REPORT

INVESTIGATION

Y13/0024/10/

GEOTECHNICAL
AND
ENVIRONMENTAL
ENGINEERS

Head Office
The Old Dairy
Swanborough Farm
Swanborough
Lewes
East Sussex
BN7 3PF

Telephone
0870 777 1574

Facsimile
0870 777 1577

Website
www.AshdownSI.co.uk

Email
contact@AshdownSI.co.uk

Regional Office
Hertfordshire
(Contact via Head Office)

BIGGINS WOOD
FOLKESTONE
KENT

GEOTECHNICAL
AND
CONTAMINATION (PHASE I AND II)
ASSESSMENT REPORT

Report No. LW21271 October 2010

Report prepared for the benefit of:

Ravensbourne Investment Ltd
c/o Smith-Woolley & Perry
43 Castle Hill Avenue
Folkestone
Kent
CT20 2RB

BIGGINS WOOD
FOLKESTONE
KENT

GEOTECHNICAL
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1. INTRODUCTION

Development proposals are yet to be established for the Site at Biggins Wood, which is situated to the north of Elvington Crescent and Charles Close and to the south of the M20 motorway in Folkestone, Kent. It is understood that development options may include a mixture of residential and commercial (employment) end use. It is assumed for the purposes of this assessment that any residential development would include areas of private gardens and soft landscaping.

Ashdown Site Investigation Limited was commissioned to carry out a ground investigation and combined geotechnical and contamination risk assessment of the Site by Mr C Evans of:

Smith-Woolley & Perry
43 Castle Hill Avenue
Folkestone
Kent
CT20 2RB

The instruction to proceed was received on behalf of the client, Ravensbourne Investment Ltd, by email dated 8th September 2010.

The purpose of the works was to:

i. assess the expected geology and hydrogeology underlying the Site;
ii. establish the development history and most recent Site use;
iii. identify potential sources of on-site and off-site contamination;
iv. establish the potential for on-site migration of contamination from off-site sources;
v. identify sensitive receptors that may be at risk from any contamination migrating from the Site and develop a preliminary conceptual model;
vi. assess ground and groundwater conditions prevailing at the Site;
vii. provide information to assist others in undertaking design of foundations, ground floors, road pavements and retaining walls.
viii. test for the presence of potentially hazardous contamination and gas in the ground;
ix. provide a quantitative contamination risk assessment; and
x. provide a quantitative site specific conceptual model.

The analysis and discussions contained in this report are based on the ground conditions encountered during the site work together with the findings from a programme of laboratory analyses, a walkover survey, reference to historical Ordnance Survey maps and published geological and environmental information from various sources. The latter have been obtained from interrogation of database information compiled by GroundSure Limited. The possibility of a variation in ground and groundwater conditions away from the positions investigated should not be overlooked. Groundwater conditions can vary both seasonally and due to other effects.

Copies of the historical maps and geo-environmental data referred to in this report are included in a separate bound volume, entitled Geo-Environmental Data and Historical Maps (Ashdown Site Investigation Limited, Report Number LW21271/map, dated September 2010).

It is noted that the investigation was undertaken and the report was prepared specifically for the Client's project and the recommendations given may not be appropriate to alternative schemes. The copyright for the report and licence for use shall remain vested in Ashdown Site Investigation Limited (the Company) who disclaim all responsibility or liability (whether at common law or under the express or implied terms of the Contract between the Company and the Client) for any loss or damage of whatever nature in the event that this report is relied on by a third party, or is issued in circumstances or for projects for which it was not originally commissioned, or where the exploratory hole records and test results contained therein are interpreted by anyone other than the Company.

The general methodology adopted for the investigation of the Site follows the guidance published within:

- BS10175:2001 Investigation of Potentially Contaminated Sites - Code of Practice;
- BS5930:1999 +A2:2010 Code of Practice for Site Investigations.
- BS EN 1997-2:2007 Geotechnical Design – Part 2: Ground investigation and testing;
- CLR11 - Model Procedures for the Management of Land Contamination;
- PPS23 Planning and Pollution Control;
- Environment Agency Research and Development Publication 20, 1999 "Methodology for the Derivation of Remedial Targets for Soil and Groundwater to protect water resources".

The risk assessment presented in this report follows 'source-pathway-receptor' techniques for the determination of whether a site is contaminated, which are standard practice in the UK, being intrinsic to the Contaminated Land (England) Regulations 2000 - Part 2A of the Environmental Protection Act 1990.

The report considers end users as the most sensitive human health receptors. If significant risks to construction workers are identified by the preliminary assessment attention is drawn to this. No assessment of risk from acute exposure has been undertaken in this connection.

This report is not intended to be either an ecological or archaeological assessment. An appropriate specialist should be consulted about any concerns that may arise in this regard.

A previous Site Investigation Report (Report Ref. 81.RJJ/DC.14/15) was produced by Kent County Council (KCC) in April 1991. The report presents the results of intrusive site investigation work including geotechnical laboratory testing and provides information on the geotechnical suitability of the Site for light industrial development that was proposed at the time. Reference to pertinent sections of the KCC report is made within this assessment.

PHASE 1 CONTAMINATION ASSESSMENT (DESK STUDY)

1.1 Site Location and Walkover Survey

The Site comprises a roughly rectangular shaped plot of land covering an area of approximately 4 hectares, located at Caesar's Way, Folkestone, Kent and is centred on the approximate Ordnance Survey national grid reference TR 2027 3746. A site location plan and site plan are presented as Figure 1 and Figure 2, respectively.

At the time of the walkover survey the Site was unoccupied with no structures present. Ground cover consisted of a mixture of rough grass and dense brambles with occasional semi-mature trees located across the Site, but also included broken ground, with concrete, brick and rubble. A rubble stockpile was present adjacent to the northern part of the eastern boundary of the Site, consisting of brick, concrete, and crushed stone. Further smaller piles of debris, including building rubble were noted at other locations across the Site. The Site is accessed off Caesar's Way to the east via a narrow unmade strip of land. The entrance to the Site was secured by a metal palisade fence and a set of metal gates. The Site is predominantly flat, and level, but at the time of the walkover survey was noted to be rutted in places. The Site is at a higher elevation than surrounding land. The elevated position of the Site in relation to the surrounding land, combined with evidence of building waste and dense bramble cover is suggestive of a former landfill on the Site.

The Site is bound to the north by the M20 motorway, to the south by residential properties and associated gardens, and to the west by the playing fields of Harcourt Primary School. Mature trees were noted to be present on the northern and western boundaries of the Site. A wooden post and rail fence was also present on the northern boundary. The southern boundary was delineated by a mix of rough grass and dense bramble cover. A number of current and former industrial premises were located immediately to the north east and east of the Site. These included a former concrete batching works, an existing coach storage and repair yard, including above ground fuel storage tanks, and an unspecified works/warehouse style unit with an associated electricity substation.

1.1.1 Potential Contamination Sources Identified by Walkover Survey

The following potential sources of contamination have been identified from the walkover survey:

On Site

- Possible former landfill. Potential presence of fill materials and associated metal, PAH, petroleum hydrocarbon and asbestos contamination and landfill gas generation (carbon dioxide and methane).

Off Site

- Adjacent coach storage and repair yard to the east of the Site. Potential on-site migration of petroleum hydrocarbons from fuel storage tanks and parking and maintenance of coaches.
- Adjacent concrete batching plant to the north east of the Site. Potential on-site migration of petroleum hydrocarbons.
- Adjacent works/storage warehouse to the east of the Site. Potential on-site migration of petroleum hydrocarbons.

A substation was located to the east of the Site. Substations are a potential source of localised PCB contamination. Given the localised nature of the contamination and the distance from the Site it is considered that this source does not present a significant risk to the Site.

1.2 Geological Data Review

1.2.1 Expected Geology

The stratigraphic unit that may be anticipated on-site is presented in the following table. In preparing the table reference has been made to the British Geological Survey 1:50,000 series scale map Sheet 305, the British Geological Survey lexicon of named rock units and the maps included within Appendix A (Section 1) of the accompanying Geo-Environmental Data and Historical Maps Volume.

Table 1. Anticipated Geological Strata

Type	Stratum	Age
Bedrock Geology	Gault Formation - Mudstone	Albian

Gault Formation

The Gault Formation generally consists of fossil rich dark coloured very weak and weak mudstone and siltstone which typically weathers to a stiff clay. The lower part of the Formation is often dark green and sandy. The Gault has a high plasticity, and can be expected to have a severe seasonal swelling/shrinkage behaviour.

1.2.2 *Ground Stability & Geological Features*

A review of the data presented within the Geo-Environmental Data and Historical Maps Volume report has been undertaken. The following summarises the data and the assessment of potential risk that the ground hazard/feature may pose to the Site. Ashdown Site Investigation Ltd (ASI Ltd) has commented, where appropriate, on the potential risk to the Site from the ground hazard/feature reported by the GroundSure data.

Table 2. Landslips, Solid Geology and Faults

Section	Remarks	ASI Ltd Assessment
Landslips	Landslide deposits are recorded 284m to the north east of the Site.	The geological unit underlying the Site is known to be characterised by extensive landslipping. The KCC Site Investigation Report found that weathered Gault Clay underlying the Site contained slicken sided shear surfaces characteristic of landslipping or severe cryoturbation but concluded that the natural materials underlying the Site should be stable in the absence of fill materials. The report stated that as fill materials had been in place for several years at the time of the investigation that slopes within the Site should be generally stable. A geotechnical assessment is presented in Section 4 of this report.

Table 3. Ground Workings, Mining, Extraction & Natural Cavities

Section	Remarks	ASI Ltd Assessment
Ground workings	1. Two historic ponds are recorded on the Site. Historic brick works, unspecified pits and a historic refuse heap are also recorded on the Site. 2. Historic brick works, unspecified pits, and a historic pond are recorded between 3m and 57m to the north east of the Site. 3. Historic brick works, an unspecified pit and a historic pond are recorded between 15m and 59m to the east of the Site. 4. Unspecified workings, historic brickworks, a historic pond, refuse heap and unspecified ground workings are recorded between 49m and 242m to the south east of the Site. 5. A historic brick works and unspecified pits are recorded between 69m and 203m to the south of the Site. 6. Unspecified historical underground workings are recorded 49m to the south east of the Site.	1. Backfilled ground workings including brick works, pits and ponds, are potential on Site sources of ground gases. Historic refuse heaps are a potential on Site source of metal, PAH, petroleum hydrocarbons and asbestos contamination. 2 and 3. The historic ground workings to the north east and east of the Site are a potential source of on-Site migration of ground gases. 4. The unspecified historic workings 49m to the south east of the Site are a potential source of on-Site migration of ground gases. Given the distance between the Site and the historic brick works, pond, refuse heap and unspecified ground workings (between 207m and 242m from the Site) it is considered that these ground workings do not present a significant risk to the Site. 5. The historic brick works 69m to the south of the Site is a potential source of on-Site migration of ground gases. Given the distance between the Site and the unspecified pits (between 144m and 203m from the Site) it is considered that these ground workings do not present a significant risk to the Site. 6. It is understood that the historical underground workings which date from 1993 are related to the surface workings located the same distance and direction from the Site. It is likely that the underground workings are associated with the brickworks that has historically operated in this vicinity. It is recommended that contact is made with the relevant local authorities to determine the extent of any underground features in the vicinity of the Site.

