Proposed Development

Midland Road, Royston

Phase II Geo-Environmental Assessment

For

Persimmon Homes Ltd

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EXECUTIVE SUMMARY

Site Description	The site occupies an area of some 3.65 hectares comprising former grassed playing fields. Levels fall steadily from about 75 metres AOD in the southwest to about 67 metres AOD in the northeast, with the northern corner falling to about 65 metres AOD.
Site History	The site remained as open fields until 1962 when it became playing fields belonging to Royston High School. Since 2011, the site has been undeveloped. A clay pit may have been present adjacent to the northeastern boundary.
Published Geology and Mining	British Geological Survey information indicates the majority of the site as underlain by glacial till (boulder clay) over Royston or Mexborough Rock sandstone of the Middle Coal Measures. The Royston coal is conjectured as outcropping to the south, potentially present at shallow depth beneath the site.
Environmental Setting	• An historic landfill is shown within the eastern part, however, previous intrusive investigations have identified ash based infill within the northeast and no putrescible content • A stream is present some 350 metres south • The solid geology is classified as a Secondary A aquifer • No groundwater abstractions within 500 metres and the site does not lie within a source protection zone • Basic radon gas protection measures are required
Ground Conditions	*GL – 0.3m* Topsoil *0.3 – 1.0m* Made Ground: 'Loose' ash, cinder, brick and burnt shale - ***Northeastern part only*** *0.3 – 1.7m* Stiff fissured clay with weathered coal seams (<300mm thick) *1.7 – 30.0m* Very weak to weak mudstone, moderately weak siltstone and moderately strong to strong sandstone
Groundwater	Perched groundwater ingresses were encountered between 1.2 and 1.4 metres with deeper strikes between 12.0 and 27.0 metres
Contamination and ground gas	Made ground comprising ash based materials are present in the northeastern part of the site. Laboratory testing has identified elevated concentrations of arsenic and copper, and to a lesser extent, lead and benzo(a)pyrene within these materials. In addition, reworked topsoil overlying the ash based made ground has been shown to contain elevated levels of arsenic and zinc. Both these materials are considered as potentially presenting a significant of risk to site end users. No putrescible materials have been identified within the former landfill. The landfill is considered as presenting a low risk with respect to ground gas generation, a view supported by the local authority, with no ground gas assessment considered necessary, and hence, no ground gas protection measures considered necessary.
Appraisal	**Remediation** – The use of a 600mm thick cover of clean capping, subject to local authority approval, will be necessary within gardens where ash based soils are to remain. Likewise, the provision of a minimum of 300mm thick clean capping within landscaped areas will be necessary. Excepting the reworked topsoil in the area of the former landfill in the northeastern part, the remaining topsoil is considered suitable for re-use as part of the development. Reworked topsoil, if re-used, should be subject to a minimum of 300mm clean capping. **Foundations** – Traditional pad and strip foundations at about a metre bearing upon the natural stiff clays are considered suitable with an allowable bearing capacity of 150 kN/m^2 considered appropriate. In areas of made ground, foundations will be required to extend into the underlying stiff clays proved at

	about 1.5 metres below existing ground levels by the use of trench fill techniques. Where coal seams are exposed, these should be excavated and blinded with concrete with foundations bearing upon stiff clay or rock as appropriate. Where trees or hedges are within influencing distance, foundations should be deepened in accordance to current guidelines assuming a medium volume change potential for the natural clays and a low volume change potential for the mudstones. **Floor slabs** – Suspended floor slabs should be used in the area of the former landfill in the northeast or where plots are considered to be affected by the influence of trees, elsewhere, ground bearing slabs are recommended. Similarly where the made ground thickness exceeds 600mm a suspended floor should be used. **Gas protection measures** – No protection measures in respect of landfill gas are required, however, basic radon protection is necessary. **Service Supply Pipes** – with respect to natural soils, no special precautions are considered necessary, however, the advice of the water authority should be sought with respect to placement within the ash based made ground. **Off Site Disposal of Materials** - A preliminary assessment suggests that the natural soils can be regarded as inert with the ash based made ground classified as stable non-reactive hazardous waste. **Excavations and Dewatering** – If man entry is proposed into excavations the use of full support to excavation sides is recommended. The use of hydraulic breakers should be anticipated where sandstone is present or deeper excavations are proposed. No significant ingress of groundwater is anticipated, however, in the long term or in deeper excavations any ingress should be controlled adequately by pumping from sumps within the excavations. **External Works Design** - It is recommended that a CBR value of 3% be used where natural clay and ash based soils are present at formation level. **Sulphate Attack on Buried Concrete** – Within ash based soils, buried concrete should be designed to BRE Special Digest 1:2005 Design Sulphate Class DS-2 with an ACEC site classification AC-3z, elsewhere, DS-1 with an ACEC site classification AC-1 is appropriate. **Surface Water Drainage** – Field testing in the locality indicates surface water disposal by way of soakaways as unsuitable.

1 INTRODUCTION

1.1 3e Consulting Engineers Limited (3e) was commissioned by persimmon Homes Ltd to carry out a Phase II geo-environmental assessment for a residential development on part of the site of the former Royston High School, Barnsley. The development is to comprise 143 housing plots with associated car parking, access roads and areas of soft landscaping. This report highlights ground related environmental and geotechnical considerations in relation to the proposed development, as indicated on the latest proposals included as **Appendix A**.

1.2 The objectives of this assessment were:

- To determine the potential risks posed by contamination arising from historical or current activities on or in the vicinity of the site
- To assess the potential for shallow coal mining related risks
- To determine the geotechnical parameters of the sub soils to assist with the design of foundations and pavements.

