FWS CONSULTANTS LTD
Environmental and Geological Consultants

Merrington House, PO Box 11, Merrington Lane Trading Estate, Spennymoor, Co Durham DL16 7UU
Tel: 01388 420633 Fax: 01388 819705 Web: www.fwsconsultants.com

CONTAMINATION AND GEOTECHNICAL INVESTIGATION OF THE S R GENT PREMISES, DODWORTH ROAD, BARNSLEY

CLIENT:
Price Waterhouse Coopers
Benson House
33 Wellington Street
LEEDS
LS1 4JP

PROPERTY SURVEYORS:
Eddisons Commercial Ltd
Pennine House
Russell Street
LEEDS
LS1 5RN

1082/April 2006

DIRECTORS: F W Smith PhD. F.I.M.M.M. C.Eng. C.Sci B D B Underwood BSc. MSc. M.I.M.M.M. C.Sci CONSULTANTS: J P L Dearlove PhD
J M Overy BSc. Hons. (Civ. Eng.) MIHT FGS C Flett BSc. MSc. FGS D Breckon BSc. MIHT. FGS M Lakey BSc. MSc
C Adams PhD. FGS C P Bell BSc ASSOCIATES: N Rendell BSc. C.Geol. FGS D J Haynes PhD

FWS Consultants Ltd
Company Registration No: 3944252

constructionline

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CONTAMINATION AND GEOTECHNICAL INVESTIGATION OF THE S R GENT PREMISES, DODWORTH ROAD, BARNSLEY

1 INTRODUCTION

1.1 General Background

FWS Consultants Ltd (FWSC) was instructed by Eddisons Commercial Ltd, on behalf of Price Waterhouse Coopers, to undertake a contamination and geotechnical investigation of the accessible parts of the SR Gent premises at Dodworth Road, Barnsley. The factory has recently ceased operations after going into receivership. A small number of staff continue to be employed for general factory clearance, pending a forthcoming auction, and to staff the factory shop, but there were no manufacturing operations at the time of the investigation. It is proposed to offer the site for sale, potentially for a residential development, which has been assessed in this report, although other developments, such as commercial/industrial, may be considered.

1.2 Objectives

The objectives of the investigation were to:-

i) determine the previous uses of the site and immediate surrounding area;

ii) assess current readily available information on the environmental setting of the site and immediate surrounding area, particularly with regard to potential contamination;

iii) undertake a site inspection, to include discussions with the selling agents;

iv) determine as far as reasonably possible the nature, concentration and distribution of certain contaminants in the groundmass on the site;

v) determine potential hazards and the related risks, due to any identified contamination, to construction workers, future occupants, the building and service lines, vegetation, neighbouring properties, underlying groundwater and nearby surface water;

vi) determine the indicative potential foundation requirements for developing the site;

vii) determine the scope for any additional investigation or remedial works required, if appropriate, to enable the proposed development to take place.

No formal building survey (fabric or services) or any assessment of structures was undertaken as part of the investigation.

1.3 Scope of Investigation

The investigation was carried out as a single phase investigation consisting of a desk study; site visit; fieldwork; chemical, asbestos and geotechnical laboratory testing of

selected samples; gas monitoring and groundwater sampling; and the compilation of an interpretative report.

A preliminary site inspection and meeting with site personnel was carried out on 14 February to review the proposed programme and to discuss potential locations for the boreholes. We were advised by the client that, whilst the overall site comprises the SR Gent factory premises and a Shell filling station in the north of the site, only the factory premises were to be included in the intrusive investigation, as the filling station will continue operations after the sale.

The desk study consisted of a review of available historical OS maps (Appendix 1) obtained from Landmark Information Group (Landmark), published information produced by the British Geological Survey (BGS) and a Coal Authority Report (Appendix 2). A review of information obtained from an environmental report produced by Landmark (Appendix 3), using 250 m, 500 m and 1 km search radii centred on the site, was also carried out. This database gives access to a range of UK providers including the Environment Agency, Health and Safety Executive, National Radiological Protection Board, English Nature, Countryside Agency, Catalist Ltd, Department for Environment, Food and Rural Affairs, and the local authority.

The main fieldwork was carried out between 20 February and 24 February 2006 and consisted of the drilling of 25 boreholes to a maximum depth of 6.0 m using a tracked mini drill rig (MBs) and the drilling of six boreholes to a maximum depth of 11.0 m using a cable percussion drilling rig (BHs). Four of the exploratory holes were located around the Shell filling station.

The fieldwork was undertaken in general accordance with guidelines laid out in the British Code of Practice BS10175:2001 (Ref. 1) and BS5930:1999 (Ref. 2). All of the boreholes were logged by an experienced geoenvironmental consultant. Representative soil samples were collected from both boreholes for chemical and asbestos testing. Representative soil samples were initially tested for organic vapours by headspace analysis using a Thermo Electron 580S portable organic vapour meter (OVM), calibrated on isobutylene. The soil samples for chemical analysis were placed in HDPE bags and glass jars and transported to AES Ltd, an MCERTS/UKAS accredited laboratory. Selected soil subsamples were analysed for asbestos by MIS Ltd, a UKAS accredited laboratory. Selected soil samples were also transported to Professional Soils Laboratory Ltd (PSL) for geotechnical testing.

In-situ standard penetration tests (SPTs) were carried out in the cable percussion boreholes to give an indication of relative densities of granular soils and to allow an assessment of the condition of the rockhead materials. In some instances, penetration tests were carried out in the natural cohesive deposits to provide guidelines for pile design parameters. On completion, all of the cable percussion boreholes and three of the mini rig boreholes were equipped with 50 mm diameter HDPE standpipes, with a lower slotted section surrounded by gravel below an upper plain section surrounded by a bentonite seal, for gas/groundwater monitoring purposes. The installations were completed with gas valves and lockable steel covers, concreted in at the surface. Prior to this, the underlying portions of the boreholes were backfilled, where necessary, with the arisings, and covered with a bentonite seal. The relevant boreholes were subsequently purged (three well volumes), during the monitoring period, and water

samples collected using dedicated HDPE bailers. The standpipes were monitored for methane, carbon dioxide and oxygen concentrations, and total gas flow, and the general weather conditions were recorded, at approximately weekly intervals for four weeks.

2 SITE DESCRIPTION

2.1 Site Location

The irregular shaped site is centred on approximate NGR 432950, 406140 and occupies an area of approximately 4.5 ha. It is located in what is generally a residential area, approximately 1.5 km to the west of central Barnsley, and about 0.7 km from Junction 37 of the M1.

The site is bordered to the north by Dodworth Road and recreational open space beyond; to the west, southwest and northeast by residential housing; to the south by recreational open space; and to the east by recreational open space and The Firs and Dorothy Residential Care Home.

2.2 Site Features

Access to the factory site is made from Dodworth Road by means of a manned security office and security barriers. The configuration of the barriers allows for either access to the main visitor car park immediately to the east, in front of the factory (and used continuously by visitors to the factory shop, located in the northwestern corner of this building), or for access for deliveries, etc., to the southern part of the site.

The site generally slopes gently from north to south, but rises in the southwestern corner, to a level approximately 5 m above the rest of the site, formed by a grassed mound with a small car park constructed on the top. The factory site comprises two large buildings, a handful of out buildings housing an electricity sub station, a gas governor, a compressor room, etc., substantial areas of tarmac hardstanding and some minor areas of landscaping. The building occupying the north of the site comprises the main factory offices, and dining facilities at the northern end, a small engineering workshop and a large open-plan operational area. At the time of the fieldwork, this area had been largely cleared of machinery, apart from two long (material cutting?) machines, and the remaining open area was in use to display office equipment, furniture and some items of machinery ready for subsequent auction. For the purposes of this report this building is referred to as Building 1.

Building 2, the larger building, occupies the southern and eastern part of the site. This had, historically, comprised two separate buildings that have been subsequently linked together by the construction of an additional factory building between the two. Inside the building there are clear demarcations separating the three sections of the building. The interior of Building 2 contains extensive factory infrastructure, predominantly long lines of racks, used to store and manoeuvre hanging garments, over two floors within the building. Several metal staircases allowed access to the first floor, which comprised a metal mesh floor. Whilst the wide aisles ensured problem-free access throughout the building for the mini drill rig, the low infrastructure and metal ceiling to the first floor restricted the location of the boreholes considerably due to the height clearance required for the mast.

The main reception for visitors to the factory is located on the northern end of Building 1. Visitor car parking is also provided between the building and the Shell petrol filling station and also to the east of the garage, with a wooden fence and line of conifers marking the northeastern site boundary. The petrol filling station is separated from the factory site by a white wooden fence with trees and shrubs and a narrow grassed border. There are also a few mature trees in a grassed area to the west of the filling station and an ornamental fish pond, containing some very large koi carp, with a patio seating area to the northwest of Building 1.

The eastern site boundary borders an access road to the adjacent residential care home and the two are separated by a palisade fence and line of conifer trees. The old quarry wall is clearly visible along this boundary and, as the quarry wall rises and the site gently slopes away, there is a height difference of some 6 to 7 m from the factory floor level and the top of the sandstone escarpment. The sloping area between the quarry wall and the factory has been grassed with some seating added. Approximately half way down the eastern side of Building 1, the historical quarry opens out in an easterly direction. This area is tarmac covered and used predominantly as a car park. A small one storey prefabricated building is also sited in the northwestern corner of this open area. A fairly narrow space between Buildings 1 and 2 provides vehicular access to this car park, and also incorporates a 'walkway' between the two buildings for personnel, forklift trucks, etc.

The historical quarry wall continues to form the eastern site boundary to a point close to the northeastern corner of Building 2, where it gradually dips to almost ground level and then extends further to the east, beyond the site boundary. The area beyond the fence has been developed into a recreational grassed area, forming a horse-shoe shape of low ground (probably delineating the extent of the old quarry), with a footpath. The northeastern corner of the site backs onto domestic gardens. To the south, along the eastern edge of Building 2, the boundary is delineated by a metal palisade fence, with a variable gap of up to 5 m between the fence and the eastern extent of Building 2. This strip of land (approximately 40 m long) is partly covered in pea gravel, along the side of the building, and partly overgrown with grass, weeds and shrubs. Several exit doors, presumably fire exits, open out, from Building 2, onto concrete plinths set into the gravel.