Section	Remarks	ASI Ltd Assessment
Mining	Unspecified historical workings are recorded 49m to the south east of the Site.	It is understood that the historical workings which date from 1993 are related to the surface workings located the same distance and direction from the Site that are assessed in point 4, above: It is likely that the underground workings are associated with the brickworks that has historically operated in this vicinity. It is recommended that contact is made with the relevant local authorities to determine the extent of any mining features in the vicinity of the Site.

The GroundSure data indicates the absence of any significant faults within 500m of the Site.

The Site is in an area where less than 1% of properties are above the action level requiring protective measures to be included within new buildings in respect of radon gas. No radon protective measures are reported by the BGS to be necessary in the construction of new dwellings.

No significant risk to the Site associated with natural cavities is reported.

The maximum hazard rating of natural subsidence within the Site boundary (including a 50m buffer zone) is moderate. This hazard rating is based on the interrogation of the six British Geological Survey (BGS) natural ground stability datasets (GeoSure). These are reviewed individually in the table below.

Table 4. Natural Ground Subsidence Hazards

Section	Risk Assessment (GroundSure)	Remarks & ASI Ltd Assessment
Soil Volume Change Potential (Shrink-Swell)	Moderate	The GroundSure report records ground conditions of predominantly high plasticity on the Site. Trees or shrubs should not be planted or removed near to buildings without expert advice about their effect and management. For new build, consideration should be given to advice published by the National House Building Council (NHBC) and the Building Research Establishment (BRE).

There is reported to only be either a low or negligible risk of landslides, ground dissolution, compressible deposits, collapsible deposits or running sand deposits at the Site.

Site specific geotechnical assessment is discussed further is Section 4 of this report.

1.2.3 *Background Soil Chemistry*

The GroundSure GeoInsight report provides information on background soil chemistry. The following estimated mean concentrations of metals are reported.

Table 5. Background Mean Soil Concentrations of Metals

Metal	Mean Soil Concentration (mg/kg)	Remarks & ASI Ltd Assessment
Arsenic	<15	The mean soil concentrations indicated are not considered to be significantly elevated for the proposed use.
Cadmium	<1.8	
Chromium	60-90	
Nickel	15-30	
Lead	<150	

1.2.4 *Potential Contamination Sources identified by Geological Data Review*

The following potential sources of contamination have been identified from the geological data review:

On Site

- Backfilled ground workings and historic refuse heaps. Potential metal, PAH, petroleum hydrocarbons, asbestos and ground gases.

Off Site

- Historic ground workings to the north east and east of the Site. Potential on-site migration of ground gases.
- Unspecified historic surface and subsurface workings 49m to the south east of the Site. Potential on-site migration of ground gases.
- Historic brick works 69m to the south of the Site. Potential on-site migration of ground gases.

1.3 Environmental Data Review

Records of potentially contaminative activities, authorisations, pollution incidents and land uses recorded by the regulatory authorities and compiled by GroundSure in their EnviroInsight Report have been reviewed. Data are supplied by the British Geological Survey (BGS), Environment Agency, Health Protection Agency, The Coal Authority and Local Authorities.

Locations of registered potentially hazardous industrial or other land uses, records of pollution incidents affecting controlled water, water abstraction licences and waste water discharge licences are shown on the maps presented in the accompanying Geo-Environmental Data and Historical Maps Volume report.

The information and potential risks to or from the various sources is assessed below.

Table 6. Authorisation, Incidents and Registers

Section	Remarks	ASI Ltd Assessment
Records of Part A(2) and Part B Activities and Enforcements	A concrete batching plant is recorded 102m to the north east of the Site.	The operation of plant at the concrete works is a potential source of on-site migration of petroleum hydrocarbon contamination.
Records of Licensed Discharge Consents	Three licensed discharge consents (for miscellaneous or sewage discharges) are recorded between 416m and 453m to the west of the Site.	Given the distance between the discharge consent locations and the Site and the location of the receiving waters, it is considered that the discharge consents do not present a significant risk to the Site.

Table 7. Current Land Uses

Section	Remarks	ASI Ltd Assessment
Current Industrial Data	1. A number of electricity substations are recorded between 14m and 245m from the Site to the north east, south east, and south west. 2. A coach hire and rental facility is recorded 20m to the east of the Site. 3. An unspecified works is located 28m to the east of the Site. 4. Tanks are recorded 43m to the east of the Site. 5. An unspecified works is recorded 66m to the east of the Site. 6. A number of tanks are recorded between 100m and 199m to the north east, east, and south of the Site.	1. Electricity substations are a potential source of localised polychlorinated bi-phenyl contamination. In view of the localised nature of the contamination and the distance between the substations and the Site, it is considered that the substations do not present a significant risk to the Site. 2 and 4. The coach hire and rental facility are a potential source of on-site migration of petroleum hydrocarbons due to possible vehicle parking and maintenance that may have occurred. It is understood that the recorded storage tanks are used for fuel storage in connection with the coach hire facility. 3 and 5. The unspecified works to the east of the Site are potential sources of on-site migration of petroleum hydrocarbons. 6. The recorded tanks, if used for fuel storage are potential sources of on-site migration of petroleum hydrocarbons. In view of the distance between the tanks and the Site it is considered that these tanks are unlikely to present a significant risk to the Site.

Table 8. Designated Environmentally Sensitive Sites

Section	Remarks	ASI Ltd Assessment
Designated Environmentally Sensitive Sites	The Folkestone to Etchinghill Escarpment which is designated as a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC) is located 464m to the north east of the Site. Two listings for the Kent Downs Area of Outstanding Natural Beauty (AONB) are recorded 314m and 485m to the north of the Site. The Site is situated within a Nitrate Vulnerable Zone.	In view of the distance between the SSSI, SAC and AONB and the Site and the nature of the potential development options for the Site (residential and commercial) it is considered that the Site is unlikely to present a significant risk to the environmentally sensitive sites. Given the nature of the development options for the Site (residential and commercial) it is considered that the potential end uses of the Site are unlikely to present a significant risk to the Nitrate Vulnerable Zone.

No landfills or waste sites likely to impact the site have been identified.

1.3.1 *Potential Contamination Sources Identified by Environmental Data Review*

The following potential sources of significant contamination have been identified by the Environmental Data Review.

On Site

- No significant sources of contamination have been identified by the environmental data review.

Off Site

- Concrete batching plant to the north east of the Site. Potential on-site migration of petroleum hydrocarbons.
- Coach hire and rental facility to the east of the Site. Potential on-site migration of petroleum hydrocarbons from storage tanks and parking and maintenance of coaches.
- Works to the east of the Site. Potential on-site migration of petroleum hydrocarbons.

1.4 Hydrogeology and Hydrology

1.4.1 Groundwater Vulnerability & Soil Classification

On the 1st April 2010 the Environment Agency implemented new aquifer designations that are consistent with the Water Framework Directive. These designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems.

The aquifer designation data is based on geological mapping provided by the British Geological Survey. Reference has been made to Aquifer Designation Maps available on the Environment Agency website (http://www.environment-agency.gov.uk).

The Gault Formation beneath the Site is classified as Unproductive Strata. Unproductive Strata are deposits with low permeability that have negligible significance for water supply or river base flow.

1.4.2 Abstractions Licences

Four groundwater abstraction licences are recorded between 260m and 899m to the north east and 503m to the east of the Site. Given the impermeable nature of the geology underlying the Site and the distance between the Site and the locations of the abstraction licences it is considered that the Site is unlikely to present a significant risk to the licensed groundwater abstractions.

1.4.3 Potable Water Abstraction Licenses and Source Protection Zones (SPZs)

Four potable water abstraction licences are recorded between 260m and 899m to the north east and 503m to the east of the Site. Given the impermeable nature of the geology underlying the Site and the distance between the Site and the locations of the abstraction licences it is considered that the Site is unlikely to present a significant risk to the licensed potable water abstractions.

The Site does not lie within an Environment Agency Source Protection Zone with regard to the protection of the quality of groundwater that is abstracted for potable supply. A source protection Zone type 3 (Total Catchment) is located 35m to the south of the Site.

1.4.4 Surface Water

The data indicates that the nearest significant surface water feature (the Pent Stream) is located 104m to the south west of the Site. Ordnance survey map information from 2010 shows a small surface water drain approximately 60m to the north east of the Site immediately to the south of the M20 motorway.

1.4.5 Flooding

The Site does not lie within an Environment Agency Zone 2 or Zone 3 floodplain. However the Site lies 119m from an Environment Agency Zone 2 floodplain and 128m from a Zone 3 floodplain. There are no flood defences, areas benefiting from flood defences or areas used for flood storage within 250m of the Site.

The British Geological Survey reports a negligible susceptibility to groundwater flooding within 50m of the Site. The BGS consider the confidence rating of their data in this area to be moderately high.

1.5 Site History

Historical Ordnance Survey maps covering the area of the Site have been reviewed. It is noted that each map presents information applicable at the time of the survey (or revision date) and is subject to surveying and cartographic errors and/or advances. Revisions to maps are made at irregular intervals and it is possible that significant developments may have taken place on or within the vicinity of the Site that have not been revealed by the maps.

In the following table 'In Vicinity of Site' generally considers features of relevance within approximately 250m of the Site boundary, but may also include more distant features if considered to be pertinent to the assessment of the development history.

The Site is shown to be largely covered by mature trees at the time of the earliest inspected historical map which dates from 1872. A small brickworks is shown within the eastern extremity of the Site. Between this time and the mid-1970s land on Site and in the vicinity of the Site was used for expanding brick works operations and associated excavations and infrastructure. By the mid 1970s the excavations within and in the vicinity of the Site appear to have been backfilled. The land in the vicinity of the Site in which excavations were formerly present has largely been redeveloped for industrial/commercial and residential use. The land within the Site has remained otherwise undeveloped until the present day.

The 1981 KCC Site Investigation Report reported that a portion of the Site was occupied by a brickworks and associated clay pit until around 1962 and that subsequently the southern area of the Site was used as a refuse dump by the local authorities.

Significant details depicted on the historical maps are identified in the following table.