1.3 To this end the study has included:

- Review of Eastwood and Partners (E&P) report, referenced 'Phase 1 Geotechnical and Geo-Environmental Desktop Report, Royston High School, Barnsley, Ref. 33461 Issue 3, January 2011'
- Review of 3e report, 'Midland Road, Royston – Preliminary Site Investigation, Ref. LTR/12040/1CL/1/JR, June 2012'
- An intrusive investigation comprising the excavation of trial pits, sinking of rotary percussive boreholes and laboratory testing.

1.4 This report presents the factual information available during this appraisal, interpretation of the data obtained and recommendations relevant to the proposed development as outlined above. The comments and opinions presented in this report are based on the findings of E&P desk study information and ground investigation carried out by 3e Consulting Engineers Limited.

1.5 This report has been prepared for the sole use of Persimmon Homes Ltd and their professional advisors. If any unauthorised third party comes into possession of this report, they

rely upon it entirely at their own risk and 3e Consulting Engineers Limited does not owe them any Duty of Care or Skill.

2 THE SITE

Location and description

2.1 The site, centred on National Grid Reference 436290 411840, is located northeast of Royston town centre and immediately southeast of Common Lane. The site is bound by Common Lane and housing to the northwest, allotments and housing to the northeast, a supermarket and undeveloped land to the southeast and housing and undeveloped land to the southwest.

2.2 The site is irregular, occupying an area of approximately 3.65 hectares and comprises former grassed playing fields. A fenced footpath, Warren Walk, passes through the site in a southwest to northeast direction. Levels fall steadily from about 75 metres AOD in the southwest to about 67 metres AOD in the northeast, with the northern corner falling to about 65 metres AOD. A topographical survey of the site is included on **Figure 1**.

3 SITE HISTORY AND GEO-ENVIRONMENTAL SETTING

History

3.1 The E&P desk study contains a comprehensive review of the site's history and this is summarised below. The desk study was undertaken for a larger site, of which the subject site forms part of.

On site

Map dates	On-site features
1854 – 1962	Open fields
1962 – 2011	Playing fields as part of Royston High School
2011 – present	Undeveloped

Off site

Dates	Features (generally within 250m)	Distance	Direction
1918 – 1975	Probable clay pit	Adjacent	Northeast
1893 – 1918	Sandstone quarry	230m	South
1906	Tank	100m	Southwest
1906	Tank	100m	Southeast

Geo-environmental setting

3.2 This section is based principally upon a search of information available on public registers and obtained through an Envirocheck search undertaken as part of the E&P desk study, together with other sources as indicated. The salient points are summarised below.

- Majority of the site is underlain by glacial drift (boulder clay) covering Royston or Mexborough Rock sandstone of the Middle Coal Measures
- The Royston coal seam is conjectured to outcrop south of the site dipping northwards and underlies the site
- A Coal Authority mining report (ref. 00000861-11) identifies the extreme northern part as being the subject of a subsidence claim in 1980, discharged by repair. This relates to deep mining beneath the site at that time. In addition, a recent mining report (ref.

71000350150001) identifies an adjacent property to the northwest as being the subject of a subsidence claim, again, this is in relation to past deep coal mining.

- The solid geology is classified as a Secondary A aquifer
- A stream is present some 350 metres south
- Site does not lie within a source protection zone and no abstractions within 500 metres
- The eastern part of the site and is recorded as a former local authority registered landfill, however, this is discussed more fully below
- Basic radon protection is required for new development

Historic landfills

3.3 Preliminary intrusive investigations at the site recorded deposits of ash and cinder within the northeastern part. In addition, intrusive works within the eastern part, did not record the presence of any made ground, despite being located within the area defined as an historic landfill. A concurrent intrusive investigation recently undertaken on the adjacent site to the southwest on behalf of Kier Developments did not identify the presence of a landfill, even though within an area highlighted as being an historic landfill. These findings confirm the absence of a landfill with the designation likely to relate to enabling works associated with development of the former playing fields. Subsequent communication with Barnsley Council's contaminated land team, **Appendix B**, confirmed the potential risk of landfill gas generation as low with no gas monitoring required. The proposed intrusive works will further determine the extent of the filled ground within the confines of the subject site.

Previous intrusive investigation

3.4 The earlier preliminary investigation proved made ground of ash and cinder to a maximum depth of 1.4 metres in the northeastern part of the site. Elsewhere, beneath a cover of topsoil, and beneath the made ground, natural stiff clays were proved with weak mudstone, moderately weak siltstone and moderately strong sandstones present at between 1.5 and 2.5 metres. Generally, excavations remained dry, however, free groundwater was noted at 1.2 metres at the base of the ash based made ground in the northeast.

3.5 Chemical testing of the ash based made ground recorded elevated concentrations of arsenic above residential assessment criteria. A single sample of topsoil recorded an elevated concentration of arsenic in excess of the assessment criteria.

4 PRELIMINARY SITE CONCEPTUAL MODEL

4.1 The E&P desk study contained a conceptual site model (CSM) for the site with a preliminary risk assessment undertaken for potential receptors. This summarised the understanding of the existing site and its historical development, the site geology, the potential contaminant sources, transport pathways and receptors in order to assess potential pollutant linkages.

4.2 It is proposed to re-develop the site with housing, car parking, access roads and areas of soft landscaping. A summary of the potential contamination sources, pathways and receptors, as highlighted within the E&P desk study, is included below.

