



Report  
Title:

# Phase 2 Geo-Environmental Site Investigation

Project  
Name:

## Bartons Road, Havant



Report  
Reference:

**BRD4469-OR2-C**

Date:

**July 2025**

**BRD Environmental Ltd**

Hawthorne Villa, 1 Old Parr Road,  
Banbury, Oxfordshire, OX16 5HT  
01295 272244 info@brduk.com  
www.brduk.com

# REPORT CONTROL SHEET

|              |                                              |
|--------------|----------------------------------------------|
| REPORT TITLE | PHASE 2 GEO-ENVIRONMENTAL SITE INVESTIGATION |
| PROJECT      | BARTONS ROAD, HAVANT                         |
| CLIENT       | STONEBOND                                    |

| REPORT REFERENCE | ISSUE DETAIL                                             | DATE       | PREPARED BY              | CHECKED BY  |
|------------------|----------------------------------------------------------|------------|--------------------------|-------------|
| BRD4469-OR2-A    | First Issue, gas monitoring still ongoing                | 08/09/2024 | N Kimber & L Chippington | J Brockwell |
| BRD4469-OR2-B    | Second Issue, following completion of all gas monitoring | 21/10/2024 | J Brockwell              | J Brockwell |
| BRD4469-OR2-C    | Third Issue, following updates to development layouts    | 30/07/2025 | J Brockwell              | J Brockwell |

## BRD Environmental Limited

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- Contamination Assessment
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Hawthorne Villa, 1 Old Parr Road, Banbury, Oxfordshire. OX16 5HT

T: 01295 272244

[www.brduk.com](http://www.brduk.com)

[info@brduk.com](mailto:info@brduk.com)

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Phase 2 Geo-Environmental Site Investigation  
Bartons Road, Havant  
BRD4469-OR2-C Havant SI

# REPORT LAYOUT

This report is divided into the following four sections: Summary Report, Technical Report, Supporting Information and Appendices.

## SUMMARY REPORT

This expanded executive summary provides the main findings of the work undertaken in brief non-technical language. This section provides an overview of the key outcomes for the benefit of non-specialists and concludes with the main recommendations. This section should only be relied upon in the context of the whole report and the Technical Report should be referred to with respect to any design decisions.

## TECHNICAL REPORT

The main report section is intended to provide the technical detail of the investigation and is intended to provide the level of information required by current guidance documents and practice. The Technical Report is written in a language that, in part, assumes knowledge of subject matter so that it can be written in as concise a form as possible. Its intended audience is peers, regulators and other professionals in related disciplines.

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| <p>This section of the report provides background details of a generic nature together with specific technical approaches adopted by BRD and details of the guidance documents that are commonly referenced in the report. The section also includes explanations of technical terms to assist non-specialist readers in understanding the Technical Report. It should be noted that not all the information within this section is necessarily applicable to this specific report.</p> |           |

## APPENDICES

The final section of the report presents the factual data collected and employed as part of the investigation.

### APPENDIX 1 SITE PLANS

|                                |                                                                                               |
|--------------------------------|-----------------------------------------------------------------------------------------------|
| Site Location Plan             | Ref. BRD4469-OP2-A                                                                            |
| Revised Conceptual Site Model  | Ref. BRD4469-OP6-C                                                                            |
| Proposed Development Layout    | 'Proposed Site Layout',<br>Edgingtons Architects, ref.<br>6087 - SK002, dated August<br>2024. |
| Exploratory Hole Location Plan | Ref. BRD4469-OD1-A                                                                            |

### APPENDIX 2 EXPLORATORY HOLE & MONITORING RECORDS

|                                     |                    |
|-------------------------------------|--------------------|
| Logs of trial pits.                 | Ref. TP201-TP216   |
| Photographic records of trial pits. | Ref. BRD4469-OP5-A |
| Logs of boreholes.                  | Ref. WS201-WS208   |
| Gas monitoring records.             | 6 x A4 pages       |
| Groundwater monitoring records.     | 1 x A4 page        |

### APPENDIX 3 LABORATORY TEST RESULTS

|                                 |               |
|---------------------------------|---------------|
| DETS report 24-08965 & 24-09252 | 37 x A4 pages |
| SPT report 45476_1              | 16 x A4 pages |



## SUMMARY REPORT - GENERAL INFORMATION

| SUBJECT                         | COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CURRENT SITE CONDITION</b>   | The site is currently unoccupied and derelict. The former SSE offices have been demolished leaving a surface of demolition rubble across the site in the location of the former offices. A large stockpile of crushed concrete is also located in the centre of the site.                                                                                                                                                                                                                                                                                                                                                                         |
| <b>PROPOSED DEVELOPMENT</b>     | The proposed development is for 90No. residential dwellings, comprising 32No. apartments and 58No. houses.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>HISTORICAL SUMMARY</b>       | The earliest available map from 1867 shows the site as agricultural. A stream was shown in the eastern and southern areas of the site, however by 1957 it was no longer present. By 1972, office buildings had been constructed on site. By the same time, a petrol station had been constructed to the southwest and an electricity substation to the east. By 1991 the offices had been extended. They were then demolished at some point between 2016 and 2019, with the crushed arisings remaining on site.                                                                                                                                   |
| <b>PUBLISHED GEOLOGY</b>        | <p>No superficial deposits are indicated to be present. However, Head Deposits are shown adjacent to the east and River Terrace Deposits approximately 160m south. Both deposits can be composed of clay, silt, sand or gravel.</p> <p>The shallowest bedrock is shown to be the Bognor Sand Member, which is typically described as a fine- and medium-grained sand.</p> <p>The Bognor Sand Member is underlain by the London Clay Formation, which typically comprises grey-brown silty clay.</p>                                                                                                                                               |
| <b>ACTUAL GROUND CONDITIONS</b> | <p>The investigation has proved Made Ground from surface across the majority of the site. The northern half has deeper Made Ground, including demolition crush material, and the southern half of site has shallow Made Ground.</p> <p>Generally underlying the Made Ground are Head Deposits typically composed of clayey sandy gravel, but locally clay. Underlying the Made Ground or Head Deposits is the Bognor Sand Member composed of sand. In trial pit TP204 in the northern half of site, a thin band of Alluvial organic clay associated with a backfilled stream/ditch was encountered between the Made Ground and Head Deposits.</p> |
| <b>HYDROGEOLOGY</b>             | <p>The Bognor Sand Member is designated as a Secondary A Aquifer.</p> <p>The site is located within a groundwater Source Protection Zone 1 (Inner Protection Zone) - Subsurface activity only (1c). This means the aquifer is confined and will only be affected by deep subsurface activity such as deep drilling.</p>                                                                                                                                                                                                                                                                                                                           |
| <b>HYDROLOGY</b>                | <p>The closest identified surface water feature to the site is a stream approximately 311m east of site.</p> <p>The site is outside of areas classified at risk from Extreme Flooding from Rivers or Seas without Defences.</p>                                                                                                                                                                                                                                                                                                                                                                                                                   |

## SUMMARY REPORT - GEOTECHNICAL

| SUBJECT                            | COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EXCAVATIONS</b>                 | <p>It should be possible to forward excavations employing normal equipment, however a buried concrete slab was encountered in trial pit TP202 at 0.8m depth, and therefore it is advised provision is made for the removal of some existing substructures.</p> <p>For excavations down to approximately the groundwater, which is anticipated to be in the region of 1.5m-1.7m bgl depth, excavations are anticipated to remain stable in the short term and specific groundwater control is unlikely to be required at this site. For deeper excavations pumping from a sump alone is unlikely to be sufficient to keep the excavation dry and it is recommended advise is sought from a specialist.</p> |
| <b>SLOPE STABILITY</b>             | It is considered that slope stability is unlikely to be a concern at this site.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>SUB-SURFACE CONCRETE</b>        | Design Sulphate Class of DS-1 and Aggressive Chemical Environment for Concrete class of AC-1 applies.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>PAVEMENT DESIGN</b>             | <p>Preliminary design California Bearing Ratios (CBR) are recommended for the following ground types,</p> <p>Made Ground - less than 2%</p> <p>Fine-grained Head Deposits - 3%</p> <p>Coarse-grained Head Deposits &amp; Bognor Sand Member - 20%</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>FOUNDATIONS</b>                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>LIKELY FOUNDATION TYPE</b>      | <p>Across most of the site conventional shallow/trench fill foundations should be suitable. Due to the variation in the surface soils, the foundations should be reinforced. Further investigation to delineate the area where the Bognor Sand Member is closer to the surface may enable standard strip footings without reinforcement in those areas.</p> <p>However, in localised areas of the site underlain by thicker Made Ground in excess of 1.5m depth, an alternative deeper foundation solution, such as piling, may be required.</p>                                                                                                                                                          |
| <b>VOLUME CHANGE POTENTIAL</b>     | <p>Head Deposits - Assume a high volume change potential given the variation in near surface soil type.</p> <p>Bognor Sand Member - Assume a low volume change potential.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>ESTIMATED FOUNDATION DEPTHS</b> | <p>The minimum footing depth required is 1.0m, and generally 1.5m where required to allow for restricted new tree planting. Regardless, all foundations should be taken down through the Made Ground, and locally Alluvium, and into the Head Deposits or Bognor Sand Member.</p> <p>Should the foundation be emplaced entirely within the Bognor Sand Member then the low volume change potential can be assumed and the required NHBC Standards for tree influence can be followed.</p>                                                                                                                                                                                                                 |
| <b>HEAVE PROTECTION</b>            | Is likely to be required for some plots.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

## SUMMARY REPORT - CONTAMINATION ISSUES

| SUBJECT                                  | COMMENTS                                                                                                                                                                                                         |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SOIL RISKS TO HUMAN HEALTH               | No unacceptable contamination in respect of human health have been identified by this investigation.                                                                                                             |
| LANDFILL GAS                             | Landfill gas protection measures are not required.                                                                                                                                                               |
| RADON GAS                                | Radon gas protection measures are not required.                                                                                                                                                                  |
| RISKS TO THE WATER ENVIRONMENT           | No unacceptable contamination risks to water resources have been identified by this investigation.                                                                                                               |
| RISKS TO BUILDING MATERIALS AND SERVICES | No unacceptable contamination risks to building materials or services have been identified by this investigation.                                                                                                |
| REMEDIATION                              | No remedial works are considered necessary to facilitate the development at this stage.                                                                                                                          |
| ASBESTOS                                 | No asbestos has been detected in the soil samples tested.                                                                                                                                                        |
| WASTE SOIL DISPOSAL                      | It is considered that the Made Ground and natural sub-soils disposed of from the site would be classified as 'non-hazardous waste,' and would likely be characterised for disposal to landfill as 'inert waste.' |

## SUMMARY REPORT - KEY RECOMMENDATIONS

### RECOMMENDATIONS

#### Contamination

Based on the investigations undertaken, the site does not present any contamination risks and as such should not warrant any remediation.

#### Geotechnical

As noted above, to allow a more detailed assessment of the extent of the localised deeper Made Ground in the central and northwestern areas, further investigations are recommended. Likewise, it would be prudent to undertake more detailed investigation of the north eastern section and some peripheral areas to more accurately delineate the extent of the shallow Bognor Sand Member. Should the need for piling be identified then there will also need to be some deep boreholes to determine pile design parameters.

The initial phase of investigation would likely involve machine excavated trial pitting in the first instance. Should a need for piling be identified then this would be followed by some cable percussive boreholes to confirm deeper ground conditions for pile design. In-situ Standard Penetration Tests should be conducted during forwarding of the boreholes and collected soil samples submitted for appropriate geotechnical laboratory testing.

In addition, to allow determination of groundwater levels during the wetter months of the year, longer term groundwater monitoring over the winter months could be considered. This may also have an impact on the number of plots requiring piled foundations, as shallower groundwater could impact on the ability to form trench fill footings.

# 1. INTRODUCTION TO TECHNICAL REPORT

## 1.1. CONTRACT DETAILS

|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CLIENT</b>            | Stonebond Properties (Guildford) Limited trading as Stonebond.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>SITE</b>              | Land situated off Bartons Road at the former SSE Office, in the town of Havant.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CLIENT'S ADVISORS</b> | BRD Environmental Limited (BRD) has been commissioned directly by the Client.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>REPORT CONTEXT</b>    | It is understood that the Client intends to purchase the site and develop it for residential housing.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>REPORT TYPE</b>       | Combined geotechnical ground investigation and Phase 2 contamination assessment.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>REPORT OBJECTIVES</b> | <p>The site has been the subject of a desk study, referenced as follows:</p> <ul style="list-style-type: none"><li>• 'Phase 1 Environmental Desk Study - Bartons Road, Havant', BRD Environmental Ltd, report ref. BRD4469-OR1-A, dated August 2024.</li></ul> <p>The desk study identified a number of potential contamination sources that required further investigation and identified the need for some geotechnical investigation to inform the design of the new development.</p> <p>The purpose of this report is to present the findings of the Phase 2 ground investigation, and to present both geotechnical and contamination assessments of the ground conditions revealed.</p> |

## 1.2. SCOPE OF WORKS

The agreed scope of works was:

- Mobilisation to site and production of health and safety documentation.
- Two days of windowless sampling using a percussive drilling rig to provide approximately 8-10No. boreholes to a nominal depth of 5m, ground conditions permitting. Undertake Standard Penetration Tests (SPT) at 1m intervals. Installation of a 5m depth combined gas and groundwater monitoring well (nominal 50mm diameter) into 6No. boreholes. Installations will be finished with a flush fitting metal stopcock cover.
- Two days of trial pitting using a mechanical excavator to provide approximately 14-16No. trial pits to a nominal depth of 3m, ground conditions permitting.
- All exploratory points will be logged and sampled in general accordance with BS5930:2015+A1:2020 by supervising Geo-Environmental Consultant.
- In-situ geotechnical testing of fine soils using a Hand Shear Vane and/or Pocket Penetrometer.
- Determination of the accurate location and level of exploratory points by topographical grade GPS unit.