Table 9. Summary of Significant Historical Maps

Map Details	On-site	In Vicinity of Site	Significant Potential Contamination Sources
1872 1:2,500	The majority of the Site is shown to be covered by mature trees. A brick works and pond are shown within the extreme eastern part of the Site. A track is shown running through the north eastern corner of the Site, connecting the brickworks to the east with an area of cleared vegetation within a wooded area to the north of the Site.	The Site is situated within an area of largely open land (presumably farmland), including open fields and areas covered by mature trees. A pond, presumably associated with the adjacent brickworks, is shown approximately 80m to the south east of the Site. A brick works is shown approximately 130m to the south of the Site. A number of industrial type buildings are shown on land immediately to the east of the Site.	
1896 1:10,560	The excavations associated with the brick works to the south of the Site are shown extending within the southern boundary of the Site.	A pond is shown adjacent to the brick works approximately 50m to the south of the Site. A laundry is shown approximately 160m to the south east of the Site.	Laundries are potential sources of contamination from the chemical constituents of cleaning products that may be present. Due to the distance between the laundry and the Site it is considered that the laundry does not present a significant risk to the Site.
1898 1:2,500	A small pond, adjacent to the track and presumably associated with the brick works is shown in the eastern part of the Site.		
1906 1:10,560	The excavation associated with the brick works to the south of the Site is now shown to extend further into the eastern part of the Site.	A large excavation and associated kilns are shown on previously undeveloped land approximately 20m to the north east of the Site. Residential development is shown in the vicinity of Kent Road approximately 170m to the south of the Site.	

INVESTIGATION LOMOTOED

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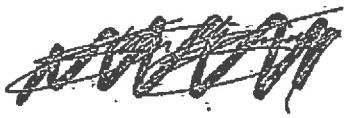
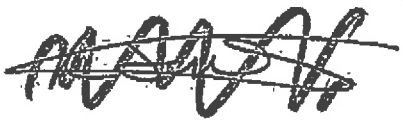
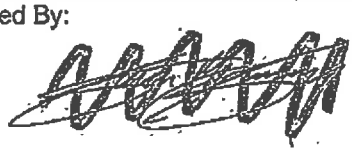
Report No. LW21271 October 2010

PHASE 1 CONTAMINATION ASSESSMENT (DESK STUDY)	
Prepared By:  David Wilkes BSc MSc FGS	Approved By:  Steven McSwiney BA mod Geol MSc FGS
FACTUAL REPORT	
Prepared By:  Rebecca Jones BSc FGS	Approved By:  Steven McSwiney BA mod Geol MSc FGS
GEOTECHNICAL ASSESSMENT	
Prepared By:  Rebecca Jones BSc FGS	Approved By:  Steven McSwiney BA mod Geol MSc FGS
PHASE 2 CONTAMINATION ASSESSMENT	
Prepared By:  David Wilkes BSc MSc FGS	Approved By:  Steven McSwiney BA mod Geol MSc FGS

Map Details	On-site	In Vicinity of Site	Significant Potential Contamination Sources
1931 1:10,560	The excavation associated with the brick works to the south of the Site is now shown to extend within the central area of the Site. An elongate structure (presumably a conveyor associated with the brickworks) is shown extending from the centre of the Site to the brick works to the south of the Site. A small square building is shown adjacent to the southern boundary of the Site. The pond in the extreme eastern part of the Site is no longer shown. The small pond adjacent to the track in the eastern part of the Site is no longer shown.	The large excavation to the north east of the Site has been extended and now comes to within 10m of the eastern boundary of the Site. The pond approximately 80m to the south east of the Site is no longer shown. The pond previously 50m to the south of the Site now extends to within 3m of the southern boundary of the Site.	The former ponds in the eastern part of the Site, if backfilled, are a potential source of metal and PAH contamination within made ground soils and a potential source of ground gases. The former ponds 50m to the south and 80m to the south east of the Site, if backfilled, are a potential source of on-Site migration of ground gases. Given the distance between the ponds and the Site and the nature of the geology underlying the Site, which would retard the migration of ground gases, it is considered that these former off-Site ponds are unlikely to present a significant risk to the Site.
1937 1:2,500		The excavation to the north east of the Site has been extended onto previously undeveloped land to the north of the Site.	

Map Details	On-site	In Vicinity of Site	Significant Potential Contamination Sources
1957 **1:1,250**	The excavation in the centre of the Site is now shown to be filled by a pond. The excavations in the eastern part of the Site are no longer shown. The small square building adjacent to the southern boundary of the Site is no longer shown. The conveyor is no longer shown.	The original industrial buildings immediately to the east of the Site are no longer shown. The pond which extended to within 3m of the southern boundary of the Site is no longer shown. Residential development has occurred on previously unoccupied land (Charles Crescent) and on land formerly occupied by the brickworks (Elventon Close) to the south of the Site. The extent of the off-Site brickworks excavation to the south of the Site is no longer shown.	The excavations in the eastern part of the Site, if backfilled, are a potential source of metal and PAH contamination within made ground soils and a potential source of ground gases. Demolition of the small building adjacent to the southern boundary of the Site may have resulted in the presence of made ground soils and associated metal and PAH contamination. The brickworks excavations immediately to the south of the Site and the pond 3m to the south of the Site, if backfilled, are potential sources of on-Site migration of ground gases.
1966 **1:1,250**		A telephone engineering centre set within a previously undeveloped parcel of land is shown immediately adjacent to the south eastern corner of the Site. Harcourt County Primary School is now shown on previously undeveloped land to the west of the Site.	
1973 **1:10,000**	The pond and excavations in the centre of the Site are no longer shown.	The excavations to the north east of the Site are now indicated as disused.	The former pond and excavations within the centre of the Site are a potential source of metal and PAH contamination within made ground soils and are a potential source of ground gases.

Map Details	On-site	In Vicinity of Site	Significant Potential Contamination Sources
1982 1:2,500		A variety of buildings and infrastructure on the footprint of the concrete batching plant to the north east of the Site and the coach maintenance depot to the east of the Site are shown for the first time. The M20 motorway is shown running on an embankment immediately to the north of the Site. The brick works and associated excavation immediately to the north east of the Site are no longer shown.	The concrete batching plant to the north east of the Site is a potential source of on-Site migration of petroleum hydrocarbons. The coach maintenance depot to the east of the Site is a potential source of on-Site migration of petroleum hydrocarbons. The brick works and associated excavations immediately to the north east of the Site are a potential source of on-Site migration of ground gases.
1986 1:1,250		A large building and associated electricity substation is shown on the footprint of the works to the east of the Site for the first time. Further residential development has occurred on former brickworks land immediately to the south of the Site.	The works to the east of the Site is a potential source of on-Site migration of petroleum hydrocarbons. Given the localised nature of the contamination and the distance between the substation and the Site it is considered that the substation does not present a significant risk to the Site.
1989 1:1,250		The tracks and infrastructure of the channel tunnel rail terminal are shown immediately to the north of the M20 motorway approximately 70m to the north of the Site.	

1.5.1 *Potential Contamination Sources identified by Historical Map Review*

The following potential sources of contamination have been identified from the historical map review:

On Site

- Former ponds in the eastern part of the Site. Possible presence of made ground soils/fill material. Potential metal and PAH contamination of soils. Potential source of ground gases.
- Former excavations in the eastern part of the Site. Possible presence of made ground soils/fill material. Potential metal and PAH contamination of soils. Potential source of ground gases.
- Demolition of small building adjacent to the southern boundary of the Site. Possible presence of made ground soils. Potential metal and PAH contamination.
- Former pond and excavations within the centre of the Site. Possible presence of made ground soils/fill material. Potential metal and PAH contamination of soils. Potential source of ground gases.

Off Site

- Former brick works excavations and pond immediately to the south of the Site. Potential source of on-site migration of ground gases.
- Concrete batching plant to the north east of the Site. Potential source of on-site migration of petroleum hydrocarbons.
- Coach maintenance depot to the east of the Site. Potential source of on-site migration of petroleum hydrocarbons.
- Former brick works and associated excavations immediately to the north east of the Site. Potential source of on-site migration of ground gases.
- Works to the east of the Site. Potential source of on-site migration of petroleum hydrocarbons.

1.6 Preliminary Contamination Risk Assessment

1.6.1 Basis of Preliminary Contamination Risk Assessment

An appropriate preliminary risk assessment of a site in terms of contamination status considers the potential sources of contamination, the potential receptors and how the sources and receptors may be linked (the pathways).

A potentially significant risk is only deemed to exist where a potentially significant pollutant linkage has been identified i.e. where a potentially significant source is linked to the receptor via a significant pollutant pathway. A site is considered suitable for use where no significant pollutant linkages are present.

This preliminary risk assessment takes into account the proposals for the Site, key features noted from the walkover survey, information from the database search and any potential risks identified from the review of historical Ordnance Survey maps and other data.

The level of risk is determined using the following risk matrix:

		Likelihood of significant effect			
Severity of potential effect		Unlikely	Low Likelihood	Moderate Likelihood	High likelihood
	Very Minor	Negligible	Very Low	Low	Low/Moderate
	Minor	Very Low	Low	Low/Moderate	Moderate
	Moderate	Low	Low/Moderate	Moderate	High
	Severe	Low/Moderate	Moderate	High	Very High

The risk assessment is based on the Site being developed for possible range of end uses, including residential development incorporating private gardens. Once more definite development proposals for the Site have been formulated and/or if the proposed end use is altered, a revised risk assessment may be required.

1.6.2 Preliminary Risk Assessment for Human Health

The following potential sources of contamination that may pose a risk to end users have been identified by the risk assessment:

1) Possible former landfill. Potential presence of fill materials and associated metal, PAH, petroleum hydrocarbon and asbestos contamination and landfill gas generation (carbon dioxide and methane) within and from backfilled former excavations and ponds in the central and eastern areas of the Site.

   The walkover survey identified the presence of potential fill materials and evidence of landfilling across the Site. The historical map review and geological data review have identified excavations and

brickworks operations that extended across the eastern and central areas of the Site that have presumably been subject to backfilling with fill materials to restore the Site to current ground levels, which are elevated above the surrounding land. The geological data review identified historic refuse heaps within the Site. It is considered to be highly likely that landfill materials are present within the central and eastern areas of the Site. The likelihood of a significant pollution effect is considered to be high. Depending upon the nature of the materials contained within the landfill the severity of the potential effect is considered to be moderate or severe. The overall assessment of the risk to human health is considered to be High or Very High.

2) Demolition of a small building adjacent to the southern boundary of the Site. Possible presence of made ground soils. Potential metal and PAH contamination.

   The demolition of a small building adjacent to the southern boundary of the Site may have resulted in the presence of made ground soils and metal and PAH contamination. The likelihood of a significant pollution effect is considered to be low. The severity of the potential effect is considered to be moderate. The overall assessment of the risk to human health is considered to be Low/Moderate.

3) Adjacent coach storage and repair yard to the east of the Site. Potential on-site migration of petroleum hydrocarbons from storage tanks and parking and maintenance of coaches.