To the south of Building 2 another tarmacced area opens out, enclosed by the old quarry wall on the eastern, southern and western sides. The quarry face rises to approximately 5 to 6 m above the factory level, at its highest point; the top 1 to 2 m comprising grass, trees and shrubs and a 2 m high concrete post and wire fence. At the time of the fieldwork, this area was being used to store a number of articulated trailers and tractor units, but would have also been used for loading/unloading into the southern end of the factory, as indicated by the loading bays. This area also houses a large circular water tank and pump house for the factory's sprinkler system. A small locked metal shed (unknown use or contents) was located alongside the pump house together with a raised bunded tank (approximate dimensions; 2 m x 1.5 m x 1 m). Although not indicated, this is likely to contain either heating oil or diesel. Other items stored in this area include two empty drums each of Elf Lubricant and Automotive TFR alkaline cleaner, several wooden pallets and some sacks of rock salt. Vehicular access to this southern part of the site is made via an access road that rises steeply uphill in the southwestern corner of the site. (This area probably represents stone that

was not quarried out.) A further car park is located on top of this topographical high feature (approximately 5 m above the site level), although coned off preventing its use at the time of the fieldwork. The tarmac is of particularly poor quality in this small car park, having been rutted by heavy plant and also some evidence of subsidence due to slope instability. The slopes to the east, north and west are grassed with a few small trees.

The recreational grassed area extends round to the south of the site, beyond the southern site boundary, and around to the southwest of the site. (The footpath also extends around and follows the entire length of the western boundary, running alongside the houses, to Dodworth Road.) There are padlocked double gates in the fence in the southwestern corner of the site, blocked by a wooden pallet of sacks of rock salt.

The area to the south of Building 1 and to the west of Building 2 had been used for the main transport operations. At the time of the fieldwork a large number of articulated trailers had been parked along the southern part of this area. Along the southern side of Building 1 there were several re-cycling skips that were still in use, together with a large stack of pallets. A further large circular water tank, identical to the one in the southern part of the site, and housing water for the sprinkler system, was situated behind the line of trailers, at the base of the grass slope. Beside this tank, stood a brick built compressor house that provided compressed air to operate some of the machinery, and also a metal container for the storage of liquid petroleum gas bottles.

The western boundary comprises a combination of concrete post and wire fencing, topped with barbed wire, metal post and wire fencing and a short section of brick wall. From approximately half way along the site, to the entrance with Dodworth Road, the boundary also comprises a grassed bank up to the fence, approximately 3 m in height at its highest point, planted with a few mature trees. This bank flattens out to a grassed area with seating and a lay-by for parking. The grassed area leads up to a wooden 'garden' shed, a brick built sub station and a brick built gas governor.

Detritus scattered around the site was generally confined to wind blown debris along the site margins. This comprised drinks cans and bottles, fast food containers and packets, pieces of polythene and paper. The exception to this was a pile of various types of rubbish behind the circular water tank in the south of the site. This comprised broken road cordon barriers, plastic bags, cardboard, fast food containers, drinks cans and bottles, and piles of soil.

The site and adjacent areas were also inspected for invasive plant species. Several areas of Japanese Knotweed infestation were in evidence:

- along the eastern margin, beside the gas governor (a stretch of approximately 10 m by 1 m wide along the site boundary);

- along the western end of the southern site boundary (a clump of approximately 7 m x 10 m extent);

- along the low walled northern boundary with Dodworth Road, to the west of the petrol filling station (a stretch of approximately 5 m by 1 m) and also within the

vegetation within the western boundary with the filling station (a stretch of approximately 5 m, but the extent of the infestation within the existing thick vegetation still needs to be determined);

- approximately 7 m beyond the southern boundary fence, on top of the quarry face in the south of the site. At present this is well outside the site boundary, but has the potential to encroach closer over time if not managed appropriately.

2.3 Site History

Information on the historical development of the site was obtained from the OS maps provided by the Landmark Group. Copies of the main maps are provided in Appendix 1.

The first edition map (1855) shows the majority of the site to be under agricultural use. A sandstone quarry is shown in the northern corner, adjacent to Dodworth Road, a northwest/southeast orientated track cut across the southwestern corner of the site, and a small stream orientated north/south cut across the northwestern corner. A railway lay approximately 170 m beyond the northern site boundary. The area at this time was predominantly agricultural in nature. By 1893 the small sandstone quarry in the northern corner had been infilled and the track diverted along the western boundary of the site, so it no longer crossed the site. At this time a brick works, with associated clay pits, kiln and buildings, had become established to the northwest, on the opposite side of Dodworth Road, between the road and the railway. Three old shafts are also identified within the brickworks site. By 1906 the clay pits had extended onto the northern part of the present site and a tramway extended northwards from this pit, passing beneath Dodworth Road, to the clay pits on the northern side of the road. A very small building is shown on the site, in the northern margin of the pit. The pits had also been extended on the main brickworks site, to span the entire area between the road and the railway, and the western most pit incorporated a body of water at this time.

Between 1906 and 1931 the excavation of the clay pit had extended to the southeast and had covered a large portion of the present site. The tramway had also extended and reorientated to a northwest/southeast alignment, leading direct to the main building of the brickworks. The very small building previously situated in the north of the site had been removed and the small stream had been culverted beyond the western part of the site. In addition, several residential buildings had been established just to the west of the site, bordering the southern side of Dodworth Road, and also to the northeast of the site, bordering the northern side of Dodworth Road. The clay excavations immediately to the north of the site are shown as rough pasture at this time, indicating that excavation of the clay had ceased and the pits abandoned. Approximately 80 m to the northeast of the site, spoil heaps and two shafts had also become established (although the shafts were already identified as 'old'). More houses and allotment gardens had been established to the east beyond the spoil heaps.

By 1956 the extent of the clay pit had reached the southern site boundary and beyond the eastern site boundary, although the pit was identified as 'old clay pit' at this time and the ornament around the southern and eastern boundaries indicates a quarry, rather than pit. Further residential development had also occurred at this time, adjoining the

northeastern and western boundaries; the latter development leading from a new road (Broadway) 75 m from the western site boundary.

By 1960, the clay pit/quarry had not encroached any further and is identified as disused. The eastern extreme of the excavation contained a pond at this time; the pond itself spanned the eastern boundary. Further residential development had also taken place adjacent to the western boundary and the brickworks buildings to the north had been demolished, the clay pits infilled, and the area levelled, with only the disused shafts and three buildings remaining. There is no indication of the stream to the west or to the north of the site at this time.

At some time between 1966 and 1969 a petrol filling station had become established in the north of the site, adjacent to Dodworth Road, and the area of the site immediately to the south of the filling station (northwest of the centre of the site) is identified as a refuse tip. Residential development had also extended around the southwestern corner of the site at this time.

The pond that had spanned the eastern site boundary had been infilled at some time between 1973 and 1975 and development of the site had begun with a rectangular building, identified as a clothing factory, occupying the south of the site. By 1978 the entire site had been developed with three large buildings (the southern building having been extended), a few smaller buildings, access roads and hardstanding. At some time before 1991, the two southern most buildings had been joined to form one large building. Two circular tanks are identified; one in the southeastern corner, and another to the west of the largest building. At this time a footpath had also been established leading from the housing estate to the east of the site, past the southern site boundary, and along the western boundary to the housing estate to the west of the site.

The configuration of site buildings remains the same to the present day.

3 ENVIRONMENTAL SETTING

3.1 Geology

Published information from the British Geological Survey (Ref. 3) indicates that the site is underlain by Carboniferous Middle Coal Measures strata (typically mudstone, shale, coal and sandstone horizons), with sandstone originally directly below the eastern portion of the site. There are no drift deposits indicated to be present.

3.2 Mining Information

A recently commissioned coal mining report (Appendix 2) from the Coal Authority has indicated that the site is within the likely zone of influence on the surface from workings in eight seams of coal at 40 m to 330 m depth but, as the last date of working was 1972, ground movement from these past workings should by now have ceased. The Coal Authority advise (via a subsequent telephone conversation) that the shallowest seam to have been worked is the Swallow Wood seam and they consider any further unrecorded workings, between 0 and 30 m deep, highly unlikely. The site is not within the zone of likely influence on the surface from any present, or known future, underground coal workings. The site is reported not to be located within the

boundary of a previous opencast site, or within 200 m of a current opencast site, or within 800 m of a known future opencast site.

The Coal Authority has no record of any mine entries on the site, or within 20 m of the site boundary. The Coal Authority has no records of any fault or other line of weakness at the surface having affected the stability of the property, or of any notice of the risk of the land being affected by subsidence being given under the Coal Mining Subsidence Act 1991, or of any related damage notice or claim having been given, made or pursued in respect of the property since 1 January 1984. The property does not lie within a geographical area in respect of which notices of entitlement to withdraw support have been published or revoked. The site does not lie within a geographical area for which a court order has been served to allow coal to be mined in the national interest.

3.3 Hydrology

A review of Environment Agency information in the Envirocheck report (Appendix 3) indicates that there are no surface water bodies, for which it has quality data, within the 1 km search radius, and no discharge consents within the same radius. The Agency records one pollution incident within the 250 m search radius; a minor incident involving a spillage of oil on the site itself in 1996. There are no enforcement or prohibition notices recorded within 1 km of the site, or licensed surface water abstractions within the same radius.

Information acquired on the Environment Agency's website indicates that the site is not within a flood plain, or area of extreme flood, and is therefore at low risk from flooding, with the chance of it flooding each year estimated at 0.1%, i.e. 1 in 1000, or less.

3.4 Hydrogeology

The underlying strata are classified as a minor aquifer on the Agency's Groundwater Vulnerability Classification (Ref. 4), originally overlain by soils of a high leaching potential (a worst case vulnerability classification is assumed due to the urban nature of the area and the limited amount of data available). There are no recorded groundwater abstractions on or within 500 m of the site. The site does not lie within an Environment Agency Groundwater Protection Zone.

3.5 Landfills, Waste Treatment and Transfer Sites

The local authority and the BGS both record landfills on the site that correspond with the area on the historical maps identified as a refuse tip. No further information is provided in the Envirocheck search. The local authority also records a landfill nearby, on the opposite side of Dodworth Road, in the area of the historical brick works and clay pits, and also records landfills 174 m and 188 m to the north, close to the railway.

Information obtained from Barnsley Metropolitan Borough Council (Appendix 4) advises that it has no further information regarding the materials disposed of within the sites. In addition, gas monitoring using a spiker bar has been undertaken on the site itself, and also on the site on the opposite side of Dodworth Road, revealing elevated

levels of methane and carbon dioxide (no data provided). This has resulted in a Category 1 status being applied to the site by the Council, which indicates that it could have elevated levels of methane and/or carbon dioxide present.

There are no Waste Transfer sites or Treatment/Disposal sites within the 250 m search radius.

3.6 Licensed Authorisations

The Envirocheck database does not record any IPPC [Part A] authorisations for regulating major processes emitting discharges direct to land, water or air, or any IPC [Part B] consents for processes emitting discharges direct to air, within 450 m of the site. There are two recorded local authority PPCs (air pollution control) for processes emitting discharges direct to air within the 250 m radius. One of these relates to the petrol filling station on the site itself, and the other relates to respraying operations at Polar Motor Co Ltd, 212 m to the northeast of the site.

The Agency has no recorded radioactive consents relating to the site or within 700 m of the site.