Sources of contamination

On site

- Contamination associated with potential imported made ground – metals, non-volatile and volatile hydrocarbons
- Contamination associated with former landfill shown as occupying part of the site – no risk as no putrescible materials present

Off site

- Former landfill located to the southwest – no risk of ground gas as no putrescible materials confirmed as present
- Former tanks located to the west and east – volatile hydrocarbons

Potential pollution pathways

- Humans – direct contact, soil and dust ingestion dust and vapour inhalation
- Lateral migration into nearby surface watercourses, although none nearby
- Vertical migration into underlying aquifer
- Vertical and lateral migration of ground gas into buildings and service runs, unlikely as no putrescible materials identified in former landfill
- Potable water supply pipes
- Aggressive ground conditions - buried concrete

Receptors

- Construction workers
- Site end users
- Nearby watercourses
- Underlying aquifer

Pollutant linkage assessment

4.3 A qualitative risk assessment of the likelihood of any pollutant linkage being present and its potential significance is summarised in the table below:

Pollution linkage assessment

Contamination source	Pathway	Potential receptors	Linkage and assessment
Contaminants associated with potential made ground – metals and non-volatile hydrocarbons	Direct contact, ingestion, dust ingestion and inhalation	Humans: Site workers	Yes, can be removed by the use of appropriate PPE and limited exposure. However, no significant contaminants anticipated.
	Direct contact, ingestion, dust ingestion and inhalation	Humans: End users	Yes, however, pathways are broken in areas of proposed hardcover, further risk assessment or use of capping.
Contaminants associated with potential made ground – metals and volatile hydrocarbons	Direct contact, ingestion, dust and vapour inhalation	Humans: Site workers	Yes, can be removed by the use of appropriate PPE and limited exposure. However, no significant contaminants anticipated.
	Direct contact, ingestion, dust and vapour inhalation	Humans: End users	Yes, however, localised remediation or use of hydrocarbon barrier. However, no significant contaminants anticipated.
Contaminants associated with potential made ground – metals and non-volatile hydrocarbons	Lateral migration	Nearby watercourse	Potentially yes, however, presence of extensive cohesive soils will reduce infiltration of water and therefore reduce the potential for leaching. Also, no nearby significant watercourses.
	Vertical migration	Underlying aquifer	Potentially yes, however, presence of extensive cohesive soils and argillaceous solid strata will retard any potential downward migration of water into aquifer.
	Direct contact of potable water supply pipes	Humans: End users	Potentially yes.
	Direct contact	Buried concrete	Potentially yes.

Ground gas risk assessment

4.4 Taking cognisance of the desk study findings, the following summarises the gas risk for the site:

Potential gas source	Hazard	Risk rating	Justification
Made ground (CH_4, CO_2)	Humans: health risk Buildings: explosion	Low	Limited made ground and no putrescible material is likely to be present on the site.
On site and nearby landfills (CH_4, CO_2)	Humans: health risk Buildings: explosion	Low	Investigation of landfill on site and adjacent off site landfill has not identified the presence of putrescible materials.
Radon	Humans: health risk	Medium	Basic precautions required.
OVERALL RISK		**Low to medium**	

5 RATIONALE FOR INTRUSIVE INVESTIGATION

5.1 The ground investigation has been designed by 3e and the principal environmental and geotechnical concerns with regard to the proposed redevelopment of the site are summarised as follows.

- Assessment of the type, nature and thicknesses of shallow soils by trial pitting to allow the recovery of samples and chemical laboratory testing
- Sampling of the ash based made ground in the former landfill and chemical testing for determination of risk to human health
- Assessment of the type, nature and thicknesses of shallow soils by trial pitting to allow the recovery of samples and laboratory testing for foundation and pavement design
- Rotary open hole percussive drilling to determine the presence of the Royston coal seam, nature and extent of any of past workings and assessment of the thickness of competent rock cover
- Assessment of the requirement for remedial ground consolidation by drill and grout.

6 METHOD OF INVESTIGATION

Fieldwork

6.1 An intrusive site investigation has been carried out taking cognisance of the findings of the desk study. The work comprised the excavation of trial pits and sinking of rotary percussive open boreholes at locations as shown on **Figure 1**. The positions of the exploratory holes reflect the proposed development footprints and also provide a general coverage of the site.

6.2 Site works were carried out between 4 and 11 April 2013 and comprised the following:

- Twenty four mechanically excavated trial pits (TP301 to TP224) to depths of between 1.4 and 3.1 metres
- Four rotary percussive boreholes (P1 to P4) to depths of between 24 and 30 metres.

6.3 During the excavation of the trial pits the strata were logged, groundwater seepages noted, samples recovered for laboratory testing and in situ testing undertaken where appropriate.

6.4 The rotary percussive boreholes were logged during their advancement with flushings noted for changes in colour, rate of penetration, groundwater seepages and any loss of flush returns recorded. Gas monitoring was undertaken during drilling.

6.5 Upon completion of the drilling works the boreholes were backfilled with arisings mixed with cement and the upper metre sealed with a bentonite plug.

6.6 All exploratory works were undertaken under engineering supervision by a qualified geo-environmental engineer.

6.7 The positions of the exploratory holes, together with others undertaken as part of the earlier intrusive investigation, are shown on the Exploratory Hole Location Plan included as **Figure 1**.

6.8 Fieldwork and soil descriptions were carried out in general accordance with BS5930:1999, "Code of Practice for Site Investigations".

Laboratory testing

Contamination related testing

6.9 In order to provide a general assessment of contamination, seven samples of made ground, four of topsoil, three of reworked topsoil and four of shallow natural soils were screened for the following determinands:

- *Metals*; Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc and Boron
- *Semi Volatile Organics;* Speciated polyaromatic hydrocarbons (PAH)
- *Total organic carbon*
- *pH*
- *Water soluble sulphate*

6.10 In addition, five samples of ash based made ground were submitted for arsenic bio-accessibility testing to further assess the risk posed to human end users.

6.11 Nine samples of natural soils were scheduled for water-soluble sulphate and pH determinations to assess the soil chemistry with respect to sulphate attack on buried concrete.

6.12 The analyses were carried out at an MCERTS registered and UKAS accredited laboratory.

Geotechnical testing

6.13 Geotechnical related testing comprised the following testing:

- Twelve Atterberg limits determinations to classify the natural clays, including three samples of mudstone, and to assess their shrinkage potential
- Nine remoulded CBR tests on shallow natural soils and made ground to assist with pavement design.