   The presence of a coach storage and maintenance facility and tanks for the storage of fuel oils immediately adjacent to the eastern boundary of the Site is a potential source of on-site migration of petroleum hydrocarbon contamination. The likelihood of a significant effect is considered to be moderate. The severity of the potential effect is considered to be moderate. The overall assessment of the risk to human health is judged to be Moderate.

4) Adjacent concrete batching plant to the north east of the Site. Potential on-site migration of petroleum hydrocarbons.

   The presence of the concrete batching plant and the likely use and storage of mobile and fixed plant and storage of fuel oils adjacent to the eastern boundary of the Site is a potential source of on-site migration of petroleum hydrocarbon contamination. The likelihood of a significant effect is considered to be moderate. The severity of the potential effect is considered to be moderate. The overall assessment of the risk to human health is judged to be Moderate.

5) Adjacent works/storage warehouse to the east of the Site. Potential on-site migration of petroleum hydrocarbons.

The presence of the works to the east of the Site and the potential use and storage of mobile and fixed plant and storage of fuel oils is a potential source of on-site migration of petroleum hydrocarbon contamination. The likelihood of a significant effect is considered to be moderate. The severity of the potential effect is considered to be moderate. The overall assessment of the risk to human health is judged to be Moderate.

6) Former brick works and associated excavations immediately to the north east and east of the Site. Potential on-site migration of ground gases.

The former brickworks and associated excavations to the north east and east of the Site have been subject to redevelopment for a variety of land uses including a concrete batching plant and the line of the M20 motorway and channel tunnel rail terminal. Backfilled excavations are a potential source of on-Site migration of ground gases. Given the proximity of the former excavations immediately to the north east of the Site it is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human health is judged to be Moderate.

7) Unspecified historic surface and subsurface workings 49m to the south east of the Site. Potential on-site migration of ground gases.

The presence of unspecified ground and subsurface workings to the south east of the Site is thought likely to be associated with the wider brick works activities that have occurred in the vicinity of the Site. Backfilled excavations are a potential source of on-site migration of ground gases. Given the distance between the workings and the Site and the nature of the underlying geology which would retard the migration of ground gases it is considered that the likelihood of a significant effect is low. The severity of the potential effect is moderate. The overall assessment of the risk to human health is Low/Moderate.

8) Brick works excavations and pond immediately to the south of the Site. Potential source of on-site migration of ground gases.

The former brick works and associated ponds and excavations to the south of the Site have been subject to residential development with properties on Elventon Close, Biggins Wood Road and Dennis Way. Backfilled excavations are a potential source of on-Site migration of ground gases. Given the proximity of the former excavations immediately to the south of the Site it is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human health is judged to be moderate.

A preliminary human health risk assessment conceptual model is presented in the following table of this report and is presented diagrammatically as Figure 3.

Table 10. Preliminary Human Health (End Users) Conceptual Model – Potential Pollutant Linkages and Initial Assessment of Risk

Contaminant Source	Potential Pathway(s)	Likelihood	Severity	Initial Assessment of Risk to Human Health
Possible former landfill. Potential presence of fill materials and associated metal, PAH, petroleum hydrocarbon and asbestos contamination and landfill gas generation (carbon dioxide and methane) within and from backfilled former excavations and ponds in the central and eastern areas of the Site.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown produce and soil attached to homegrown produce, Inhalation of indoor and outdoor soil dust. Inhalation of soil gases, Inhalation of soil vapours.	High	Moderate or Severe	High or Very High
Demolition of a small building adjacent to the southern boundary of the Site. Possible presence of made ground soils. Potential metal and PAH contamination.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown produce and soil attached to homegrown produce, Inhalation of indoor and outdoor soil dust.	Low	Moderate	Low/Moderate
Adjacent coach storage and repair yard to the east of the Site. Potential on-site migration of petroleum hydrocarbons from storage tanks and parking and maintenance of coaches.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown produce and soil attached to homegrown produce, Inhalation of indoor and outdoor soil dust, Inhalation of soil vapours.	Moderate	Moderate	Moderate
Adjacent concrete batching plant to the north east of the Site. Potential on-site migration of petroleum hydrocarbons.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown produce and soil attached to homegrown produce, Inhalation of indoor and outdoor soil dust, Inhalation of soil vapours.	Moderate	Moderate	Moderate

Contaminant Source	Potential Pathway(s)	Likelihood	Severity	Initial Assessment of Risk to Human Health
Adjacent works/storage warehouse to the east of the Site. Potential on-site migration of petroleum hydrocarbons.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown produce and soil attached to homegrown produce, Inhalation of indoor and outdoor soil dust, Inhalation of soil vapours.	Moderate	Moderate	Moderate
Former brick works and associated excavations immediately to the north east and east of the Site. Potential on-site migration of ground gases.	Inhalation of soil gases.	Moderate	Moderate	Moderate
Unspecified historic surface and subsurface workings 49m to the south east of the Site. Potential on-site migration of ground gases.	Inhalation of soil gases.	Low	Moderate	Low/Moderate
Brick works excavations and pond immediately to the south of the Site. Potential source of on-site migration of ground gases.	Inhalation of soil gases.	Moderate	Moderate	Moderate

1.6.3 *Preliminary Risk Assessment for Controlled Water*

The following potential sources of contamination at the site that could affect controlled waters have been identified by the risk assessment:

1) Possible former landfill. Potential presence of fill materials and associated metal, PAH and petroleum hydrocarbon contamination within backfilled former excavations and ponds in the central and eastern areas of the Site.
2) Demolition of a small building adjacent to the southern boundary of the Site. Possible presence of made ground soils. Potential metal and PAH contamination.

As the Site is expected to be underlain by the Gault Formation which is classified as Unproductive Strata and the Site does not lie within an Environment Agency Source Protection Zone with regard to the extraction of water for potable supply the sensitivity of the underlying natural soils is considered to be very low. In addition the impermeable nature of the underlying strata is expected to retard the migration of potential contaminants within water percolating through made ground

soils from the surface. In view of the above it is considered that there is no significant risk to controlled waters from the potential contaminants within landfill materials and made ground soils within the Site.

A preliminary controlled water risk assessment conceptual model is presented in the following table of this report and is presented diagrammatically as Figure 3.

Table 11. Preliminary Controlled Water Conceptual Model – Potential Pollutant Linkages and Initial Assessment of Risk

Contaminant Source	Potential Pathway(s)	Likelihood	Severity	Initial Assessment of Risk to Human Health
Possible former landfill. Potential presence of fill materials and associated metal, PAH and petroleum hydrocarbon contamination within backfilled former excavations and ponds in the central and eastern areas of the Site.	No pathway identified	Not applicable	Not applicable	No significant risk
Demolition of a small building adjacent to the southern boundary of the Site. Possible presence of made ground soils. Potential metal and PAH contamination.				

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GEOTECHNICAL
AND
CONTAMINATION (PHASE I AND II)
ASSESSMENT REPORT

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2. FACTUAL REPORT

2.1 Ground Investigation

2.1.1 Introduction

The ground investigation comprised the excavation of a series cable percussion, and dynamic sampler boreholes. The fieldwork was carried out between the 20th and 24th September 2010. The exploratory hole locations are shown on the Site Plan (Figure 2).

Due to the presence of protected reptiles on site the borehole locations were positioned with agreement from ecologist Martin Newcombe and works undertaken to cause minimum damage to sensitive areas.

Descriptions of the strata encountered and comments on groundwater conditions are shown in the exploratory hole records given in Appendix A. Notes to assist in the interpretation of the records are also contained in the appendix.

2.1.2 Investigation and Sampling Strategy

The investigation comprised a mixture of targeted sampling in areas identified as posing or being subject to potentially significant risks by the desk study and walkover survey work, together with non targeted sampling over other areas to provide spatial coverage. The sampling locations were also dictated by access constraints around the Site. The following table provides a summary of the rationale behind the positioning of the exploratory holes.

The pattern and density of sampling adopted is considered adequate for a quantitative assessment of the extent of contamination at the Site. The results from the ground investigation, together with the desk study work, provide information allowing preparation of a quantitative risk assessment.

Table 12. Sampling Location Rationale

Exploratory Hole	Reason for positioning
Boreholes WS1, WS2, BH1 and BH2.	Located adjacent to the coachworks, works and concrete batching plant to the east and north east of Site.
Remaining Positions	Non-targeted contamination sampling to investigate extent and nature of backfilled materials on Site.

2.1.3 *Methodology*

2.1.3.1 *Cable Percussion Boreholes*

Six boreholes (designated BH1 to BH6) were bored to depths of between 10m and 15m below ground level.

The drilling and in situ testing procedures adopted during the cable percussion borehole investigation are outlined in Appendix A.

2.1.3.2 *Dynamic Sampler Boreholes*

Sixteen boreholes (designated WS1 to WS16) were drilled to depths of between 1.0m and 5.0m below ground level.

The dynamic sampler boreholes were formed by a series of 1.0m long hollow steel tubes, ranging in diameter from 35mm to 100mm, driven into the ground by means of a track-mounted drop weight. The sampler was extracted from the ground using a hydraulically operated jack and the enclosed samples recovered in 1.0m long perspex liners. The system enables sub-samples to be taken for detailed examination and laboratory testing.

2.1.4 *Sampling*

Undisturbed and disturbed samples of soil were taken at the depths shown in the exploratory hole records and collected in either plastic liners, plastic bags or amber jars fitted with gas tight lids. On collection amber jars were stored in cool boxes with cooling blocks to maintain temperatures below 4°C and transferred to refrigerators upon return to the office until forwarded to the external accredited laboratory.

2.1.5 *In Situ Testing*

The depths of in situ testing, together with the test results, are given on the exploratory hole records or are summarised separately in Appendix A. Notes providing additional information on the tests that were performed are also included in Appendix A.

Standard Penetration Test

Standard penetration testing (SPT) was carried out within the cable percussion boreholes for the assessment of the relative density of more coarse grained soils. The SPT tests were carried out in accordance with BS EN ISO 22476-3:2005

DPSH Dynamic Probe (Super Heavy) Testing

Dynamic probe testing was carried out adjacent to dynamic sampler boreholes WS10, WS11, WS12, WS13 and WS15. The dynamic probing was undertaken in accordance with BS EN ISO 22476-2:2005 using a super heavy probing geometry.

The DPSH configuration is similar to that of the standard penetration test (SPT) except that the blow counts are recorded over 100mm increments rather than 300mm for the SPT.

Undrained Shear Strength

Undrained shear strength determinations were made in situ within the fine grained soils using a Geonor hand shear vane as part of the dynamic sampling investigation.

Additionally undrained shear strength determinations were made within samples of the fine grained soils held in the dynamic sampler liners using a hand penetrometer. Although samples taken by the dynamic sampling technique cannot be regarded as being undisturbed for testing purposes, penetrometer testing can provide a useful indication of the strength of the material.

