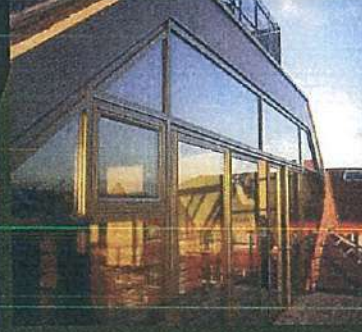




GROUND INVESTIGATION REPORT

FORMER MONCKTON COKE WORKS, NR BARNSELY

FOR Hargreaves (UK) Services Ltd

August 2015

Ground Investigation Report
Former Monckton Coke Works, Nr Barnsley
for
Hargreaves (UK) Services Ltd

G15009	Ground Investigation Report, Former Monckton Coke Works, Nr Barnsley
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1	25.11.15	additional soil and groundwater analysis incorporated	JR/JMH	SB/JMH

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1.0 Introduction

1.1 Commission

Patrick Parsons Ltd (PPL) was commissioned by Hargreaves (UK) Services Ltd (HG) to undertake a ground investigation at their site at the former Monckton Coke Works, near Barnsley. The extent of the site pertaining to this report is presented in the Site Features Plan Drawing No. G15009-700, included in **Appendix A**.

1.2 Proposals

It is proposed to redevelop the site with a mixed land-use, comprising residential, retail, commercial and leisure facilities incorporating areas of public open space.

1.3 Objectives

The objectives of the intrusive investigation were to assess ground conditions across the site, to determine geotechnical parameters for use in foundation design and to obtain samples of soils and groundwater for assessment of the contamination status of the site. The findings of the investigation are to be used to allow development constraints to be identified which would inform the master planning of the development site and also to provide factual information to allow HG to obtain the discharge of the existing IPC licence for the site. Though this report does not provide comment on the IPC license.

1.4 Limitations

This report has been prepared for Hargreaves (UK) Services Ltd and their appointed agents only and should not be relied upon by any third party without the written permission of PPL. If any unauthorised third party comes into possession of this report, they rely on it at their own risk and the authors do not owe them any Duty of Care or Skill. This report is based on and limited to an assessment of the information and ground conditions identified here. PPL is not responsible for ground conditions not revealed during these investigations.

1.5 Previous Reports

PPL has been provided with information/reports prepared by others, including:

Monckton Coke and Chemical: Phase 1a Site Report. Reference ILM081/1a, Issue 1. ABB Eutech, 22 August 2001

Monckton Coke and Chemical: Phase 1b/2 Site Report. Reference ILM092/1b-2, Issue 1. ABB Eutech, 19 April 2002

Environmental Due Diligence: Monckton Coke and Chemical Works. Reference 12022228-001. WSP Environmental UK, June 2005

Environmental Assessment: Monckton Coke and Chemicals Limited. Reference 16492-R1(00). RSK STATS Geoconsult Limited, dated May 2011

RSK letter report on groundwater sampling, reference 321453(H)L01(00), dated 19 August 2013

Data Review and Preliminary Risk Assessment: Monckton Coke and Chemicals Limited. Reference 321789(H)-R1(00). RSK Environment Limited, dated November 2014.

These reports were referred to in the design of the latest phase of ground investigation, specifically RSK 2014 report, and should be read in conjunction with this report.

2.0 Site Details

Site Location: The site is located off Lund Hill Lane, Royston, to the northeast of Barnsley, South Yorkshire. The site is located around NGR 437460mE, 412020mN.

Site Area: The main operational site covers approximately 14 hectares (approximately 36 Acres). The site is divided into 3 separate areas; namely the Stock Yard (northern area), the Former Production and By-Products area (central area) and the Southern area, as presented on Drawing No. G15009-700 included in **Appendix A**.

2.1 Site Description

The site is accessed off the B6428 (Lund Hill Lane). This road forms the southern and eastern site boundaries, with a railway (in cut) forming the western boundary. A path (former railway) and soil bund (approximately 4 to 5m high) and of unknown composition delineates the majority of the northern boundary. This bund also runs along part of the western boundary and north eastern boundary. The 3 principal site areas are discussed below.

Stock Yard - North

Comprising the coke import, storage and loading area including associated static and mobile plant. An engineering workshop and electricity substation are located at the eastern boundary and a plant servicing workshop is present in the southern central part. An above ground fuel tank is located immediately to the south of this workshop building.

The extreme north eastern corner (behind the soil bund) may potentially be infested by Japanese Knotweed, subject to professional inspection and confirmation.

Former Production and By-Products Area - Central

This comprises the former coke manufacturing plant with associated by-product manufacture and electricity generation (CHP plant), which includes offices, workshops and non-production areas. The coke ovens (42 no.) are set within a battery in the northern part with plant associated with production of tar, benzole and ammonia located south of the ovens. The CHP plant occupies the southern part. Generally, the condition of the hardstanding is poor showing evidence of cracking and staining. The vessel bunds are stained and leaking and associated pipe work and tanks are corroded.

Southern Area

An effluent treatment facility discharging into the sewer network occupies this area. Elsewhere, coarse vegetation and semi-mature trees are present.

Existing ground levels are at their highest in the central southern part (By-products area) at approximately 72.0m AOD falling steeply towards the southern boundary (to approximately 62.0m AOD) and steadily northwards where they are at approximately 60.0m AOD in the north western corner of the site.

2.2 Adjacent Land Uses

The site lies to the northeast of the township of Royston in a semi-rural setting, though with the remnants of a significant mining industry, with former collieries and associated infrastructure, now under varied commercial land-use or derelict, awaiting re-development. Residential development is present within 50m of the southwestern site boundary.

3.0 Geoenvironmental Setting and Site History

3.1 Geoenvironmental Setting

The geoenvironmental setting of the site is well documented, however the salient points are listed below.

