the material is categorised as WAC suite D).

Therefore, if 2 WAC tests were needed as part of the characterisation works this would cost an additional £250. £250

The above work would need to be carried out with care so as to avoid damage to the subsurface pits etc. containing contaminants which might then be released and could enter the River Roch. There would also need to be an emergency procedure in place to cover this risk including the provision of equipment and operative to stand by. It is estimated that this would cost in the order of £2,500 to obtain pumping facilities and an operator for the duration of the work. However, this cost is based on a preliminary professional assessment and more accurate costs would be obtained from a specialist contactor. Say, £2,500

Total Estimated 3rd Party Costs £11,250

13.7 Remedial Options and Estimated 3rd Party Costs

The remedial options discussed here have been compiled without regulatory approval that would need to be sought prior to undertaking any remedial works.

There is some risk that the regulators may not agree with the assumptions made and therefore may require further testing/remedial works to be undertaken.

13.7.1 *Removal of contamination source in the vicinity of TP4*

Assuming the worst-case scenario and the second phase of intrusive work identifies that the whole of the former contractor's compound in the east of the site is contaminated in the 1.2-1.8mbgl horizon;

Surface area of contaminated ground: $800m^2$

Thickness of contaminated ground (1.2-1.8mbgl horizon):	0.6m
Therefore; volume of hazardous contaminated material:	480m^3
Dispose of 480m^3 of hazardous material (appx. 864tonnes at £80/tonne):	£70,000

To deal with the top 1.2m of material we assume that ~15% of it would be classified as 'hazardous':

Volume of hazardous contaminated material:	144m^3
Disposal of 144m^3 (appx. 260tonnes at £80/tonne)	£21,000

Total cost of disposing of the top 1.8m of ground from the former contactors enclosure (worst case scenario): £91,000

And depending on the levels required for the site it may also be necessary to import and compact inert material at a general cost of approximately £10/m^3.

It may however be worth undertaking a detailed Quantitative Risk Assessment (QRA) to fully assess the risks to the environment posed by the contaminated ground in the TP4 area which in turn would allow more accurate volumes for treatment to be calculated. Undertaking a QRA may significantly reduce the volume and also the costs detailed above.

13.7.2 *Removal of subsurface source of the shallow groundwater hydrocarbon contamination*

If the trenching is successful in identifying the underground source of the shallow groundwater contamination, and it is found to be a pit/basement or some other form of subsurface structure filled with hydrocarbon/oily material, then the following associated costs can be estimated for the remediation. These calculations are based on many assumptions regarding the nature of the source and are therefore purely illustrative.

The source is likely to be in the form of a dense, hydrocarbon sludge that will probably have to be pumped out of the ground by a specialist contractor due to its high water content, rather than be excavated manually.

Disposing of contaminated waste of such a consistency is also likely to be difficult but if it is assumed that a volume of waste of say, 10m^3 is encountered (appx. 20tonnes) then it could cost in the range of £1,600 to dispose of.

N.B. The size of this source and hence the volume of material is only conjectured at this stage. The cost estimated here is highly sensitive to the actual volume of the source which is currently not known – hence the need for the characterisation.

The extent of the further remedial work required to address the shallow groundwater contamination will only be determined by liaison with the Environment Agency, as it is possible that source removal alone may be acceptable. However, remediation of the contaminated groundwater may be required.

13.8 Outstanding Environmental Issues

- Appropriate health and safety measures would need to be employed by works that may come into contact with the contaminated material during site redevelopment. This would be addressed through adherence to the CDM Regulations.

- Gas monitoring did not highlight any abnormal ground gas conditions on the site that would warrant further investigation. A Characteristic Situation 1 has been determined for the site using the Wilson and Card methodology, as discussed in Section 7.3.

- Clean service trench fill will be required to minimise the risk to the infrastructure (pipework) but as this is now standard practice on development sites it is therefore not considered as an abnormal.

- The importation of clean topsoil for the landscaping of the site is also considered a normal procedure in redevelopments and though it is required in this case to minimise the risk to plant life, it should not be considered as an abnormal.