California Bearing Ratio Tests

In situ testing using a hand-held Farnell cone penetrometer was conducted at shallow depths within boreholes WS5, WS9, WS14 and WS16.

2.1.6 *Installations*

Gas and groundwater monitoring standpipes were installed to depths of 3.0m within nine of the dynamic sampler boreholes. Descriptions of the installations are shown in the exploratory hole records given in Appendix A.

The concentrations of gases and depths to groundwater were recorded within the standpipes on three occasions between 29th September and 13th October 2010 as part of the monitoring programme. The readings are presented in Appendix A.

2.2 Laboratory Testing

Results from the laboratory tests are provided in Appendix B.

2.2.1 *Geotechnical Testing*

Geotechnical testing was undertaken by Ashdown Site Investigation Ltd in accordance with the methods given in BS1377:1990 Parts 1 to 8 'Methods of test for soils for civil engineering purposes'. Notes to assist with the interpretation of the tests are contained within Appendix B.

The types and numbers of tests carried out are detailed in the following table. The significance of the results is discussed in Section 4.

Table 13. Geotechnical Testing

Type of test	No. of samples tested
Moisture Content	25
Atterberg Limits	5
Triaxial Compression	12
Laboratory Shear Vane	20
Water Soluble sulphate and pH	7

2.2.2 *Chemical Testing*

Chemical testing of selected samples was scheduled by Ashdown Site Investigation Ltd, and was undertaken by a laboratory with recognised (UKAS and MCERTS) accreditation for quality control.

The types and numbers of tests undertaken are detailed in the following table. The rationale for testing is discussed further in Section 5.

Table 14. Chemical Testing

Determinand	No. of soil samples tested
Arsenic	11
Cadmium	11
Chromium	11
Lead	11
Mercury	11
Nickel	11
Selenium	11
Copper	8

Determinand	No. of soil samples tested
Zinc	8
Hexavalent Chromium	11
Water Soluble Boron	8
pH	8
Organic Matter	8
Speciated PAHs	11
Speciated Petroleum Hydrocarbons (Equivalent Carbon Weight Fractions)	4
Speciated Petroleum Hydrocarbons (Aromatic and Aliphatic Equivalent Carbon Weight Fractions) and BTEX compounds (benzene, toluene, ethylbenzene and xylene)	2

2.3 Ground Conditions

2.3.1 Stratigraphy

2.3.1.1 Surface Covering

Exploratory holes WS1, WS2, WS9, WS10 and WS16 were excavated through a surface cover of topsoil.

No surfacing materials were encountered within the remaining boreholes.

2.3.1.2 Made Ground

Made ground, generally comprising clay containing a variable proportion of silt, sand and gravel of brick, flint, chalk, clinker, ash, concrete, sandstone, glass metal and organic matter was recorded to depths of between 0.8m and 5.2m below ground level.

The greatest depth of made ground was recorded in the central and southern part of the site and is considered to represent the infilled brickfield excavation/landfill.

Hydrocarbon (fuel/oil) staining and odours were noted within the made ground soils encountered within boreholes BH6, WS5, WS6, WS10, WS11, WS12 and WS13.

No made ground soils were encountered within boreholes BH1, BH5, WS1, WS3, WS4, WS7, WS8 or WS16 all of which were located in the northernmost part of the site.

2.3.1.3 Gault Formation

Beneath the made ground, where penetrated, the boreholes encountered generally stiff clay becoming very stiff to hard with depth to the full depth of investigation.

Hydrocarbons odours were noted in these natural soils within borehole WS14.

These soils are considered to be representative of the Gault Formation soils indicated on the published geological map.

2.3.2 Stability and Groundwater Conditions

Instability was recorded locally within the made ground soils encountered.

Groundwater was encountered within boreholes BH6 at a depth of 2.8m and in WS10 at a depth of 2.2m during the intrusive works. The remaining exploratory holes were dry during the period of the intrusive works.

With the exception of the standpipe installed in WS3 which remained dry, standing water was recorded at depths of between 0.4m and 3.0m below ground level within the standpipes during the monitoring visits carried out.

3. GEOTECHNICAL ASSESSMENT

At the time of preparation of this report no specific development option for the site had been finalised and no details were available concerning the loads likely to be applied to the foundations. However it is understood that development options for the site are likely to include a mixture of residential and commercial buildings.

3.1 Foundations

3.1.1 Soil Shrinkage/Heave Potential

The soils of the Gault Formation have been classified as clays of high to very high plasticity and with plasticity indices in the range of 41% to 51% the soils may be expected to exhibit a high volume change potential.

It is recommended that precautions against shrinkage and heave for any foundation system (spread footings, piles, pile caps and ground beams) constructed within the fine grained Gault Formation soils should assume a high volume change potential and take into account current guidance such as that given by the National House Builders Council (NHBC).

Whilst this report has been prepared to provide advice to assist designers in undertaking detailed design, the report itself does not represent a detailed design statement. All detailed foundation design including assessment of minimum founding depths for spread foundations, requirements for sleeving or reinforcing of piled foundations and requirements for placement of void formers must take into account the volume change potential of the soil and the presence of trees (previous, present and proposed). In this connection attention is drawn to the presence of mature trees and shrubs around and across the Site.

3.1.2 Spread Foundations

Made ground was recorded across the site to depths of between 0.8m and 5.2m below ground level. Any made ground should be regarded as potentially variable in nature and state of compaction and, as such, unsuitable as a founding medium for shallow footings. New footings should be constructed below the made ground and any soils disturbed by the construction or removal of any previously existing foundations and services.

In view of the depth of made ground recorded across the central and southern part of the site it is considered that this area will be unsuitable for the construction of spread foundations. The Gault Formation soils encountered at relatively shallow depth in the northern part of the site would be suitable as a founding medium for shallow foundations subject to assessment of the requirement to deepen foundations to protect against soil volume change movements.

For preliminary design purposes, a net allowable bearing capacity of 150kN/m^2 may be assumed for the construction of spread (pad or strip) foundations up to

1.0m across bearing within the minimum firm clay soils of the Gault Formation. The quoted bearing capacity is expected to limit settlement to less than 25mm. Subject to any precautions required to protect against the effects of soil shrinkage or heave caused by trees, a minimum depth to formation of 1.0m should be adopted.

3.1.3 Piled Foundations

In consideration of the depth of made ground across the central and southern part of the site it is suggested that piled foundations will be required in this area. Piled foundations may also be more economic in other areas of the site where consideration of potential heave/shrinkage movements may require excessively deep conventional footings.

It is considered that the Gault Formation would provide support to piled foundations by side adhesion (skin friction) and end bearing.

The proven ground conditions would indicate that bored piles could be employed to provide a suitable foundation solution. However the method of installation will have to accommodate the presence of groundwater and the very stiff and hard clay soils encountered at depth.

Dependant on the method employed it is considered likely that driving displacement (driven piles) through the very stiff and hard clays at depth would prove difficult and noise may be disruptive to nearby properties and their occupants such that their use may not be permitted.

For the purposes of this initial discussion and for reasons given above, consideration has been given to the adoption of cast in situ piles (e.g. CFA). The use of CFA piles would prove beneficial as this method does not require casing or the use of bentonite slurries. However, there are certain practical constraints that should be taken into account in the selection of pile type when considering the incorporation of pile reinforcement.

Calculations to determine illustrative working loads for axially loaded piles have been undertaken; each calculation assumes a single pile acting in compression. Calculated indicative capacities are presented in the following table. Available capacities may vary for piles acting in tension.

The competency of the soil profile used for these calculations has been based on the examination of the recovered samples and the results of in situ and laboratory testing. For the purpose of calculating indicative pile capacities, a modelled ground profile comprising made ground to a depth of 5m overlying very stiff to hard clay has been adopted.

In consideration of the high volume change potential of the natural clay soils and presence of deep made ground, for the purposes of the calculation, the benefit of shaft resistance in the upper 5m has been discounted.

Potential downdrag loads caused by consolidation of the made ground have not been allowed for in the estimate of pile capacity. However if additional loading of the ground surface is proposed, such as would be induced by raising of ground levels, significant negative skin friction could occur.

Table 15. Indicative axially loaded pile working capacities

Working Loads of Piles (kN)			
Length (m)	Size (mm)		
	300	400	500
10	170	250	340
12	240	345	460
15	345	485	635

Notes:
The structural strength of the concrete used in construction may limit the available working loads of the piles. Indicated pile lengths are from existing ground level. The benefit of shaft resistance within the upper 5m has been discounted.

Working capacities for pile groups should be assessed when final design details are known, although for preliminary design purposes it is likely that piles spaced at least 3 x pile diameter from other piles in any group will behave as single piles.

Where preliminary and working pile load tests are undertaken it may be appropriate to reduce Safety Factors, although 2.5 may be a minimum local authority requirement. Should testing not be undertaken it is suggested that a factor of safety of at least 3.0 should be adopted.

For all piling options it is recommended that the advice of specialist foundation contractors be sought at the earliest opportunity. Piling specifications should be obtained from specialist contractors with reference to their particular products as this may affect the calculated capacity.

The selection of piling techniques should not only consider attainable pile capacities but also consider access constraints applicable to particular plant and potential vibration effects on existing adjacent structures.

3.2 Groundwater

Where encountered, groundwater was recorded at depths of between 0.4m and 3.0m below ground level. The potential for perched groundwater at various levels within the made ground should not be overlooked.

Excavations beneath the water table, and particularly in more coarse grained soils, may require positive groundwater control to maintain adequately dry working conditions and excavation stability. Where encountered, ingress of perched water is expected to be adequately managed by pumping from sumps.

3.3 Stability of Excavations

All excavations within deep made ground soils should be assumed to be subject to short term instability. It is expected that excavations within the fine grained Gault Formation soils will be stable in the short term.

Where excavations are required to remain stable in the made ground or in the medium or long term elsewhere they should be suitably supported or side slopes battered back to a safe angle of repose.

Where personnel access is required to any excavation its stability should be assessed by a suitably qualified and experienced responsible person. For general guidance it is recommended that personnel access to unsupported excavations greater than 1.2m depth should be prohibited.

3.4 Aggressivity to Concrete

In consideration of the soils encountered beneath the site and its historical usage it is recommended that 'brown field conditions' be assumed for the purposes of assessing the aggressivity of the chemical environment for concrete classification (ACEC class). Given the noted occurrence of groundwater, 'mobile groundwater' conditions should also be assumed.

Chemical analysis of the soil indicates a sulphate content falling into Design Sulfate Class DS-1 to DS-3 of Table C2 of the Building Research Establishment Special Digest No 1 "Concrete in aggressive ground", 2005. The results of the pH tests indicate that the underlying soils are alkaline.

In accordance with the BRE digest, a DS-3 Design Sulfate Class and an AC-3 ACEC classification should be assumed as a minimum for the design of concrete in contact with the ground at the site.