- The solid strata underlying the site are undifferentiated Carboniferous Middle Coal Measures with the Mexborough Rock sandstone present beneath the majority of the site apart from the north and southern parts. The Royston coal seam outcrops across the south of the site and is present at shallow depth in this area. No superficial soils are present
- Previous intrusive investigations at the site have recorded ash-based made ground to between less than 1m and 3m depth underlain by sandstone and mudstone, weathered in their upper parts. Limited thicknesses of cohesive superficial soils were proved in the northern part of the site
- The southern part is defined as a Development High Risk Area with regard to potential past shallow mining. The northern part of the site was a former deep coal mine with 3 capped disused mine shafts present.
- A former sandstone quarry impinged onto the south eastern site boundary and a former clay pit was present along the northern boundary of the site
- The site has been used for tipping of colliery spoil. Immediately to the west the area was used for disposal of mine waste. A former landfill within 100m southwest received household waste and other landfills within 250m west and southwest received various commercial, domestic and liquid wastes
- The solid strata are classified as a Secondary A aquifer
- The nearest surface watercourse is Lineside Dyke running along the western boundary within the railway cutting and Pools Dike approximately 120m west. The disused Barnsley Canal is present within approximately 20m of the site to the west
- The site is affected by radon.

3.2 Site History

The site history and that of its surroundings are extensively researched. A summary of the main historical features influencing the site are presented below.

Since the mid 19th century the site remained as agricultural land with a railway forming the western boundary.

During the late 19th century until the mid 20th century Monckton Main colliery occupies the northern part with 3 shafts shown. A brickworks and associated clay pit impinge onto the northern site boundary. Coke ovens, a gas works, 'powder magazines' and tanks are shown in the central and central southern part of the site with numerous railway sidings across the majority of the site (a railway tunnel is present in the northern part of the site). A sandstone quarry crosses the south eastern site boundary.

In the 1960s a mine is recorded in the north and mineworks in the south of the site with interconnecting rail lines both on and off site to the east. Earthworks are shown along the north and eastern boundaries.

During the latter part of the 20th century the railway lines on the site become disused. The former mine in the north is shown as 'disused' and a former tip (spoil heap) is present off site to the east.

The current effluent plant is shown during the 1990s. Since 2000, the site is shown generally as existing with the addition of the CHP plant in the southern part.

4.0 Summary of Previous Investigations

Information is available from earlier intrusive investigations undertaken at the site over the last 15 years. The main findings with regard to identified soil and groundwater contamination are presented below.

4.1 Phase 1b/2 Site Report, ABB Eutech (2002)

- Establishment of baseline conditions with regard to soil and groundwater contaminant concentrations within the operational part of the site (re. IPC permitting).
- Evidence of visual and olfactory hydrocarbon impact of soils and groundwater including free phase product.
- Elevated concentrations of TPH, BTEX, PAH, phenols and total sulphate within soils in the by-products area together with PAH, BTEX, SVOC, TPH and cyanide within groundwater (MW5) located close to the western site boundary within the by-products area. In addition, elevated leachate concentrations with respect to BTEX were recorded from the western boundary railway cutting.

4.2 Environmental Assessment, RSK (2011)

- Assessment of the contamination status of soil and groundwater within the operational site area (production and by-products).
- Visual and olfactory evidence of hydrocarbon impact of soils and the underlying solid strata was noted.
- Elevated concentrations of hydrocarbons, PAHs and VOCs with respect to the generic commercial GACs were present within the soils and groundwater in and around the by-products area.

4.3 Additional Groundwater Sampling, RSK (2013)

- Monitoring well BH205 located within the eastern part of the by-products area displayed a significant thickness of DNAPL, possibly comprising PAHs derived from coal tars. Contaminant concentrations with the remaining wells were as the 2011 results.

5.0 Fieldwork and Testing

The following scope of fieldwork was undertaken to determine ground conditions and to assess contamination in soils and groundwater, and geotechnical abnormal constraints to development, the most sensitive land use being residential.

Based on a review of previous reports prepared by others, cited above, the following scope of ground investigation and laboratory testing was carried out. The exploratory holes are presented with respect to their location across the site.

5.1 Stock Yard Area

- Excavation of 16 No. trial pits (TP102 to TP110, TP1 to TP5, TP31 and TP32) to assess ground conditions, *in situ* testing and obtain samples for laboratory analysis;
- Drilling of 6 No. mini percussive (window sampler) boreholes (WS1 to WS6) to assess ground conditions, *in situ* testing and obtain samples for laboratory analysis;
- Drilling of 5 No. rotary boreholes (RBH1D, RBH2A, RBH3A, BH302 and BH303) to install groundwater (and ground gas) monitoring wells;

5.2 Production and By-Products Area

- Excavation of 24 No. trial pits (TP101, TP6 to TP14, TP16 to TP28 and TP33) to assess ground conditions, *in situ* testing and obtain samples for laboratory analysis;
- Drilling of 4 No. rotary boreholes (RBH4A, BH301, BH304 and BH305) to install groundwater (and ground gas) monitoring wells;

5.3 Southern Area

- Drilling of 3 No. mini percussive (window sampler) boreholes (WS7, WS9 and WS10) to assess ground conditions, *in situ* testing and obtain samples for laboratory analysis;
- Drilling of 1 No. rotary borehole (RBH5) to install a groundwater (and ground gas) monitoring well;

5.4 All Areas

- Laboratory geotechnical testing including water soluble sulphate, pH, moisture content, Atterberg limits and calorific value determinations;
- Laboratory chemical soil testing of Made Ground and natural soils, comprising heavy metals, metalloids, non-metals, hydrocarbons, SVOCs and VOCs and asbestos presence determination.

The ground investigation fieldwork was undertaken between 29th April and 19th June 2015.

A plan (prepared by the contractor Van Elle) showing the location of the exploratory holes is included as PPL Drawing No. G15009-701, included in **Appendix A**.

6.0 Ground Conditions

6.1 Reworked Topsoil

Isolated occurrences of reworked topsoil (50 to 200mm thick) were present in the south eastern part of the stock yard and in the southern part of the site around the location of the effluent treatment plant.

6.2 Hardstandings

Reinforced and unreinforced concrete hardstanding covered the majority of the production and by-product areas as well as the eastern edge of the stock yard. Thicknesses varied between 200 and 500mm.

6.3 Made Ground

Made ground was encountered across the entire site at thicknesses ranging from 0.2 to in excess of 4.0m below existing ground levels (begl).

Across the northern stock yard area, a mantle of reworked coke was present at between 0.2 and 1.1m thick.