7 RESULTS OF THE INVESTIGATION

Soil profile

7.1 Detailed descriptions of the materials encountered together with observations of groundwater behaviour and sampling information are given in the exploratory hole records included as **Appendix B**. Exploratory hole records (TP01 to TP20) for the earlier preliminary intrusive investigation undertaken by 3e in May 2012 are included for completeness. Due to the variations of the strata, it is recommended that individual exploratory hole records are consulted. Routine gas monitoring during the intrusive works did not indicate elevated concentrations of mine related gasses. The major strata encountered are discussed below.

Topsoil and reworked topsoil

7.2 A cover of between 100mm and 400mm of topsoil was proved. Trial pit TP316 proved reworked topsoil containing cinder, burnt shale and part brick.

Made ground

7.3 Confined to the northeastern part of the site only, made ground comprising 'loose' ash and cinder with burnt shale, brick, glass and pottery fragments was proved to a maximum depth of 1.4 metres below existing ground levels at a location in the extreme northern corner of the site. These materials relate to the former landfill at the site and no evidence of putrescible content was confirmed.

Natural clays (glacial drift and residual clays)

7.4 Natural clays were proved either beneath the topsoil or made ground. Due to homogeneity of these clays, it was not possible to easily differentiate whether they were of glacial origin or the result of the in situ weathering of the underlying Coal Measures mudstone, hence they have been treated as one stratum. They typically comprised stiff, locally firm, fissured clays with variable gravel content and cobbles or boulders noted, and were proved to depths of between 1.2 and in excess of 3.0 metres.

Coal Measures

7.5 The majority of exploratory holes encountered very weak to weak mudstone, moderately weak siltstone or moderately weak to strong sandstone beneath the superficial soils. Trial pits TP307 and TP308 in the east of the site proved completely weathered coal of inferior quality at between 0.6 metre and 0.8 metre and at thicknesses of between 100mm and 300mm. In all cases, the coal was intact with no evidence of past exploitation. Sequences of mudstone and sandstone were proved within the boreholes to a maximum depth of 30 metres.

In situ testing

Hand shear vanes

7.6 Hand shear vanes were undertaken in the shallow clays encountered within the trial pits, these results are summarised below.

Depth BGL (m)	Field undrained shear strength range (kN/m^2) (Average Value)
0.0 to 1.0	66 to 118 (88)
1.0 to 2.0	43 to 113 (82)
2.0 to 3.0	66 to 108 (92)

CBR assessment

7.7 Mexe cone penetrometer tests were undertaken within the trial pits at depths of between 500mm and 600mm in natural clay soils to assess the strength of potential subgrades. The indicative CBR values recorded ranged between less than 1% and 6% with the majority of the results at about 1% to 2%. A summary of the results is presented below.

CBR value range (%)	Frequency of results
0 – 1.0	5
1 – 1.9	19
2 – 2.9	13
3 – 3.9	11
4 – 4.9	6
5 – 5.9	5
6 – 6.9	1

Visual and olfactory evidence of contamination

7.8 Excepting the presence of ash based made ground soils, no visual or olfactory evidence of significant contamination was observed during the fieldwork, particularly any evidence of petroleum hydrocarbon impact of soils.

Groundwater

7.9 During the excavation of the trial pits shallow perched groundwater ingresses were encountered at depths of between 1.2 and 1.35 metres at the base of the ash based made ground and exceptionally at 1.4 metres within the rock strata. Deeper water ingresses within the boreholes were encountered at depths of between 12.0 and 27.0 metres within the sandstone.

Progress of Exploratory Holes

7.10 Excavation of the trial pits through moderately strong to strong sandstone, at locations within the southwestern part of the site, proved difficult, generally at between 1.8 and 2.6 metres with progress suspended at depths of between 2.1 and 2.4 metres.

Stability of Excavations

7.11 Excavation faces were observed as unstable and spalling above 1.5 metres within ash based made ground. Within natural strata, all excavations were noted as stable.

Contamination related testing

7.12 The results of the contamination testing are included as **Appendix D**.

7.13 Generally, the results have been assessed using guidelines introduced by DEFRA between 2009 and 2011 (CLEA guidelines) and by the joint Land Quality Management Ltd (LQM) and Chartered Institute of Environmental Health (CIEH) in 2009. The CLEA guidelines include Soil Guidelines Values (SGVs) appropriate to standard land uses. SGVs are currently available for a limited number of metalloid and organic contaminants and provide generic assessment criteria for assessing the risk to human health. The LQM/CIEH guidelines include Generic Assessment

Criteria (GAC) appropriate to standard land uses and applicable to a wider range of both inorganic and organic contaminants.

7.14 With regard to the initial assessment of the site, the SGVs and LQM/CIEH GACs given for a residential end use with plant uptake have been used.

7.15 With respect to lead, the Environment Agency is currently revising the technical reports in response to the DEFRA withdrawal of the SGV after their review of contaminated land regime as published in the 'Way Forward' documents. Consequently no UK SGV is currently available for lead, nor is the toxicological data complete to allow use of the current CLEA model. Previously the SGV for lead was 450mg/kg for a residential setting, whilst not ideal this presents the most appropriate current reference. A summary of the contamination related testing carried out is presented as follows:

Topsoil

Determinand	Maximum conc. mg/kg	Minimum conc. mg/kg	Location of maximum concentration	No of samples tested	Site Assessment Criteria (SAC) mg/kg	No of samples exceeding SAC
Arsenic	46	2.7	TP311 @ 0.1m	7	32(1)	**1**
Cadmium	<0.2	N/A	N/A	7	10(1)	0
Chromium	30	20	TP304 @ 0.1m	7	3000(2)	0
Lead	235	19	TP311 @ 0.1m	7	450(3)	0
Mercury	<0.5	N/A	N/A	7	170(1)	0
Selenium	0.8	<0.3	TP311 @ 0.1m	7	350(1)	0
Boron	1.1	0.7	Various	7	291(2)	0
Copper	135	18	TP311 @ 0.1m	7	200(2)	0
Nickel	31	17	TP311 @ 0.1m	7	130(1)	0
Zinc	650	65	TP314 @ 0.1m	7	450(2)	**1**
PAH compounds:						
Acenapthylene	<0.1	N/A	N/A	7	400(2)	0
Acenapthalene	<0.1	N/A	N/A	7	480(2)	0
Anthracene	0.4	<0.1	TP307 @ 0.1m	7	4900(2)	0
Benzo[a]anthracene	0.9	0.1	TP309 @ 0.05m	7	4.7(2)	0
Benzo(a)pyrene	0.9	<0.1	TP311 @ 0.1m	7	0.94(2)	0
Benzo[b]fluoranthene	1.0	<0.1	TP311 @ 0.1m	7	6.5(2)	0
Benzo[ghi]perylene	0.5	<0.1	TP311 @ 0.1m	7	46(2)	0
Benzo[k]fluoranthene	0.4	<0.1	TP311 @ 0.1m	7	9.6(2)	0
Chrysene	1.0	<0.1	TP311 @ 0.1m	7	8(2)	0
Dibenz[a,h]anthracene	0.1	<0.1	TP311 @ 0.1m	7	0.86(2)	0
Fluoroanthene	2.1	0.3	TP311 @ 0.1m	7	460(2)	0
Flourene	0.2	<0.1	TP307 @ 0.1m	7	380(2)	0
Indeno[123-cd]pyrene	0.4	<0.1	TP311 @ 0.1m	7	3.9(2)	0
Napthalene	0.3	<0.1	TP311 @ 0.1m	7	3.7(2)	0
Phenanthrene	1.4	0.2	TP311 @ 0.1m	7	200(2)	0
Pyrene	1.7	0.2	TP311 @ 0.1m	7	1000(2)	0
TOC (%)	4.23	1.16	Average 2.7	7	-	N/A

Notes:

(1) CLEA soil guidance value for commercial end use (based on 2.5% SOM)

(2) LQM/CIEH GAC for commercial end use (based on 2.5% SOM)
(3) In the absence of current guidelines, CLEA soil guidance value for residential end use prior to withdrawal (2009)

7.16 With respect to topsoil, concentrations of arsenic and zinc are in excess of the assessment criteria within two samples. These are samples of reworked topsoil recovered from the area of the former landfill and overlie ash based made ground.

7.17 In view of the exceedance of the assessment criteria statistical analyses, as outlined in DEFRA publication CLR7 and assuming the whole site as one averaging area, has been carried out for arsenic and zinc. A copy of the statistical analyses is included as **Appendix E** and summarised in the following table.

Statistical analyses of the topsoil

Determinand	Upper Confidence Value (mg/kg)	GAC (mg/kg)	Grubbs Test (Outliers)	GAC exceeded
Arsenic	45.01	32(1)	No	**Yes**
Zinc	539.54	450(2)	No	**Yes**

Notes:

(1) LQM/CIEH GAC for residential end use with plant uptake (assuming 2.5% SOM)
(2) LQM/CIEH GAC for residential end use (based on 2.5% SOM)

7.18 The statistical analyses of the topsoil indicate that there is a potential risk to end users from arsenic and zinc. However, this is confined to the reworked topsoil covering the area of the former landfill only and located within the northeastern part of the site.

Made ground

Determinand	Maximum conc. mg/kg	Minimum conc. mg/kg	Location of maximum concentration	No of samples tested	Site Assessment Criteria (SAC) mg/kg	No of samples exceeding SAC
Arsenic	149	26	TP312 @ 0.6m	7	32(1)	**6**
Cadmium	<0.2	N/A	N/A	7	10(1)	0
Chromium	33	21	TP312 @ 0.6m	7	3000(2)	0
Lead	659	25	TP317 @ 0.4m	7	450(3)	**1**
Mercury	2.3	<0.5	TP317 @ 0.4m	7	170(1)	0
Selenium	2.4	<0.3	TP312 @ 0.6m	7	350(1)	0
Boron	2.3	0.8	TP313 @ 0.5m	7	291(2)	0
Copper	298	39	TP312 @ 0.6m	7	200(2)	**6**
Nickel	55	32	TP312 @ 0.6m	7	130(1)	0
Zinc	265	64	TP312 @ 0.6m	7	450(2)	0
PAH compounds:						
Acenapthylene	<0.1	N/A	N/A	7	400(2)	0
Acenapthalene	<0.1	N/A	N/A	7	480(2)	0
Anthracene	0.7	<0.1	TP310 @ 0.8m	7	4900(2)	0
Benzo[a]anthracene	1.3	0.3	TP310 @ 0.8m	7	4.7(2)	0
Benzo(a)pyrene	1.2	<0.1	TP310 @ 0.8m	7	0.94(2)	**1**
Benzo[b]fluoranthene	1.5	<0.1	TP310 @ 0.8m	7	6.5(2)	0
Benzo[ghi]perylene	0.5	<0.1	TP310 @ 0.8m	7	46(2)	0
Benzo[k]fluoranthene	0.7	<0.1	TP310 @ 0.8m	7	9.6(2)	0
Chrysene	1.3	<0.1	TP310 @ 0.8m	7	8(2)	0
Dibenz[a,h]anthracene	0.2	<0.1	TP310 @ 0.8m	7	0.86(2)	0
Fluoroanthene	3.0	0.2	TP310 @ 0.8m	7	460(2)	0
Flourene	0.1	<0.1	TP310 @ 0.8m	7	380(2)	0
Indeno[123-cd]pyrene	0.5	<0.1	TP310 @ 0.8m	7	3.9(2)	0
Napthalene	1.2	0.4	TP309 @ 0.4m	7	3.7(2)	0
Phenanthrene	2.5	0.6	TP310 @ 0.8m	7	200(2)	0
Pyrene	2.4	<0.1	TP310 @ 0.8m	7	1000(2)	0
TOC (%)	4.48	1.21	Average 3.3	7	-	N/A