- Geo-Environmental Technician to undertake a total of 6No. combined gas, vapour and groundwater monitoring visits. For gas, the determination of oxygen, carbon dioxide, methane, hydrogen sulphide and carbon monoxide concentrations, together with atmospheric pressure and flow rates, using portable equipment. For vapours, determination of the concentration of volatile organic compounds by photo ionisation detector. For groundwater, the determination of groundwater levels.
- Groundwater sampling to be undertaken on the first monitoring visit, with the purging of monitoring wells and the collection of groundwater samples for testing using sampling equipment dedicated to each well.
- Chemical testing of soil samples with the budget based on the following testing schedule:
  - 12No. Metals Suite - As, Cd, Cr, CrVI, Hg, Pb, Se, Cu, Ni and Zn.
  - 12No. Inorganics Suite - water soluble sulphate, pH, organic matter.
  - 12No. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
  - 8No. Banded aliphatic/aromatic Total Petroleum Hydrocarbons (TPH).
  - 8No. Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE) compounds.
  - 8No. Polychlorinated Biphenyls (PCB) - 7 Congeners.
  - 12No. Asbestos quantification.
  - 3No. Semi-Volatile Organic Compounds (SVOC) suite.
- Chemical testing of 6No. water samples for the following testing schedule:
  - Metals Suite - As, Cd, Cr, CrVI, Hg, Pb, Se, Cu, Ni and Zn.
  - Inorganics Suite - sulphate, pH.
  - Speciated Polycyclic Aromatic Hydrocarbons (PAH).
  - Banded aliphatic/aromatic Total Petroleum Hydrocarbons (TPH).
  - Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE) compounds.
  - Polychlorinated Biphenyls (PCB) - 7 Congeners.
- Geotechnical testing as appropriate to the nature of the ground conditions encountered, but the budget is based on the following testing schedule:
  - 6No. Moisture content.
  - 6No. Plasticity indices.
  - 5No. Particle size distribution by wet sieve and follow on hydrometer.
  - 8No. pH and water soluble sulphate analysis - soil.
  - 8No. Total sulphate and sulphur analysis - soil.
  - 6No. pH and sulphate analysis - water (as part of contamination testing).
- Provision of a combined factual and interpretative investigation report. Factual findings to include all exploratory point records, monitoring and test results. Interpretative reporting to include a summary of information from desk study research, a Generic Quantitative Contamination Risk Assessment (GQRA), waste classification and a Geotechnical Assessment providing comments on pavement design, concrete classification, soakaway feasibility, foundation design recommendations.

### 1.3. REPORT LIMITATIONS

Any site boundary lines depicted on plans included within this report are approximate only and do not imply legal ownership of land. Any observations of tree species, asbestos containing materials within structures or invasive weeds, does not constitute a formal survey of such features. The identification of such features is therefore tentative only. In the case of Japanese Knotweed, BRD can undertake separate surveys for this plant undertaken by a Property Care Association qualified surveyor.

The report does not consider whether sensitive ecology or archaeology is present as these require consideration by professionals specialising in these matters. It should be recognised that the collection of desk study information may not be exhaustive and that other information pertinent to the site may be available.

The recommendations, interpretations and conclusions of this report are based solely on the ground conditions found at the exploratory holes. Due to the variability in the nature of ground, conditions between exploratory holes can only be interpreted and not defined. The description of the site and the ground conditions is accurate only for the dates of the field works. In particular, groundwater levels can vary due to seasonal and other effects.

The assessment and interpretation of contamination risks is based on the scope of works agreed with the Client together with the budgetary and programme constraints imposed. Further investigation, analysis and assessment of contamination may be required by regulators or other third parties with an interest in the site. An ecological risk assessment of contaminated soils is beyond the scope of this report. This report is concerned with assessing those contamination risks which apply to the future use of the site through the proposed development as part of the planning regime. The assessment does not consider the risk to current site users or continued future use of the site in its current state. If development of the site should occur that differs from that proposed, then the findings of the contamination assessment would need to be re-evaluated.

At the time of writing, detailed information on the proposed structure, such as detailed layout, loadings and serviceability limits, was not available. Accordingly, where geotechnical design advice is provided it is on the prescriptive basis allowed for by Eurocode 7: employing conventional and conservative design rules. The scope of this investigation excludes a formal slope stability study and any observations made regarding slopes are for information only.

## 2. SITE CHARACTERISTICS

### 2.1. SITE SETTING

|                                   |                                                    |
|-----------------------------------|----------------------------------------------------|
| <b>SITE ADDRESS AND POST CODE</b> | Former SSE Offices, Bartons Road, Havant, PO9 5TH. |
| <b>NATIONAL GRID REFERENCE</b>    | 472160E, 108010N.                                  |

### 2.2. SITE DESCRIPTION

| <b>SUBJECT</b>                  | <b>COMMENTS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CURRENT SITE DESCRIPTION</b> | <p>The site is currently unoccupied and derelict. The former SSE offices have been demolished leaving a surface of demolition rubble across most of the site and a large stockpile of crushed concrete in the centre of the site.</p> <p>The site slopes by just over 3m from the north to the south. However, the natural slope of the site has been changed due to the historical development and the also the recent demolition works.</p> <p>Along the northern edge is a retaining wall. The retaining wall is around 3m from the site boundary. The top of the wall is in line with the adjacent road level, which is around 1m higher than the general site level.</p> <p>The site starts to slope from the north; however, the central area of the site has previously been regraded. The demolition area slopes by around 0.60m over approximately 90m. There is a steeper slope along the southern edge of the demolition arisings, in the central southern area of the site. The rest of the southern area gradually slopes by around 1m to the southern boundary.</p> <p>The boundaries of the site are generally overgrown with vegetation, with some areas of grass and other low vegetation and saplings across the site. Off-site, but bordering the northern boundary, are a number of mature trees.</p> |
| <b>SURROUNDING LAND USE</b>     | <p>The site is set in a mixed residential and commercial area within Havant.</p> <p>Directly north of the site is Bartons Road, beyond which are residential houses. Directly east of the site is a football ground, with associated infrastructure, and an electric substation and office building. A storage tank is located next to the electric substation, but the contents are unknown. Directly south of the site is Martin Road, beyond which are residential houses and another small electric substation. There is a garage just to the southwest of the site with a road, the B2149, forming the rest of the western boundary, beyond which are residential houses and flats.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>PROPOSED DEVELOPMENT</b>     | <p>The proposed development is for 90No. residential dwellings, comprising 32No. apartments and 58No. houses.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

| SUBJECT                   | COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>HISTORICAL SUMMARY</b> | The earliest available map from 1867 shows the site as agricultural. A stream was shown in the eastern and southern areas of the site, however by 1957 it was no longer present. By 1972, office buildings had been constructed on site. By the same time, a petrol station had been constructed to the southwest and an electricity substation to the east. By 1991 the offices had been extended. They were then demolished at some point between 2016 and 2019, with the crushed arisings remaining on site.                                                                                                                                                                                                                                 |
| <b>PUBLISHED GEOLOGY</b>  | <p>No superficial deposits are indicated to be present. However, Head Deposits are shown adjacent to the east of the site, and River Terrace Deposits approximately 160m to the south. Both of these deposits can be composed of clay, silt, sand or gravel.</p> <p>The shallowest bedrock is shown to be the Bognor Sand Member, which is typically described as fine- and medium-grained sand. The London Clay Formation underlies the Bognor Sand Member and typically comprises silty clay.</p>                                                                                                                                                                                                                                             |
| <b>RADON</b>              | Radon gas protection measures are not required.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>HYDROGEOLOGY</b>       | <p>The Bognor Sand Member is designated as a Secondary A Aquifer.</p> <p>The site lies within a Zone 1 (Inner Protection Zone) - Subsurface activity only (1c). This means the aquifer is confined and will only be affected by subsurface activity such as deep drilling. As the aquifer is confined at depth, the risk to the SPZ from surface activities would typically be negligible, unless deep subsurface activity exposing the aquifer is to occur.</p> <p>Based on the BGS maps for the area, the SPZ1c will relate to the deeper Chalk aquifer which forms a drinking water resource. However, this is present at a significant depth beneath the site and is confined by the overlying Lambeth Group and London Clay Formation.</p> |
| <b>HYDROLOGY</b>          | <p>The closest surface water feature to the site is a small stream located approximately 311m east of site.</p> <p>The site is outside of areas classified at risk from Extreme Flooding from Rivers or Seas without Defences.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

## 2.3. PREVIOUS INVESTIGATIONS

The site has previously been subject to two ground investigations. The first was completed prior to the demolition of the on-site buildings and the second was completed following the demolition. These are referenced as follows:

- ‘Ground Investigation Report’, Soiltechnics, ref. STM3168D-GD1, dated May 2016.
- ‘Interpretive Site Investigation and Remedial Strategy Report’, Forge Environmental Management Ltd, ref. HAV164.D/SI/002, rev. 1, Dated March 2020.

These two investigation reports have been reviewed within the BRD desk study referenced as:

- ‘Phase 1 Environmental Desk Study - Bartons Road, Havant’, BRD Environmental Ltd, report ref. BRD4469-OR1-B, dated July 2025.

### 3. GROUND INVESTIGATION

#### 3.1. INVESTIGATION DESIGN

|                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| <b>METHODOLOGY</b>                            | <p>The investigation design warranted a combination of trial pits and boreholes.</p> <p>Trial pits were selected as they expose more soils than boreholes, which enables a more reliable record of the ground conditions encountered, in particular of the crushed concrete stockpile.</p> <p>Windowless sample boreholes were also selected, as monitoring installations and in-situ density tests were required in the underlying coarse soils.</p>                                     |                                    |
| <b>DATES OF SITE WORKS</b>                    | <p>The main field works were undertaken on 31<sup>st</sup> July to 2<sup>nd</sup> August 2024, with subsequent monitoring visits undertaken on the 9<sup>th</sup>, 16<sup>th</sup> &amp; 28<sup>th</sup> August, 12<sup>th</sup> &amp; 25<sup>th</sup> September and 17<sup>th</sup> October 2024.</p>                                                                                                                                                                                    |                                    |
| <b>CONSTRAINTS TO EXPLORATORY HOLE LAYOUT</b> | <p>A large stockpile of crushed demolition arisings was located in the central northern area of the site. Although samples of the stockpiled material were obtained, the ground beneath the stockpile was not accessible give the thickness/height of the stockpile.</p> <p>Due to services along the eastern boundary, no exploratory points could be positioned in that area. Other services, although likely not present after demolition, also had to be avoided across the site.</p> |                                    |
| <b>EXPLORATORY HOLE SPACING</b>               | <p>Approximately 20m grid.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                    |
| <b>LAYOUT RATIONALE</b>                       | <b>SOURCE / FEATURE</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>EXPLORATORY HOLE</b>            |
| <b>CONTAMINATION SOURCES TARGETED</b>         | Made Ground and former use of site.                                                                                                                                                                                                                                                                                                                                                                                                                                                       | TP201 to TP212 and WS201 to WS208. |
|                                               | Stockpile of crushed demolition arisings.                                                                                                                                                                                                                                                                                                                                                                                                                                                 | TP213 to TP216.                    |
|                                               | Backfilled stream.                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | TP211, TP212, WS205 and WS206.     |
|                                               | Off-site electrical substation.                                                                                                                                                                                                                                                                                                                                                                                                                                                           | TP210, TP211 and WS205.            |
|                                               | Off-site former fuel station and present-day garage.                                                                                                                                                                                                                                                                                                                                                                                                                                      | TP208 and WS202.                   |
| <b>GROUND FEATURES TARGETED</b>               | General site coverage.                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | TP201 to TP212 and WS201 to WS208. |
|                                               | Stockpile of crushed demolition arisings.                                                                                                                                                                                                                                                                                                                                                                                                                                                 | TP213 to TP216.                    |

|                                    |                                                                                                                                                                                                                                                                                   |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CONTAMINATION SAMPLING PLAN</b> | Based on the proposed end use, the sampling and analysis plan is more positively biased towards near surface samples as these represent the soils most likely to be available to future site users.                                                                               |
| <b>ANALYSIS PLAN</b>               | Given the site's history and surrounding contamination sources, BRD have scheduled a typically occurring suite of contaminants including heavy metals, Polycyclic Aromatic Hydrocarbons (PAH), Total Petroleum Hydrocarbons (TPH), asbestos and polychlorinated biphenyls (PCBs). |

### 3.2. BRD FIELDWORK

| TRIAL PITS         |                                                                                                                   |
|--------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>REFERENCES</b>  | TP201 to TP216                                                                                                    |
| <b>DEPTH RANGE</b> | From 2.90m to 3.10m.                                                                                              |
| <b>EXCAVATOR</b>   | JCB 3CX style wheeled backactor.                                                                                  |
| <b>BACKFILL</b>    | All the trial pits were backfilled with arisings upon completion and compacted with rams of the excavator bucket. |

| WINDOWLESS SAMPLING BOREHOLES  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>REFERENCES</b>              | WS201 to WS208                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>DEPTH RANGE</b>             | From 3.00m to 4.00m.                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>RIG TYPE</b>                | Premier Drilling Rig.                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>INSTALLATION / BACKFILL</b> | Boreholes WS201 to WS204, WS206 and WS207 had monitoring wells installed. These comprised 50mm nominal diameter standpipes fitted with a gas tap finished with a flush metal cover. The slotted response length of the well is shown on the individual logs. Bentonite seals are also indicated on the logs. The filter medium used was pea gravel.<br><br>Boreholes WS205 and WS208 were backfilled with arisings only. |

| MONITORING                         |                                                                                                                                                |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>TYPE</b>                        | Ground gases, vapours and groundwater.                                                                                                         |
| <b>DATES</b>                       | 9 <sup>th</sup> , 16 <sup>th</sup> & 28 <sup>th</sup> August, 12 <sup>th</sup> & 25 <sup>th</sup> September and 17 <sup>th</sup> October 2024. |
| <b>GROUNDWATER SAMPLING METHOD</b> | Samples were retrieved using a sampling bailer dedicated to each well on the first visit only.                                                 |