Beneath this mantle, hardstandings, reworked topsoil and at the surface elsewhere made ground of predominantly very loose, loose and medium dense ash-based gravelly sand or sandy gravel with variable content of cinder, clinker, coke, brick, concrete, mudstone and sandstone together with timber and metal constituents was proved. TP13 located in the western part of the production area encountered frequent large clasts of coal at between 1 and 2m begl. Granular made ground materials comprising reworked gravel and cobble size mudstone and sandstone (colliery spoil) were frequently proved across the site.

Cohesive made ground comprising reworked natural gravelly clays with variable gravel content were present within the granular materials.

The full extent of the thickness of made ground was not proved in exploratory holes TP102, TP104, TP107, TP4, TP8, TP14 and WS3 which were terminated at depths of between 1.2 and 4.0m begl due to the presence of services or obstructions.

SPT 'N' values for these materials ranged between 3 and 26, occasionally in excess of 50.

Water soluble sulphate concentrations in 13 samples of made ground were recorded at between 0.1 to 4.1g/l with pH values of ranging between 5.8 and 8.0. Total sulphate concentrations ranged between 300 to 31,000mg/kg and concentrations of water soluble chloride ranged between 11 and 39,000mg/kg.

A total of 8 samples of the coal-bearing made ground materials recorded calorific values of between 0.4 and 18.4MJ/kg.

6.4 Natural Cohesive Soils

The presence of natural cohesive strata was limited across the site and these soils were only encountered in the extreme northern and southern parts of the site at depths of between 0.4 and 3.0m begl. They generally comprised soft, firm and stiff gravelly clays, but soft organic clays were proved to 1.9m thickness in the extreme northern part of the site.

SPT 'N' values of between 3 and in excess of 50 (average 15 to 30) were recorded for these soils in the south of the site only. In accordance with CIRIA Report 143 "The Standard Penetration Test SPT: Methods and Use", 1995 a correlation factor of $C_u = \text{SPT "N"} \times 4.5$ can be used to provide an estimate of undrained shear strength in cohesive soils, which is indicative of average strengths of between 65kN/m² and 135kN/m² confirming medium to high strength soils.

Atterberg limits tests on 5 samples of this stratum from depths of 1.5 to 3.5m begl recorded plasticity indices of between 13 and 37% confirming the clay to be of low to medium volume change potential (shrinkability), in accordance with NHBC guidance. These are included as Appendix D.

6.5 Natural Residual Granular Soils

Beneath the made ground across the majority of the site, except where competent natural solid strata were encountered, natural residual granular soils comprising loose to dense gravelly sand and sandy gravel with cobble content were proved at depths of between 0.9 and 4.5m begl. These are considered to be the result of the in-situ weathering of the underlying coal measures strata (sandstone) and were generally less than 1m thick.

SPT 'N' values for these soils (where available) ranged between 8 and 38.

For all natural soils water soluble sulphate concentrations ranged between 0.1 to 1.0g/l with pH values of ranging between 4.6 and 7.6. Total sulphate concentrations ranged between 330 to 6,300mg/kg and concentrations of water soluble chloride ranged between 19 and 410mg/kg.

6.6 Natural Solid Strata

Solid strata comprising weak sandstone and very weak to weak mudstone were proved at depths of between 0.5 and 4.5m begl, in places directly beneath the made ground materials. Sandstone underlies the majority of the site at rockhead. Elsewhere, mudstone was generally present at less than 1m begl where encountered in the north eastern, southern and central eastern parts of the site. The rotary boreholes proved interbedded sequences of sandstone and mudstone to a maximum depth of 30m begl.

The exploratory hole records are included as Appendix B.

6.7 Groundwater

Groundwater ingress was noted in 16 No. exploratory holes during the investigation fieldwork as indicated in the table below.

Table 1 Groundwater Observations

Location	Depth (m begl)	Strata	Description
TP101	1.5	Gravelly clayey SAND	Probable disused drain
WS3	3.9	Cohesive MADE GROUND	Limited ingress
WS5	2.9	Cohesive MADE GROUND	Limited ingress
WS7	3.7	Sandy CLAY	Limited ingress
WS9	2.6	Sandy gravelly CLAY	Limited ingress
WS10	2.8	Sandy gravelly CLAY	Limited ingress
RBH1D	13.5	MUDSTONE	Strike (driller's description)
RBH2A	15.0	MUDSTONE	Strike (driller's description)

RBH3A	16.0	MUDSTONE	Strike (driller's description)
RBH4A	16.5	MUDSTONE	Strike (driller's description)
RBH5	14.0	MUDSTONE	Strike (driller's description)
BH301	21.0	MUDSTONE	Strike (driller's description)
BH302	15.0	SANDSTONE	Strike (driller's description)
BH303	12.0	SANDSTONE	Strike (driller's description)
BH304	4.0	SANDSTONE	Strike (driller's description)
BH305	25.0	SANDSTONE	Strike (driller's description)

An initial round of monitoring of 'at rest' groundwater levels within the shallow monitoring wells has recorded levels of between 2.3 and 4.0m begl with reduced levels for groundwater ranging between 56.1 and 62.1m AOD across the northern (stock yard) and southern parts of the site. In the deep wells levels are between 8.75 to 19.5m begl with groundwater reduced levels varying between 50.8 and 63.3m AOD across the full extent of the site.

Groundwater monitoring records are included with **Appendix B**.

6.8 Contamination – Visual and Olfactory

Visual and olfactory evidence of contamination was noted during the advancement of the exploratory holes at the site, which is summarised in the table as below.

Table 2 Contamination Evidence of Soils

Location and Area on Site	Depth (m begl)	Strata	Evidence
TP104 – NW Stock Yard	0.3 – 1.35	Cohesive ash-based MADE GROUND	Tar and bitumen odour
TP16 – NW By-products	GL – 0.4	Granular ash-based MADE GROUND	Tar and oil (free product). Hydrocarbon odour
TP16 – NW By-products	1.2 – 1.6	Granular brick MADE GROUND	Black oil (heavy free product). Hydrocarbon odour
TP16 – NW By-products	1.6 >1.8	SANDSTONE	Black oil (heavy) staining. Hydrocarbon odour
TP17 – N By-products	GL – 0.5	Coke, coal and ash MADE GROUND	Oil (heavy) spillage at surface. Hydrocarbon odour
TP22 – Central By-products	0.2 – 0.8	Granular ash-based MADE GROUND	Black oil (heavy) staining. Hydrocarbon odour
TP22 – Central By-products	0.8 – 1.1	SANDSTONE	Black staining. Hydrocarbon odour

6.9 In-ground Obstructions

During the advancement of the trial pits, multiple obstructions were encountered, which in most instances resulted in the termination of the excavation. Within the stock yard area, remnant concrete foundations and substructures were proved between 0.4 and 3.2m begl and exceptionally RBH3A encountered concrete between 0.2 and 3.5m begl. The presence of drains and service cables were also noted. In the former production area, concrete and brick foundations and substructures were encountered between 1.0 and 2.2m begl and between 0.6 and 0.9m begl within the by-products area.