Notes:

(1) CLEA soil guidance value for residential end use (based on 2.5% SOM)
(2) LQM/CIEH GAC for residential end use (based on 2.5% SOM)
(3) In the absence of current guidelines, CLEA soil guidance value for residential end use prior to withdrawal (2009)

7.19 Samples of shallow ash based made ground reported concentrations of arsenic, lead, copper and benzo(a)pyrene above their respective assessment criteria. It should be noted that elevated concentrations of copper are widespread throughout these materials.

7.20 With respect to total petroleum hydrocarbons (TPH), the analyses undertaken on the ash based materials as part of the earlier preliminary intrusive works recorded concentrations of aliphatic and aromatic compounds that were below the assessment criteria for all carbon bands.

7.21 In view of the exceedences recorded for arsenic, and taking cognisance of the elevated arsenic concentrations identified within these materials during the earlier preliminary intrusive works, bio-accessibility analyses were undertaken. The results of these tests are summarised in the following table.

Bio-accessibility results for arsenic in ash based made ground

Sample location	Total arsenic (mg/kg)	Bio-accessible arsenic (mg/kg)	Bio-accessible fraction w/w%	GAC exceeded
TP309 @ 0.4m	26	8.8	34	**No**
TP310 @ 0.8m	71	22	31	**No**
TP311 @ 0.5m	86	22	26	**No**
TP312 @ 0.6m	149	43	29	**Yes**
TP314 @ 0.6m	92	32	35	**No**

7.22 The results show that despite four of the samples recording concentrations of bioaccessible arsenic as below the assessment criteria, a single sample is at a concentration in excess of the assessment criteria, and therefore, the ash based made ground is considered as presenting a potential significant risk to end users through direct contact and ingestion.

Natural soils

Determinand	Maximum conc. mg/kg	Minimum conc. mg/kg	Location of maximum concentration	No of samples tested	Site Assessment Criteria (SAC) mg/kg	No of samples exceeding SAC
Arsenic	19	2.1	TP303 @ 0.5m	4	32(1)	0
Cadmium	<0.2	N/A	N/A	4	10(1)	0
Chromium	31	21	TP321 @ 0.1m	4	3000(2)	0
Lead	83	8.7	TP303 @ 0.5m	4	450(3)	0
Mercury	<0.5	N/A	N/A	4	170(1)	0
Selenium	<0.3	0.4	N/A	4	350(1)	0
Boron	2.8	0.6	TP312 @ 0.6m	4	291(2)	0
Copper	42	12	TP303 @ 05m	4	200(2)	0
Nickel	26	13	TP321 @ 0.7m	4	130(1)	0
Zinc	134	45	TP303 @ 0.5m	4	450(2)	0
PAH compounds:						
Acenapthylene	<0.1	N/A	N/A	4	170(2)	0
Acenapthalene	<0.1	N/A	N/A	4	210(2)	0
Anthracene	<0.1	N/A	N/A	4	2300(2)	0
Benzo[a]anthracene	<0.1	N/A	N/A	4	3.1(2)	0
Benzo(a)pyrene	<0.1	N/A	N/A	4	0.83(2)	0
Benzo[b]fluoranthene	<0.1	N/A	N/A	4	5.6(2)	0
Benzo[ghi]perylene	<0.1	N/A	N/A	4	44(2)	0
Benzo[k]fluoranthene	<0.1	N/A	N/A	4	8.5(2)	0
Chrysene	<0.1	N/A	N/A	4	6(2)	0
Dibenz[a,h]anthracene	<0.1	N/A	N/A	4	0.76(2)	0
Fluoroanthene	<0.1	N/A	N/A	4	260(2)	0
Flourene	<0.1	N/A	N/A	4	160(2)	0
Indeno[123-cd]pyrene	<0.1	N/A	N/A	4	3.2(2)	0
Napthalene	<0.1	N/A	N/A	4	1.5(2)	0
Phenanthrene	<0.1	N/A	N/A	4	9(2)	0
Pyrene	<0.1	N/A	N/A	4	560(2)	0
TOC (%)	1.26	0.15	Average 0.5	4	-	N/A

Notes:

(1) CLEA soil guidance value for residential end use (based on 1% SOM)
(2) LQM/CIEH GAC for residential end use (based on 1% SOM)
(3) In the absence of current guidelines, CLEA soil guidance value for residential end use prior to withdrawal (2009)

7.23 None of the samples of natural soils record concentrations of contaminants of concern in excess of their respective assessment criteria.

Assessment of contamination in respect to service supply pipes

7.24 The site has not supported any potentially significant contaminative activity and the results of the contamination testing, including those results procured as part of the earlier preliminary intrusive works, indicate the presence of slightly elevated petroleum hydrocarbons (C11–C20) within the ash based materials at concentrations above the threshold values recommended for the polyethylene pipes. However, in order to make an informed choice of pipe material, it is recommended that comprehensive testing suites in accordance with UKWIR (ref. 10/WM/03/21) guidance are undertaken on these materials.

Soil chemistry for concrete design

7.25 The sulphate and pH determinations undertaken on natural soils gave water soluble concentrations of between <10 mg/l and 125 mg/l with those for the made ground at between 58 mg/l and 766 mg/l; one out seven samples of made ground exceeded 500 mg/l. These results indicate a BRE Special Digest 1:2005 Design Sulphate Class DS-1 with an ACEC site classification AC-1 for natural soils and DS-2 with an ACEC site classification AC-3z for ash based made ground, due to the low pH values for these materials.