3.7 Health and Safety Executive/Planning Department Information

There are no recorded Control of Major Accident Hazards (COMAH) sites or hazardous substance consents within the 1 km search radius. There are also no recorded installations handling hazardous substances, in accordance with the Notification of Installations Handling Hazardous Substances (NIHHS) Regulations 2002, within the same radius.

3.8 Radon Risks

Current guidance (Ref. 5) on protective measures for new dwellings, or similar buildings such as offices or schools, indicates that the site does fall in an area where radon protection measures may be required based on National Radiological Protection Board (NRPB) data. The site also falls in an area for which the guidance indicates that it would be advisable to have a site specific geological assessment carried out by the BGS if new dwellings, or similar buildings, were to be considered in the future. BGS information in the Envirocheck report confirms that basic radon protection measures are necessary in the construction of such buildings.

3.9 Sensitive Land Uses

There are no recorded sites of Special Scientific Interest (SSSI), special areas of conservation, protection areas, international wildlife areas, national nature reserves, areas of outstanding natural beauty, national parks, or nitrate sensitive areas, within the 1 km search radius. The site and surrounding area lie within a nitrate vulnerable zone (nitrate polluted public drinking water sources related to agricultural activities), but this is not likely to be relevant to the proposed development.

3.10 Surrounding Industrial Operations

With the exception of the fuel station in the north of the site, there are no other current ones within 250 m of the site (one associated with the Polar Motor Company located to the northeast of the site is identified as obsolete). The area is predominantly residential in nature and thus there are very few businesses in the immediate vicinity.

4 GROUND CONDITIONS

4.1 General

The boreholes have provided more information on the nature of the soils underlying the site. The ground conditions encountered are described in the following sections and the positions of the boreholes, together with the logs, are provided in Appendix 5.

4.2 Made Ground

Made ground was encountered in all of the mini-rig and cable percussion boreholes to depths varying between 0.3 m (MB 7) and 9.0 m (BH 1), and less than 5.0 m outside the northern margin area. The deepest made ground was encountered in the northeastern corner of the site, to the east of the petrol filling station. The shallowest was encountered in the central area of the site, extending to the southwestern corner, to a topographical high, representing bedrock that had not been historically quarried.

All of the boreholes located inside the buildings encountered concrete, whilst all of the exterior boreholes were positioned over tarmac (except MB 3 which was located in an area of landscaping, and MB 24 which was located over ornamental pea gravel). All positions required pre-coring, except the latter and a handful of boreholes that were positioned over relatively thin tarmac. Twenty seven of the boreholes encountered dolomite aggregate as the upper layer of made ground (maximum depth 0.7 m; BH 6). This was absent in MB 3 (located over an area of landscaping), MB 18 (substituted by a layer of sandstone gravel and brick fragments), MB 21 (substituted by a layer of brick rubble with some concrete, sandstone and cinders) and BH 4 (substituted by a layer of mudstone gravel and brick fragments).

Beneath these upper layers, further made ground was encountered in 29 boreholes, comprising a mixture of gravel fill and clay fill, and often both in a single borehole. The gravel constituents, present in the clay also, comprised sandstone, mudstone, brick, concrete, cinders and occasional clinker, coal and red shale. Brick, concrete and sandstone were found up to cobble size. The remaining two boreholes (MB 7 and BH 4) encountered natural ground immediately beneath the upper layer of made ground (dolomite gravel fill, and mudstone and brick fill, respectively).

Three boreholes (MB 2, MB 3 and MB 23), all located in the north of the site, encountered a layer of ash up to 0.25 m thick within the top 1 m of made ground. Six boreholes (MB 1, MB 2, MB 5, MB 6, MB 21 and MB 22) encountered brick rubble, up to 0.3 m thick, also within the top 1 m of made ground.

Other artefacts within the made ground were fairly scarce, but included pieces of wood, plastic drain pipe, roofing tile, glass and a single piece of asbestos cement board

(MB 2). Thin layers of rotting vegetation were also encountered in MB 12 (grass; 1.45-1.48 m), MB 20 (grass, roots and straw; 3.8-4.1 m) and MB 24 (roots at 2.8 m).

Periods of mini-rig drilling with little or no returns were recorded in MB 9, MB 14, MB 19, MB 21 and MB 25 due, in all cases, to the pushing down of cobbles of either brick, concrete, sandstone or mudstone.

Layers of mottled clay have been recorded in the logs of seven boreholes. These were generally encountered at the base of the made ground, with the exception of MB 2, where it occurred between other made ground deposits (1.6-3.2 m).

Odours were recorded from made ground materials in MB 8 (diesel odour; 2.6-3.2 m), MB 9 (hydrocarbon odour; 3.6-3.9 m), MB 14 (slight hydrocarbon odour; 2.0-3.0 m), MB 20 (stale odour from rotting vegetation; 3.8-4.1 m, and a white spirit odour; 4.3-4.4 m), BH 1 (slight hydrocarbon odour; 0.3-0.9 m) and BH 6 (slight hydrocarbon odour; 0.1-0.7 m). Elevated OVM readings were detected in three of these samples; MB 8 (44.3 ppm), MB 9 (62.0 ppm) and MB 20 (29.6 ppm).

4.3 Natural Ground

Natural ground was encountered beneath the made ground in 27 of the boreholes at depths between 0.3 m (MB 7) and 9.0 m (BH 1). This generally comprised a moderately to highly weathered mudstone, sometimes friable and occasionally carbonaceous. Mudstone was encountered interbedded with sandstone in MB 11 from 0.45 m and a deposit of coal was encountered from 1.75 m to at least 2.0 m in MB 10. Borehole MB 6 refused on mudstone at 0.6 m. In view of the shallow mudstone encountered in MB 7, approximately 50 m to the northwest, it is likely that this represents true bedrock, rather than a mudstone cobble or boulder within made ground.

Diesel odours were detected in mudstone samples from MB 21 and MB 22, located inside, and along the western wall of, Building 1, and from MB 23, located close to MB 8 and MB 9 that also had odours within the made ground. Elevated OVM readings were detected in two of these samples; MB 21 (51.2 ppm) and MB 23 (31.4 ppm).

4.4 Groundwater

Water strikes were recorded within the made ground in three of the cable percussion boreholes (depths between 1.1 and 5.75 m) and in three of the mini rig boreholes (depths between 2.2 and 3.6 m), during drilling. A water sample was obtained from MB 9 during drilling. Water was also encountered within the natural mudstone in MB 2, MB 12, MB 21, MB 22, MB 23 and MB 24.

Samples were also taken from BHs 1, 2, 3, 4 and 6 and also MB 2 and MB 8 during the first monitoring visit. All standpipes were purged of three well volumes prior to sampling for chemical analysis. The standpipe in BH 5 remained dry for the whole of the monitoring period, whilst water levels in the remainder fluctuated slightly over this period.

Water sampled from BH 6 had an oily odour coupled with slight surface iridescence and water from MB 8 and MB 9 had diesel odours and an iridescent film on the top of both.

4.5 Foundations and Subsurface Obstructions

None of the boreholes encountered any foundations or subsurface obstructions, except those larger cobbles and boulders mentioned in Section 4.2, above. It is quite likely, however, that the foundations for the existing buildings, and possibly the ground floors, are supported on a piled system and these may be encountered during development of the site.

5 ASSESSMENT OF CHEMICAL ANALYTICAL RESULTS

5.1 Introduction

The chemical analytical results are assessed against the current UK CLEA guidelines for metals/metalloids and phenols relating to long term human health impacts for a residential with plant uptake after-use, and a combination of other guideline values, as identified, to assess the potential risk to other receptors. These include construction workers, buildings and services, landscaped borders, neighbouring properties and the underlying groundwater.

The CLEA guidelines consist of Soil Guideline Values (SGVs) derived using the Contaminated Land Exposure Assessment Model and replaced the former UK ICRCL guidelines (Ref. 6) that were withdrawn in December 2002. The CLEA SGVs are intended to be used as "intervention values", in assisting local authorities in making determinations of contaminated land, and in selecting remediation standards for individual sites. Currently published Soil Guideline Values (Ref. 7) and supporting documentation relate to the potential impact of identified contamination on human health over an individual's childhood or lifetime for certain land-uses (residential with and without plant uptake, allotments and commercial/ industrial). There are no currently available SGVs for several potential determinands and FWSC has used Generic Assessment Values (GAVs), calculated using the CLEA model, for selected determinands. Where relevant, the risks due to short term exposure, to other potential end-uses (e.g. public open space – SGVs currently being developed), and to other potential targets (e.g. controlled waters, ecosystems, buildings and services, crops or livestock) still require assessment using other good practice guidance.

FWSC has therefore used a combination of CLEA, and other guideline values for the overall assessment of the results obtained. These assessment values include, where appropriate, current Dutch Guidelines (Ref. 8), that use "target values" (TVs), below which there is no demonstrable pollution, and "intervention values" (IVs), above which the levels of the contaminants in the soil and groundwater may impair or threaten the use of the soil by humans, plants and animals and may require treatment. Although legislated application of these guidelines for clean-up is restricted to sites within the Netherlands, where soils are often in close proximity to sensitive groundwater, they have a scientific, risk assessment, basis and can provide a yardstick against which the identified contaminants can be assessed. Groundwater analytical results have been compared against Dutch IVs, and UK water quality standards (both Environmental

Quality Standards [EQS] and Drinking Water Quality Standards [WQS]). Drinking water standards are, however, generally too stringent for perched groundwaters with no use as a potable source, or any potential connection to deeper aquifers or surface waters, and should be used only where they are relevant to the site being assessed (Ref. 9).

A total of 77 soil samples (comprising 61 made ground and 16 natural soils) obtained from the fieldwork was analysed for pH, total sulphate, chloride, total cyanide, total phenols, toluene extractable matter, total arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. Nineteen soils were also analysed for water soluble sulphate, six soils were analysed for Semi-Volatile Organic Compounds and Volatile Organic Compounds, and eight made ground samples were also analysed for asbestos. Eight waters and five synthetic leachate samples were analysed for pH, sulphate, chloride, cyanide, phenols, total petroleum hydrocarbons (TPH), arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. Three of the water samples were analysed for Semi-Volatile Organic Compounds.

The results of the analytical testing programme are provided in the analytical sheets in Appendix 6, and summarised and assessed in the following sections with regard to the associated potential hazards.