6.10 Gas Monitoring

To date, an initial monitoring visit has been undertaken during a high falling atmospheric pressure condition. Elevated concentrations of carbon dioxide (maximum 7.6% v/v), no methane and correspondingly depressed oxygen concentrations (minimum 5.7% v/v) with minimal flows (maximum 0.4l/hr) were recorded. In accordance with CIRIA C665 the site would be classified as Characteristic Situation 2 (or NHBC traffic light Amber 1) due to carbon dioxide levels of above 5% v/v.

However, any such ground gas classification of the site should be reserved until the full monitoring programme has been completed.

7.0 Generic Human Health Risk Assessment

7.1 Developed Conceptual Site Model

The ground investigation has been undertaken to inform development zoning therefore the layout of the proposed development is unknown. However, a mixed end-use is proposed, likely comprising residential, retail, commercial and leisure with areas of public open space.

Based upon a review of intrusive findings to date and the results of the latest intrusive investigation at the site, a preliminary Conceptual Site Model (CSM) is presented as Table 3 below. This summarises the principal contaminant sources, pathways and receptors at risk at the site and the likelihood of a significant pollutant linkage between the potential contaminants and receptors with respect to the protection of human health.

Table 3 Conceptual Site Model – Human Health

Source(s)	Pathway(s)	Receptor(s)	Risk
Human Health			
General contamination in Made Ground deposits from previous mining and industrial uses which may include: heavy metals, asbestos, polyaromatic hydrocarbons (PAHs), petroleum hydrocarbons (TPH)	Indoor and outdoor inhalation of ground gas and soil vapours, the ingestion of contaminated soil and soil dust and direct contact with contaminated soil and water.	Construction workers and end users of property.	Moderate to High
Contamination arising from specific site processes i.e. coke ovens, gas works, chemical (benzole, ammonia and tar) and fuel storage areas, drains and interceptors which may include the contaminants indicated above plus cyanide, VOCs, SVOCs, chlorinated solvents and PCBs (Polychlorinated Biphenyls)	Indoor and outdoor inhalation of ground gas and soil vapours, the ingestion of contaminated soil and soil dust and direct contact with contaminated soil and water.	Construction workers and end users of property.	Moderate to High
Hazardous ground gas from deep Made Ground deposits, nearby landfills, deep and shallow mine workings and mine entries	Indoor and outdoor inhalation of ground gas and soil vapours,	Construction workers and end users of property.	Moderate to High

It is a certainty that all made ground soils will be excavated and engineered as part of the site enabling works and they have been assessed here on the assumption that the majority will remain on site and be re-used. Dermal contact, ingestion and dust inhalation pathways would be viable if contaminated made ground soils were re-used in landscaping and public open space areas.

Accordingly, both general and contaminant-specific testing of the Made Ground has been carried out for a range of potential contaminants.

The gas generation potential of the deep Made Ground encountered is assessed as being significant. Made ground is extensive, locally deep with quantities of degradable material (timber) present. As such the risk to construction and maintenance workers and future residents/end-users of the site from ground gas is deemed to be moderate to high.

The Generic Assessment Criteria (GAC) used by PPL are presented in **Appendix C**. For this site the chemical analysis results are being compared against both GAC for residential end-use with home grown produce and for a commercial end-use, assuming a conservative Soil Organic Matter value of 1%.

7.2 Soil Analyses and Data Screening

17 No. samples of the Made Ground soils were tested at the laboratory for a range of organic and inorganic chemical compounds.

- **Metals** - Arsenic, Cadmium, Chromium, Hexavalent Chromium, Copper, Lead, Mercury, Nickel, Selenium and Zinc.
- **Inorganics** - pH, Sulphate Aqueous Extract as SO₄, Total Sulphate as SO₄, Chloride Aqueous Extract, Total Sulphur, Ammonium as NH₄ and Aqueous Nitrate as N.
- **Petroleum Hydrocarbons (TPHs)** – Texas band speciation
- **Polyaromatic Hydrocarbons (PAHs)** - USEPA priority 16 PAH compounds
- **BTEX and MTBE**
- **SVOCs and VOCs**
- **Asbestos Screen**

Soils – Residential GAC

The results of the chemical analyses have been compared directly against the GAC appropriate for a residential end-use with home grown produce (conservative). Elevated concentrations of arsenic (39 mg/kg) above the GAC were recorded within samples of Made Ground recovered from the stock yard. Elevated concentrations of lead (210 and 430mg/kg) and arsenic (53mg/kg) above the GAC were recorded within samples of Made Ground recovered from the by-products area. 15 No. Made Ground samples recovered from the by-products part of the site recorded elevated concentrations of a significant proportion of PAH compounds (including naphthalene) as being significantly in excess of the GAC. Samples of Made Ground (5 No.) from the stock yard area recorded concentrations of several PAHs (including naphthalene) in excess of the GAC. TPH Aromatic (C16-21) and to a lesser extent Aromatic (C10-12, C12-16 and C21-35) were present at concentrations elevated above the GAC in the Made Ground sampled from the vicinity of the by-products area. A single sample of Made Ground from the western production area recorded an elevated concentration of benzene above the GAC. Cyanide (TP17, 22 & 27)), Benzene (TP22 & 25) and chromium (TP17) were also found at elevated levels in the By-products area.

The majority of SVOCs and VOCs recorded concentrations at below the limit of detection of the laboratory. However, with respect to the VOCs, a sample of Made Ground recovered from the western production area recorded the presence of 1,3,5 – Trimethylbenzene (170ug/kg) and 1,2,4 – Trimethylbenzene (460ug/kg). Likewise, SVOC derivatives 2-Methylnaphthalene, dibenzofuran and carbazole were identified in the majority of samples taken from the Made Ground present across

the stock yard in the north of the site. Total phenol concentrations recorded 1300mg/kg for a sample of made ground recovered from the western production area of the site. All of the above are reported in terms of their detected presence, but in the absence of published GAC data cannot be compared to such criteria.