### 3.3. LABORATORY TESTING

| GEOTECHNICAL TESTING                                                                                                                                                                                                                                                                                                                                       |                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| The soil samples for geotechnical testing were forwarded to the laboratory of Soil Property Testing Ltd with pH and sulphate analysis undertaken at the laboratory of DETS Ltd. The geotechnical testing suite is detailed below. The UKAS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices. |                          |
| TEST                                                                                                                                                                                                                                                                                                                                                       | NUMBER OF SAMPLES TESTED |
| Moisture content                                                                                                                                                                                                                                                                                                                                           | 4                        |
| Liquid and plastic limits                                                                                                                                                                                                                                                                                                                                  | 4                        |
| Particle size distribution by wet sieve                                                                                                                                                                                                                                                                                                                    | 4                        |
| Particle size distribution by wet sieve and hydrometer                                                                                                                                                                                                                                                                                                     | 4                        |
| pH and Water-soluble Sulphate                                                                                                                                                                                                                                                                                                                              | 8                        |
| Total Sulphur and Sulphate                                                                                                                                                                                                                                                                                                                                 | 8                        |

| SOIL CHEMICAL TESTING                                                                                                                                                                                                                                                                            |                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| The soil samples for contamination and/or chemical geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices. |                          |
| SOIL TESTS                                                                                                                                                                                                                                                                                       | NUMBER OF SAMPLES TESTED |
| Arsenic, Cadmium, Chromium, Chromium VI, Copper, Lead, Mercury, Nickel, Selenium, Zinc                                                                                                                                                                                                           | 12                       |
| Speciated Polycyclic Aromatic Hydrocarbons (PAH)                                                                                                                                                                                                                                                 | 12                       |
| Total Petroleum Hydrocarbons (TPH) with full carbon banding and aliphatic/aromatic split                                                                                                                                                                                                         | 8                        |
| Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) plus Methyl Tert Butyl Ether (MTBE)                                                                                                                                                                                                            | 8                        |
| Organic Matter                                                                                                                                                                                                                                                                                   | 12                       |
| Asbestos Quantification                                                                                                                                                                                                                                                                          | 12                       |
| Semi-Volatile Organic Compounds (SVOCs)                                                                                                                                                                                                                                                          | 3                        |
| Polychlorinated Biphenyls (PCBs)                                                                                                                                                                                                                                                                 | 8                        |
| Waste Acceptance Criteria (WAC) testing                                                                                                                                                                                                                                                          | 1                        |

| GROUNDWATER CHEMICAL TESTING                                                                                                                                                                                                                                                                      |                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| The water samples for contamination and/or chemical geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices. |                          |
| WATER TESTS                                                                                                                                                                                                                                                                                       | NUMBER OF SAMPLES TESTED |
| Arsenic, Cadmium, Chromium, Chromium VI, Copper, Lead, Mercury, Nickel, Selenium, Zinc                                                                                                                                                                                                            | 6                        |
| Speciated Polycyclic Aromatic Hydrocarbons (PAH)                                                                                                                                                                                                                                                  | 6                        |
| Total Petroleum Hydrocarbons (TPH) with full carbon banding and aliphatic/aromatic split                                                                                                                                                                                                          | 6                        |
| Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) plus Methyl Tert Butyl Ether (MTBE)                                                                                                                                                                                                             | 6                        |
| Polychlorinated Biphenyls (PCBs)                                                                                                                                                                                                                                                                  | 6                        |
| pH                                                                                                                                                                                                                                                                                                | 6                        |
| Sulphate                                                                                                                                                                                                                                                                                          | 6                        |

## 4. GROUND CONDITIONS

### 4.1. OVERVIEW

The ground conditions encountered are similar to that of the previous investigations, which all varies slightly to that of the mapped geology. Made Ground was encountered from surface, which was generally underlain by Head Deposits onto bedrock of the Bognor Sand Member, however locally Alluvium was also encountered in one location between the Made Ground and the Head Deposits.

Details of the various stratigraphic units are given in the following sections.

### 4.2. ARTIFICIAL GROUND

#### 4.2.1. Made Ground - Demolition Area

The crushed arisings from the demolition of the former buildings has been spread across the area of the former buildings in the central and some of the northern areas, levelling the area. The material was encountered in trial pits TP202 to TP206 and TP210 and boreholes WS204 and WS208. It typically comprised light grey to brown, sandy gravel of concrete, brick, plastic, redundant cables, wood, glass and rebar, and included some cobble sized brick and concrete. The base of the crush material varied between 0.3m (TP205) and 1.0m bgl (TP206), but was typically around 0.4m depth.

Trial pits TP213 to TP216 were forwarded into the crushed arisings stockpile in the central area. The material was similar to that spread across the site and ranged from brown, very gravelly sand to very sandy gravel, with the gravel component similar as that previous described.

Beneath the crush material, further Made Ground was encountered in trial pits TP202 to TP206 and TP210 and boreholes WS204 and WS208, down to depths generally ranging from 0.8m to 1.0m, but a maximum depth of 2.3m bgl. This Made Ground typically varied from a gravelly, sandy clay to a gravelly, clayey sand, however locally it comprised clayey, sandy gravel. The gravel content included quartzite, flint, concrete, brick, fabric, ceramic, plastic, redundant cables and metal.

#### 4.2.2. Made Ground - Rest of Site

Trial pit TP201 and boreholes WS206 and WS207 were forwarded in the small area north of the placed crush material. They all encountered Made Ground typically comprising a brown or grey mottled orange brown gravelly sandy clay, locally with cobbles, with the gravel and cobbles consisting mainly of brick and concrete and some wood, slate, quartzite and flint. This Made Ground was typically encountered down to 0.4m bgl, however locally was encountered down to 0.8m bgl.

Trial pits TP211, TP212 and borehole WS205 were forwarded in the partially vegetated area to the east of the placed crush material. Made Ground was encountered from ground level at TP211 and TP212 and beneath Made Ground/Topsoil at WS205, from 0.1m bgl, down to a typical depth of 0.4m bgl. It typically comprised gravelly sand, but locally clayey sandy gravel, with the gravel generally consisting of concrete and some flint, plastic, brick, ceramic and glass. In addition, some cobbles of concrete were encountered locally.

Trial pits TP207 to TP209 and boreholes WS201 to WS203 were forwarded in the lower southern area of site and encountered Made Ground from surface down to depths between 0.2m and 0.6m bgl. In this area the Made Ground typically comprised gravelly sand or sandy gravel with the gravel including brick, including whole bricks, rebar, concrete and glass.

### **4.3. MADE GROUND TOPSOIL**

Made Ground/Topsoil was only encountered from ground level down to 0.1m bgl at one location, WS205, in the eastern area. It comprised slightly gravelly, slightly sandy, slightly organic clay with gravel of flint.

### **4.4. SUPERFICIAL DEPOSITS**

#### **4.4.1. Head Deposits**

Head Deposits were encountered beneath the Made Ground at most test locations, at depths down to 0.7m to 2.8m bgl. It generally comprised clayey, sandy gravel, but locally comprised slightly sandy slightly gravelly clay. The gravel was typically flint but also included some quartzite and sandstone.

#### **4.4.2. Alluvium**

Alluvium was encountered in trial pit TP204 only, in the location of an historic field boundary ditch in the central area of the site, between the Made Ground and Head Deposits, from 0.8m to 1.2m bgl. It consisted of bluish grey with occasional brown mottling, silty clay with a natural black staining and organic odour.

### **4.5. BEDROCK**

#### **4.5.1. Bognor Sand Member**

The Bognor Sand Member was encountered across the site, generally beneath the Head Deposits, or Made Ground where the Head Deposits were not present, down to the base of the exploratory holes at depths down to 4.0m bgl. It typically comprised slightly clayey sand.

### **4.6. GEOTECHNICAL COMMENTS**

Following ingress of groundwater seepages, the sides of TP201, TP202 and TP209 collapsed at depths below 1.4m, 2.4m and 2.2m bgl respectively. In addition, boreholes WS201, WS202, WS204 and WS205 also suffered some collapse, below 2.5m to 3.2m bgl, following strikes of groundwater.

The boreholes were all terminated as a consequence of the dense or very dense Bognor Sand Member strata, between 3.00m and 4.00m bgl.

### **4.7. CONTAMINATION OBSERVATIONS**

No visual or olfactory evidence of contamination was noted during the forwarding of exploratory holes.

## 4.8. GROUNDWATER BEHAVIOUR

During the progressing of the trial pits, the following general observations of groundwater behaviour were made.

Groundwater was only encountered within the Bognor Sand Member as ingresses. The depths of these ingresses are displayed in the table below. The groundwater was typically encountered deeper than 2.00m bgl.

| EXP. POINT | DEPTH (BGL) | EXP. POINT | DEPTH (BGL) |
|------------|-------------|------------|-------------|
| TP201      | 2.50m       | WS201      | 2.10m       |
| TP202      | 2.80m       | WS202      | 2.10m       |
| TP203      | 3.00m       | WS203      | 2.10m       |
| TP207      | 2.80m       | WS204      | 3.10m       |
| TP208      | 2.60m       | WS205      | 3.20m       |
| TP209      | 2.60m       | WS206      | 2.20m       |
| TP211      | 2.70m       | WS207      | 3.10m       |
| TP212      | 2.70m       | WS208      | 2.10m       |

## 4.9. GROUNDWATER MONITORING

The following table summarises the groundwater levels from the three rounds of monitoring undertaken at the site. As discussed earlier, a further three visits are still scheduled.

| DATE     | RESTING GROUNDWATER RANGE | COMMENTS                                                                                                                                                                                                                                                                       |
|----------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09/08/24 | From 1.79m to 3.16m bgl.  | Groundwater levels remained fairly consistent across the monitoring visits with the shallowest levels, relative to ground level, recorded at WS207, and the deepest at WS204.<br><br>Most of the recorded groundwater levels are within the Bognor Sand Member.                |
| 16/08/24 | From 1.82m to 3.19m bgl.  |                                                                                                                                                                                                                                                                                |
| 28/08/24 | From 1.77m to 3.11m bgl.  |                                                                                                                                                                                                                                                                                |
| 12/09/24 | From 1.70m to 2.84m bgl.  |                                                                                                                                                                                                                                                                                |
| 25/09/24 | From 1.49m to 2.77m bgl.  | By these last two visits, the impact of the very wet September and October is noticeable in the groundwater as the levels are shallower in comparison to the preceding visits. Of note, WS201, WS203, WS206 and WS207 are all at similar levels (between 1.39m and 1.47m bgl). |
| 17/10/24 | From 1.39m to 2.40m bgl.  |                                                                                                                                                                                                                                                                                |

## 5. GEOTECHNICAL PROPERTIES

### 5.1. COARSE SOIL PARAMETERS

#### 5.1.1. Standard Penetration Tests

The SPT N-values increased with depth and ranged from 7 to 41 at depths down to 2.0m, below 2.0m depth they ranged from 16 to >50.

Using an energy ratio of 86%, at depths down to 2.0m the corrected  $N_{60}$  values range from 11 to 66, indicating strata that was medium dense to very dense.

Using the approach by Stroud (1985) and based upon a conversion of  $c_u = 5.0N_{60}$ , the SPT result from 1.2m depth at WS01 indicates the shear strength of the fine-grained Head Deposits at this location is 56kpa, indicating medium strength soils.

#### 5.1.2. Particle Size Distribution

The grading curves of one sample of Head Deposits, three of the Bognor Sand Member and four of the material making up the stockpile in the central area of the site subject to PSD determination revealed the following results.

| GRADING RANGE (MM)   | CRUSHED DEMOLITION ARISING MADE GROUND (%) | HEAD DEPOSITS (%) | BOGNOR SAND MEMBER (%) |
|----------------------|--------------------------------------------|-------------------|------------------------|
| <0.063 - Fines       | 1 to 2                                     | 18                | 7 to 31                |
| 0.063 to 2.0 - Sand  | 18 to 26                                   | 6                 | 66 to 93               |
| 2.0 to 90.0 - Gravel | 72 to 81                                   | 76                | 0 to 3                 |

### 5.2. FINE SOIL PARAMETERS

#### 5.2.1. Index Property Testing

|                       |                                                                                              |
|-----------------------|----------------------------------------------------------------------------------------------|
| SOIL TYPE             | Head Deposits (Clay & Gravel beds).                                                          |
| PLASTICITY INDEX (PI) | 48% and 49% (Two samples: High volume change potential).                                     |
| MODIFIED PI           | 7% (One sample: Non-shrinkable soil type).<br>16% (One sample: Low volume change potential). |
| NHBC CLASS            | Gravel beds: Low volume change potential.<br>Clay beds: High volume change potential.        |

#### 5.2.2. Undrained Shear Strength

This section discusses all of the laboratory and in-situ tests that produce either direct or indirect measures of undrained shear strength.