Geotechnical testing

7.26 The results of the geotechnical testing are presented in **Appendix F**.

7.27 The results of the Atterberg limits determinations undertaken on a total of nine samples of natural clays and three of mudstone are summarised below.

A*tterberg limit determinations*

Strata type	PI range (%) (Degree of plasticity)	Modified PI range (1)	Frequency samples per modified PI class (%)			Estimated volume change potential (1)
			<20%	20 - 40%	>40%	
Natural clay (<1.0 to 2.0m)	19 to 32 (intermediate to high)	19 to 32	5	4	0	Low to medium
Mudstone (1.0 to 2.0m)	20 to 24 (intermediate to high)	17 to 20	3	0	0	Low

(1) As defined within NHBC Chapter 4.2 'Building Near Trees' (2008)

7.28 Results of the remoulded CBR tests undertaken on the residual granular soils, residual clays and a sample of reworked natural clay are summarised as below.

Summary of remoulded CBR results

Strata	Depth (m) BGL	CBR result (%)	Moisture content (%)
Natural clays	0.6	4	27
	0.55	4	30
	0.5	3 to 4	32
	0.55	4 to 5	24
	0.7	4	29
	0.6	3	27
	0.55	4	26
Ash made ground	0.6	9 to 10	44
	0.4	3	43

7.29 The samples of shallow clay recorded CBR values of between 3% and 5%, typically 4%. With respect to the ash based made ground, CBR values of between 3% and 10% were recorded.

8 DISCUSSION

8.1 The proposed redevelopment comprises 2 to 2.5 storey housing with car parking, access roads and areas of soft landscaping. Existing ground levels fall steadily towards the northeast with no re-profiling of the site proposed. The development proposals are indicated on the site layout included as **Appendix A**.

Contamination

Risk philosophy

8.2 The presence of contamination is generally only of concern if there exists an actual or potentially unacceptable risk under current legislation (i.e. Section 57 of the Environment Act 1990). The interpretation of "unacceptable risk" is termed to be one where:

"Significant harm is being caused or there is a significant possibility of such harm being caused, (where harm is defined as harm to health of living organism or other interference with the ecological systems of which they form a part of and, in the case of man, includes harm to his property); or pollution of controlled waters is being caused"

8.3 The potential for harm to occur requires three conditions to be satisfied:

- *Presence of substance (potential contaminants/pollutants) that may cause harm* ***(Source of Pollution)****;*
- *The presence of a receptor, which may be harmed, e.g. the water environment or humans, buildings, fauna and flora* ***(The receptor)****;*
- *and the existence of a linkage between the source and the receptor* ***(The Pathway)****.*

8.4 Therefore, the presence of a measurable concentration of contaminant within the ground and subsurface environment does not automatically imply that a contamination problem exists, since contamination must be defined in terms of pollutant linkages and unacceptable risk of harm.

8.5 The nature and importance of both pathways and receptors, which are relevant to a particular site, will vary according to the intended use of the site, its characteristics and its surroundings.

Revised site conceptual model

Ground conditions

8.6 In general, the ground conditions comprised a mantle of topsoil across the site at thicknesses of between 100mm and 400mm. Made ground, confined to the northeastern part only, comprised ash, cinder, brick and burnt shale to a maximum depth of 1.4 metres in the extreme northern corner. Directly beneath the topsoil, or underlying the made ground, natural stiff clays were proved to between 1.2 and in excess of 3 metres underlain by very weak to weak mudstone, moderately weak siltstone or moderately strong to strong sandstone. Minor poor quality coal seams less than 300mm thick were proved above a metre in the eastern part of the site. Interbedded mudstones and sandstones were proved to a maximum depth of 30 metres.

8.7 Shallow perched groundwater is present at between 1.2 and 1.4 metres below existing ground levels, deeper seepages within the rock were proved at between 12.0 and 27.0 metres.

Contamination Sources

Soil

8.8 Potential contaminated made ground comprised ash based materials in the area of the former landfill. No evidence of potentially significantly contaminated materials was noted, particularly with respect to petroleum hydrocarbons. Laboratory testing has identified widespread elevated concentrations of arsenic and copper within the ash based made ground together with lead and PAHs, benzo(a)pyrene, the latter to a lesser degree. In addition, reworked topsoil overlying the ash based materials and the former landfill in the northeastern part of the site recorded elevated concentrations of arsenic and zinc. All these aforementioned contaminants could potentially present a significant risk to human health. The natural soils are not regarded as contaminated.

Ground gas

8.9 The presence of deep made ground or putrescible materials likely to present a source of ground gas have not been identified at the site. Therefore, the site does not present a risk through the generation of ground gas and no gas monitoring is required.

Revised pollution linkage assessment

8.10 In light of the findings of the intrusive investigation, a re-assessment of potential pollutant linkages has been made as follows:

Contamination Source	Pathway	Potential Receptors	Linkage Complete
Contaminants associated with made ground – metals and non volatile PAHs	Direct contact, ingestion, dust inhalation	Humans: Site workers	Yes, but transient removed by the use of appropriate PPE and hygiene precautions
	Direct contact, ingestion, dust inhalation	Humans: End users	Yes. Use of a minimum of 600mm of clean capping in gardens and 300mm areas of soft landscaping where ash based soils are present to break potential pathways to end users
	Lateral migration	Nearby watercourse	No. Hardcover will prevent infiltration of water and reduce the potential for leaching. Also, the presence of extensive low permeability cohesive soils would attenuate contaminant migration
	Vertical migration	Underlying aquifer	No. Hardcover will prevent vertical migration, formal drainage systems and the presence of extensive cohesive soils and argillaceous solid strata will retard any potential downward migration of water into aquifer.
	Direct contact of potable water supply pipes	Humans: End users	Potentially yes, the use of specialist protected pipes may be appropriate.
Contaminants associated with reworked topsoil covering former landfill – metals	Direct contact, ingestion, dust inhalation	Humans: Site workers	Yes, but transient and would be removed by the use of appropriate PPE and hygiene precautions.
	Direct contact, ingestion, dust inhalation	Humans: End users	Potentially yes. These soils should not be re-used unless placed beneath 600mm clean cover, therefore breaking any pathways to end users in gardens and 300mm in landscape areas.