None of the samples of Made Ground from the southern part of the site analysed recorded exceedances of the GACs for any of the determinants.

Soils – Commercial GAC

The results of the chemical analyses have been compared directly against the GAC appropriate for a commercial end-use. The majority of determinants recorded concentrations below those of the GAC. However, a sample of Made Ground from the western part of the production area recorded significantly elevated concentrations of the majority of PAHs (including naphthalene) above the GAC. 5 No. Made Ground samples analysed from the by-products area recorded concentrations of various PAHs, including Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(123cd)pyrene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene and Dibenzo(a,h)anthracene in excess of the GAC. Chromium (TP17) and Free cyanide (TP22 & 27) were also encountered at elevated levels in samples from the by-products area

None of the Made Ground samples recovered from the northern stock yard area or the southern part of the site recorded concentrations of determinants as being above the GAC.

Soils – Other

Calorific value determinations on 8 No. samples of the coal-bearing Made Ground recovered from across the stock yard ranged between 0.4 and 18.4MJ/kg with 5 No. at 6MJ/kg or over and 2 No. above 10MJ/kg.

Asbestos was found to be present in 4 out of 15 of the Made Ground samples screened from across the site. Unbound chrysotile fibres were positively identified within 2 samples recovered from the northern extent of the stock yard (TP107 and TP108). A sample of Made Ground from the by-products area tested positive for the presence of unbound Amosite and chrysotile fibres.

7.3 Risk to Services

An assessment of the potential risk to buried services from potentially contaminated soils has not been undertaken as part of this investigation. This should be undertaken once enabling works have been completed and a masterplan has been formulated. Chemical analyses should be undertaken for all mandatory and additional contaminants listed in the UKWIR Report Ref No. 10/WM/03/21 "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites".

8.0 Controlled Waters Risk Assessment

8.1 Developed Conceptual Site Model

As previously cited, the exact layout of the proposed development is unknown, however a mixed end-use is intended, likely comprising residential, retail, commercial and leisure with areas of public open space.

From a review of intrusive findings to date and the results of the latest intrusive investigation at the site, a preliminary Conceptual Site Model (CSM) is presented as Table 4 below. This summarises the principal contaminant sources, pathways and receptors at risk at the site and the likelihood of a significant pollutant linkage between the potential contaminants and receptors with respect to the protection of controlled waters.

Table 4 Conceptual Site Model – Controlled Waters

Source(s)	Pathway(s)	Receptor(s)	Risk
Controlled Waters			
General contamination in Made Ground deposits from previous mining and industrial uses which includes: heavy metals, polyaromatic hydrocarbons (PAHs), petroleum hydrocarbons (TPH)	Leaching of contaminants within the Made Ground through natural deposits into the underlying aquifer or adjacent controlled waters	Solid strata aquifer groundwater Lineside Dyke and Pools Dike Barnsley Canal	Moderate to High Low to Moderate Low
Presence of LNAPLs / DNAPLs (light/dense non aqueous phase liquids) from leaking tar tanks, historic fuel spills, leaking and damaged drains / interceptors	Migration of liquid phase contamination through Made Ground and Natural Deposits to the aquifer beneath the site or Lineside Dyke/Pools Dike or the Barnsley Canal	Solid strata aquifer groundwater Lineside Dyke and Pools Dike Barnsley Canal	Moderate to High Low to Moderate Low

The potential for migration of leached contaminants to enter controlled surface waters and the underlying Secondary A aquifer is considered as being a moderate to high risk given the absence of any cohesive superficial soil cover, shallow rock and proximity of surface watercourses. There is considered likely to be a viable pathway between soil contaminants and the underlying groundwater and as such a quantitative groundwater risk assessment has been undertaken.

It is a certainty that all Made Ground soils will be excavated and engineered as part of the site enabling works and they have been assessed here on the assumption that the majority will remain on site and be re-used. Leaching and migration pathways to the Lineside Dyke and Pools Dike may be viable if contaminated Made Ground soils were re-used and remained on site. Accordingly, general soil leachability testing of the Made Ground has been carried out for a range of potential contaminants and the results have been compared against the freshwater Environmental Quality Standards (EQS) and Drinking Water Standards (DWS) Tier 1 GAC, presented in **Appendix C**. Published information by Yorkshire Water assesses the local controlled surface waters as having a hardness value of 111mg/kg CaCO₃ or high. This has been used to select appropriate EQS.

8.2 Soil Analyses and Data Screening

5 No. samples of the Made Ground were tested for a range of leachable organic and inorganic chemical compounds. 10 no water samples were tested for the same determinants.

- **Metals** - Arsenic, Cadmium, Chromium, Hexavalent Chromium, Copper, Lead, Mercury, Nickel, Selenium and Zinc.
- **Inorganics** - pH
- **Petroleum Hydrocarbons (TPHs)** – Texas band speciation
- **Polyaromatic Hydrocarbons (PAHs)** - USEPA priority 16 PAH compounds
- **BTEX and MTBE**
- **SVOCs and VOCs**

8.3 Assessment of soil leachability results

The majority of the soil leachability determinants were recorded at concentrations below the limit of detection of the laboratory. Detected concentrations of some dissolved metals were recorded, however these were below the GAC for both surface and groundwaters.

8.4 Assessment of groundwater results

Elevated levels of the following determinants were recorded above GAC for surface waters (Environmental Quality Standards).

- Ammonia (RBH1D, RBH2A, RBH3A, RBH4A, RBH5, BH301, BH302, BH303, BH304 & BH305) – whole site
- Nickel (RBH2A, BH301, BH302 & BH303) – Stockyard and by products area
- Benzene (RBH4A) - By products area
- TPH Aromatic C12-16 (RBH1A) - Stockyard
- TPH Aromatic C10-12 & C16-21 (BH305) - By products area
- Total cyanide (BH304) - By products area
- Naphthalene & Anthracene (BH305) - By products area
- Cadmium (BH302 & BH304) – Stockyard and by products area

Elevated levels of the following determinants were recorded above GAC for ground waters (Drinking Water Standards).