- As a result of the contamination identified in the made ground, several of the samples tested are determined as hazardous based on the 'Hazardous Waste Assessment Criteria'. This therefore presents an important consideration for the development itself, which should be designed to minimise excavation and disposal.

14 CONCLUSIONS & RECOMMENDATIONS

The assessments made in this report have been undertaken using professional judgement without consultation with the appropriate regulatory bodies. There is a risk that the regulators may not agree with the assumptions made and therefore, may require further testing / remedial works to be undertaken. The scope of any remediation scheme designed will have to be agreed with the Environmental Health Officer of Rochdale Metropolitan Borough Council and the Environment Agency. It is recommended that the regulators are contacted at the earliest opportunity and any remediation strategy approved.

14.1 Ground Conditions

The ground investigation identified the general sequence of strata to comprise black, hardcore gravel overlying made ground overlying natural sands, silts and gravels (Alluvium) with clay below overlying Lower Coal Measures. Made ground was found to be between 0.4m and 2.9m in thickness. The Alluvium was 10.7m-11.75m thick where the base was proven and the clay layer below this was encountered in all 4 of the boreholes at a thickness of ~4m and could be Glacial Till. The Coal Measures below began with a layer of weathered sandstone and mudstone at between 11.5-12.2mbgl (108.74-107.57mAOD). Subsurface structures such as infilled basements and service pits were also identified during the intrusive works (BH2, TP2 and TP5).

Perched water was found at one location within the made ground and within the subsurface structures. Shallow groundwater was encountered within the natural Alluvium at between 1.2m-2.8mbgl and deeper groundwater within the Coal Measures was found to be artesian. The artesian pressures appear to be confined by the layer of clay at the base of the alluvium.

Groundwater within the alluvium is in continuity with the River Roch and the onsite groundwater flow direction (Figure 4b) appears to be towards the stretch of the river flowing past the northwest of the site. It is therefore suggested that a proportion of the river's baseflow is cutting the corner off the river's path and flowing underneath the site. The presence of shallow groundwater that is in continuity with the River Roch may present flooding implications for the site and the shallow groundwater levels mean that it would be prudent to minimise excavation during the redevelopment to avoid having to carry out site wide dewatering, which may affect the River.

As an additional item; eradication work is currently underway to treat the Japanese Knotweed (*Fallopia japonica*) infestations noted during the site walkover and within the Extended Phase 1 Habitat Survey Report (760140/R/01). The work is being carried out by a specialised contractor in accordance with best practice procedures and with consultation of the Environment Agency regarding the proximity of the treatment works to a controlled water body. It was necessary to commission this work as soon as possible in order to target the growing season of the plant (June to September) as otherwise there could have had been a significant risk to the viability of the proposed redevelopment timescales. However, it is an express condition of the contractors carrying out the treatment works, that there is to be no work undertaken on the site without prior agreement. Such work could impact the effectiveness of the treatment process and potentially worsen the situation.

14.2 Geotechnical Assessment

The geotechnical assessment indicates that the variable nature of the made ground means that it does not represent a suitable founding stratum and therefore, the main structures proposed are likely to require deep foundations. These would be in the form of basement rafts with thickened beams between columns founded on the deeper soils, or piled foundations.

However, the presence of the subsurface structures (former basements, foundations and service pits), the possibility of opening up pathways into the aquifer and the artesian groundwater should be considered when deciding upon a suitable foundation technique.

In addition, the construction of undercroft car parks in excavations with sloping sides is not considered appropriate due to the shallow groundwater present at the site. Dewatering or water exclusion techniques will need to be employed to allow the work to proceed.

Adopting conditions of a brownfield site with mobile groundwater, a Design Sulphate Class of DS-2 and an ACEC Class of AC-2 should be used. This would result in a low risk of sulphate attack to below ground concrete.

The findings of the ground investigation will require further review to enable detailed design once the proposed construction details are known.

14.3 Contamination Identified

Site wide contamination of hydrocarbons (TPH, DRO and BaP) within the made ground exists as well as localised hotspots of alkaline pH, sulphide and lead. The phytotoxic compounds boron and copper are also identified in localised hotspots on the site. There is also a significant hotspot of hydrocarbon and BaP contamination within a 0.6m layer at TP4. Due to constraints during the site investigation in May 2006 the area surrounding TP4 could not be investigated and so the lateral extent of the contamination is unknown and requires further investigation.