5.2 Soils

TABLE 1: MADE GROUND

Determinand	*Units*	*Assessment Value (AV)*	*No. of samples*	*No. of samples exceeding AV* [A]	*Max*	*Min*	*Mean* [B,C]
pH	-	<5	61	0	10.8	6.7	-
Sulphate (Total)	mg/kg	1000	61	26	6300	50	1060
Chloride	mg/kg	100	61	17	870	5	109
Sulphate (Extractable)	g/l	0.5	17	4	1.6	0.05	0.46
Cyanide (Total)	mg/kg	20	61	0	1.2	0.2	0.23
Toluene Extractable Matter	mg/kg	2500	61	6	33000	215	2165
Phenolics (as phenol)	mg/kg	5	61	0	3.7	0.5	0.61
Arsenic (Total)	mg/kg	20	61	3	31	1.2	9.5
Cadmium	mg/kg	8	61	0	0.6	0.1	0.15
Chromium	mg/kg	130	61	2	700	4	42
Copper	mg/kg	600	61	0	110	3	34
Lead	mg/kg	450	61	1	1100	7	45
Nickel	mg/kg	50	61	3	91	7	31
Zinc	mg/kg	3000	61	0	310	8	98
Mercury	mg/kg	8	61	0	0.93	0.03	0.1
Total Petroleum Hydrocarbons	mg/kg	5000	8	4	32000	35	7604
Asbestos	%	detected	8	0	-	-	-

[A] or below AV for pH

[B] arithmetic mean except for lead (geometric mean)

[c] all data related to human health passed mean value test (US_{95}<AV) except TEM and TPH, as discussed in text.

TABLE 2: NATURAL SOILS

Determinand	*Units*	*Assessment Value (AV)*	*No. of samples*	*No. of samples exceeding AV* [A]	*Max*	*Min*	*Mean* [B,C]
pH	-	<5	16	0	9.0	6.6	-
Sulphate (Total)	mg/kg	1000	16	0	920	50	245
Chloride	mg/kg	100	16	0	100	5	28
Sulphate (Extractable)	g/l	0.5	2	0	0.17	0.05	0.11
Cyanide (Total)	mg/kg	20	16	0	0.4	0.2	0.21
Toluene Extractable Matter	mg/kg	2500	16	0	2700	215	515
Phenolics (as phenol)	mg/kg	5	16	0	0.5	0.5	0.5
Arsenic (Total)	mg/kg	20	16	0	12	0.4	4
Cadmium	mg/kg	8	16	0	0.7	0.1	0.17
Chromium	mg/kg	130	16	0	33	9	18
Copper	mg/kg	600	16	0	63	9	38
Lead	mg/kg	450	16	0	48	16	29
Nickel	mg/kg	50	16	3	100	14	44
Zinc	mg/kg	3000	16	0	140	28	93
Mercury	mg/kg	8	16	0	0.36	0.03	0.05
Total Petroleum Hydrocarbons	mg/kg	5000	2	2	10000	9600	9800

[A] or below AV for pH

[B] arithmetic mean except for lead (geometric mean)

[c] all data related to human health passed mean value test (US_{95}<AV) except except nickel and TPH, as discussed in text.

pH

The pH values of the made ground samples ranged from slightly acidic to very strongly alkaline (6.7 to 10.8). The pH values of the natural soils ranged from slightly acidic to moderately alkaline (6.6 to 9.0). The lack of any significant acidity in the groundmass materials will tend to decrease the potential for aggressive ground conditions with respect to concrete structures, and the availability of any metal contamination present that could be potentially phytotoxic (harmful to vegetation) in any future landscaped borders.

Sulphate

The total sulphate concentrations (by BS1377) of the made ground samples ranged from <100 to 6,300 mg/kg. The total sulphate concentrations of the natural soils fell within the range <100 to 920 mg/kg.

Recent guidance (Ref. 10) for assessing concrete requirements in aggressive ground is based on water soluble sulphate analysis in soils and, where applicable, sulphate levels in groundwater. Water soluble sulphate analysis (by BS1377) was carried out on 15 made ground samples and four natural soil samples, including all those with the highest total sulphate levels. Concentrations of <0.1 to 1.6 g/l were determined for the made ground (with the mean of the highest 20% equal to 1.2 g/l) and of <0.1 to 0.17 g/l for the natural ground (with the highest of the two values equal to 0.17 g/l). The overall

soil sulphate results indicate that sulphate resistant concrete will be required, as discussed in Section 7.5.

The elevated total sulphate levels, and the presence of ash, indicate that the soils are likely to be potentially aggressive with regard to buried metal pipes (Ref. 11).

Chloride

Seventeen of the soil samples (all made ground) had a chloride concentration (870 mg/kg maximum) in excess of the trigger concentration of 100 mg/kg, suggested by the German Gas and Water Association (given in Ref. 11) for potential corrosion of buried metal pipes. The levels identified thus again indicate that the soils are likely to be potentially aggressive with regard to buried metal pipes.

Cyanide

None of the soil samples tested had a total cyanide level, or 95th percentile mean value for the natural or made ground, in excess of the Dutch Intervention Values for free cyanide and complex cyanide (20 and 50 mg/kg respectively). The maximum value tests with respect to both made ground and natural soils indicate the potential presence of outliers in the data sets. However, since there are only five positive values, and the remaining 72 undetected (<0.4 mg/kg), these do not represent potential contamination 'hotspots' that would potentially require further investigation. The low levels of cyanide identified (1.2 mg/kg maximum), therefore, give no cause for concern with regard to human health hazards, water contamination or phytotoxicity.

Phenols

None of the soil samples tested had a concentration (3.7 mg/kg maximum; MB 22/3) that exceeded the level of 5 mg/kg, above which protective measures are normally advised for drinking water pipes, due to the potential permeation of plastic service pipes and tainting of drinking water supplies by simple phenols (Ref. 12). Therefore, all of the detected concentrations were well below the recently published CLEA SGVs with regard to long term human health for residential or commercial development (78 to 78,100 mg/kg depending on type of development and soil organic matter content). Seventy two of the phenol levels were undetected (<1.0 mg/kg) and thus the data population is artificially biased towards these results, and do not indicate that the positive levels are contamination 'hotspots' requiring further investigation.

No levels were detected that would potentially cause odours, known health problems or be aggressive to concrete (about 100, 2,000 and 1,000 mg/kg respectively; Ref. 12), and thus the general levels identified give no cause for concern.

Toluene Extractable Matter (TEM)

Toluene extract analysis provides a general indication of pollution by oil/tar based contamination by measuring the total amount of organic matter (including oils, tars, pitch, and natural humus and vegetable matter), and of elemental sulphur, that is soluble in a strong organic solvent (toluene).

Five samples of made ground had concentrations of TEM (3.3% maximum) that exceeded the Dutch IV for mineral oil (0.5 %), and the concentrations of these samples, and of a further two samples (one comprising of natural mudstone), also exceeded our internal Assessment Value of 0.25% for residential developments. All of these samples were taken from boreholes in the northern half of the site.

A number of soil samples, including some of the above, had marked odours and/or visible iridescence. A summary of the field observations and OVM readings from these samples is given below:-

SAMPLE	MATERIAL	OVM (ppm)	OBSERVATIONS
MB 8/4	Gravel Fill	44.3	Diesel odour, no iridescence
MB 9/5	Clay Fill	62.0	White spirit odour, no iridescence
MB 20/6	Clay Fill	29.6	White spirit odour, no iridescence
MB 21/4	Mudstone	51.2	Diesel odour, slight iridescence
MB 22/3	Gravel Fill	8.2	Creosote/tarry odour, no iridescence
MB 23/5	Mudstone	31.4	Diesel odour, no iridescence

The three soils with the highest TEM values were further analysed by thin layer chromatography to indicate the potential contamination sources, which were identified as diesel type oil (in MB 2/1) and coal tar materials (in MB 22/3 and BH 1; 0.3-0.8 m).

Total Petroleum Hydrocarbons

Ten samples, comprising the seven samples with TEM concentrations higher than 0.25%, together with an additional three samples (MB 8/4, MB 20/6 and MB 23/5), based on the field observations were further tested for total petroleum hydrocarbons (TPH).

TPH analysis by gas chromatography (FID) covers the diesel (C_{10}-C_{30}) and heavy oil (C_{30}-C_{40}) ranges. Six of the values obtained (four made ground and two natural mudstone samples; 32,000 mg/kg maximum) were above the Dutch IV (5,000 mg/kg) for mineral oil. All of these samples were taken from locations in the northern half of the site. One of the made ground samples (MB 8/4) corresponded to made ground immediately above rockhead; one of the made ground samples (MB 22/3) corresponded to a layer of gravel fill from 1.6 to 1.9 m; and two made ground samples (MB 2/1 and BH 1, 0.3-0.8 m) corresponded to shallow deposits (maximum depth 0.45 m). The two natural mudstone samples (MB 21/4 and MB 23/5) corresponded to samples taken to a maximum of 1.55 m below rockhead.

Semi-Volatile Organic Compounds and Polycyclic Aromatic Hydrocarbons (PAHs)

The six samples identified during the fieldwork to have elevated organic vapours (see table above) were further analysed for Semi-Volatile Organic Compounds (SVOCs), and a further two, with elevated TEM and TPH concentrations, for the coal tar constituent PAHs (16 EPA compounds) only.

The values of total PAHs obtained varied between <1 and 3,764.1 mg/kg. CLEA guideline values are in preparation for assessing the long term health hazards of individual compounds such as benzo(a)pyrene and naphthalene, therefore FWSC has used generic assessment values (GAVs), based on the CLEA model, for these determinands. Four of the values of benzo(a)pyrene (160 mg/kg maximum) and three values of naphthalene (120 mg/kg maximum) exceed the respective GAVs for residential development with plant uptake (1.28 and 1.73 mg/kg), adopting the most stringent value based on soil organic matter content and soil type.

The majority of the remainder of the SVOCs were undetected. We are advised by the laboratory that, of those that were detected, all are likely to be associated with coal tar products and, therefore, closely associated with the corresponding elevated PAHs.

Based on the samples tested, the levels of benzo(a)pyrene and naphthalene identified are likely to represent a potential human health hazard, and there also remains the potential for PAHs to cause contamination of drinking water (via permeation of vapours through plastic pipes), or groundwater, or constitute an odour or phytotoxicity problem for the proposed development.

Volatile Organic Compounds

The six samples with the elevated organic vapours were also analysed for Volatile Organic Compounds (VOCs). CLEA guideline values are available for toluene and ethylbenzene, whilst GAVs have been used for those substances where toxicity data is available and allows their calculation to assess the long term health hazards of individual compounds.

For ease of reference, these have been summarised below. All GAVs quoted are the most stringent after consideration of soil type and soil organic matter.