- Ammonia (RBH1D, RBH2A, RBH4A, RBH5, BH302, BH303, BH304 & BH305) – whole site
- Sulphate (RBH1D, RBH2A, RBH3A, RBH4A, RBH5, BH301, BH302, BH303, BH304 & BH305) – whole site
- Naphthalene & Anthracene (BH305) - By products area
- Phenols, Arsenic & BTEX (RBH4A) - By products area
- Nickel (RBH2A, BH301, BH302 & BH303) – Stockyard and by products area
- Selenium (RBH1D, BH303 & BH305) – Stockyard and by products area
- TPH Aromatic C12-21 (BH305) - By products area
- Free Cyanide (BH304) - By products area

9.0 Conclusions and Recommendations

The site is proposed for a mixed end-use development comprising residential, retail, commercial and leisure with areas of public open space. At the time of writing a development layout or masterplan was not available.

9.1 Foundations

The most recent ground investigation and earlier intrusive investigations have identified granular and cohesive Made Ground soils to in excess of 4m begl overlying natural predominantly loose to dense residual granular soils or to a lesser extent medium and high strength clays. Either directly beneath the Made Ground or beneath the superficial soils, very weak and weak mudstone and sandstone strata were proved with mudstone only present at rockhead in the northeastern, eastern and southern part of the site.

The following assessment is based on the requirement for extensive earthworks across the site as part of the enabling works to facilitate development plateaus on the site, as a consequence of the fall in existing site levels to the north and south.

It is likely that a mix of foundation solutions would be required due to the variability of ground conditions at the site and depths to competent strata. Where Made Ground is shallow, traditional spread foundations are considered suitable, possibly with localised trench fill, bearing upon the weathered residual soils and rock. In areas of deep Made Ground the use of piled foundations is likely with pile socketed into the underlying rock. The presence of deep and significant remnant foundations and substructures should be anticipated and pre-boring and breaking out of obstructions will be required. The advice of a specialist piling contractor should be sought to allow determination of the most appropriate piling method, pile length and construction and to allow budget costs to be provided. The piling method adopted will need to be robust enough to deal with the presence of such structures. It is likely that following extensive earthworks and engineering of site-derived materials, the use of raft foundations or vibro improvement of soils may be appropriate, depending upon final loadings. A final foundation solution would be determined after further targeted intrusive investigation works have been undertaken and once final levels and ground engineering strategies are determined. These works would most efficiently be carried out in conjunction with the remediation of the site.

At this stage, the weathered granular residual soils are considered capable of sustaining static loads of at least 150kN/m^2 with less than 25mm total settlement, with loads of at least 300kN/m^2 appropriate for the competent sandstone and at least 200kN/m^2 for the weathered mudstone. The loading capacity of engineered soils will depend on the nature of the materials and method of placement, but as a preliminary recommendation such materials would be considered capable of sustaining static loads of at least 50kN/m^2 with less than 25mm total settlement.

9.2 Floor Slabs

The use of suspended floors is considered appropriate given the nature and thickness of Made Ground at the site. However, in areas where Made Ground thicknesses are less than 600mm or where considerable engineering of these soils has been undertaken, then the use of ground bearing slabs may be appropriate.

9.3 Highways and Infrastructure

For the natural cohesive soils and residual granular soils likely to be at formation, preliminary design CBR values of 2% and 3% respectively are recommended with a CBR value of 1% for Made Ground soils, subject to proof-rolling and treatment of any soft spots. Where deep Made Ground is present some re-engineering may be necessary with incorporation of a capping layer and a geotextile may also be required. *In situ* CBR testing will be required, to confirm pavement design, subject to the scope of site enabling works and proposed finished levels. Adoption of site roads may be a requirement by the local authority and subject to their design and approval.

9.4 Groundworks

Generally, excavations within the Made Ground and natural soils should be achievable using conventional plant. However, the use of hydraulic breakers should be anticipated due to the likelihood of the presence of extensive remnant foundations and substructures at the site. Their use should also be anticipated within the rock strata. Excavations will require full support and battering back, in accordance with CIRIA Report 97 Trenching Practice (2nd Edition, 2001). Man entry into unsupported excavations should be prohibited. Excavations should be blinded to prevent softening of the bearing stratum during periods of adverse weather.

Free groundwater is likely to be encountered below 2m depth bgl and adequate control should be achievable using conventional pumped sumps in deeper excavations.

9.5 Buried Concrete Assessment

On the basis of the chemical test results and observations on site, a Class DS-4 AC-5 classification for Made Ground and DS-2 AC-3z for natural soils may be assumed, in accordance with BRE Special Digest 1: 2005 and assuming mobile groundwater conditions.

9.6 Drainage

The use of soakaways is not recommended due to impacted (contaminated) Made Ground and relatively shallow rock (Secondary A aquifer). The use of permeable pavements is potentially viable, subject to control of pollutants and suitability for heavy trafficking, as appropriate.

9.7 Mine Workings and Shafts Stabilisation

The Royston coal seam outcrops across the southern part of the site and is present at shallow depth beneath this part of the site. The southern part lies within a Development High Risk Area and is considered to be potentially at risk from past shallow coal mining, subject to confirmatory intrusive investigations.

Three former mine shafts on site have been confirmed as filled and capped by the Coal Authority. Correspondence is appended. Drawing no G15009-704 shows the estimated location of the mine shafts by superimposition of historical plans on satellite imagery of the site. The constraint posed will therefore be minimal especially as rockhead and the reinforced concrete caps are so shallow. Their precise location should be established and a non-structural zone demarked determined by depth to rock at their location.

9.8 Flooding

The EA website indicates the site as not being within 250m of a Flood Zone 2 or 3. It is recommended that expert advice is taken as regards the requirement for a site specific flood risk assessment ahead of redevelopment of the site.

9.9 Contamination

The developed conceptual site model and risk assessment derived from the results of the intrusive investigations to date indicate that the Made Ground soils and upper natural soils are significantly impacted by heavy metals, TPH, BTEX, PAHs, cyanide, unbound asbestos (Amosite and chrysotile) and potentially solvents including phenols with the potential to significantly harm the human health of construction operatives and end-users of the site.