#### 5.2.2.1. Hand Shear Vane

|                                              |                                                                                                                                                                                             |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SOIL TYPE</b>                             | Head Deposits (Clay beds)                                                                                                                                                                   |
| <b>UNCORRECTION RESULTS <math>\mu</math></b> | Hand vane tests were carried out in the fine-grained Head Deposits soils at three locations at depths between 0.5m and 0.7m and recorded results ranging from 54kPa to 100kPa.              |
| <b>CORRECTION FACTOR AND JUSTIFICATION</b>   | The plasticity index (PI) results varied from 7% to 49%; to allow a conservative approach a PI of 40% has been used. After Bjerrum 1972, employing Plasticity Index, PI ~40 so $\mu=0.84$ . |
| <b>DISCUSSION OF CORRECTED RESULTS</b>       | The corrected results ranged 45kPa to 84kPa, indicating soils that were medium and high strength.                                                                                           |

### 5.3. SULPHATE AND pH

|                          | ALL ON-SITE SOILS                                       |                                                          |                            |                 |
|--------------------------|---------------------------------------------------------|----------------------------------------------------------|----------------------------|-----------------|
|                          | Sulphate                                                |                                                          | pH                         |                 |
| Characteristic Value     | 300 mg/l                                                |                                                          | 6.9 units                  |                 |
| Justification            | Mean of highest 20% results rounded to nearest 100mg/l. |                                                          | Lowest groundwater result. |                 |
|                          | No. of tests                                            | Results Range                                            | No. of tests               | Results Range   |
| Soil                     | 20                                                      | 12 - 335 mg/l                                            | 20                         | 6.9 - 9.9 units |
| Groundwater              | 6                                                       | 14 - 170 mg/l                                            | 6                          | 6.9 - 7.5 units |
| Total Potential Sulphate | 8                                                       | Not applicable as pyrite unlikely in the samples tested. |                            |                 |

## 6. GEOTECHNICAL ASSESSMENT

### 6.1. INTRODUCTION

It is our understanding the development proposals comprise mainly two-storey housing, with associated infrastructure. There is also one apartment building included, which will be four storeys in height. The Proposed Development Plan is included in Appendix 1.

From assessment of the nature of the ground conditions and the type of proposed structures, it is considered that the situation falls within EC7 Geotechnical Category 1.

Should the nature of the development be changed then the results of this investigation would need to be reviewed and reassessed.

### 6.2. EXCAVATIONS

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>STABILITY</b> | <p>Any excavation requiring man entry should be battered back to a safe angle, supported by an appropriate proprietary trench support system or adequately shored to provide safe working conditions. Shoring to any excavation requiring man entry must be designed by a suitably qualified and experienced engineer. Any support system will require regular inspection as detailed in published guidelines to ensure the excavation support is adequate and appropriate for the ground conditions present.</p> <p>Some side wall collapse of the trial pits and in the boreholes was encountered following ingress of groundwater. On this basis, it is anticipated narrow trench excavations should remain stable in the short-term down to the groundwater, which is anticipated to be in the region of 1.5m-1.7m bgl depth (see below). However, for deeper excavations, or if groundwater is encountered at a shallower depth than expected, then side wall supports will be required.</p> <p>Groundwater levels are likely to be shallower in the wetter winter months and consideration could be given to extending monitoring over the winter to allow a more detailed assessment of conditions during this wetter period.</p> <p>In addition, in localised areas Made Ground was encountered to depths below 1.5m. Made Ground is typically variable in nature and strength and, although, side wall instability was not encountered at all these locations, we recommend side wall supports be used where deeper Made Ground is encountered.</p> |
| <b>EQUIPMENT</b> | <p>It is possible some substructures are still present in the ground, for example a concrete slab was encountered in TP202 at 0.8m depth.</p> <p>However, given that none of the other trial pits or window sampler boreholes were terminated short due to obstructions, it is considered conventional hydraulic plant should be sufficient to progress excavations in the soils encountered. Should any existing substructures be encountered then the use of specialist break plant is likely to be required.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## GROUNDWATER CONTROL

Groundwater strikes and seepages were encountered at most of the test locations, typically at depths below 2.1m bgl. The follow-on monitoring of the boreholes has recorded standing water levels between 1.4m and 3.2m bgl depth.

Based on the observations made during this investigation, it is considered the local groundwater level is likely to be in the region of 1.5m-1.7m bgl depth. Therefore, for excavations down to approximately 1.5m bgl depth specific groundwater control, beyond limited pumping from sumps or bailing out to deal with slight seepages or surface water ingress during periods of inclement weather, is unlikely to be required at this site.

However, for excavations below 1.5m bgl depth groundwater ingress should be anticipated and provision made for its control. In this eventuality, we would recommend consultation with a specialist groundwater control contractor.

It is likely that the groundwater level will be shallower during the wetter winter months, and as noted above, consideration could be given to extending the period of monitoring to allow a more detailed assessment of the local groundwater conditions during this period.

Any groundwater control system should be designed and operated to minimise the loss of fines from the soil matrix as this could adversely affect settlement.

## 6.3. SLOPE STABILITY AND RETAINING WALLS

The site slopes by just over 3m from the north to the south, however, due to historical development the natural slope has been altered to allow for development. No obvious signs of instability were noted during the investigation, and it is assumed that at its current angle the slope is stable.

It is likely that some re-grading of the slope or the use of retaining structures will be required in order to accommodate the proposed development. Parameters to aid the design of temporary and permanent retaining walls are given in the table below.

| Stratum                             | Bulk Density $\gamma_B$ (kN/m <sup>3</sup> ) | Undrained Shear Strength $S_u$ (kPa) | Angle of Shearing Resistance $\phi'_{peak}/\phi'_{crit}$ (°) | Apparent Cohesion $c'$ (kPa) |
|-------------------------------------|----------------------------------------------|--------------------------------------|--------------------------------------------------------------|------------------------------|
| Made Ground                         | -                                            | -                                    | -                                                            | -                            |
| Head Deposits - Clay                | 17                                           | 60                                   | 22                                                           | 0                            |
| Head Deposits - Gravel              | 19                                           | -                                    | 30                                                           | -                            |
| Alluvium                            | 17                                           | 60                                   | 22                                                           | 0                            |
| Bognor Sand Member (up to 1m depth) | 19                                           | -                                    | 30                                                           | -                            |
| Bognor Sand Member (below 1m depth) | 19                                           |                                      | 34                                                           |                              |

## 6.4. SUB-SURFACE CONCRETE

| ALL ON-SITE SOILS     |                 |
|-----------------------|-----------------|
| SITE / SOIL CATEGORY  | Natural ground. |
| DESIGN SULPHATE CLASS | DS-1            |
| GROUNDWATER REGIME    | Mobile.         |
| ACEC CLASS            | AC-1            |

## 6.5. PAVEMENT CONSTRUCTION

Made Ground thicker than 0.5m covers much of the site, and for these soils it is recommended that a preliminary design California Bearing Ratio (CBR) of less than 2% is assumed at this stage. Across the rest of the site variable Head Deposits, ranging from sandy gravelly clay to clayey sandy gravel were encountered at 0.5m depth. Based on the classification testing results, for formations in the clay Head Deposits a preliminary design California Bearing Ratio (CBR) of 3% is recommended and for the gravel Head Deposits and Bognor Sands Member, 20% is recommended.

Some of the soils at formation depth will be frost susceptible, therefore a minimum total pavement construction of 450mm is required. The cohesive deposits will be prone to rapid degradation during wet weather working and this should be avoided where possible.

All unsuitable soils, such as topsoil or desiccated soils, should be removed from beneath proposed paved areas. The exposed sub-grade formation should then be proof rolled to reveal any excessively soft or compressible zones and any such features identified also removed by excavation. Where unsuitable materials are removed, the resultant voids should be filled in layers with appropriately compacted suitable granular fill. To reduce the loss of granular construction materials into the sub-grade, consideration should be given to utilising a geotextile starter layer across the formation level.

## 6.6. PRELIMINARY FOUNDATION RECOMMENDATIONS

### 6.6.1. Introduction

The development proposals include mainly houses, but also one apartment building, all typically two to three storeys in height. The investigation has shown the ground conditions to generally comprise Made Ground over Head Deposits onto the Bognor Sand Member. In some locations the Head Deposits were not present. In one location, TP204, a thin band of Alluvium, comprising some organic clay, was encountered between the Made Ground and Head Deposits.

The Made Ground soils were generally encountered down to less than 1.0m depth, however locally they were encountered down to depths between 1.5m and 2.3m bgl. The Head Deposits generally comprised medium dense, becoming dense with depth, clayey sandy gravel, however locally they comprised stiff slightly gravelly slightly sandy high volume change potential clay. The Bognor Sand Member generally comprised medium dense slightly clayey sand.

### 6.6.2. Floor Slabs

Due to the depth of Made Ground across the site, fully suspended floor slabs designed and constructed in accordance with NHBC Standards are recommended at this development.

### 6.6.3. Traditional Footings

It is considered the Head Deposits and Bognor Sand Member are suitable as a founding material and, therefore, except for areas of deeper Made Ground (see below), the site is considered suitable for the adoption of shallow strip/trench fill footings. Foundations should be taken through Made Ground and the localised Alluvium to bear in either the underlying Head Deposits or Bognor Sand Member.

Taking into account the variable nature of the Head Deposits encountered across the site and the high volume change classification for the fine-grained Head Deposits, it is considered that this classification should be assumed for this stratum and therefore a minimum founding depth of 1.0m is recommended. Given the variation in soil type, the use of reinforcement to avoid differential settlement is also required for all foundations in this stratum.

Where the Head Deposits are absent and the Made Ground is thinner, the Bognor Sand Member is at a shallow enough depth for shallow strip/trench fill footings. Typically, this occurs around the periphery of the site and in the north eastern section in particular. Given its granular nature the Bognor Sand Member should be considered to be similar to the granular Head Deposits and as such a conservative low volume change potential should be considered. However, given the surface disturbance and the variation in soil type, a minimum founding depth of 1.0m is also recommended for foundations in this stratum. Whilst reinforcement is not required for any foundations emplaced entirely within the Bognor Sand, given the variability in shallow soil types observed across the site, reinforcement should still be assumed unless a targeted investigation confirms the presence of the Bognor Sand, or if the foundation excavation is inspected by a geotechnical specialist.

At 1.0m depth a presumed bearing value of 100kN/m<sup>2</sup> is considered appropriate for foundations up to 1m wide; immediate and long term settlement should be within tolerable limits with most taking place during the construction period and the rest over several years.

As noted above, the fine-grained Head Deposits have been classified as having a high volume change potential when assessed against NHBC standards and therefore the minimum foundation depth required is 1.0m, but 1.5m where required to allow for restricted new tree planting. The granular Head Deposits and the Bognor Sands have been classified as having a low volume change potential and therefore require a minimum foundation depth of 0.75m, or 1.0m where required to allow for restricted new tree planting.

Under the NHBC Standards, foundation depths have to be increased if they are within the influence zone of felled trees, existing trees or proposed tree planting. It should be noted that where trees are in groups the resulting competition for resources can lead to deeper root systems than allowed for in the NHBC Standards. In any event, foundations should be taken below any roots encountered in foundation trench excavation. Where the required foundation depth varies around a structure, this can be accommodated by forming steps in the foundation as per NHBC Standards.

Where foundation depths exceed 1.50m in clay soils and are within the zone of influence of existing or felled trees or where foundations cut through tree roots, a compressible void former will be required against the internal faces of new foundations in order to accommodate potential long term soil heave. Such precautions against heave should be designed and constructed in accordance with NHBC Standards.

During construction, any soft spots found at foundation formation level should be excavated and replaced with lean mix concrete. Foundation excavations should be kept dry and left open for the minimum amount of time possible. Where foundations cannot be completed immediately, a blinding layer of concrete should be placed.

#### *6.6.3.1. Localised Areas of Deeper Made Ground*

At three test locations, Made Ground in excess of 1.5m depth was encountered. Two of the locations were in the central area, TP206 and WS204, and one was in the northwestern area, TP202. At these locations taking conventional spread foundations down through the Made Ground and into the underlying Head Deposits or Bognor Sand Member will potentially cause issues with groundwater ingress.

Depending on the level of risk the developer is prepared to take on, an alternative foundation solution could be considered for these areas, such as piling. At this stage, we recommend some targeted further investigations to more accurately delineate the extent of the affected areas. If it is determined that piled foundations are required, then some deep boreholes to return pile design parameters will be required. The number of these boreholes will be dependent on the extent of the deeper Made Ground.

In addition, longer term monitoring over the wetter winter months could be considered to allow a more accurate determination of likely groundwater levels during these periods.

### **6.7. RECOMMENDATIONS FOR FURTHER GEOTECHNICAL WORK**

As noted above, to allow a more detailed assessment of the extent of the localised deeper Made Ground in the central and northwestern areas, further investigations are recommended. Likewise, it would be prudent to undertake more detailed investigation of the north eastern section and some peripheral areas to more accurately delineate the extent of the shallow Bognor Sand Member. Should the need for piling be identified then there will also need to be some deep boreholes to determine pile design parameters.

The initial phase of investigation would likely involve machine excavated trial pitting in the first instance. Should a need for piling be identified then this would be followed by some cable percussive boreholes to confirm deeper ground conditions for pile design. In-situ Standard Penetration Tests should be conducted during forwarding of the boreholes and collected soil samples submitted for appropriate geotechnical laboratory testing.

In addition, to allow determination of groundwater levels during the wetter months, longer term groundwater monitoring over the winter months could be considered. This may also have an impact on the number of plots requiring piled foundations, as shallower groundwater could impact on the ability to form trench fill footings.