Remediation assessment

8.11 The ash based made ground is considered as potentially presenting a significant risk to end users of the site. In gardens, the use of a minimum 600mm thick clean capping should be

used if the ash based made ground is to remain in place. Elsewhere, in areas of soft landscaping, a 300mm thick clean capping layer should be adequate, however, the final thicknesses of capping should be determined during consultation with the local authority.

8.12 Due to the ash based materials containing burnt shale, which have expansive properties, placement of these materials should be avoided beneath floor slabs or adjacent to subsurface concrete because of their potential to cause heave. Ideally, they should be placed beneath capping in garden areas or beneath areas of soft landscaping.

8.13 If the reworked topsoil overlying the former landfill in the northeastern part of the site is to be re-used during the redevelopment, then it should be placed beneath 300mm clean cover to break any pathway to end users.

8.14 The topsoil covering the remainder of the site, where it is directly overlying the natural soils, is regarded as not presenting a potential risk to human health and is considered suitable for re-use as part of the development.

8.15 If during demolition and site clearance or development areas of possible contamination are exposed, or conditions differ significantly from those identified, then appropriate advice should be sought.

Protection of service supply pipes

8.16 With respect to underground services, it is considered that no special precautions will be required where service pipes are to be laid within natural soils, however, within the ash based made ground consideration should be given to using specialist protected pipes with further testing in accordance with UKWIR guidelines recommended. The advice of manufacturers should be sought with respect to the use of appropriate materials in accordance with the current guidelines.

Foundations

8.17 Existing ground levels are to be maintained with no significant re-profiling of the site proposed.

8.18 The intrusive investigation proved a cover of topsoil with made ground up to 1.4 metres in the northeastern part, underlain by generally stiff clays and very weak to weak mudstone, moderately weak siltstone and moderately strong to strong sandstone present at between 1.2 and in excess of 3 metres. Weathered coal seams between 100mm and 300mm thickness were present above a metre in the eastern part of the site.

8.19 The natural stiff clays are considered suitable for supporting traditional pad and strip foundations at about a metre below existing ground levels with an allowable bearing capacity of 150 kN/m^2 considered appropriate. In areas of made ground, foundations will be required to extend into the underlying stiff clays proved at about 1.5 metres below existing ground levels by the use of trench fill techniques. Settlements are not expected exceed 25mm within the stiff clays.

8.20 Where coal seams are exposed, these should be excavated through and sealed with foundations bearing upon stiff clay or rock as appropriate.

8.21 Where trees or hedges are within influencing distance, foundations should be deepened in accordance to current guidelines assuming a medium volume change potential for the natural clays and a low volume change potential for the mudstones, if appropriate.

Floor slabs

8.22 The use of suspended floor slabs should be used in the area of the former landfill in the northeast where made ground is in excess of 600mm or where plots are within influencing distance of trees. Elsewhere, ground bearing slabs can be used with soils proof rolled and any soft spots removed.

Mining

8.23 Published geological information suggests that the site is underlain by the Royston coal seam, potentially at shallow depth, which may have been mined historically.

8.24 Four rotary percussive boreholes put down at the site did not prove the presence of any significant coal seams or evidence of exploitation of any coal seams within 30 metres of the

surface. Therefore, the site can be regarded as stable with respect to mining requiring no additional no structural precautions in this respect.

Excavation and dewatering

8.25 If man entry is proposed into excavations the use of full support to excavation sides is recommended.

8.26 No major problems are anticipated using conventional plant during excavations within the soils present at the site. However, consideration should be given to the use of hydraulic breakers where sandstone is present at shallow depth, likely to be in the southwestern part of the site, or where excavations require deepening.

8.27 Generally, no significant groundwater ingress into excavations is anticipated in the short term, however, if left open for longer periods, any seepages that may develop should be adequately controlled by localised pumping from sumps. Seasonal variations within the groundwater table should be anticipated.

Disposal of materials

8.28 A preliminary assessment of ash based materials based on concentrations of mineral oil of below 500mg/kg, PAHs of less than 100mg/kg and TOC values of between 3% and 5% suggests that these materials are suitable for disposal to a landfill licenced for stable non-reactive hazardous waste. The natural soils are suitable for disposal as inert waste. However, the final classification of materials for disposal can only be made once they have been generated and if necessary WAC testing undertaken. In the first instance, it would be prudent to discuss the results of the testing with a licensed waste carrier to assess disposal costs.

Gas protection measures

8.29 No protection measures are required within with respect to landfill gas but basic radon, protection measures are required.

Sulphate attack on buried concrete

8.30 The results of the chemical analyses for ash based made ground indicate a BRE Special Digest 1:2005 Design Sulphate Class DS-2 with an ACEC site classification AC-3z and with respect to natural soils, DS-1 with an ACEC site classification AC-1. Buried concrete should be designed accordingly.

External works design

8.31 Based on the results of the Mexe cone penetrometer and laboratory testing, a CBR value of 3% should be adopted for design of external works on the natural clay and ash based made ground subgrades.

Surface water drainage

8.32 Field testing of the adjacent site to the south has shown the ground as unsuitable for disposal of surface water by way of soakaway.