VOLATILE ORGANIC COMPOUND	GAV (mg/kg)	MAX VALUE (mg/kg)	NO. OF SAMPLES EXCEEDING ASSESSMENT VALUE
1,1,1,2-tetrachloroethane	0.87	<0.01	0
1,1,1-trichloroethane	6.33	<0.01	0
Benzene	0.02 (SGV)	0.12	1
Xylene	3.08	0.22	0
Tetrachloroethene	0.05	<0.01	0
Toluene	3.0 (SGV)	0.076	0
Vinyl Chloride	0.00086	<0.01	-
1,2-dichloroethane	0.01	<0.01	0

With the exception of a single value of benzene (MB 22/3, from a made ground horizon from 1.6 to 1.9 m deep), therefore, the values obtained do not indicate a significant risk to human health. (NB: the GAV for vinyl chloride is set very low on the assumption that vegetables will be grown in the soil, and intimate contact the soils will be made by future residents. In reality, none of these soils are suitable for growing purposes and appropriate material will need to be imported for use in gardens.)

The majority of the VOCs were undetected and, of those individual compounds that were detected, we are advised by the laboratory that all are likely to be associated with coal tar products and, therefore, closely associated with the corresponding elevated PAHs.

Metals/Metalloids

Arsenic, cadmium, chromium, lead, mercury and nickel can be hazardous to health and current UK, CLEA derived, SGVs have been produced to assess their potential impact on human health over an individual's childhood or lifetime for residential use, allotments and commercial/industrial use, assuming direct exposure to the given concentrations in the soil at the ground surface. Currently no SGVs have been produced to replace the original ICRCL guidelines for open space/parks/playing field development. Copper and zinc are not normally hazardous to health, unless concentrations are significantly elevated, but can be phytotoxic and thus former ICRCL guidelines related to the potential adverse effects on uses where plants were to be grown for these elements (and for nickel).

One sample of made ground had a lead concentration (1,100 mg/kg maximum) that exceeded the SGV for residential development with plant uptake (450 mg/kg). The calculated geometric mean (45 mg/kg) of the lead values in the made ground samples, as required under CLEA guidance, was well below this SGV. The maximum value test indicates that this value represents a statistical outlier, which potentially could require further investigation. However, this made ground sample (MB 2/1) was taken from a 0.25 m layer of ash. Although ash was also found, occasionally, in other made ground samples, this sample was the only relatively homogenous deposit found during the investigation. Ash is commonly high in heavy metals, including lead, and therefore, rather than identifying a significant contamination hot spot, the statistical analysis has simply highlighted an uncommon made ground type on this site and therefore should be considered as a separate statistical population.

The levels of arsenic (31 mg/kg maximum) in three of the samples of made ground also exceeded the residential with plant uptake SGV (20 mg/kg). The calculated arithmetic mean (9.5 mg/kg) of the arsenic values in the made ground samples was well below this SGV, and the mean and maximum value tests were both satisfied. However, the occasional elevated levels of arsenic indicate that some protection measures are required for areas likely to be designated as domestic gardens.

Two samples of made ground had a chromium concentration (700 mg/kg maximum) that exceeded the SGV for residential development with plant uptake (130 mg/kg), and also suggested possible contamination 'hotspots' from the maximum value test. This SGV assumes that all chromium present is the potentially harmful chromium VI ion, and therefore these two samples were further submitted for chromium VI analysis. Neither was found to have a concentration of chromium VI above the detection level of 0.1 mg/kg, therefore falling well below the SGV.

Three samples of made ground and three samples of natural ground had nickel concentrations (91 and 100 mg/kg maxima respectively) that exceeded the SGV for residential with plant uptake (50 mg/kg). The arithmetic means for the made ground

samples and natural soils were 31 mg/kg and 44 mg/kg respectively, both below the SGV.

None of the soil sample concentrations, or the respective means, for made ground or natural soil, for cadmium, copper, or mercury exceeded the corresponding SGVs for a residential development with plant uptake (1-8, dependent on soil pH, 600, 3000 and 8 mg/kg respectively). Forty two of the mercury levels and 52 of the cadmium levels were undetected (<0.06 mg/kg and <0.2 mg/kg respectively) and thus the data population is artificially biased towards these results, rather than indicating that the positive levels are contamination 'hotspots' requiring further investigation.

The chief hazards associated with these elements are ingestion of contaminated soils by children or, at higher levels, inhalation of dust and, if relevant, the uptake of these elements by plants, such as fruits and vegetables, and their subsequent ingestion by consumption. Some remedial action is indicated to be required in any areas designated for gardens, therefore, as well as taking appropriate precautions during any future soil moving operations.

All of the concentrations of copper, nickel or zinc were below values that could be potentially phytotoxic for planted trees (600, 250 and 3,000 mg/kg respectively; Ref. 13) and thus give no cause for concern. However, as the made ground soils are unlikely to provide a suitable growing medium, it would be prudent to ensure that any future vegetation is planted in soil that is appropriate (composition and thickness) for the purpose (see Sections 10.4 and 10.12).

Asbestos

A single small fragment of asbestos cement board was encountered in MB 2 and, as a precaution, the soil sample from that particular horizon of MB 2 and seven other samples of made ground materials were submitted for testing for potential asbestos fibres. Concerns regarding asbestos materials relate to the fact that inhalation of all forms of respirable asbestos may lead to lung fibrosis (asbestosis) and exposure to all forms of respirable asbestos fibre is also associated with cancer. None of the samples tested contained asbestos fibres. No related special precautions are therefore indicated to be required with regard to the general excavation of the soils on site, based on the samples analysed. Since, however, a piece of asbestos cement board has been identified in the fill materials, and asbestos can be potentially dispersed or buried on brownfield sites, it is important that a careful watch be kept during any future excavations, for fibrous materials and, if discovered, a further assessment carried out.

Calorific Value

Calorific value analysis was carried out on eight samples of carbonaceous mudstone to give a general indication of their potential combustibility. The assessment of whether a soil sample can ignite and smoulder is not straight forward, but work done by the fire research station (Ref. 14) has shown that, under laboratory conditions, smouldering can propagate in test samples lower than 7,000 kJ/kg, while samples with calorific values exceeding 10,000 kJ/kg are almost certainly capable of sustaining smouldering. Three contributory factors are normally necessary for underground fires. The soils must be

combustible; there must be access for a flow of air, i.e. an oxygen supply; and there must be a source.

Values obtained in the tests ranged from <100 to 2,960 kJ/kg. These low values suggest the mudstone is not capable of combustion. However, a seam of coal was intercepted during the drilling of MB 10. This is likely to be a very localised deposit in an area where historic quarrying has not been carried out and some precautionary measures will be required for any future development if exposing the coal seam in this part of the site.

5.3 Groundwater Analysis

TABLE 3: GROUNDWATERS

Determinand	*Units*	*Assessment Value (AV)*	*No. of samples*	*No. of samples exceeding AV* [A]	*Max*	*Min*	*Mean*
pH	-	5.5 - 9.5	8	1	10.2	7.3	-
Chloride	mg/l	250	8	1	280	39	148
Sulphate	mg/l	250	8	0	130	6	70
Arsenic	mg/l	0.05	8	0	0.0051	0.0002	0.001
Cadmium	mg/l	0.005	8	0	0.001	0.001	0.001
Chromium	mg/l	0.05	8	0	0.002	0.002	0.002
Copper	mg/l	2	8	0	0.044	0.002	0.007
Lead	mg/l	0.025	8	0	0.0065	0.0065	0.0065
Mercury	mg/l	0.001	8	0	0.00004	0.00004	0.00004
Nickel	mg/l	0.02	8	1	0.028	0.003	0.008
Zinc	mg/l	5	8	0	0.015	0.002	0.004
Cyanide (Total)	mg/l	0.05	8	1	0.14	0.01	0.026
Phenolics (as phenol)	mg/l	0.03	8	1	0.04	0.01	0.014
Total Petroleum Hydrocarbons	mg/l	0.6	8	4	4900	0.014	1140
Total Polycyclic Aromatic Hydrocarbons	mg/l	0.0001	3	3	6.147	0.024	2.452

[A] or outside range for pH

The pH values of the eight groundwater samples ranged from slightly alkaline to very strongly alkaline (7.3 to 10.2). Only one of the chloride levels was slightly elevated (280 mg/l maximum) and none of the sulphate levels were elevated (130 mg/l maximum) in comparison with UK Drinking Water Quality Standards (WQS) maximum values (Ref. 15) of 250 mg/l for both.

One of the levels of phenols (0.04 mg/l) and one of the levels of cyanide (0.14 mg/l) exceeded the respective assessment values of 0.03 mg/l (UK freshwater EQS) and 0.05 mg/l (WQS). One level of nickel (0.028 mg/l) also slightly exceeded the respective WQS value of 0.02 mg/l.

None of the arsenic, cadmium, chromium, copper, lead, mercury and zinc concentrations exceeded the corresponding WQS/freshwater EQS assessment values (0.05, 0.005, 0.05, 2, 0.025, 0.001 and 5 mg/l respectively).

Four of the TPH levels were above the Dutch IV for mineral oil (0.6 mg/l). Two of the levels were significantly higher than the others (MB 8; 4,900 mg/l and MB 9/W; 4,200 mg/l). Both of these boreholes were located in the northeast of the site and correspond with elevated levels of TPH in the soils in these boreholes, and in the vicinity (see above). At the time of sampling, water from MB 8 was noted to have an iridescent film and a diesel odour and the water from MB 9/W, taken at the time of drilling, was noted to have a mixed odour of diesel and white spirit.

The remaining two levels were significantly lower (19 and 1.6 mg/l). The sample from BH 6 (19 mg/l TPH), located in the southeastern corner of the site, was noted to have an 'oily' odour. None of the other waters had any visible iridescence.

The three samples noted to have odours and/or iridescence were further analysed for SVOCs to provide a semi-quantitative analysis. All three samples also had elevated total PAHs (MB 9/W; 6.147 mg/l, MB 8; 1.185 mg/l and BH 6; 0.024 mg/l). The majority of the remainder of the SVOCs were undetected and, of those that were detected, all are likely to be associated with coal tar products and, therefore, closely associated with the corresponding elevated PAHs.

Based on the samples analysed, therefore, contamination of the perched shallow groundwater is limited to occasional slightly elevated levels of phenols, cyanide and nickel, elevated levels of TPH and PAHs below the northeastern part of the site and slightly elevated TPH and PAHs below the southeastern corner of the site.

5.4 Leachate Analysis

TABLE 4: LEACHATES

Determinand	*Units*	*Assessment Value (AV)*	*No. of samples*	*No. of samples exceeding AV*[A]	*Max*	*Min*	*Mean*
pH	-	5.5 - 9.5	5	2	10.5	7.4	-
Chloride	mg/l	250	5	0	11	3.0	5.8
Sulphate	mg/l	250	5	0	250	8.9	92.8
Arsenic	mg/l	0.05	5	0	0.0031	0.00015	0.0099
Cadmium	mg/l	0.005	5	0	0.001	0.001	0.001
Chromium	mg/l	0.05	5	0	0.0015	0.0015	0.0015
Copper	mg/l	2	5	0	0.0015	0.0015	0.0015
Lead	mg/l	0.025	5	0	0.0065	0.0065	0.0065
Nickel	mg/l	0.02	5	0	0.012	0.0025	0.0044
Zinc	mg/l	5	5	0	0.0089	0.002	0.0034
Cyanide (Free)	mg/l	0.05	5	0	0.01	0.01	0.01
Phenolics (as phenol)	mg/l	0.03	5	2	0.11	0.01	0.044
TPH	mg/l	0.01	5	5	10	0.086	4.32
Mercury	mg/l	0.001	5	0	0.00004	0.00004	0.00004

[A] or outside range for pH

Five selected made ground samples from across the site were subjected to leaching following procedures derived by the NRA. The resulting "leachates" were then analysed for a number of parameters that could be compared with UK Drinking Water Standards (WQS) or freshwater (EQS) maximum values (Ref. 9). This provides an initial assessment of any potential impact the site may have on controlled waters.