Leachability analyses has demonstrated that these contaminants do not appear to be readily mobilised with the potential for leaching and impact of nearby watercourses revised to low. Further leachability testing is recommended in close proximity to water courses

The results of the groundwater analyses have identified significant contamination of the groundwater. Levels of Ammonia, Sulphate, PAHs, Benzene, Aromatic TPH fractions, cyanide and heavy metals are elevated above surface water environmental quality standards. However, these water samples are all from within rock and are unlikely therefore to be in hydraulic connection with shallow surfacewaters.

The same results have been assessed against drinking water standards with elevated ammonia, sulphate, PAH, Phenols, BTEX, cyanide, heavy metals and TPH recorded in many locations. Although background water quality is likely to be poor from historic mining activity and its effects on naturally occurring pyritic minerals in the rock, it is likely that much of the contamination is linked to the historic activity of the coke works.

Significant quantities of high calorific value soils have also been identified on site and although it is understood that as much coke as economically practical will be removed from site for commercial sales, it is envisaged there will be a significant volume of material which is a combination of coke and underlying soils. We understand that only part of the coking yard is underlain by hardstanding; the remainder is underlain by soils.

9.9.1 Remediation

Remediation of soils and groundwater will be a prerequisite of development of the site. It is envisaged that remediation will be largely restricted to organic and particularly hydrocarbon contamination of soils. The source of groundwater contamination is likely to be historic spills, leaks and the dilute and disperse waste disposal practices prevalent in the past. As such removal of such gross contamination in the soils will effectively reduce ongoing pollution of the water environment.

The most economic method of hydrocarbon treatment is either natural attenuation or bioremediation. Both these methods are suited to long term treatment programmes, with bioremediation requiring space to stockpile material.

Bioremediated material would be treated to a level where it can either be reused on site freely, or reused with some additional protective measures, or alternatively removed from site but at a significantly reduced cost due to its reduced environmental impact. For example, as non-hazardous waste at one of the more numerous (and therefore hopefully closer) non-haz landfills rather than

as hazardous waste with high haulage costs to one of the (more distant) rare facilities capable of receiving such material.

Natural attenuation involves allowing natural processes of degradation, naturally occurring bioremediation, dispersion, dilution etc to reduce the environmental impact of the contamination over time. Ongoing monitoring is required to demonstrate this is occurring. Some form of source removal is typically also required, in the form of hotspot or tank removal for example.

As much high calorific value material (coke and coal contaminated soils) should be removed from site as possible, ideally as a fuel source and thereafter should be reused on site at depth and well compacted to reduce oxygen flow and separate from any sources of combustion.

Groundwater remediation may be necessary if source removal is not successful, and will primarily be required as a result of hydrocarbon pollution. A variety of insitu or pump and treat methods are available (physical, chemical or biological). Further investigation and groundwater monitoring will be necessary to understand these pollutant linkages, however it is proposed that a source removal strategy be adopted initially, accompanied by monitored natural attenuation of groundwater pollution.

9.10 Potable Water Supply

Based on a preliminary assessment of chemical analyses to date, the use of PE-Al-PE barrier pipe would be recommended to mitigate the risk of water pipe damage and contamination of piped drinking water from Made Ground soils. The final decision will require assessment of results of further chemical testing in accordance with UKWIR recommendations.

9.11 Waste Disposal

Any materials the developer intends to discard during construction would be classed as wastes and must be appropriately handled in accordance with current Waste Legislation and taken off-site in accordance with the Duty of Care Regulations 1991. The developer should be aware of and utilise the waste hierarchy where possible – Reduce → Reuse → Recycle → Recovery → Disposal. Where materials are unable to remain on site and disposal is the only option, the waste should be classified and sent to an appropriate waste receiving facility. Waste Acceptance Criteria (WAC) testing would be required by the waste receiving facility prior to disposal.

A preliminary assessment of chemical testing results to date would suggest that a proportion of Made Ground materials would be classified as Hazardous due to elevated concentrations of TPH, PAHs and the presence of asbestos. It is recommended that asbestos quantification testing is undertaken to better classify these materials.

Development proposals and associated earthworks should consider waste management licensing requirements and costs associated with reuse or disposal of waste materials generated on site.

Silica bricks used to line the ovens will require careful waste management during decommissioning and demolition. This issue will be addressed separately as part of a specific investigation.

9.12 Ground Gas

To date, monitoring has recorded elevated concentrations of carbon dioxide (maximum 7.6% v/v), no combustible gas, minimal positive flow (maximum 0.4 l/hr) and depressed oxygen concentrations (minimum 5.7% v/v). The presence of putrescible made ground sources have been encountered during the intrusive works. Monitoring results to date equate to a gas screening value

GSV) of less than 0.07 l/hr (upper limit for Characteristic Situation 1). However, carbon dioxide concentrations of above 5% v/v would classify the site as **Characteristic Situation 2**, in accordance with CIRIA C665 guidance or **NHBC Amber 1**.

It is recommended that a final gas risk classification is reserved until completion of monitoring and liaison and approval from the local authority.

The site is in an area where basic radon protective measures are currently required for new development. This is likely to require the incorporation of a radon membrane within solum construction.

9.13 Invasive Plant Species

Earlier investigations noted the presence of potential Japanese Knotweed infestation within the extreme northeastern part of the site. It is recommended that this and the remainder of the site be surveyed and confirmed by a specialist. Knotweed eradication is most economically undertaken over a number of years and this issue should be dealt with at the earliest opportunity.

9.14 Regulatory Approvals

It is recommended that this report is provided to the local authority and NHBC, or other buildings insurance provider, for approval of the recommendations.

9.15 Further investigation

Further investigation will be necessary to inform remediation strategies for each part of the site, most effectively undertake once master planning and zoning for different land uses has been determined.