3.5 Ground Floors

In view of the variable thickness of made ground and the presence of soils of high volume change potential, it is recommended that ground floors be suspended for all sensitive structures.

It is recommended that ground bearing floor slabs should be employed only for non sensitive areas. Differential movement between the floor slab and walls and across the floor slab itself should be anticipated. It is therefore recommended that ground bearing floors should be fully debonded from walls and should be suitably reinforced top and bottom to enable spanning of soft spots. Formations should be adequately proof rolled and any excessively soft materials excavated and replaced with a suitable engineered fill.

3.6 Pavement Design

In situ Farnell cone penetrometer tests for the direct estimation of California bearing ratio indicated CBR values ranging between 2% and >10% but typically in the range 2% and 8% in the made ground and 2% to 5% in the underlying Gault Formation soils.

The former Department of the Environment, Transport and the Regions Design Manual for Roads and Bridges, Volume 7 (Pavement Design & Maintenance), Section 2, Part 2 1994 provides a useful correlation between soil type and equilibrium (long term) CBR values. This guidance suggests a design equilibrium CBR value of 2% to 3% applicable to the natural soils for the construction of thin (300mm) pavement in average construction conditions and assuming a low groundwater table.

Based upon review of the in-situ test results and the quoted guidance it is suggested that a CBR value of 2% may be adopted for preliminary pavement design.

All formations should be proof rolled and any very loose, bulky, soft, degradable or otherwise unsuitable materials thus identified should be removed and replaced with well compacted coarse grained fill. Prepared subgrades should be protected from severe adverse weather by ensuring they are graded to falls to prevent ponding, and they should be reasonably protected from trafficking during construction.

The subgrade may be assumed not to be susceptible to frost heave.

It should be noted that within the central part of the site that is underlain by deep made ground deposits, differential settlement of pavements is likely to occur in the longer term. It is recommended that surfaces and drainage services should be designed to incorporate enhanced falls.

If new roads are to be adopted the local highway authority should be consulted with reference to the acceptability of the proposed figures prior to designs being finalised and construction undertaken.

3.7 Retaining Structures

It is recommended that retaining structures should be designed using effective shear strength parameters. Suggested unfactored geotechnical parameters (most probable) for use in design are provided in the following table.

Table 16. Most Probable Values of Geotechnical Parameters

Stratum	Internal Angle of Shearing Resistance (°)	Cohesion . (kN/m^2)	Unit Weight (kN/m^3)
Made Ground	25	0	18.0
Gault Formation	23	0	19.5

It is noted that BS EN 1997 Part 1 (Geotechnical Design – General Rules) requires characteristic values to be selected as a cautious estimate of the value affecting the occurrence of the limit state. In this context characteristic values can be values lower or higher than the most probable value depending on whether unfavourable or favourable actions are being considered. The values presented in the above table will need to be adjusted in consideration of the specific analysis being undertaken for design purposes.

4. PHASE 2 CONTAMINATION ASSESSMENT

4.1 Basis of Risk Assessment

In consideration of the findings of the phase 1 contamination assessment the following commonly occurring significant contaminants have been considered for assessment: arsenic, cadmium, chromium, lead (including lead compounds), mercury, nickel, copper, zinc, selenium, boron, petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAH). The polycyclic aromatic hydrocarbons were speciated into the sixteen individual compounds specified by the United States Environmental Protection Agency (USEPA). In view of the potential for ground gases from on-site and off-site sources the standpipes were monitored for concentrations of carbon dioxide, methane, oxygen, carbon monoxide and hydrogen sulphide.

Though identified as a potential source, no suspected asbestos containing materials were identified within the soils arising from the exploratory holes. Testing for this contaminant was therefore not undertaken.

Soils

The results from the majority of the analyses can be assessed by way of careful consideration of the proposed end use as well as physical features of the soil type and wider environment as part of a quantitative 'Contaminated Land Exposure Assessment' or 'CLEA model' assessment.

Quantitative risk assessment using the CLEA model is the method preferred by the regulatory authorities in the UK to assist in determining the contamination status of soils in terms of risk to human health.

Gas

The assessment of the results of the standpipe monitoring has been undertaken in general accordance with the guidance contained within CIRIA C665 "Assessing risks posed by hazardous ground gases to buildings" (2007).

4.2 Analysis of Contamination Test Results

Results from the chemical (contamination) testing are summarised in Appendix B.

A quantitative assessment of the results of this investigation has been undertaken comparing soil contaminant concentrations on Site against Soil Screening Values generated by Ashdown Site Investigation Ltd using the CLEA Model, published by the Environment Agency. For further information on the derivation of these values see the notes in Appendix C. The chemical data used within the CLEA model is also summarised within Appendix C. The data was obtained from various sources including guidance documents published by the Environment Agency and other statutory bodies.

In view of the potential for residential development on the Site the soil screening values used in this assessment have been calculated using the default "Residential" land use as set out in Science Report SC050021/SR3, January 2009. The critical receptor for this land use is considered to be a young female child resident on Site from birth to age 6. Exposure routes that are considered include the potential for direct ingestion of the soil, the outdoor and indoor ingestion of dust and the potential inhalation of dust and vapours. As private garden areas may be proposed exposure routes for ingestion of site grown vegetables and soil attached to vegetables have also been included.

Statistical Analysis

The data set used in the assessment comprised eleven samples of the made ground soils. In general these are considered to represent a soil mass with a pH of 8 and an organic content of around 1%.

Statistical analysis of the data set has been undertaken in line with guidance set out in 'Comparing Soil Contamination Data with a Critical Concentration' report, published by the CIEH/ CL:AIRE (May 2008). The report replaces the (now withdrawn) guidance set out in CLR7.

The CIEH/CL:AIRE guidance provides a framework for assessing measured contaminant concentrations on a Site against user defined critical concentrations – or indicators of risk.

Under a planning scenario, the null hypothesis tested is whether the true population mean is greater than a "critical concentration". The critical concentration used within this assessment is the relevant screening value for the proposed end use.

The null hypothesis can be rejected if it can be shown (with a sufficient degree of confidence) that the true population mean lies below the critical concentration. The confidence level recommended within the guidance is 95% i.e. the statistical evidence must show that there is 95% likelihood that the true population mean lies below the critical concentration. In this instance the Site is considered suitable for the proposed use.

Where there is insufficient evidence to reject the null hypothesis, further risk assessment and/or remediation may be necessary.

Guidance on comparing soil contamination data with a critical concentration are provided in Appendix C. The summary sheets from the statistical analysis are also presented in Appendix C.

4.2.1 *Inorganic Contamination*

The following table summarises the calculated soil screening values along with sample means and 95th percentile upper confidence limits.

Table 17. Soil Screening Values and Upper Confidence Limits for Inorganic Contaminants

Contaminant	Soil Screening Value (mg/kg)	Sample Mean (mg/kg)	95% Upper Confidence Limit (mg/kg)	Can H_o be rejected	Evidence against H_o (%)
Arsenic	32	23.16	53.69	No	61
Cadmium	10	0.5	0.5	Yes	100
Chromium	3000	39.91	46.73	Yes	100
Lead	226	143.91	200.88	Yes	99
Mercury	170	0.51	0.55	Yes	100
Nickel	130	37.18	45.40	Yes	100
Copper	2330	228.75	1029.32	Yes	99
Zinc	3750	160.13	341.41	Yes	100
Selenium	350	0.96	1.43	Yes	100
Chromium VI	4.3	2.0	2.0	Yes	100
Boron	300	1.78	2.26	Yes	100

The statistical analysis indicates that with the exception of arsenic, the recorded levels of inorganic contaminants in the samples tested should not be considered to be significantly elevated. The null hypothesis can be rejected with 99% or 100% confidence for all of the other inorganic contaminants tested. The arsenic level of 92.0mg/kg recorded in the sample obtained from borehole WS15 at 1.6m is above the critical concentration for a residential end use (32mg/kg). The statistical analysis suggests that this result should be treated as a statistical outlier. It is possible that the elevated arsenic concentration is related to the presence of ash or clinker in the sample, however it is considered inappropriate to remove this sample from the dataset as ash and clinker have been recorded in made ground soils elsewhere within the Site. As a result the recorded levels of arsenic should be considered to be significantly elevated in the context of a residential setting and the made ground soils beneath the Site should at this stage be considered to be impacted with arsenic contamination.

Statistical analysis that has been undertaken using soil screening values calculated for a "Commercial" land use indicates that the recorded levels of all of the inorganic contaminants tested would not be considered to be significantly elevated. The null hypothesis can be rejected with 100% confidence in all cases. Therefore in the context of a commercial setting the made ground soils beneath the Site would not be considered to be significantly impacted with inorganic contamination.

4.2.2 *Organic Contamination*

4.2.2.1 *Polycyclic Aromatic Hydrocarbons (PAH)*

Polycyclic Aromatic Hydrocarbons (PAH) are a group of chemicals that contain two or more benzene rings fused together. The samples tested recorded concentrations of total PAH in the range of between <0.01mg/kg and 165.37mg/kg.

Individual PAH compounds exhibit a range of physical properties and human toxicities and therefore, where they are present, a risk assessment cannot effectively be made against the total PAH concentration.

To allow an assessment to be made, the PAH concentrations within the soil samples were speciated to give concentrations of 16 individual PAHs defined by the United States Environmental Protection Agency (USEPA).

Benzo(a)pyrene and Naphthalene

Benzo(a)pyrene is recognised as a significant carcinogen and is normally considered to be the primary driver for remediation where PAH contamination is identified. It is typically a product of partly combusted fuel (soot/ exhaust residue) and it is also common in tarmacadam road pavement, coal tar, coal ash and clinker. Where it is not associated with fuel spills and, where found associated with ashy soils or tarmacadam, for example, it may not be especially volatile. As such whilst PAH in soil can be hazardous by inhalation, this is usually as dust and particles in smoke, rather than as vapours. It tends to bind readily to soils and therefore will not easily leach to groundwater, thus minimising the risk of its migration through the ground.

Naphthalene is most commonly associated with the distillation of coal tar and as such is often associated with the presence of clinker and tarmacadam road pavement. Naphthalene is the lightest PAH and consequently has a higher volatility than others. It is less tightly bound to soils than benzo(a)pyrene and therefore exhibits greater mobility.

The following table summarises the calculated soil screening values along with sample means and 95th percentile upper confidence limits.