The pH values obtained ranged from slightly alkaline to strongly alkaline (7.4 to 10.5). All of the sulphate and chloride concentrations (250 and 11 mg/l maxima respectively) were at or below the corresponding WQS of 250 mg/l for both determinands.

Two of the levels of phenols (0.11 and 0.08 mg/l) exceeded the UK freshwater EQS of 0.03 mg/l. None of the cyanide levels (all <0.02 mg/l) exceeded the WQS of 0.05 mg/l.

None of the values of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc exceeded the corresponding assessment values (0.05, 0.005, 0.05, 2, 0.025, 0.001, 0.02 and 5 mg/l respectively).

Four of the TPH levels (10, 6.8, 3.4 and 1.3 mg/l), all from samples from boreholes in the north of the site, were above the Dutch IV for mineral oil (0.6 mg/l). The highest value (10 mg/l) corresponded with a sample from MB 22 with a soil TPH value of 7,400 mg/kg.

The identified levels indicate that the leachate potential of the made ground materials tested is limited to localised elevated levels of TPH and slightly elevated levels of phenol in the northern part of the site.

6 ASSESSMENT OF GAS MONITORING RESULTS

Methane, often associated with carbon dioxide gas, can originate from a number of sources including natural sediments (peat, river silt and Coal Measures), mines, landfills and waste deposits. Methane can be flammable (open spaces) or explosive (confined spaces) at concentrations between 5% and 15% by volume in air. Elevated levels of carbon dioxide affect human respiration and can prove fatal.

Readings of methane, carbon dioxide and oxygen, and total gas flow rate, were monitored in the nine borehole standpipes, using a Geotechnical Instruments MkIIC Infra-Red Gas Analyser and a FG60 Gas Flow meter, on completion of the relevant drilling. Observations of the prevailing weather conditions and measured atmospheric pressure were also recorded on these occasions. The results are given in Appendix 7 and discussed below.

Methane was detected in four of the boreholes (maximum concentration 0.5% by volume; BH 4) during the first monitoring visit and in one borehole (BH 4; maximum concentration 0.7% by volume) for the remaining three visits.

Levels of carbon dioxide (CO_2) were occasionally slightly elevated (6.7% maximum) in some of the standpipes on each occasion, with all of the levels falling in the range likely to be found in certain normal soils (up to about 7%; Ref. 16). Four of the CO_2 levels exceeded 5% (MB 4 and MB 8), the level above which special precautions are advised for foundation and floor construction design (Ref. 17). Depressed oxygen levels were recorded

in the boreholes with the higher CO_2 levels and elevated methane during the monitoring period, with significantly depressed levels on several occasions (5.0% minimum) in BH 1.

No significantly elevated total gas flow rate (0.2 l/hour maximum) was recorded in any of the standpipes on any of the occasions monitored. Atmospheric pressure conditions ranged from 981 to 1013 mbar at the time of carrying out the monitoring.

Current guidance (Ref. 18), which was introduced to provide a more holistic approach to the specification of gas protection measures, characterises gassing sites in terms of limiting borehole gas volume flow rates and gas concentrations, and identifies a typical scope of measures for each "Characteristic Situation" for residential buildings, and for office/commercial/industrial development. Although if the highest concentration of either methane or carbon dioxide (6.7% carbon dioxide) is combined with the highest gas flow rate recorded in any standpipe (0.2 l/hour) a relatively low gas volume rate (i.e. 0.067 x 0.2 = 0.013 l/hour) is produced, for design purposes, the exceedance of the additional limiting factor (5% CO_2 by volume) indicates that Characteristic Situation 2 gas protection measures are required in future buildings (see Section 10.6), based on the current monitoring. Recent guidance (Ref. 19) makes recommendations on typical minimum periods and frequency of gas monitoring, based on individual site conditions. Those likely to be applicable to this site include a high sensitivity of development i.e. housing, coupled with a low to moderate gas generation potential, based on the ground encountered and gas monitoring undertaken during this investigation. We would therefore recommend a further eight monitoring visits over a period of three to four months to confirm the gas regime present on the site. On the basis of the current data required, it would be prudent to adopt Characteristic Situation 2 gas protection measures incorporating a gas resistant membrane (i.e. equivalent to Characteristic Situation 3 measures), where necessary (see Section 10.4), to prevent potential ingress of organic vapours into any future buildings.

Appropriate precautions should also be taken by personnel entering deep, unventilated excavations during the redevelopment works.

7 ASSESSMENT OF RISK

7.1 Introduction

Current government guidelines (Ref. 20) support sustainable development both by reducing the damage from past activity and by permitting contaminated land to be kept in, or returned to, beneficial use wherever practicable. The government is committed to this 'suitable for use' approach which requires remedial action only where the contamination poses unacceptable actual or potential risk to health and the environment, considering the actual or intended use of the site, and where there are cost effective means to treat the land. The guidelines indicate that the potential for harm should be considered as part of a risk assessment. They also set out the requirements for local authorities, assisted by the Environment Agency particularly where water pollution is involved, to identify and assess potentially contaminated land and, where applicable, potential remedial requirements. If the site can be shown to present no significant harm, or the significant possibility of such harm, to human health, protected ecosystems or property, or the likely pollution of controlled waters, by considering the potential impact of contamination sources on appropriate receptors (targets) via relevant pathways, then the site can be considered uncontaminated with

respect to that development. The analytical results have been interpreted with regard to this approach for the proposed redevelopment of the site for residential houses with gardens. Obviously the site could be considered for other types of development, such as commercial/industrial, and would involve interpretation of the results using the appropriate criteria at the time.

7.2 Conceptual Model

Based on the results of this investigation, contamination in the made ground materials consisted of elevated levels of sulphate and chloride, and occasional elevated levels of TPH, total PAHs (including benzo(a)pyrene and naphthalene), arsenic, nickel and total chromium, an isolated slightly elevated level of benzene and an isolated elevated lead value. Levels of cyanide, phenols, cadmium, chromium VI, copper, zinc and mercury were generally low. Contamination in the natural ground consisted of localised elevated levels of TPH and total PAHs in the shallow mudstone strata. Levels of SVOCs and VOCs were generally low and, where detected, likely to be associated with the elevated PAHs. No asbestos fibres were identified in the soil samples tested. Levels of potential contamination in the perched groundwater consisted of elevated levels of TPH and PAHs, largely confined to the northeastern corner of the site (with slightly elevated TPH and PAHs in the southeastern corner) and isolated slightly elevated levels of chloride, phenols and cyanide. Potential contamination in the leachate samples is limited to slightly elevated levels of TPH and occasional slightly elevated levels of phenols from soils in the northern part of the site. No significant total gas flow rates were detected in any of the standpipes during the monitoring period. Slightly elevated carbon dioxide, methane and significantly depressed oxygen levels were recorded during the monitoring period. BGS information recommends that basic protective measures should be taken in buildings with regard to radon.

The potential receptors that could be affected by the above include:-

- construction workers;
- future occupants;
- future buildings and services;
- planted vegetation;
- neighbouring properties;
- underlying groundwater.

Potential pathways for the identified contamination to affect these receptors include:-

- direct contact with the soils/groundwater by construction workers/future occupants;
- ingestion/inhalation of contaminated soil/dust by construction workers/future occupants and by people on neighbouring properties;
- potential ingestion of garden produce by future occupants;
- direct contact with contaminated soil/groundwater by buildings/services;

- migration of contamination onto adjacent properties, or into underlying groundwater;

- plant root uptake of potential contaminants;

- migration of gas through the groundmass into service trenches and under, or into, future buildings.

The risks posed by the identified contamination to the relevant receptors are assessed in the following sections.

7.3 Construction Workers

As the chief hazards associated with metals/metalloids are ingestion of contaminated soils by children or, at higher concentrations, inhalation of dust, the levels identified herein will not pose a significant hazard to site workers, nor to people on neighbouring properties, providing appropriate precautions are taken during any excavation or removal of these materials to reduce the potential for human exposure to dust.

The potential hazards posed by the oily soils/groundwater to construction workers via inhalation are likely to be low due to the generally low levels of organic vapours recorded and the general depth of their occurrence. Skin/eye contact with alkaline, or localised oily, soils on the site, that can result in conditions such as dermatitis, should be avoided by wearing appropriate safety clothing, including clean overalls, protective boots and gloves (or using barrier creams).

Sensible site precautions (Ref. 21) will prevent unnecessary general exposure and will protect the health of site workers, and any people on neighbouring properties. Localised low levels of oxygen were detected during the monitoring visits and, as a prudent measure, no deep and unventilated excavations on site should be entered by construction workers without prior monitoring for oxygen levels and the potential presence of toxic or asphyxiant gases.

7.4 Future Occupants

Private gardens are anticipated in the proposed development of the site. With regard to the identified levels of arsenic and certain metals, particularly nickel and lead, in the made ground materials on site, the dominant potential exposure pathway in the CLEA model is the direct ingestion of soil and soil-derived indoor dust, with consumption of homegrown vegetables contributing up to 30% of total oral exposure (Ref. 7). It would be prudent, therefore, to ensure that, in all potential garden areas where any existing soils could be exposed by digging, or used for growing garden produce for consumption in the future, the potential risks relating to long term chronic exposure are reduced by covering these existing soils with imported soils of a known chemical composition, as discussed in Sections 10.4 and 10.12.

The incorporation of appropriate membranes in any future buildings will protect the future occupants from any risks related to landfill gas, radon, or, where appropriate, organic vapours.

Following site redevelopment, with the recommended precautions, future building occupants will have no exposure to the identified potential contamination sources on site, and therefore will not be subject to any related significant risk.

7.5 Building Materials and Services

The sulphate concentrations identified in the typical soils and groundwater encountered indicate that Design Sulphate Class DS-2, ACEC Class AC-2 concrete will be required for future building structures coming into contact with the soils/groundwater on site.

The elevated total sulphate concentrations, and the presence of ash, indicate that the soils are likely to be potentially aggressive with regard to buried metal pipes. Some protection for these service pipes is indicated to be required.