## 7. RISK ESTIMATION - SOILS

### 7.1. HUMAN HEALTH

The Generic Assessment Criteria (GAC) employed below are for residential land use as this is appropriate to the majority of the proposed development.

| CONTAMINANT            | UNITS | NUMBER OF TESTS | MAXIMUM CONCENTRATION | GAC    | NUMBER EXCEEDING GAC |
|------------------------|-------|-----------------|-----------------------|--------|----------------------|
| Arsenic                | mg/kg | 12              | 13                    | 37     | 0                    |
| Cadmium                | mg/kg | 12              | <0.2                  | 22     | 0                    |
| Chromium (total)       | mg/kg | 12              | 31                    | 910    | 0                    |
| Chromium (hexavalent)  | mg/kg | 12              | <2                    | 21     | 0                    |
| Copper                 | mg/kg | 12              | 22                    | 2,400  | 0                    |
| Lead                   | mg/kg | 12              | 116                   | 200    | 0                    |
| Mercury                | mg/kg | 12              | <1                    | 11     | 0                    |
| Nickel                 | mg/kg | 12              | 40                    | 180    | 0                    |
| Selenium               | mg/kg | 12              | <3                    | 250    | 0                    |
| Zinc                   | mg/kg | 12              | 111                   | 3,700  | 0                    |
| pH                     | Units | 20              | 6.9-9.6               | <5-10> | 0                    |
| Naphthalene            | mg/kg | 13              | <0.1                  | 2.3    | 0                    |
| Acenaphthylene         | mg/kg | 13              | <0.1                  | 170    | 0                    |
| Acenaphthene           | mg/kg | 13              | <0.1                  | 210    | 0                    |
| Fluorene               | mg/kg | 13              | <0.1                  | 170    | 0                    |
| Phenanthrene           | mg/kg | 13              | 0.14                  | 95     | 0                    |
| Anthracene             | mg/kg | 13              | <0.1                  | 2,400  | 0                    |
| Fluoranthene           | mg/kg | 13              | 0.23                  | 280    | 0                    |
| Pyrene                 | mg/kg | 13              | 0.19                  | 620    | 0                    |
| Benzo(a)anthracene     | mg/kg | 13              | 0.14                  | 7.2    | 0                    |
| Chrysene               | mg/kg | 13              | 0.18                  | 15     | 0                    |
| Benzo(b)fluoranthene   | mg/kg | 13              | 0.30                  | 2.6    | 0                    |
| Benzo(k)fluoranthene   | mg/kg | 13              | <0.1                  | 77     | 0                    |
| Benzo(a)pyrene         | mg/kg | 13              | 0.17                  | 2.2    | 0                    |
| Indeno(1,2,3-cd)pyrene | mg/kg | 13              | 0.14                  | 27     | 0                    |
| Dibenzo(a,h)anthracene | mg/kg | 13              | <0.1                  | 0.24   | 0                    |
| Benzo(ghi)perylene     | mg/kg | 13              | 0.13                  | 320    | 0                    |
| TPH Aliphatic C5-C6    | mg/kg | 8               | <0.01                 | 42     | 0                    |
| TPH Aliphatic C6-C8    | mg/kg | 8               | <0.05                 | 100    | 0                    |
| TPH Aliphatic C8-C10   | mg/kg | 8               | <2                    | 27     | 0                    |
| TPH Aliphatic C10-C12  | mg/kg | 8               | <2                    | 130    | 0                    |
| TPH Aliphatic C12-C16  | mg/kg | 8               | <3                    | 1,100  | 0                    |
| TPH Aliphatic C16-C35  | mg/kg | 8               | <10                   | 65,000 | 0                    |
| TPH Aliphatic C35-C44  | mg/kg | 8               | <10                   | 65,000 | 0                    |

| CONTAMINANT                                                                                                                                                                                                                   | UNITS | NUMBER OF TESTS | MAXIMUM CONCENTRATION | GAC   | NUMBER EXCEEDING GAC |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|-----------------------|-------|----------------------|
| TPH Aromatic C5-C7                                                                                                                                                                                                            | mg/kg | 8               | <0.01                 | 70    | 0                    |
| TPH Aromatic C7-C8                                                                                                                                                                                                            | mg/kg | 8               | <0.05                 | 130   | 0                    |
| TPH Aromatic C8-C10                                                                                                                                                                                                           | mg/kg | 8               | <2                    | 34    | 0                    |
| TPH Aromatic C10-C12                                                                                                                                                                                                          | mg/kg | 8               | <2                    | 74    | 0                    |
| TPH Aromatic C12-C16                                                                                                                                                                                                          | mg/kg | 8               | <2                    | 140   | 0                    |
| TPH Aromatic C16-C21                                                                                                                                                                                                          | mg/kg | 8               | <3                    | 260   | 0                    |
| TPH Aromatic C21-C35                                                                                                                                                                                                          | mg/kg | 8               | <10                   | 1,100 | 0                    |
| TPH Aromatic C35-C44                                                                                                                                                                                                          | mg/kg | 8               | <10                   | 1,100 | 0                    |
| Benzene                                                                                                                                                                                                                       | mg/kg | 8               | <2                    | 0.87  | 0                    |
| Toluene                                                                                                                                                                                                                       | mg/kg | 8               | <5                    | 130   | 0                    |
| Ethylbenzene                                                                                                                                                                                                                  | mg/kg | 8               | <2                    | 47    | 0                    |
| Xylene (total of all types)                                                                                                                                                                                                   | mg/kg | 8               | <2                    | 56    | 0                    |
| Methyl Tert Butyl Ether (MTBE)                                                                                                                                                                                                | mg/kg | 8               | <5                    | 49    | 0                    |
| Semi-Volatile Organic Compounds (SVOCs)                                                                                                                                                                                       | mg/kg | 3               | <LOD                  | LOD*  | 0                    |
| Polychlorinated Biphenyls (PCBs)                                                                                                                                                                                              | mg/kg | 8               | <LOD                  | LOD*  | 0                    |
| Asbestos quantification                                                                                                                                                                                                       | %     | 12              | <0.001                | 0.001 | 0                    |
| Notes: *Limit of detection: Given the large amount of compounds in this group, coupled with the lack of GAC for certain compounds, any concentrations above the limit of detection will be highlighted in the first instance. |       |                 |                       |       |                      |

None of the samples record any contaminants at concentrations exceeding their respective assessment criteria.

| DISCUSSION OF RESULTS  |                                                                                                                       |
|------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>METALS</b>          | None of the metal compounds are elevated above the human health assessment criteria.                                  |
| <b>PAH</b>             | None of the PAH compounds are elevated above the human health assessment criteria.                                    |
| <b>TPH</b>             | None of the TPH compounds are elevated above the human health assessment criteria.                                    |
| <b>BTEX &amp; MTBE</b> | None of the BTEX or MTBE compounds are elevated above the human health assessment criteria.                           |
| <b>SVOC</b>            | None of the SVOC compounds are elevated above the human health assessment criteria.                                   |
| <b>PCBS</b>            | None of the PCB compounds are elevated above the human health assessment criteria.                                    |
| <b>ASBESTOS</b>        | Asbestos has not been detected in any of the samples analysed or visually identified in any of the soils at the site. |

## 7.2. WATER ENVIRONMENT

It is not appropriate to consider human health assessment criteria for human health in relation to the risk to the water environment, but currently there are no generic soil assessment criteria in respect of the water environment. In the first instance it is more appropriate to consider groundwater analysis, which has been undertaken and presented in the following Section 8. However, the soils testing cannot be ignored and therefore the recorded concentrations should be initially assessed based on professional judgement.

The contaminant concentrations recorded in the soils at the site are not considered to be at such levels that they would present any significant risk to the underlying water environment.

## 7.3. BUILDING MATERIALS

| CONTAMINANT                                                                       | UNITS | NUMBER OF TESTS | MAXIMUM CONCENTRATION | GAC  | NUMBER EXCEEDING GAC |
|-----------------------------------------------------------------------------------|-------|-----------------|-----------------------|------|----------------------|
| pH                                                                                | units | 20              | 6.9-9.6               | <5.5 | 0                    |
| Sulphate (w/s)                                                                    | mg/l  | 20              | 300                   | 500  | 0                    |
| Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits | mg/kg | 3               | <LOD                  | 2    | 0                    |
| Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits      | mg/kg | 8               | <LOD                  | 10   | 0                    |
| Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits      | mg/kg | 8               | <LOD                  | 500  | 0                    |
| Sum of BTEX + MTBE above detection limits                                         | mg/kg | 8               | <LOD                  | 0.1  | 0                    |
| Phenols                                                                           | mg/kg | 3               | <LOD                  | 2    | 0                    |
| Cresols and chlorinated phenols                                                   | mg/kg | 3               | <LOD                  | 2    | 0                    |
| Naphthalene                                                                       | mg/kg | 13              | <0.1                  | 0.5  | 0                    |
| Benzo(a)pyrene                                                                    | mg/kg | 13              | 0.17                  | 0.5  | 0                    |

### RESULTS EXCEEDING BUILDING MATERIALS ASSESSMENT CRITERIA

None of the samples record any contaminants at concentrations exceeding their respective assessment criteria.

## 8. RISK ESTIMATION - WATER

### 8.1. GROUNDWATER

| CONTAMINANT            | UNITS | NUMBER OF TESTS | MAXIMUM CONCENTRATION | AQUEOUS SOLUBILITY | GAC    | NUMBER EXCEEDING SOLUBILITY / GAC |
|------------------------|-------|-----------------|-----------------------|--------------------|--------|-----------------------------------|
| Arsenic                | µg/l  | 6               | 4.2                   | -                  | 50     | -/0                               |
| Cadmium                | µg/l  | 6               | 0.5                   | -                  | 5      | -/0                               |
| Chromium (hexavalent)  | µg/l  | 6               | <20                   | -                  | 50     | -/0                               |
| Chromium (total)       | µg/l  | 6               | 3.4                   | -                  | 50     | -/0                               |
| Copper                 | µg/l  | 6               | 58.6                  | -                  | 50     | -/1                               |
| Lead                   | µg/l  | 6               | 15.3                  | -                  | 50     | -/0                               |
| Mercury                | µg/l  | 6               | <0.04                 | -                  | 1      | -/0                               |
| Nickel                 | µg/l  | 6               | 15.5                  | -                  | 20     | -/0                               |
| Selenium               | µg/l  | 6               | 4.7                   | -                  | 10     | -/0                               |
| Zinc                   | µg/l  | 6               | 182                   | -                  | 5,000  | -/0                               |
| pH                     | Units | 6               | 6.9 - 7.5             | -                  | 6 to 9 | -/0                               |
| Naphthalene            | µg/l  | 6               | 4.11                  | 25,000             | 2      | 0/1                               |
| Acenaphthylene         | µg/l  | 6               | 0.04                  | 3,800              | -      | 0/-                               |
| Acenaphthene           | µg/l  | 6               | 0.59                  | 16,100             | -      | 0/-                               |
| Fluorene               | µg/l  | 6               | 0.35                  | 1,900              | -      | 0/-                               |
| Phenanthrene           | µg/l  | 6               | 0.66                  | 1,100              | -      | 0/-                               |
| Anthracene             | µg/l  | 6               | 0.12                  | 45                 | -      | 0/-                               |
| Fluoranthene           | µg/l  | 6               | 0.07                  | 230                | -      | 0/-                               |
| Pyrene                 | µg/l  | 6               | 0.06                  | 130                | -      | 0/-                               |
| Benzo(a)anthracene     | µg/l  | 6               | <0.01                 | 3.8                | -      | 0/-                               |
| Chrysene               | µg/l  | 6               | <0.01                 | 2                  | -      | 0/-                               |
| Benzo(b)fluoranthene   | µg/l  | 6               | <0.01                 | 2                  | -      | 0/-                               |
| Benzo(k)fluoranthene   | µg/l  | 6               | <0.01                 | 0.8                | -      | 0/-                               |
| Benzo(a)pyrene         | µg/l  | 6               | <0.01                 | 3.8                | LOD    | 0/0                               |
| Indeno(1,2,3-cd)pyrene | µg/l  | 6               | <0.01                 | 0.2                | -      | 0/-                               |
| Dibenzo(a,h)anthracene | µg/l  | 6               | <0.01                 | 0.006              | -      | 0/-                               |
| Benzo(ghi)perylene     | µg/l  | 6               | <0.008                | 0.26               | -      | 0/-                               |
| Total PAH              | µg/l  | 6               | 6                     | -                  | 0.2    | -/1                               |
| TPH Aliphatic C5-C6    | µg/l  | 6               | <10                   | 36,000             | 15,000 | 0/0                               |
| TPH Aliphatic C6-C8    | µg/l  | 6               | <10                   | 5,400              | 15,000 | 0/0                               |
| TPH Aliphatic C8-C10   | µg/l  | 6               | <10                   | 430                | 300    | 0/0                               |
| TPH Aliphatic C10-C12  | µg/l  | 6               | <10                   | 34                 | 300    | 0/0                               |
| TPH Aliphatic C12-C16  | µg/l  | 6               | <10                   | 0.76               | 300    | 0/0                               |
| TPH Aliphatic C16-C21  | µg/l  | 6               | <10                   | 0.003              | -      | -                                 |
| TPH Aliphatic C21-C35  | µg/l  | 6               | <10                   | -                  | -      | -                                 |

| CONTAMINANT                      | UNITS | NUMBER OF TESTS | MAXIMUM CONCENTRATION | AQUEOUS SOLUBILITY | GAC  | NUMBER EXCEEDING SOLUBILITY / GAC |
|----------------------------------|-------|-----------------|-----------------------|--------------------|------|-----------------------------------|
| TPH Aromatic C5-C7               | µg/l  | 6               | <10                   | 1,800,000          | 10   | 0/0                               |
| TPH Aromatic C7-C8               | µg/l  | 6               | <10                   | 590,000            | 700  | 0/0                               |
| TPH Aromatic C8-C10              | µg/l  | 6               | <10                   | 65,000             | 300  | 0/0                               |
| TPH Aromatic C10-C12             | µg/l  | 6               | <10                   | 25,000             | 90   | 0/0                               |
| TPH Aromatic C12-C16             | µg/l  | 6               | <10                   | 5,800              | 90   | 0/0                               |
| TPH Aromatic C16-C21             | µg/l  | 6               | <10                   | 650                | 90   | 0/0                               |
| TPH Aromatic C21-C35             | µg/l  | 6               | <10                   | 6.6                | 90   | 0/0                               |
| Benzene                          | µg/l  | 6               | <1                    | 1,800,000          | 10   | 0/0                               |
| Toluene                          | µg/l  | 6               | <5                    | 590,000            | 74   | 0/0                               |
| Ethylbenzene                     | µg/l  | 6               | <5                    | 180,000            | 300  | 0/0                               |
| Xylene (total of all types)      | µg/l  | 6               | <10                   | 200,000            | 30   | 0/0                               |
| Methyl tert-butyl ether (MTBE)   | µg/l  | 6               | <10                   | -                  | 15   | -/0                               |
| Polychlorinated Biphenyls (PCBs) | µg/l  | 6               | <0.1                  | <LOD               | <LOD | 0/0                               |