Table 18. Soil Screening Values and Upper Confidence Limits for naphthalene and benzo(a)pyrene

Contaminant	Soil Screening Value (mg/kg)	Sample Mean (mg/kg)	95% Upper Confidence Limit (mg/kg)	Can H_o be rejected	Evidence against H_o (%)
Naphthalene*	0.6	0.43	1.33	No	38
Benzo(a)pyrene*	0.8	4.69	7.49	No	2

* Based on a SOM concentration of 1%

The statistical analysis indicates that the recorded levels of naphthalene and benzo(a)pyrene should be considered to be significantly elevated in the context of a residential setting. The levels of naphthalene recorded in the samples taken from boreholes WS10 at 1.0m (1.71mg/kg) and WS13 at 1.1m (1.87mg/kg) are above the critical concentration for a residential end use (0.6mg/kg). The levels of benzo(a)pyrene recorded in the samples taken from boreholes WS10 at 1.0m (5.67mg/kg), WS12 at 0.5m (2.36mg/kg), WS13 at 1.1m (14.20mg/kg), WS14 at 0.75m (3.31mg/kg), WS6 at 1.0m (8.75mg/kg), WS15 at 0.5m (3.89mg/kg) and WS15 at 1.6m (12.70mg/kg) are above the critical concentration for a residential end use (0.8mg/kg). It is likely that the recorded levels of both contaminants are as a result of the presence of clinker within the made ground soils. As a result of the generally elevated levels of both contaminants that have been recorded within samples taken from boreholes across the Site these results are not considered to be statistical outliers. Consequently the recorded levels of naphthalene and benzo(a)pyrene should be considered to be significantly elevated in the context of a residential setting and at this stage the made ground soils beneath the Site should be considered to be impacted with naphthalene and benzo(a)pyrene contamination.

Statistical analysis that has been undertaken using soil screening values calculated for a "Commercial" land use indicates that the recorded levels of both contaminants should not be considered to be significantly elevated. The null hypothesis can be rejected with 100% confidence in both cases. Therefore in the context of a commercial setting the made ground soils beneath the Site would not be considered to be impacted with PAH contamination.

4.2.2.2 *Petroleum Hydrocarbons and BTEX compounds*

Petroleum hydrocarbons encompass a large number of individual chemical compounds found within substances such as petrol, diesel, lubricating oil, waxes and tar based substances. Consequently they are associated with a wide range of land uses and encountered on a large number of sites investigated, from fuel filling stations and car maintenance garages to more innocuous land uses such as domestic garages and car parking areas.

Petroleum hydrocarbons can be split into aromatic (containing benzene rings) and aliphatic fractions. Once split into aromatic and aliphatic fractions it is necessary for assessment purposes to further speciate into fractions according to the equivalent carbon number and similarities in fate and transport properties.

It is considered best practice (where petroleum hydrocarbons have been identified and require further assessment), to carry out the aromatic/aliphatic split and grouping as outlined in the Environment Agency Report "The UK approach to evaluating human health risks from petroleum hydrocarbons in soils" (Environment Agency, 2005). It is also considered necessary to test for the individual petroleum hydrocarbons Benzene, Toluene, Ethyl benzene and Xylenes (collectively known as BTEX compounds). This is due to the higher toxicity of these compounds, and in particular the carcinogenic nature of benzene.

Six samples were tested for the concentration of petroleum hydrocarbons. The results of four samples were speciated according to equivalent basic carbon weight fraction. Two additional samples were further speciated into aromatic and aliphatic splits and BTEX compounds. This approach to testing was undertaken because the toxicity of the various chemical compounds of petroleum hydrocarbons varies significantly.

Soil screening values for equivalent carbon fractions of petroleum hydrocarbons have been calculated as a joint project between LQM and CIEH and published in 'The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment' 2nd Edition, 2009." The screening values have been developed for the standard "Residential" land use as set out in Science Report SC050021/SR3, January 2009.

The following table lists the screening values for equivalent carbon weight fractions calculated for 1% organic content.

Table 19. Soil Screening Values for petroleum hydrocarbons calculated by LQM/CIEH.

Petroleum Hydrocarbon Fraction	Screening Value (mg/kg)
Aliphatic EC 5-6	30
Aliphatic EC >6-8	73
Aliphatic EC >8-10	19
Aliphatic EC >10-12	93
Aliphatic EC >12-16	740
Aliphatic EC >16-35	45000
Aliphatic EC >35-44	45000
Aromatic EC 5-7	65
Aromatic EC >7-8	120
Aromatic EC >8-10	27
Aromatic EC >10-12	69
Aromatic EC >12-16	140
Aromatic EC >16-21	250
Aromatic EC >21-35	890

The test results determined on two of the samples (from boreholes WS12 and WS14 in which hydrocarbon staining and odours were recorded) were split into aromatic and aliphatic fractions and speciated according to equivalent carbon number. The two samples were also tested for the presence of BTEX compounds. Neither of the samples recorded significantly elevated levels of petroleum hydrocarbons. Neither of the samples recorded BTEX compounds above the limit of detection of the test.

Three of the four samples in which the results were speciated according to basic carbon weight fraction (which were taken from boreholes WS5, WS11 and WS13 in which hydrocarbon staining and/or odour was recorded) did not record significantly elevated levels of petroleum hydrocarbons. The level of heavy range fuels (in carbon band C_{21}-C_{35}) of 1765mg/kg recorded in the fourth sample, which

was taken from borehole WS10 at 1.0m, is above the relevant soil screening value for residential use (890mg/kg) assuming the compounds are fully aromatic. A slight hydrocarbon odour and heavy hydrocarbon staining were recorded at the depth from which the sample was taken. The made ground soils in the vicinity of borehole WS10 should be considered to be significantly impacted with petroleum hydrocarbons in the context of a residential end use.

The level of heavy range fuels (1765mg/kg) recorded in borehole WS10 at 1.0m is significantly below the relevant soil screening value for a commercial end use (28000mg/kg). The soils that have been tested are therefore not significantly impacted with petroleum hydrocarbons in the context of a commercial development.

4.2.3 *Ground Gas Risk Assessment*

Monitoring of the gas concentrations within the standpipes in the nine boreholes was carried out on three occasions. Peak levels of carbon dioxide of up to 17.6% and peak methane concentrations of up to 15.7% were recorded. No detectable gas flow was recorded from any of the boreholes.

The gas risk assessment for the Site has been carried out generally in accordance with the guidance presented in CIRIA document C665 (2007).

The assessment is based upon the calculation of a site specific Gas Screening Value (GSV), calculated by multiplying the total concentration (percentage) of the gas recorded, by the gas flow rate (l/hr) measured within the borehole. In the absence of any detectable flow rates the GSV have been calculated assuming that a flow rate equal the limit of detection of the instrument (0.1l/hr) is present.

The following GSV values based on the readings taken to date were determined:

Carbon Dioxide GSV = 0.176 x 0.1 = 0.0176
Methane GSV = 0.157 x 0.1 = 0.0157

For standard low rise housing, the NHBC have developed a characterisation system which compares the calculated GSV or typical maximum values to generic "traffic light" scenarios. These are summarised in table 8.7 of the CIRIA document.

On the basis of the calculated Gas Screening Values for both methane and carbon dioxide the Site would be classified as "Green". However, as the maximum level of carbon dioxide recorded is seventeen times the typical maximum value for a green characterisation and the maximum level of methane is fifteen times the typical maximum value for a green characterisation it is considered that the Site should be classified as "Amber 1". For an "Amber 1" classification gas protection measures comprising ventilated sub-floor voids and installation of a gas resistant membrane within the floor slab will be required within all buildings at the Site.

For developments other than standard low rise housing an alternative characterisation system is applied. Table 8.5 of the CIRIA document shows the

Characteristic Situation associated with the various GSVs. The calculated GSVs put the Site into Characteristic Situation 1. However, as the maximum recorded methane and carbon dioxide concentrations are higher than the typical concentrations quoted in the table for Characteristic Situation 1, it is considered that the Site should be classified as Characteristic Situation 2. Table 8.6 of the CIRIA document details the protection measures required for each Characteristic Situations. For Characteristic Situation 2, the development will require sub floor ventilation and the provision of a gas resistant membrane within the floor slab in order to prevent the ingress of ground gases.

4.3 Quantitative Contamination Risk Assessment

The quantitative risk assessment takes into account the findings of the intrusive works and laboratory testing along with on site observations in order to identify potentially significant risks. A significant risk is only deemed to exist where a significant pollutant linkage has been identified i.e. where a significant source is linked to the receptor via a significant pollutant pathway.

The level of risk is determined using the following risk matrix:

		Likelihood of significant impact			
Severity of potential impact		Unlikely	Low Likelihood	Moderate Likelihood	High likelihood
	Very Minor	Negligible	Very Low	Low	Low/Moderate
	Minor	Very Low	Low	Low/Moderate	Moderate
	Moderate	Low	Low/Moderate	Moderate	High
	Severe	Low/Moderate	Moderate	High	Very High

The risk assessment is based on the Site being developed for housing. It is assumed that any housing development on the Site will include areas of private garden. Should the proposed end use be altered, a revised risk assessment may be required.

4.3.1 Quantitative Contamination Risk Assessment for Human Health

The following sources of contamination that may pose a risk to end users have been identified by the investigation at the Site:

1) Elevated concentrations of arsenic within the underlying soils.

   The level of arsenic that has been recorded within the sample taken from borehole WS15 in the southern area of the Site is above the critical concentration for a residential end use. It is considered that the elevated levels are as a result of the presence of the fill materials at this location. As the made ground soils at this location are similar to those encountered elsewhere within the Site the made

ground soils should be considered to be impacted with arsenic contamination. It is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human health from the arsenic contamination is Moderate.

2) Elevated concentrations of naphthalene within the underlying soils.

The levels of naphthalene that have been recorded within boreholes WS10 and WS13 in the centre of the Site are above the critical concentration for a residential end use. It is considered that the elevated levels are as a result of the fill materials at these locations. The made ground soils beneath the Site should be considered to be impacted with naphthalene contamination. It is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human health from the naphthalene contamination is Moderate.

3) Elevated concentrations of benzo(a)pyrene within the underlying soils.

Elevated levels of benzo(a)pyrene have been recorded within a number of boreholes across the central and southern parts of the Site. It is considered that the elevated levels are as a result of the fill materials at these locations. The made ground soils beneath the Site should be considered to be impacted with benzo(a)pyrene contamination. It is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human health from the benzo(a)pyrene contamination is Moderate.

4) Elevated concentrations of petroleum hydrocarbons within made ground soils in the vicinity of borehole WS10.

The level of heavy range fuels that has been recorded within the sample taken from borehole WS10 in the central area of the Site is above the critical concentration for a residential end use. It is considered that the elevated levels are as a result of the presence of the fill materials at this location. The made ground soils in the vicinity of borehole WS10 should be considered to be impacted with petroleum hydrocarbon contamination. It is considered that the likelihood of a significant effect is moderate. The severity of the potential effect is moderate. The overall assessment of the risk to human

health from the petroleum hydrocarbon contamination is Moderate.

5) Elevated concentrations of methane and carbon dioxide.

   The risk posed by the recorded elevated levels of methane and carbon dioxide will be manifest within structures founded directly within the ground. The likelihood of any significant effect within unprotected structures is considered to be moderate and the severity of the potential effect also to be moderate. An overall Moderate risk is considered to be presented to human health by the levels of gases recorded.