10.0 Development Constraints

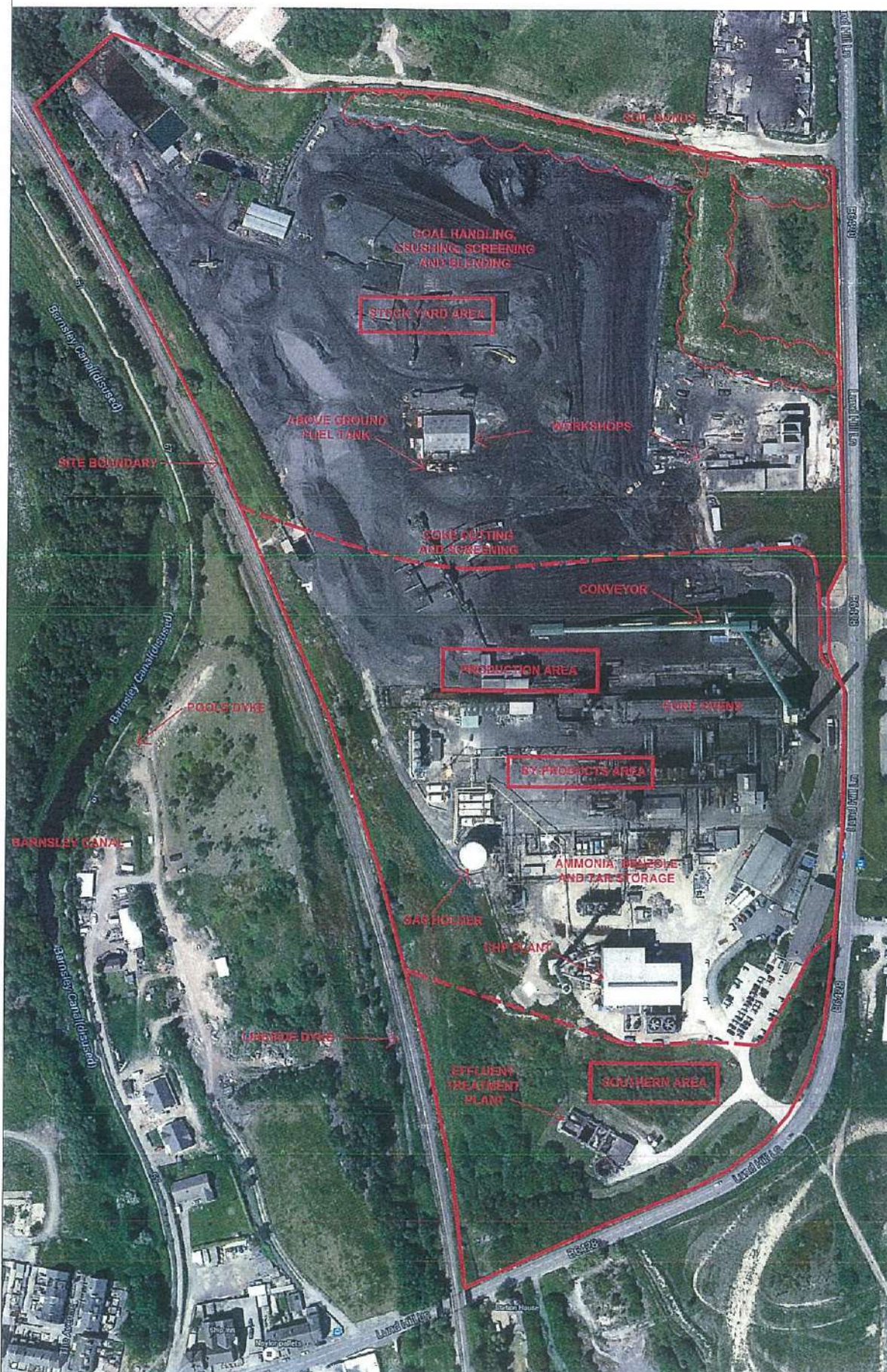
The historical and existing use of the site presents significant constraints to the redevelopment of the site. These are presented as PPL Drawing No. G15009-702, included in **Appendix A**, and summarised below.

Development constraints	Potential solutions
Significant soil contamination by Arsenic, Lead, TPH, BTEX, PAHs, SVOC and asbestos	Encapsulation (or relocation) of inorganic, asbestos and PAH contaminants beneath hardstandings or clean cover in landscaped areas. Treatment of hydrocarbons by bioremediation or monitored natural attenuation.
Likely significant groundwater contamination by heavy metals, cyanide, TPH, BTEX, PAHs and SVOC	Source removal then monitored natural attenuation with possible localised groundwater remediation insitu or by pump and treatment (activated carbon filtration, air sparging or a variety/combination of biological or chemical methods)
Silica bricks and associated airborne dust	To be addressed following separate investigation, though best solution will be to encapsulate on site possible in stabilised form depending upon structural properties
Deep made ground of variable chemical and geotechnical quality	Deeper probably piled foundations or vibro improvement with suspended floor slabs
Possible railway tunnel in the northern part of the site	Further investigation required to confirm location, depth and associated nature of constraint. Provisionally this area may have to be excluded from structural development.
Capped mine shafts (3 No.) in the northern part of the site	Further investigation required to locate shafts and confirm competence of capping. May require capping, treatment or exclusion from structural development
Former infilled sandstone quarry in the southeastern edge of the site	Gas monitoring and more detailed investigation required to confirm nature of constraint. May have to be excluded from structural development
Soil bund of unknown composition within the north/northeastern part of the site.	Further investigation required to ascertain contamination and geotechnical properties. Propose to reuse on site depending upon quality and quantity.
Ground gas derived from on site deep made ground and potentially mining together with off site migration of landfill gas and radon	Further monitoring required but likely that combined vapour, gas and radon membranes will be required in a significant portion of the developed site.
Remnant buried foundations and substructures	These will significantly hinder earthworks and foundation construction and should be grubbed up, crushed and reused on site for piling mat and capping materials

Potential shallow coal mining beneath the southern part of the site	Further investigation required and possible treatment or exclusion from structural development
Former infilled clay pit in the extreme north of the site	Gas monitoring and more detailed investigation required to confirm nature of constraint. May have to be excluded from structural development
Historic above and below ground fuel tanks	All above ground structures will be removed as part of decommissioning and demolition of the site. Buried tanks, pipework etc should be similarly emptied, gas freed, decommissioned and removed from site.
Possible presence on site or at least on perimeter of invasive Japanese Knotweed	Invasive weeds survey required and if necessary herbicide treatment commenced at the earliest opportunity (spraying season is April to October). Three or four years sometimes required for herbicide treatment, otherwise, rhizome contaminated soils to be sieved and buried on site at depth.
High Calorific (coke/coal contaminated) soils	As much coke/coal removed mechanically as possible. High CV soils will be required to be well compacted at depth to eliminate oxygen flow and contact with any sources of combustion

Appendix A Drawings

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Drawing
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