## RESULTS EXCEEDING ASSESSMENT CRITERIA

Generally, none of the samples record any contaminants at concentrations exceeding their respective assessment criteria. The only exceptions to this are discussed below.

|                    |                                                                                                                                                                                                                                                                                                                                              |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>COPPER</b>      | The sample of groundwater from borehole WS204 recorded a concentration of copper at 58.6µg/l, which is marginally elevated above the GAC of 50µg/l. Given that the GAC is a stringent threshold for a drinking water standard, this slight exceedance is not considered to present a cause for concern and as such is not discussed further. |
| <b>NAPHTHALENE</b> | The sample of groundwater from borehole WS201 recorded a concentration of copper at 4.11µg/l, which is elevated above the GAC of 2µg/l.                                                                                                                                                                                                      |
| <b>TOTAL PAH</b>   | The sample of groundwater from borehole WS201 recorded a concentration of Total PAH at 6µg/l, which is elevated above the GAC of 0.2µg/l.                                                                                                                                                                                                    |

## 9. RISK ESTIMATION - GAS

### 9.1. RESULTS SUMMARY

The following table summarises the findings from all six monitoring visits.

| PARAMETER            | MINIMUM  | MAXIMUM | COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------|----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methane              | 0.0%     | 0.3%    | No significant concentrations recorded.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Carbon Dioxide       | 0.0%     | 4.8%    | Slightly elevated concentrations recorded in WS206, however, still all below the 5% threshold.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Oxygen               | 13.4%    | 20.3%   | The oxygen levels were depleted as carbon dioxide concentrations increased.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Hydrogen Sulphide    | 0ppm     | 1ppm    | No significant concentrations recorded.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Carbon Monoxide      | 0ppm     | 2ppm    | No significant concentrations recorded.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Atmospheric pressure | 1013mB   | 1016mB  | One visit was undertaken during a rising pressure trend, one during a steady pressure trend and one during a falling pressure trend.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Groundwater levels   | 1.39m    | 3.19m   | Borehole WS207 consistently has the shallowest groundwater and borehole WS204 has the deepest, albeit that by the last visit on 17/10/2024, the levels in WS201, WS203, WS206 and WS207 were all quite similar.                                                                                                                                                                                                                                                                                                                                                                              |
| Flow rate            | -1.0l/hr | 0.6l/hr | No significant positive flows recorded, with the highest representative flow being 0.6l/hr.<br><br>Some negative flows down to -1.0l/hr were recorded. Negative flows are indicative of 'draw down' in the boreholes. These can be a factor of the effect of drilling on the immediate ground conditions, the creation of a partial vacuum as a result of monitoring, groundwater behaviour or due to certain geological conditions. In terms of the contamination risk assessment, this does not present a cause for concern as the net effect is to reduce the emission of gas at surface. |

## 9.2. GAS REGIME CHARACTERISATION

### 9.2.1. Gas Source

| GAS SOURCE                                 | GENERATION POTENTIAL | COMMENTS                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Backfilled historic drainage ditch/stream. | Low                  | The ditch/stream is likely to have been shallow with limited potential for organic material. However, the organic material could still generate a small amount of ground gas under anaerobic conditions. Some organic clay Alluvium was encountered at one test location, which is likely derived from the former drainage ditch. |
| Made Ground                                | Moderate risk        | The deep Made Ground on site has the potential to contain organic material. Organic material buried at depth under anaerobic conditions can generate ground gases. Small quantities of degradable materials were recorded in the Made Ground, such as wood. However, the amount of such material was not considered significant.  |

### 9.2.2. Monitoring Frequency and Duration

| SENSITIVITY OF DEVELOPMENT                      | High (Residential with gardens)                                        |              |
|-------------------------------------------------|------------------------------------------------------------------------|--------------|
|                                                 | IDEALISED                                                              | ACTUAL       |
| MONITORING PERIOD                               | Three months                                                           | Three months |
| TOTAL NUMBER OF VISITS                          | Six visits                                                             | Six visits   |
| NUMBER OF VISITS DURING FALLING PRESSURE TRENDS | At least two visits                                                    | Two visits   |
| COMMENT                                         | The monitoring programme complies with the requirements of CIRIA C665. |              |

### 9.2.3. Building Type

In accordance with BS8485:2015+A1:2019, the development mainly comprises Type A buildings. These buildings are in private ownership with no controls over the use of and alterations to the building. This building type typically comprises private dwellings. The development also comprises a single Type B building. These buildings have centralised control of any alterations and change of use, but limited or no control of maintenance activities. Typical examples include managed apartments, multiple occupancy offices, some retail premises, some parts of public buildings and parts of hotels.

### 9.3. GAS SCREENING VALUES

|                | MAXIMUM GAS<br>CONCENTRATION<br>(fraction)  | MAXIMUM GAS FLOW<br>RATE<br>(l/hr) | MAXIMUM GAS<br>SCREENING VALUE<br>(l/hr) |
|----------------|---------------------------------------------|------------------------------------|------------------------------------------|
| Methane        | 0.003                                       | 0.6                                | 0.0006                                   |
| Carbon Dioxide | 0.048                                       | 0.6                                | 0.029                                    |
|                |                                             |                                    |                                          |
| Methodology    | BS8485:2015+A1:2019.                        |                                    |                                          |
| Gas Regime     | Characteristic situation 1 - Very low risk. |                                    |                                          |

### 9.4. GAS PROTECTION MEASURES

#### 9.4.1. Radon Gas

The site is not situated within an area where radon gas protection measures are required in new buildings.

#### 9.4.2. Volatile Organic Compounds

The site is not affected by Volatile Organic Compounds (VOC) contamination.

#### 9.4.3. Methane and Carbon Dioxide

Based on the full gas monitoring programme, the site does not require landfill gas protection measures.

## 10. RISK EVALUATION

### 10.1. REVISED CONCEPTUAL MODEL

|                                      |                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ADDITIONAL POLLUTANT LINKAGES</b> | <p>During the ground investigation, no additional sources of contamination were identified.</p> <p>Some marginally elevated PAH concentrations were detected in the groundwater in WS201, however, these are not considered to present any significant risks (as discussed in more detail below).</p>                     |
| <b>INVALID POLLUTANT LINKAGES</b>    | All of the potential pollutant linkages identified at the start of the ground investigation were proven to be invalid.                                                                                                                                                                                                    |
| <b>LIMITATIONS AND UNCERTAINTIES</b> | The area beneath the large demolition crush stockpile could not be investigated. However, all of the potential contamination sources have been targeted by the exploratory holes and therefore it is considered that a sufficient number of exploratory points have been completed for contamination assessment purposes. |

### 10.2. UPDATED CONTAMINATION RISK ASSESSMENT

The pollutant linkages identified in the revised conceptual site model will now be evaluated as to their severity:

| SOURCES AND CONTAMINANTS                                                                                                                     | PATHWAYS                                                 | RECEPTORS                       | UPDATED POTENTIAL RISK |
|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------|------------------------|
| <p>Made Ground.</p> <ul style="list-style-type: none"> <li>Metals.</li> <li>Hydrocarbons.</li> <li>Asbestos containing materials.</li> </ul> | <p>Direct contact</p> <p>Inhalation</p> <p>Ingestion</p> | Future residents                | Negligible risk.       |
|                                                                                                                                              | Vertical and horizontal migration                        | Groundwater and surface water   | Negligible risk.       |
|                                                                                                                                              | Direct contact                                           | Building materials and services | Negligible risk.       |
| <p>Made Ground.</p> <ul style="list-style-type: none"> <li>Landfill gases (mainly carbon dioxide and methane).</li> </ul>                    | Inhalation of ground gases                               | Future residents                | Negligible risk.       |
| <p>Stockpile of Crushed Concrete.</p> <ul style="list-style-type: none"> <li>Asbestos containing materials.</li> </ul>                       | Inhalation of fibres                                     | Future residents                | Negligible risk.       |
| Previous use by SSE.                                                                                                                         | <p>Direct contact</p> <p>Inhalation</p> <p>Ingestion</p> | Future residents                | Negligible risk.       |

| SOURCES AND CONTAMINANTS                                                                                                                                                                                                         | PATHWAYS                                  | RECEPTORS                       | UPDATED POTENTIAL RISK |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------------------|------------------------|
| <ul style="list-style-type: none"> <li>Petroleum hydrocarbons (diesel, petrol or heating oil).</li> <li>Petroleum hydrocarbons (dielectric mineral oil).</li> <li>Polychlorinated biphenyls.</li> </ul>                          | Vertical and horizontal migration         | Groundwater and surface water   | Negligible risk.       |
|                                                                                                                                                                                                                                  | Direct contact                            | Building materials and services | Negligible risk.       |
| Backfilled stream. <ul style="list-style-type: none"> <li>Metals.</li> <li>Hydrocarbons.</li> <li>Asbestos containing materials.</li> </ul>                                                                                      | Direct contact<br>Inhalation<br>Ingestion | Future residents                | Negligible risk.       |
|                                                                                                                                                                                                                                  | Vertical and horizontal migration         | Groundwater and surface water   | Negligible risk.       |
|                                                                                                                                                                                                                                  | Direct contact                            | Building materials and services | Negligible risk.       |
| Backfilled stream. <ul style="list-style-type: none"> <li>Landfill gases (mainly carbon dioxide and methane).</li> </ul>                                                                                                         | Inhalation of ground gases                | Future residents                | Negligible risk.       |
| Offsite electrical sub-station. <ul style="list-style-type: none"> <li>Petroleum hydrocarbons (dielectric mineral oil).</li> <li>Polychlorinated biphenyls.</li> </ul>                                                           | Direct contact<br>Inhalation<br>Ingestion | Future residents                | Negligible risk.       |
|                                                                                                                                                                                                                                  | Direct contact                            | Building materials and services | Negligible risk.       |
| Offsite former fuel station and present-day garage. <ul style="list-style-type: none"> <li>Petroleum hydrocarbons (diesel, lubricating oils, greases and/or petrol).</li> <li>Lead.</li> <li>Methyl tert-butyl ether.</li> </ul> | Direct contact<br>Inhalation<br>Ingestion | Future residents                | Negligible risk.       |

The contamination risks that are presented to the various receptor groups are discussed further in the following sections.

### SOIL RISKS TO HUMAN HEALTH

None of the samples tested during the previous investigations and the current BRD investigation have recorded concentrations above their respective generic assessment criteria (GAC).

At this stage no unacceptable contamination in respect of human health have been identified by this investigation.

### GROUND GAS RISKS

No risks from ground gases have been identified at the site.

### RISK TO WATER ENVIRONMENT

Whilst the groundwater across the site was found to be generally uncontaminated, the groundwater from borehole WS201 recorded slightly elevated concentrations of naphthalene and total PAH. The total PAH result likely reflects the elevated naphthalene as opposed to indicting any secondary source.

The Forge investigation (after the building demolition) tested one sample of groundwater and also recorded marginally elevated total PAH (and TPH). It should be noted that the recent testing has not recorded any elevated TPH concentrations.

The Forge investigation concluded that although the groundwater was shown to contain marginally elevated levels of hydrocarbons, due to the site's setting and the absence of any mechanisms for the water to impact upon the identified receptors, the site was not considered to pose a risk to the water environment. BRD would generally concur with this statement.

To further support this, the PAH concentrations in the 6No. groundwater samples collected and tested by BRD are all lower than the sample tested during the previous Forge investigation, suggesting a decline over time. In addition, only one sample records these PAH concentrations marginally elevated above the respective GACs. Therefore, based on the above factors, BRD also consider there to be a negligible risk to the water environment.

### RISK TO BUILDING MATERIALS AND SERVICES

No unacceptable contamination risks to building materials and services have been identified by this investigation.

## **10.3. RISK MANAGEMENT**

### **10.3.1. Introduction**

Generally, the site does not present any contamination risks and as such should not warrant any remediation.

It is recommended that this report is submitted to the planning department of the Local Authority, the organisation undertaking the Building Control function and warranty providers to confirm that the investigation completed to date is satisfactory.

### **10.3.2. Further Contamination Assessment**

As no exploratory holes were undertaken beneath the stockpile of crushed demolition arisings, attendance by a Geo-Environmental consultant during the site clearance should be considered to ensure that the underlying ground conditions are in keeping with the findings from the main investigation.

## **10.4. WASTE SOIL DISPOSAL**

It is considered that the Made Ground and any natural sub-soils disposed of from the site would be classified as 'non-hazardous waste' and would likely be characterised for disposal to landfill as 'inert waste'. Waste Acceptance Criteria (WAC) testing of the soils has been completed and the results are in the Appendices which confirm the soil tested complies with the inert waste limits.

However, the chemical results should be forwarded to the proposed landfill site and the waste classification confirmed prior to disposing of any surplus soils. The waste code from the European Waste Catalogue (EWC) 2002 for the soils would be 17 05 04 'Soil and Stones, not containing dangerous substances'.