A quantitative human health risk assessment conceptual model is presented in the following table. The model has been constructed based on the development of the Site for residential use, incorporating private gardens.

A diagrammatic representation of the quantitative contamination risk assessment conceptual model is presented as Figure 4.

Table 20. Quantitative Human Health Conceptual Model - Pollutant Linkages and Assessment of Risk

Contaminant Source	Potential Pathway(s)	Likelihood	Severity	Initial Assessment of Risk to Human Health
Elevated concentrations of arsenic within the underlying soils.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown vegetables and soil attached to homegrown vegetables, Inhalation of indoor and outdoor soil dust.	Moderate	Moderate	Moderate
Elevated concentrations of naphthalene within the underlying soils.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown vegetables and soil attached to homegrown vegetables, Inhalation of indoor and outdoor soil dust.	Moderate	Moderate	Moderate
Elevated concentrations of benzo(a)pyrene within the underlying soils.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown vegetables and soil attached to homegrown vegetables, Inhalation of indoor and outdoor soil dust.	Moderate	Moderate	Moderate
Elevated concentrations of petroleum hydrocarbons within made ground soils in the vicinity of borehole WS10.	Dermal contact with soil (Indoor & Outdoor), Direct soil and dust ingestion, Consumption of homegrown vegetables and soil attached to homegrown vegetables, Inhalation of indoor and outdoor soil dust, Inhalation of soil vapours.	Moderate	Moderate	Moderate
Concentrations of methane and carbon dioxide.	Inhalation of ground gases.	Moderate	Moderate	Moderate

4.3.2 *Quantitative Contamination Risk Assessment for Controlled Water*

The following on site sources that have the potential to pose a significant risk to controlled waters have been recorded by the investigation undertaken at the Site:

1) Elevated concentrations of arsenic within the underlying soils.
2) Elevated concentrations of naphthalene within the underlying soils.
3) Elevated concentrations of benzo(a)pyrene within the underlying soils.
4) Elevated concentrations of petroleum hydrocarbons within made ground soils in the vicinity of borehole WS10.

The Gault Formation underlying the Site is classified as Unproductive Strata. Due to the impermeable nature of the clay underlying the Site it is considered that the potential for significant migration of contaminants into controlled waters in the vicinity of the Site is very limited. It is therefore considered that no significant risk to controlled waters is present from the contamination that has been identified.

A quantitative controlled water risk assessment conceptual model is presented in the following table. A diagrammatic representation of the quantitative contamination risk assessment conceptual model is presented as Figure 4.

Table 21. Quantitative Controlled Water Conceptual Model - Pollutant Linkages and Assessment of Risk

Contaminant Source	Potential Pathway(s)	Likelihood	Severity	Initial Assessment of Risk to Human Health
Elevated concentrations of arsenic within the underlying soils.	No significant pathway	Not applicable	Not applicable	No significant risk
Elevated concentrations of naphthalene within the underlying soils.				
Elevated concentrations of benzo(a)pyrene within the underlying soils.				
Elevated concentrations of petroleum hydrocarbons within made ground soils in the vicinity of borehole WS10.				

4.4 Risks to Other Potential Receptors

The following general guidance is given with regards to other potential on site receptors, which may not necessarily be statutory drivers for remedial works.

4.4.1 *Construction Workers*

The presence of contamination within the fill materials has the potential to pose a direct risk to construction workers. An assessment of the risks should be undertaken before commencing works and appropriate training undertaken and appropriate Personal Protective Equipment should be issued and used where necessary.

As a minimum and in accordance with industry best practise all ground-workers should be issued with the appropriate PPE and should be instructed in safe working methods. As a precaution instructions should also be given in the recognition of potentially hazardous materials, including oily and odorous soil and water and discoloured or fibrous substances. Any oil-like substances contacting the skin must be washed off immediately using an appropriate cleanser. Operatives should be warned to avoid contact between hands and mouth before washing. The consumption of food and smoking must be confined to designated clean areas. Suitable welfare (washing) facilities should be provided. In view of the elevated levels of gas identified to date, personnel entry into confined spaces should be carefully managed to ensure that confined spaces are appropriately monitored and ventilated and that appropriate respiratory equipment is employed.

4.4.2 *Services*

The risk of damage to services from the arsenic, naphthalene, benzo(a)pyrene and petroleum hydrocarbon contamination identified is considered to be low/moderate. It is considered that the service provider's requirements represent the most informed decision when it comes to the protection of their services. It is recommended that the developer should contact all service providers with regard to specific precautions they may require.

4.4.3 *Planting*

Maximum concentrations of the phytotoxic elements copper, zinc and boron of 1513mg/kg, 385mg/kg and 3.2mg/kg, respectively, were recorded within the samples tested. A horticulturist should be consulted with regard to any specific planting schemes.

4.5 Recommendations

Whilst the works undertaken to date would suggest that the near surface soils are not significantly impacted by contamination, given the size of the site and its history, it is recommended that further sampling, testing and analysis should be undertaken in critical areas once the development proposals are known. Given the presence of the landfill on site and the levels of gases recorded to date, further monitoring of standpipes is also recommended.

Ultimately various options for remediation of the Site will need to be considered. The remediation works which are eventually adopted will need to be detailed within a separate remediation strategy, along with a verification plan. This should be produced once this risk assessment report and the findings of supplementary works discussed above have been reviewed and approved by the local authority.

4.6 Handling and Disposal of Waste and Quality of Imported Materials

4.6.1 Waste Management

Soils and other materials taken for disposal should be handled, transferred and disposed of as controlled waste in accordance with the requirements of the Waste Management, Duty of Care Regulations. Copies of waste transfer notes detailing the site address, the waste type, details of the haulage contractor and full details of the disposal site must be kept.

The Site Waste Management Plans Regulations, 2008, require a site waste management plan to be prepared and implemented by clients and principal contractors for all construction projects with an estimated cost greater than £300,000 excluding VAT. The plans must record details of the construction project, estimates of the types and quantities of waste that will be produced, and confirmation of the actual waste types generated and how they have been managed. More detailed reporting requirements apply to projects exceeding £500,000.

4.6.2 Quality of Imported Soils

Full details of the source of any imported soils should be documented (including topsoil). Any material from a potentially contaminated (e.g. industrial) site should be rejected. It is recommended that chemical (contamination) testing results are obtained and supplied for comment prior to accepting the soils on Site. As a minimum the contaminants tested for should include arsenic, cadmium, chromium, lead, mercury, nickel, selenium and the polycyclic aromatic hydrocarbon benzo(a)pyrene. The material should be free from petroleum hydrocarbons, and contain no significant quantity of putrescible material (incl. wood or paper). Materials must comply with current CLEA guidance for the proposed end use of the Site.

It is stressed that the quality of any materials imported onto the Site is critical to the successful completion of any remediation works.

5. CONCLUSIONS

The following conclusions present a summary of the main findings of the investigation. However, no reliance should be placed on any point of the conclusions until the whole of the report has been read as other sections of the report may put into context the information contained herein.

5.1 Geotechnical Assessment

- The ground investigation confirmed the underlying soils to comprise a significant thickness of made ground, overlying Gault Formation deposits.
- Where encountered, groundwater was recorded at depths of between 0.4m and 3.0m below ground level. The potential for perched groundwater at various levels within the made ground should not be overlooked.
- Precautions against shrinkage and heave for any foundation system (spread footings, piles, pile caps and ground beams) constructed within the fine grained Gault Formation soils should assume a high volume change potential and take into account current guidance such as that given by the National House Builders Council (NHBC).
- A net allowable bearing capacity of 150kN/m^2 may be assumed for the construction of spread (pad or strip) foundations up to 1.0m across bearing within the minimum firm clay soils of the Gault Formation.
- In consideration of the depth of made ground across the central and southern part of the site, and due to the precautions that are likely to be required to protect spread footings from the effects of soil volume changes, it is suggested that a piled foundation would offer a more viable foundation solution. Indicative pile capacities are included in the body of the report.
- Excavations beneath the water table, and particularly in more coarse grained soils, may require positive groundwater control to maintain adequately dry working conditions and excavation stability. Where encountered, ingress of perched water should be adequately managed by pumping from sumps.
- All excavations within deep made ground soils should be assumed to be subject to short term instability. Where excavations are required to remain stable in the made ground or in the medium or long term elsewhere they should be suitably supported or side slopes battered back to a safe angle of repose.
- A DS-3 Design Sulfate Class and an AC-3 ACEC classification should be assumed as a minimum for the design of concrete in contact with the ground.
- In view of the variable thickness of made ground and the presence of soils of high volume change potential, it is recommended that ground floors be suspended for all sensitive structures.

- An equilibrium CBR of 2% may be assumed for the design of pavement bearing on the subgrade soils. The subgrade is not likely to be susceptible to frost heave. Differential settlement of pavements constructed over areas of deep made ground is likely to occur in the longer term. It is recommended that surfaces and drainage services should be designed to incorporate enhanced falls.

- Retaining structures should be designed using effective shear strength parameters.

5.2 Contamination Status Assessment

- The Site is currently unoccupied with no structures present. Ground cover consists of a mixture of rough grass and dense brambles with occasional semi-mature trees located across the Site. Broken ground is also present, with concrete, brick and rubble located across the Site.

- The Site does not lie within an Environment Agency Source Protection Zone with regard to the protection of the quality of groundwater that is abstracted for potable supply.

- The Site was largely covered by mature trees at the time of the earliest inspected historical map which dates from 1872. A small brickworks was present within the eastern extremity of the Site. Between this time and the mid-1970s land on Site and in the vicinity of the Site was used for expanding brick works operations and associated excavations and infrastructure. By the mid 1970s the excavations within and in the vicinity of the Site appear to have been backfilled. The site has remained otherwise undeveloped until the present day.

- The testing undertaken has identified the following contaminants at levels in excess of critical concentrations for a residential end use – arsenic, naphthalene, benzo(a)pyrene and petroleum hydrocarbons.

- The levels of contaminants identified are below critical concentrations for a commercial end use.

- The works undertaken to date would suggest that the near surface soils are not significantly impacted by contamination. However given the size of the site and its history, it is recommended that further sampling, testing and analysis should be undertaken in critical areas once the development proposals are known. Due to the presence of the landfill on site and the levels of gases recorded to date, further monitoring of standpipes is also recommended.

- Quantitative conceptual models have been prepared of the complete pollutant linkages that have been identified in relation to human health and controlled waters. These are presented in Tables 20 and 21. A diagrammatic conceptual model is presented as Figure 4.

- It is advised that the local authority has ultimate jurisdiction over contamination assessment, and, as such, they must be involved in discussions relating to the scope of the investigation works undertaken and the conclusions drawn, along with any specific proposals for remedial action.

Ashdown Site Investigation Limited
October 2010