At present, special precautions for resistance to attack by phenols and oils/tars are indicated to be required for plastic service drains, service pipes or any other polymeric materials used in the current soils. If any local pockets of oily contaminated ground are encountered during excavations, or in pipe trenches, they should be removed, disposed of at an appropriate landfill, and the excavations/trenches backfilled with clean fill.

Some special gas precautions are indicated to be required based on the monitoring carried out. Gas precautions, as specified in Section 10, should be incorporated in the foundations of future buildings on the site. If a residential development is to be pursued, a further eight monitoring visits over three or four months are recommended to further assess the conditions and confirm the gas precautions required. Some basic radon protection measures are indicated to be required in the future buildings.

7.6 Plants

No significant levels of potentially phytotoxic elements have been detected in the made ground materials. However, the generally coarse and rubbly nature of the made ground materials encountered on site is unlikely to provide a suitable growing medium. It would be prudent, therefore, to ensure that any future vegetation is planted in soil that is appropriate (composition and thickness) for the purpose (see Sections 10.4 and 10.12).

Several clumps of Japanese Knotweed were observed around the site margins during the fieldwork. This is one of the most invasive plants in Britain. Roots go down to 2 m and fragments of root as small as 10 mm can cause new plants. It does not seed in this country, but spreads by transfer of root fragments. It can grow up through tarmac, walls, paved areas and thin concrete, as well as over-running landscaped planting. The Wildlife and Countryside Act 1981 makes it an offence to plant, or cause Japanese Knotweed to grow in the wild. All plant material and soil containing it (especially the roots) is regarded as a 'controlled waste' and is subject to various legal controls in terms of transportation and off-site disposal at an appropriately licensed landfill if this is required. Options to eradicate/remove and dispose of this weed will have to be taken into consideration when planning or undertaking future development operations.

7.7 Neighbouring Properties

The generally low lying nature of the site, relative to the surrounding areas means that the potential for off-site migration of any significant contamination from the soils or shallow perched groundwater (that could significantly affect neighbouring properties) is generally low, based on the current investigation. Additional investigation, however, should be carried out to further define the extent of the contamination and the potential for related off-site migration (see Section 10.2).

7.8 Groundwater

Occasional elevated levels of TPH and PAHs have been identified in the perched groundwater in the made ground and also in the uppermost weathered mudstone bedrock in the northeastern part and southeastern corner of the site. Based on the current investigation, the levels identified in the groundwater samples indicate that the potential for downward migration of the contamination, into the underlying minor aquifer, is low. Further investigation should be undertaken to determine the extent of the shallow groundwater contamination in the northeastern part of the site (see Section 10.2).

8 GEOTECHNICAL CONSIDERATIONS

8.1 Introduction

It is understood that there are no definite development proposals for the site at this stage. We have been asked to consider a residential housing development, but other development proposals may be considered and, therefore, the following comments are of a necessarily general nature and should be reviewed in the light of future definitive proposals.

8.2 Foundations

It is apparent that some infilling has taken place previously to varying depths across the site but the evidence of the exploratory holes suggests that this is unlikely to have been carried out in a controlled, engineered manner. The made ground generally comprises a mixture of gravel and sandy clay in varying proportion, invariably underlain by the weathering products of the underlying mudstone or, rarely, sandstone. It is possible, depending on proposed levels, that structural foundations of strip footings could be used for parts of the site, extended down through the made ground to found in the bedrock at depths varying between approximately 0.6 m and 3 m. Foundations for individual buildings should found in consistent strata.

Where extended footings are to be considered, formations should be carefully appraised by a suitably qualified engineer and footings further extended as appropriate.

Foundations extending to greater depths in parts of the site may prove uneconomic and consideration has been given to the possibility of utilising ground improvement techniques such as vibro-replacement. The effectiveness of any ground improvement scheme would be fundamentally dependant on the individual contractors method of working and the type of system involved. If this was to be considered, then the advice

of specialist contractors should be sought in determining the most appropriate method in the prevailing conditions and in providing design parameters appropriate to that type.

Alternatively, the structural loads could be transferred through the made ground into the underlying mudstone/sandstone by means of a shallow piled foundation system. The choice of a suitable pile type should be made in collaboration with experienced piling contractors who will, on the basis of their experience, provide pile design parameters appropriate to the chosen type. Careful consideration must be given to the seating of the piles such that they fully penetrate any made ground, including remnants of quarry workings, and must be adequately socketed into the rock. A driven pile, which might be unstable at the toe on an inclined rock surface, is therefore unlikely to be a suitable option in the prevailing circumstances. Allowance should be made for additional loadings due to negative skin friction on the pile shafts where significant changes in ground levels and/or surface loadings are proposed.

In view of the potential differential movements within the made ground, in its current condition, either a suspended floor system should be utilised, or the ground improvement or piling schemes could be extended to incorporate the ground floor loadings of the buildings. Formations should be carefully inspected and proof rolled and any soft spots removed and brought up to level with suitable, well compacted material.

A further alternative could be to excavate out the made ground to the base of the quarry, where practicable, and to selectively crush and screen the resulting material to produce a suitable fill which could then be properly placed and compacted to form a appropriate base on which raft foundations for low rise domestic development could be utilised. This may also be advantageous in dealing with some of the contamination aspects which are discussed elsewhere in the report.

8.3 Excavations

The nature of the made ground materials present is such that excavations should not be expected to remain stable, even in the short term. All excavations and ground works must be carried out in accordance with current good practice, with due regard to potential instability problems in the soils above the bedrock.

From the groundwater information resulting from the investigation, it appears that ingress of large quantities into moderately shallow excavations is unlikely and should be controllable by normal pumping.

8.4 Design of Vehicular Areas

Deposits likely to be present at formations near to existing ground levels across the site are likely to vary from made ground (mainly of sandy gravelly clay, with varying content of waste building materials), through to natural sandy gravelly clay or weathered mudstone bedrock. The made ground is thicker towards the extreme northern, central, and eastern areas, and in view of its uncertain history and condition, may be subject to a little more settlement than areas of shallower made ground.

Formations should be proof rolled and any soft/loose spots, topsoil or oversize material should be removed and replaced with suitable granular material prior to recompaction.

9 SUMMARY AND CONCLUSIONS

9.1 The site occupies an area of approximately 4.5 ha and is situated approximately 1.5 km to the west of central Barnsley, in a predominantly residential area. The site is occupied by a Shell petrol filling station and two large factory buildings belonging to SR Gent, although in view of recent receivership, factory operations have now ceased. The factory shop was still trading at the time of this investigation. The filling station is unaffected by these developments and continues to trade, although, at the Client's request, was omitted from this investigation.

9.2 The site was under agricultural use until sandstone quarrying began in the northern corner of the site prior to 1855. This small quarry was infilled before clay pits were excavated in the north of the site, some time between 1893 and 1906, to supply the brickworks that had become established to the north, on the opposite side of Dodworth Road. By 1931 the clay pit had extended to cover a large portion of the present site and, by 1956, had reached the southern site boundary. Residential development around the site began before 1931 and continued into the 1960s. By 1960 a pond had become established that spanned the eastern boundary. The petrol station was established on the north of the site between 1966 and 1969 and, immediately to the south, the area of old quarry was identified as a refuse tip at this time. Development of the site with the three original factory buildings began between 1973 and 1975. Some time prior to 1991 the two southernmost buildings had been joined to form one large building.

9.3 The site is underlain by Carboniferous Middle Coal Measures strata, with sandstone originally directly underlying the eastern part of the site. The site is within the likely zone of influence on the surface from workings in eight seams of coal between 40 and 330 m. The Coal Authority advises that the likelihood of unrecorded workings at shallower depth is highly unlikely. Working ceased in 1972 and ground movements from these past workings should by now have ceased. On the basis of available information, the surface of the site is not likely to be at risk from these abandoned mine workings. The Coal Measures are classified as a minor aquifer by the Environment Agency.

9.4 Environment Agency information indicates that there are no discharge consents, recorded enforcement and prohibition notices, or licensed surface water or groundwater abstractions within at least 1 k m of the site. The Agency records one minor pollution incident on the site, relating to a spillage of oil in 1996. The site does not lie within a Groundwater Protection Zone and is at a low risk from flooding.

9.5 Part of the site itself is recorded by the local authority and the BGS as a landfill, and coincides with the area marked as a refuse tip on the historical maps, together with a further landfill sites to the north, on the opposite side of Dodworth Road. There are no waste treatment or transfer sites within 250 m of the site. There are two recorded local authority PPCs within 250 m of the site (one relates to the petrol filling station, on the site itself), no IPPC authorisations or IPC consents within 450 m of the site, no radioactive consents within 700 m, and no NIHHS or COMAH sites, hazardous

substances consents, or sensitive nature areas within 1 km of the site. The site does lie in an area where basic radon protective measures are necessary.

9.6 Made ground was encountered in all of the boreholes, to varying depths (minimum 0.3 m, maximum 9.0 m, but generally <5.0 m), the deepest being encountered in the northeast corner of the site. The external areas were either covered in tarmac, or had been landscaped, whilst the internal areas encountered concrete. Most positions required pre-coring prior to drilling. In the majority of the excavations the upper hardcover was underlain by dolomite aggregate. No further made ground was encountered in two of the boreholes located in the centre of the site, whilst elsewhere thicker made ground comprising either a clay fill, or gravel fill (or both) comprising sandstone, mudstone, brick, concrete, cinders and occasional clinker, coal and red shale. Within the upper 1 m of made ground, brick rubble was also encountered in six of the boreholes and a layer of ash in three of the boreholes.

9.7 Natural soils were encountered in 27 of the boreholes, and generally comprised a highly weathered mudstone (mudstone interbedded with sandstone was encountered in one of the boreholes and also sandstone on its own in another). The mudstone was often friable and occasionally carbonaceous. A layer of coal was encountered from 1.75 to at least 2.0 m in MB 10, located in the southwestern corner of the site. This is the only area of the site that has been left unquarried and thus this coal has been historically removed from the remainder of the site.

9.8 Hydrocarbon odours, including diesel, white spirit and creosote/tar, were noted from several samples of made ground and natural mudstone from the northern half of the site. Some of these were accompanied by elevated organic vapour levels (62.0 ppm maximum).

9.9 Shallow perched groundwater was encountered within the made ground in six of the boreholes and, also, within the natural mudstone in six of the boreholes. Seven water samples were obtained from the standpipes installed within a number of boreholes and a further sample was obtained during drilling. All were submitted for chemical analysis. Three samples from the northeastern part of the site had oily or diesel odours with associated iridescence.

9.10 No subsurface obstructions were encountered in any of the trial pits or boreholes.

9.11 Infestation of Japanese Knotweed was recorded in three areas within the site and a further area 7 m from the southern boundary fence.