## **11. HEALTH AND SAFETY FILE INFORMATION**

### **11.1. INTRODUCTION**

The aim of the following sections is to present pertinent Health and Safety information that has arisen from the current investigation/survey works discussed in this report. The aim is to identify health and safety controls that may be necessary during any subsequent maintenance, refurbishment, demolition or construction works. The information is not exhaustive and stems only from the aspects identified within the scope of the works undertaken by BRD.

Where BRD has been appointed as a Principal Contractor, then this information shall form the Health and Safety Files as required by the Construction Design and Management (CDM) Regulations 2015.

Reports are always forwarded to the Client and they shall be responsible for ensuring this safety information is disseminated to those who need it.

The works undertaken by BRD are detailed in the previous sections of this report.

### **11.2. HAZARDS**

During the course of the BRD works the following noteworthy safety hazards have been identified:

#### **11.2.1. Contamination**

Although no contamination has been identified, as with any construction site, if any anomalous material is encountered during the redevelopment then expert environmental advice should be sought.

#### **11.2.2. Asbestos**

No asbestos containing materials were observed in the soil or on the surface. No asbestos fibres were found in the soils tested.

#### **11.2.3. Other Issues**

During the BRD works the following safety hazards were identified:

- There are multiple slip, trip and fall hazards around the site.
- There are two open manholes with missing covers.
- There is evidence that the site is subject to trespass. Measures to secure the site should be taken so that trespassers are not at risk from the existing state of the site.

### **11.3. EXISTING STRUCTURES**

The buildings have already been demolished on site.

### **11.4. HAZARDOUS MATERIALS**

BRD did not construct anything with hazardous materials.

Any soils to be imported to the site, in particular topsoil, should be tested to confirm their suitability in the development.

## 11.5. UTILITY SERVICES

No previously unidentified utility services were encountered during the BRD works.

The utility services plans held by the Client should be referred to.

The utility service companies should be contacted for records of their own equipment.

## REPORT SPECIFIC REFERENCES

- British Geological Survey sheet 316 “Fareham” Solid and Drift edition (1:50,000) published 1972.
- ‘Ground Investigation Report’, Soiltechnics, ref. STM3168D-GD1, dated May 2016.
- ‘Interpretive Site Investigation and Remedial Strategy Report’, Forge Environmental Management Ltd, ref. HAV164.D/SI/002, rev. 1, Dated March 2020.
- ‘Phase 1 Environmental Desk Study - Bartons Road, Havant’, BRD Environmental Ltd, report ref. BRD4469-OR1-B, dated July 2025.



# **SUPPORTING INFORMATION**

## **GROUND INVESTIGATION**

*Exploratory holes are logged by an experienced Geo-Environmental Consultant in general accordance with 'Code of practice for site investigations' BS5930:2015, British Standards Institution, 2015. Soil samples for chemical and geotechnical analysis are taken from the exploratory holes at intervals dictated by the nature of the soils and the objectives of the investigation.*

*Where stated on the logs of inspection pits, trial pits or boreholes (where insitu testing has not been undertaken), the relative density of coarse (sand and gravel) soils is tentative only. Such assessments of density are on the basis of visual inspection only taking into consideration such factors as drilling rates, stability of pit side walls, appearance and behaviour under excavation.*

*Where Chalk strata is encountered it is logged and graded in general accordance with CIRIA guidance 'C574 - Engineering in Chalk'. It should be recognised that where percussive drilling methods are employed, the structure of the Chalk is destroyed and therefore the grading stated on such logs is either tentative or absent where it is not possible to assess the grade.*

### **Hand Dug Inspection Pits**

*Hand tools are used to forward shallow inspection pits as a cost effective method of describing and sampling near surface soils. The technique is also used where exposure of existing footings is required. The depth reached by such techniques is a function of the nature of the ground and generally does not exceed 1.5m*

### **Trial Pits**

*Mechanically excavated trial pits allow detailed inspection of near surface ground due to the large volume of soil exposed. A wheeled backhoe loader is the usual machine for digging trial pits that are typically 3 to 4.5m deep, 0.5m wide and 3m long.*

### **Windowless Sampling Boreholes**

*This type of borehole is formed by a small tracked dynamic percussion drilling rig with samples retrieved in thin plastic liners within the narrow diameter steel sampling tubes. Borehole depths of up to 5m are typical, but in exceptional circumstances up to 15m depth can be achieved. This is the smallest type of rig that is capable of undertaking Standard Penetration Tests (SPTs).*

### **Hand Held Window Sampling**

*Hand held window sampling is a useful method of drilling narrow diameter boreholes particularly where access is difficult. Hand held mechanical percussive hammers are used to drive the sampling tube into the ground. The soil samples are collected within the hollow metal sampling tubes and inspected via the open window along one side. Window sampling boreholes can be forwarded to depths of 3m to 6m depending upon ground conditions.*

### **Cable Percussive Boreholes**

*This form of drilling involves repetitive dropping of a tube into the soil under its own weight from a tripod support. The sample is obtained from the clay cutter head in fine soils or a bailer for wet granular soils. As the borehole progresses SPTs can be undertaken and relatively undisturbed samples can be obtained. Typically these boreholes are 15 to 25m deep, but depths of double that can be achieved in soils, but only thin weak rock layers can be penetrated.*



## Rotary Boreholes

Where competent rock is required to be drilled then rotary drilling techniques are required. The drilling rigs can vary in size from small tracked units to larger units mounted on four wheel drive trucks. Rotary open hole drilling techniques break the rock into small fragments and so recovery of any samples is limited. In contrast, rotary coring retrieves excellent samples. Some rigs also allow windowless sampling to be undertaken through soil layers. There are no practical limits to the depths that this drilling method can achieve.

## Dynamic Probing

Dynamic probing comprises a sectional rod with a sacrificial cone at the base of slightly larger diameter than the rod. The rod is driven into the ground by a constant mass falling through a set distance. The number of blows required to forward the rod per 100mm is then recorded and presented in a graph of  $N_{10}$  values. The standard applicable to dynamic probing is "BS EN ISO 22476-2:2005 Incorporating corrigendum no. 1, Geotechnical investigation and testing – Field testing – Part 2: Dynamic probing" BSi, February 2007.

## Static Cone Penetration Tests

Cone Penetration Tests (CPT) consist of pushing a conical 60° cone into the ground at a constant rate and recording the force required to do this. Sensors in the cone record other information and this data can be correlated to a number of different geotechnical parameters.

## Dynamic Penetrometer

The Transport Research Laboratory Dynamic Cone Penetrometer (TRL DCP) uses an 8 kg hammer dropping through a height of 575mm to drive a 60° cone of 20mm maximum diameter into the ground. The depth driven either per blow or per several blows is recorded. The strength of each of the soil layer encountered is then calculated by converting the penetration rate (mm per blow) into an approximate California Bearing Ratio (CBR) value employing the correlation proposed by TRL.

## Gas Monitoring

Gas monitoring is undertaken with a portable gas monitor for oxygen, Methane, Carbon Dioxide, Hydrogen Sulphide and Carbon Monoxide together with recording of atmospheric pressure and any flow rate.

## Vapour Monitoring

Headspace tests and monitoring for Volatile Organic Compounds (VOC) or Semi Volatile Organic Compounds (SVOC) is undertaken using a Photo Ionisation Detector (PID). The MiniRAE models used have a 10.6 eV lamp calibrated for isobutylene. The PID is useful tool to indicate the presence of a wide range of volatile compounds, but only provides semi-quantitative data as different compounds provide a different response and thus the reading is not a true reflection of the actual concentration present.

Low PID readings can be recorded in natural uncontaminated organic soils or even as a result of atmospheric pollution. It is generally accepted by consultants and regulators that recorded values in excess 50 parts per million (ppm) represents the presence of organic compound pollutants and in excess of 100 ppm such contamination may be significant.

The headspace test procedure involves the collection of a sample of suspected contaminated soils and placing within a sample bag. A tight seal to the bag is formed with a similar volume of air trapped to that of the soil and the sample is left for fifteen minutes to allow volatilisation of any contaminants. The bag is then pierced by, and sealed around, the sample probe of the PID and a reading taken.

Borehole well monitoring is undertaken by connecting the PID directly to the gas tap on the monitoring well installation.

#### Groundwater Level Monitoring

Groundwater levels are recorded with an electronic dip meter that has a detector end that is lowered into the borehole well. An audible signal is made when water is reached and the depth recorded from the graduated tape used to lower the detector. Where there is potential for a separate Light Non Aqueous Phase Liquid (LNAPL) to be present floating on the groundwater an oil/water interface meter is used in preference to a conventional dip meter so that any such floating product can be detected.

#### Geotechnical Sampling

BRD schedule a range of geotechnical testing as appropriate to the identified ground conditions, available budget and the proposed development. Different types of soil samples are obtained as appropriate to the ground conditions and planned testing.

| <b>SAMPLE TYPE</b> | <b>SYMBOL USED ON LOGS</b> | <b>DESCRIPTION</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Disturbed</i>   | <i>D</i>                   | <i>Small disturbed soil samples of about 1 to 2 kg are collected in plastic bags.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <i>Bulk</i>        | <i>B</i>                   | <i>Large disturbed bulk samples up to about 20 to 30 kg are collected in plastic bags</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <i>Undisturbed</i> | <i>U</i>                   | <i>‘Undisturbed’ samples generally collected in plastic or metal tubes within cable percussive boreholes of 100mm diameter for samples of fine soils of firm to stiff consistency. Can also be representative of samples taken by cutting plastic sample liners from windowless sampling drilling methods. It is recognised that such samples do not generally meet Eurocode sample quality requirements for the tests commonly employed. However, given the wealth of experience with these sampling methods this continues to be common in United Kingdom practice particularly for less sensitive developments where more expensive sampling techniques are not economically justifiable.</i> |
| <i>Undisturbed</i> | <i>UT</i>                  | <i>A thin walled steel sampler developed by Archway Engineering called a UT100 in an attempt to gain better quality samples of soft to firm fine soils when using cable percussive drilling methods.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

### Contamination Sampling

BRD schedule contamination testing as appropriate to the ground conditions, available budget, potential contaminants and the proposed development. Samples are collected in single use laboratory supplied containers.

Soil samples are retrieved in plastic containers and/or amber glass jars with a lined plastic cap. Contamination samples are indicated by a 'J' on exploratory hole logs.

Water samples are collected in plastic bottles and/or amber glass jars with a lined plastic cap then placed in cool boxes together with freezer packs. Water samples are indicated by a 'W' on exploratory hole records, but generally such samples are not tested as testing from dedicated monitoring wells is preferred for sample quality reasons.

Samples retrieved from the exploratory holes are dispatched to the laboratory by overnight courier. Where samples cannot be transported directly from site they are temporarily stored in the BRD dedicated sample storage facility which includes refrigeration where necessary. The individual accreditation of the test methods is detailed in the laboratory test report.

## **GEOTECHNICAL ASSESSMENT**

Under Eurocode 7 (EC7) the following risk ranking is applied to geotechnical projects:

| <b>GEOTECHNICAL CATEGORY</b> | <b>DESCRIPTION</b>                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1</b>                     | <i>Small and relatively simple structures for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations with negligible risk. For example, straightforward ground conditions, local experience, no excavation below the water table unless this will be straight forward.</i>                                                   |
| <b>2</b>                     | <i>Conventional types of structures and foundations. No difficult soil or loading conditions. Quantitative geotechnical data and laboratory testing. Routine procedures for field and laboratory testing. Conventional structures and no exceptional geotechnical risk. For example, spread, raft and piled foundations, retaining walls, bridge piers and abutments, embankments, ground anchors, tunnels and excavations.</i> |
| <b>3</b>                     | <i>Those structures not in Categories 1 and 2 such as very large or unusual structures, structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions. Structures in highly seismic areas. Structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.</i>                                               |

## GEOTECHNICAL PARAMETERS

### Soakage Tests

Soakage tests comprise the filling of a test pit with water and recording the time taken for the water to drain away. The tests are undertaken in general accordance with 'Digest DG 365: Soakaway design' BRE, Revised 2016. The test pits are usually gravel filled for safety with a slotted vertical pipe through which water observations are made. Water is generally supplied by a tanker to allow fast filling of the pits with water. Compliant tests are filled and allowed to drain near empty three times.

### Standard Penetration Tests

The standard penetration test (SPT) determines the resistance of soils at the base of a borehole to the dynamic penetration of a split barrel sampler and the recovering of disturbed samples for identification purposes. In gravelly soils and some soft rocks a solid cone is used in preference to the sampler.

The basis of the test consists in driving a sampler by dropping a hammer of 63.5 kg mass on from a height of 760 mm. The number of blows (N value) necessary to achieve a penetration of the sampler of 300 mm is recorded. The test is described in 'Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test - BS EN ISO 22476-3:2005 Incorporating corrigendum no. 1', BSi, 2007.

The uncorrected N values of the SPT tests are recorded upon the borehole logs together with a record of blows for each 75mm test portion including the seating blows. Where the full test depth cannot be achieved due to refusal on hard stratum, the number of blows and the distance achieved is recorded and the N value given as >50. The abbreviation SPT(c) is used upon the logs indicates that the test was performed with a solid cone rather than a split spoon sampler.

It is necessary to apply a correction to the N values to account for the effects of energy delivery using the equation:  $N_{60} = \frac{E_r}{60} N$  where  $E_r$  is the energy ratio of the specific test equipment.

In the case of tests in sand, for the effects of overburden and rod length the equation is modified to  $N_{60} = \frac{E_r}{60} \times \lambda \times C_N \times N$  where  $\lambda$  is the correction factor for energy losses due to the rod length and  $C_N$  is the correction factor for vertical stress due to overburden of the soil.