As a result of the contamination identified in the made ground, several of the samples tested are determined as hazardous due to their mineral oil content (and one high concentration of chromium) based on the ‘Hazardous Waste Assessment Criteria’. The samples taken from TP4 are also determined as hazardous. This therefore presents an important consideration for the development itself which should be designed to minimise excavation and disposal.

The shallow groundwater in the natural alluvium was also contaminated with hydrocarbons (GRO, TPH and BaP) but on analysis of the leachate testing on the contaminated made ground samples it is concluded that the contamination present in the made ground is not the source of the shallow groundwater contamination.

Therefore there is thought to be another, deeper source of the groundwater hydrocarbon contamination in hydraulic continuity with the shallow groundwater. Considering the historical use of the site, this source could be within an infilled service pit, storage tank or an interceptor within the drainage system that was not cleaned out when the bus station was demolished. The observations on site during the site works combined with the groundwater flow pattern on the site indicates that the source is likely to be in the south of the site, in the vicinity of TP2, BH2 and TP5. Due to the risk that this contamination is posing to the nearby controlled surface water, the River Roch, this contamination source requires further investigation as any works on the site could open up further pathways to the river. Puncturing the confining layer of clay is also to be avoided in order to prevent site issues with regards to the artesian pressures and minimise the risk of contamination potentially entering the Coal Measures aquifer below (although the artesian pressures may also help to minimise this risk).

Given the end use of offices with significant proportions of hardstanding and undercroft parking, the contaminated made ground across the main body of the site is not viewed as posing a risk to the future site occupiers. There is a risk posed to the workers during redevelopment, but it is envisaged that this will be addressed through adherence to the CDM Regulations.

The localised hotspots of phytotoxic contaminants posing a risk to plant life are likely to be remediated indirectly during the redevelopment works as new topsoil is imported to facilitate the landscaping. Likewise, the practice of importing of service trench fill on redevelopment sites should address the risk to the potential infrastructure (pipework) posed by the contaminated made ground.

14.4 Issues Requiring Further Characterisation and Remediation

There are therefore two issues remaining with respect to the site that need addressing through further characterisation and potential remediation;

1. The uncertainty with regards to the extent of the contamination identified at TP4 and following characterisation, the cost implications of the potential remedial works

2. The location and nature of the subsurface source of the groundwater hydrocarbon contamination and following location and characterisation, the extent and cost implications of the potential remedial works involved.

Note: Any excavations on the site will require consultation with the contractors currently undertaking the eradication treatment of the Japanese Knotweed on the site as any ground disturbance could cause the plant to spread further across the site.

The costs involved with these uncertainties have been estimated based on professional judgement but have been undertaken without consultation with the appropriate regulatory bodies. The estimated costs exclude VAT and Mouchel Parkman fees;

1. Characterisation of the contamination around TP4: £3,500
   WAC testing (on a nominal 5 samples, if the material is classed as WAC suite D) £625
   Remedial cost estimates £91,000
   Total cost estimated £95,125

2. Characterisation of the shallow groundwater contamination source: £8,500
   Estimated cost of having pumping facilities and operative onsite for the duration of the works, as part of the emergency procedure to protect the River Roch from contaminated water within subsurface structures (based on a preliminary professional assessment, more accurate costs would be obtained from a specialist contactor). Say, £2,500

   WAC testing (on a nominal 2 samples, if the material is classed as WAC suite D) £250
   Remedial cost estimates (disposal of hypothetical 10m^3 of contamination) £1,600
   Total cost estimated £12,850

   N.B This estimate does not make allowance for any additional costs relating to the potential sludgy nature of the source that will require specialist disposal and also does not allow for any additional works that

the Environment Agency may specify in order to remediate the contaminated groundwater itself rather than just source removal, as costed here. It is also highly sensitive to the actual volume of the source which is currently unknown – hence the need for the characterisation.

A Quantitative Risk Assessment (QRA) may also be required to fully assess the extent of the contamination once characterised and to calculate remedial targets and therefore determine more accurate volumes for treatment/disposal. This would also reduce the remediation costs.

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