9.12 Based on the results of this investigation, contamination in the made ground materials consisted of elevated levels of sulphate and chloride, and occasional elevated levels of TPH, total PAHs (including benzo(a)pyrene and naphthalene), arsenic, nickel and total chromium, an isolated slightly elevated level of benzene and an isolated elevated lead value. Levels of cyanide, phenols, cadmium, chromium VI, copper, zinc and mercury were generally low. Contamination in the natural ground consisted of localised elevated levels of TPH and total PAHs in the shallow mudstone strata. Levels of SVOCs and VOCs were generally low and, where detected, likely to be associated with the elevated PAHs. No asbestos fibres were identified in the soil samples tested. Levels of potential contamination in the perched groundwater consisted of elevated

levels of TPH and PAHs, largely confined to the northeastern corner of the site (with slightly elevated TPH and PAHs in the southeastern corner) and isolated slightly elevated levels of chloride, phenols and cyanide. Potential contamination in the leachate samples is limited to slightly elevated levels of TPH and occasional slightly elevated levels of phenols from soils in the northern part of the site. No significant total gas flow rates were detected in any of the standpipes during the monitoring period. Slightly elevated carbon dioxide, methane and significantly depressed oxygen levels were recorded during the monitoring period. BGS information recommends that basic protective measures should be taken in buildings with regard to radon.

9.13 Significant levels of oily and tarry contamination have been found in both the soils and the perched groundwater beneath parts of the site. The current investigation indicates that these are concentrated in the northeastern part of the site, although the precise extent is unclear and needs to be defined further. The historical maps show that the northern part of the site was used as a refuse tip before the establishment of the current development. Whilst the areas of contamination extend beyond the extent of the tip, as shown on the maps, it is possible that the area of tipping was greater than that shown during the time of its operation. In view of the locations and combinations of hydrocarbons (diesel, white spirit, creosote/tar) indicated to be present on the site, and the lack of any significant hydrocarbon contamination in the water samples taken from the immediate vicinity, it is unlikely that petrol filling station can be considered the source for any of these. It is more likely that potentially contaminative materials were placed into the quarry as backfill, in or near the area identified as a refuse tip on the historical maps. An oil spill is recorded as having occurred on the site in 1996, but no further information is available.

9.14 No significant potential risks to future construction workers, site occupants, buildings and underground services or landscaped borders/gardens are indicated from the identified contamination, provided appropriate precautions are taken during the proposed development, based on the current investigation. The potential risk to neighbouring properties and underlying groundwater appears to be low, based on this investigation, although further work should be undertaken in the northeastern and central parts of the site to investigate the levels and extent of the soil and perched groundwater contaminated with hydrocarbons in this area.

10 RECOMMENDATIONS

10.1 If it is proposed to sell the site for a residential development involving houses with gardens, a development scheme should be designed incorporating the findings of this investigation and reviewed in light of the proposed additional investigation findings. Further investigation will be required to determine the extent and levels of the hydrocarbon contamination in the soils and shallow perched groundwater, within the made ground and upper natural mudstone, in the northern half of the site and to further assess the potential harm to human health. This should include investigation focused in the following areas:

- the northwest of the site, around the entrance barriers, to the west of Building 1 and along the western and southern margins inside Building 1;

- between Buildings 1 and 2, to the east of Building 1 and within the northern and central parts of Building 2;

Access to the main thoroughfares should be easier now that we understand that the factory has closed, although investigation within Building 2 remains dependent on the removal of some of the factory infrastructure to allow more headroom for a drilling rig, or the utilisation of a hand held percussion window sampling drill.

10.2 The findings of the additional investigation will help refine the remediation options for the site. The final remediation strategy will, to some extent, depend on the final anticipated site levels, but, at present, in light of the findings of the current investigation, the site is best considered in two parts with two different remediation options. Area 1 comprising the entire southern half of the site (south of BH 4) and the northern part of the site, north of Building 1. Hydrocarbon contamination in these areas is restricted to shallow soils in the northern part, which can be removed by shallow scrape/excavation, and localised slightly contaminated perched water in the southeastern corner. Area 2 comprising the central and northeastern part of the site (i.e. between the northern extent of Building 1 and BH 4). Hydrocarbon contamination, in both the soils and waters, are highest within this area

10.3 The remedial measures for Area 1 will include:

- Characteristic Situation 2 gas protection measures to be incorporated into the design of future buildings in these areas. These should include either a suspended floor slab, or a passively ventilated granular/geocomposite layer below a cast in-situ reinforced concrete ground slab, depending on the foundation solution, with all joints and penetrations sealed and a lapped and taped Visqueen (or similar) membrane. There is also a requirement for the buildings to incorporate basic radon protection measures, which for ground bearing concrete floors include sealing the joints between the damp-proof membrane and service penetrations, and require joining the cavity tray to the floor membrane and sealing it.

- Protection will be required in all areas designated for gardens to prevent contact with the made ground soils and potential upward migration of contaminants. The remedial options will involve placing a soil cover system directly onto the levelled made ground. The soil cover system should include a fine-free basal granular layer of minimum thickness 0.3 m, with effective underdrainage to prevent it from becoming waterlogged, and a geotextile filter layer should be placed over the top of the breaklayer to prevent silting up with fines from the overlying soil. The breaklayer should then be covered with a minimum thickness of 0.7 m of clean, neutral or weakly alkaline, subsoil and topsoil of known composition. The recommended thickness will ensure that potential concerns relating to double digging and any long term intermixing of cover materials with underlying made ground (Ref. 22) are not likely to be significant issues.

10.4 The remedial measures for Area 2 will include:

- A combined pump and treat exercise for the perched groundwater/oily soils in the northeastern part of the site. This will involve the pumping of the water through an interceptor coupled with simultaneous bioremediation of the water, thereby reducing

the volume of any potentially significantly contaminated water that may otherwise require to be removed from site. This option will need to be assessed by a specialist bioremediation company. A hydrogeological risk assessment would also need to be carried out to establish appropriate site target levels for any remaining water.

- Characteristic Situation 3 gas protection measures to be incorporated into the design of future buildings in this area. These should include a cast in-situ reinforced concrete ground slab, with all joints and penetrations sealed, combined with a gas resistant membrane to prevent ingress of any potential vapours. This will also satisfy the requirement for the buildings to incorporate basic radon protection measures, providing the cavity tray is joined to the floor membrane and sealed.

- Protection will be required in all areas designated for gardens to prevent contact with the made ground soils and potential upward migration of contaminants. The remedial options will involve placing a soil cover system directly onto the levelled made ground. The soil cover system should include, as detailed above, a fine-free basal granular layer of minimum thickness 0.3 m, with effective underdrainage to prevent it from becoming waterlogged, and a geotextile filter layer should be placed over the top of the breaklayer to prevent silting up with fines from the overlying soil. The breaklayer should then be covered with a minimum thickness of 0.7 m of clean, neutral or weakly alkaline, subsoil and topsoil of known composition. The recommended thickness will ensure that potential concerns relating to double digging and any long term intermixing of cover materials with underlying made ground (Ref. 22) are not likely to be significant issues.

10.5 The additional works will also include:

- levelling of the borehole standpipes to identify the hydraulic gradient and allow the hydrogeological risk assessment to be undertaken;
- eight further gas monitoring visits over a three or four month period to confirm the recommendations relating to gas precautions.

10.6 Construction workers involved in any soil excavation operations on site should take normal sensible precautions, e.g. wearing clean overalls, protective boots and gloves (or barrier cream) (Ref. 21). Damping of the made ground materials should be carried out during any excavation works in dry, windy weather, or if any on-site crushing of rubble is to be carried out. During site redevelopment works, no poorly ventilated excavations should be entered without appropriate monitoring being carried out, due to the potential presence of depressed levels of oxygen and elevated levels of methane and carbon dioxide. Appropriate washing facilities should be provided on site.

10.7 All remaining fuel tanks should be emptied and disposed of by a suitably licensed contractor. Appropriate disposal facilities should be identified prior to the removal of any soil materials for site levelling/reduction, site services installation or geotechnical reasons.

10.8 Buried services prone to heating, such as electric cables, should not be placed within the area in the southwestern corner, where coal is known to exist at shallow depth, unless placed in trenches of inert backfill. This will ensure that the potentially combustible material is isolated from possible ignition sources.

10.9 The concrete specification should be Design Sulphate Class DS-2, ACEC Class AC-2 for any future structures coming into contact with the soils or groundwater encountered in this investigation.

10.10 Special requirements for resistance to attack by phenols or oils/tars are necessary for future plastic drains, service pipes, based on the current investigation, but should be reviewed in the light of further investigation and remediation solution adopted. If any local pockets of oily contaminated ground are encountered during general excavations, or in pipe trenches, they should be removed and the excavations/trenches backfilled with clean fill. No unprotected metalwork should be laid directly in the made ground materials. Additional protection (e.g. PE sleeving) would be needed for future non-zinc-coated ductile iron in the ground.

10.11 The areas of Japanese Knotweed infestation will require treatment in accordance the Environment Agency's current best practise. This can involve either; prolonged treatment with herbicide; excavation and removal of the vegetation itself and the soils contaminated with Japanese Knotweed rhizome; or, treatment and burial on site, under controlled conditions, if the final levels of the proposed development allow. Any material moved off site will require disposal at an appropriately licensed landfill.

10.12 For landscaped borders, future vegetation should be planted in soil that is appropriate (composition and thickness) for the purpose. An adequate thickness of clean imported sub/topsoil should be placed above the current soils (not less than 1.0 m to typically 1.5 m for shrubs and trees, depending on species).

10.13 For geotechnical design purposes: -

- the moderately shallow made ground over parts of the site will allow some foundations to be extended down into the stiff sandy clay or the weathered mudstone;
- formations should be carefully appraised by a suitably qualified engineer and footings further extended as appropriate;
- for greater depths of made ground, the use of ground improvement or short piled foundations into the sandstone/mudstone could be considered and the advice of specialist contractors should be sought for site specific advice in this regard;
- either a suspended floor system should be utilised, or the ground improvement or piling schemes should be extended to incorporate the ground floor loadings of the buildings;
- in view of the remediation options available, it may be advantageous to completely excavate the made ground, where practicable, selectively crush and screen the material before replacing it in a well engineered manner to allow low rise development with raft foundations;
- excavations in the made ground materials should not be expected to remain stable, even in the short term;

- it is unlikely that any significant quantities of groundwater will be encountered in shallow excavations;

- all formation materials should be well compacted and unsuitable material or soft spots should be removed prior to the placement of any sub-base materials.

10.14 As a precautionary measure, it is recommended that a site procedure is established whereby any "unusual" materials that may be located during development works are reported directly to the site management so that appropriate action can be taken if necessary.

C FLETT
ENVIRONMENTAL CONSULTANT

D BRECKON
GEOTECHNICAL ENGINEER

B. Underwood
B D B UNDERWOOD
DIRECTOR

25 April 2006

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