### Sulphate

In order to compare the laboratory soil test results with 'Concrete in aggressive ground. BRE Special Digest 1: 2005' (BRE, 2005) laboratory results are converted to  $SO_4$  mg/l. Laboratory results expressed as  $SO_3$  g/l and are multiplied by a factor of 1200 to express the results as  $SO_4$  mg/l.

### Index Property Tests

In accordance with National House Building Council (NHBC) Standards Chapter 4.2 - Building near trees, the laboratory plasticity indexes are assessed against their volume change potential. The Modified Plasticity Index is defined as the Plasticity Index of the soil multiplied by the percentage of particles with a nominal diameter of less than  $425\mu\text{m}$ . Whilst the NHBC Standards were developed for residential buildings, the advice is equally applicable to a large number of other types of low rise structures.

### Hand Shear Vane

The undrained shear strength of the fine (i.e. clay) soils at the site can be established using hand shear vane apparatus. Usually three readings are taken at every depth tested and the uncorrected results recorded on the exploratory point log. Shear vane readings from depths below 1.2m depth in trial pits are from tests performed on excavated soil. In accordance with Eurocode 7 – Geotechnical design – Part 2: Ground investigation and testing EN 1997-2:2007 the results should be corrected. BRD employ only simple correction methods as the more complex correction methodologies imply undue accuracy to a test that has distinct disadvantages and limitations.

### Pocket Penetrometers

The Pocket Penetrometer is a lightweight instrument for use by field personnel to check visual classification of soils. It is a simple test and there is inherent uncertainty related to the small volume of soil being tested and so the results should be used with appropriate caution. Pocket penetrometers are calibrated in terms of unconfined compressive strength and once converted to undrained shear strength (divide by two) the results are further reduced by a factor of 1.5 - 2.0 as the device tends to overestimate strengths.

| <i>Instrument Reading<br/>(uncompressive<br/>strength in kg/cm<sup>2</sup>)</i> | <i>Indicative Undrained<br/>Shear Strength (kN/m<sup>2</sup>)</i> | <i>Indicative<br/>Consistency</i> | <i>Indicative strength</i> |
|---------------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------------------|----------------------------|
| 1.0                                                                             | 25 - 33                                                           | Soft                              | Low                        |
| 1.5                                                                             | 38 - 50                                                           | Soft to firm                      | Low to medium              |
| 2.0                                                                             | 50 - 67                                                           | Firm                              | Medium                     |
| 2.5                                                                             | 63 - 83                                                           | Firm to stiff                     | Medium to high             |
| 3.5                                                                             | 88 - 116                                                          | Stiff                             | High                       |
| 4.5                                                                             | 113 - 150                                                         | Stiff to very stiff               | High to very high          |

# CONTAMINATION ASSESSMENT METHODOLOGY

## UK Policy

The UK Government's policy in relation to land affected by historic contamination is based on a 'suitable for use' approach. The approach recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors, such as the underlying geology of the site. Contamination risks therefore need to be assessed on a site-by-site basis. The 'suitable for use' approach limits requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to either the current use or future use of the land.

The three main drivers for contamination assessment and remediation are:

- Voluntary action.
- Development as part of the planning regime.
- Regulatory action to mitigate unacceptable risks e.g. Part 2A of the Environmental Protection Act 1990.

## Pollutant Linkages

For a contamination risk to exist there must be a 'pollutant linkage' from the contaminant (source) via a pathway (the route from contaminant to receptor) to a receptor (the entity that could be harmed). The absence of a contaminant, pathway or receptor breaks the pollutant linkage and therefore no contamination risk exists.

Contamination is typically present at a site (in the ground and/or in the underlying groundwater) as a result of a historic or current industrial use, usually as a result of leaks, spills or disposal of residues, wastes and excess raw materials from the industrial processes. Contamination may also be present due to:

- The deliberate application of chemicals e.g. the spraying of herbicide/pesticide.
- Migration of pollutants from adjacent land.
- Naturally occurring processes e.g. elevated concentrations of particular heavy metals associated with specific geological strata.

## Conceptual Site Model

The conceptual site model can be defined as a textual or graphical representation of the identified pollutant linkages for a given site. The model forms the basis for designing the investigation as the aim will be to target all of the potential pollutant linkages to determine, through the subsequent phases of risk assessment, whether or not they pose an actual risk.

It is important that the conceptual site model is updated with new information as the various investigation, risk assessment and remediation works are completed.

## Technical Guidance

The technical and legal framework for contamination assessment is complex. The process adopted through this report for assessing contamination risks is in general accordance with the following guidance, as listed below:

- 'Investigation of Potentially Contaminated Sites - Code of Practice - BS 10175:2011+A2:2017', The British Standards Institution 2017.
- Land Contamination Risk Management, Environment Agency, 2021.
- 'Guidance for the safe development of housing on land affected by contamination - R&D66: 2008', NHBC/Environment Agency, 2008.

## Risk Assessment Methodology

In line with the technical guidance, the contamination risk assessment follows a series of phased stages for each particular site:

| PHASE          | DESCRIPTION                                                                                                                                                                                       | RISK ASSESSMENT STAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>PHASE 1</b> | Generally limited to desk based research and a site walkover survey to develop an initial conceptual site model and identify what risks, if any, are likely to be presented by the site.          | <b>Hazard Identification and Assessment</b><br>A preliminary stage of risk assessment concerned with identifying and characterising the hazards that may be associated with a particular site and identifying potential pollutant linkages.                                                                                                                                                                                                                                                                                                                |
| <b>PHASE 2</b> | This phase is concerned with establishing whether contamination is present, usually through intrusive ground investigation, and then evaluating the degree and magnitude of the associated risks. | <b>Risk Estimation</b><br>A stage concerned with estimating the likelihood that receptors will suffer adverse effects if they come into contact with, or are otherwise affected by, a hazardous substance or agent under defined conditions.<br><b>Risk Evaluation</b><br>A stage of risk assessment concerned with evaluating the acceptability of estimated risks, taking into account the nature and scale of the risk estimates, any uncertainties associated with the assessment and the broad costs and benefits of taking action to mitigate risks. |
| <b>PHASE 3</b> | The appraisal and selection of remediation techniques, their implementation and verification.                                                                                                     | <b>Risk Management</b><br>The process whereby decisions are made to accept a known or assessed risk and/or the implementation of action to reduce the consequences or probabilities of occurrence.                                                                                                                                                                                                                                                                                                                                                         |

## Risk Classification

The objective of risk assessment is to identify the nature and magnitude of the potential risks and should be based on a consideration of both:

- The likelihood/probability of an event [taking into account both the presence of the hazard and receptor and the integrity of the pathway].
- The severity of the potential consequence [taking into account both the potential severity of the hazard and the sensitivity of the receptor].

There is a need for a logical, transparent and repeatable system in defining the categories of severity of consequence and likelihood as well as for the risk itself and therefore the following risk rating matrix is employed:

|             |                 | SEVERITY OF CONSEQUENCE |                   |                   |                   |
|-------------|-----------------|-------------------------|-------------------|-------------------|-------------------|
|             |                 | SEVERE                  | MEDIUM            | MILD              | MINOR             |
| PROBABILITY | HIGH LIKELIHOOD | Very High Risk          | High Risk         | Moderate Risk     | Moderate/Low Risk |
|             | LIKELY          | High Risk               | Moderate Risk     | Moderate/Low Risk | Low Risk          |
|             | LOW LIKELIHOOD  | Moderate Risk           | Moderate/Low Risk | Low Risk          | Negligible Risk   |
|             | UNLIKELY        | Moderate/Low Risk       | Low Risk          | Negligible Risk   | Negligible Risk   |

These risk classifications are defined as follows:

- **Very High Risk** - There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
- **High Risk** - Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
- **Moderate Risk** - It is possible that without appropriate remediation action harm could arise to a designated receptor. It is relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely that such harm would be relatively mild.
- **Low Risk** - It is possible that harm could arise to a designated receptor from an identified hazard. It is likely that, at worst if any harm was realised any effects would be mild.
- **Negligible Risk** - The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor.

This risk assessment matrix and classification system is based on guidance produced by Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency in connection with contaminated land assessment.

## **RISK ESTIMATION - SOILS**

### Introduction to Soil Human Health Generic Assessment Criteria (GAC)

The Environment Agency (EA) and Department of Environment Food and Rural Affairs (DEFRA) had previously issued revised guidance following the consultation about the DEFRA publication “Assessing risks from land contamination - a proportionate approach. Soil Guideline Values: the Way Forward”. This resulted in a revised version of the Contaminated Land Exposure Model (CLEA) model (version 1.06) and a few of the previously published Soil Guideline Values (SGVs) were revised.

The main legislative driver for dealing with historical land affected by contamination is Part 2A of the Environmental Protection Act 1990. Revised Statutory Guidance to support Part 2A was published in April 2012. This Guidance introduced a new four-category system for classifying land under Part 2A for cases of a Significant Possibility of Significant Harm to human health,<sup>1</sup> where Category 1 includes land where the level of risk is clearly unacceptable and Category 4 includes land where the level of risk posed is acceptably low. The impact assessment for the new Statutory Guidance stated “The new statutory guidance will bring about a situation where the current SGVs/GACs are replaced with more pragmatic (but still strongly precautionary) Category 4 screening levels (C4SLs) which will provide a higher simple test for deciding that land is suitable for use and definitely not contaminated land”. The C4SLs are still derived using the CLEA model, but adopt a slightly different approach to toxicological assessment and exposure modelling.

In March 2014, the outcome of “SP1010 - Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination - Final Project Report” (CL:AIRE) was published. Due to slightly ambiguous wording within this report, Lord de Mauley, Parliamentary Under Secretary, DEFRA wrote to all local authorities on 3 September 2014 to confirm that the published C4SLs were final and that they can be used in risk assessment undertaken under the planning regime.

Whilst there are proposals for the industry to develop C4SLs for other contaminants, these have yet to produce any new values. BRD do not believe that C4SLs could be developed by a single organisation with sufficient confidence. BRD has therefore employed other, more conservative guidance based on the CLEA model (detailed below) within this assessment for compounds where C4SLs are not available. However, it should be noted that the results of this investigation may need to be reinterpreted as new C4SLs become available.

Due to the limited number of published C4SL values at this time, the Chartered Institute of Environmental health (CIEH) and Land Quality Management Ltd (LQM) have produced Generic Assessment Criteria (GAC) known as Suitable for Use Levels (S4ULs), for use in contaminated land human health risk assessment. These S4ULs (2014) have been derived for a large number of substances using the current CLEA model and are therefore consistent with current guidance. They also incorporate the revised exposure parameters as adopted by the C4SL programme, but have not adopted the revised toxicological approach adopted by the C4SLs and so remain a more conservative assessment criteria. The substances for which SGVs were previously published have also been revised as new S4ULs in light of the new exposure parameters proposed by the C4SL programme, and therefore effectively replace the existing SGVs.

In addition, in December 2009, other GAC for less common substances were produced by the Environmental Industries Commission (EIC), The Association of Geotechnical and Geoenvironmental Specialists (AGS) and Contaminated Land: Applications in Real Environments (CL:AIRE) using the CLEA model. These are referred to as the EIC/AGS/CLAIRE GAC.

In summary, C4SLs have been used where these are available. For those substances where C4SLs have yet to be issued, then the S4ULs have been adopted or in some cases, the EIC/AGS/CLAIRE GAC. All of the previously produced SGVs have now either been withdrawn, or superseded by the respective C4SLs or S4ULs.

The only exception to this approach is the PAH compound benzo(a)pyrene (BaP) where a C4SL guideline value has been produced, whereas BRD has adopted the S4UL value. The C4SL for BaP relates to its use as a surrogate marker compound representing all of the genotoxic PAH compounds as a mixture, rather than this individual compound. BRD has therefore adopted the compound specific S4UL value as the initial screening value, for consistency with the other PAH compounds before then employing the C4SL is necessary.

It should be noted that unless otherwise stated, all the assessment criteria adopted within this report have been derived based on a sandy loam soil at pH 7 and the values quoted are for a conservative soil organic matter content of 1% where applicable (i.e. organic contaminants).

#### Human Health - Soil Generic Assessment Criteria

The results of the soils analysis have been compared to generic assessment criteria for the default exposure scenarios comprising either residential land with plant uptake, residential land without plant uptake, or commercial/industrial land use. The criteria values selected are listed in the table below and full details on the source are referred to above. Where applicable, the results have also been assessed with reference to the required statistical tests presented within CLAIRE document "Guidance on comparing soil contamination data with a critical concentration".

| ANALYSIS                      | GENERIC ASSESSMENT CRITERIA<br>(mg/kg unless stated) |                                        |                            | SOURCE                 |
|-------------------------------|------------------------------------------------------|----------------------------------------|----------------------------|------------------------|
|                               | RESIDENTIAL WITH<br>PLANT UPTAKE                     | RESIDENTIAL<br>WITHOUT PLANT<br>UPTAKE | COMMERCIAL /<br>INDUSTRIAL |                        |
| Arsenic                       | 37                                                   | 40                                     | 640                        | C4SL                   |
| Cadmium                       | 22                                                   | 150                                    | 410                        |                        |
| Chromium (total) <sup>5</sup> | 910                                                  | 910                                    | 8,600                      | S4UL                   |
| Chromium VI                   | 21                                                   | 21                                     | 49                         | C4SL                   |
| Lead                          | 200                                                  | 310                                    | 2,330                      |                        |
| Mercury*                      | 11                                                   | 15                                     | 320                        | S4UL                   |
| Selenium                      | 250                                                  | 430                                    | 12,000                     |                        |
| Nickel                        | 180                                                  | 180                                    | 980                        |                        |
| Copper                        | 2400                                                 | 7,100                                  | 68,000                     |                        |
| Zinc                          | 3,700                                                | 40,000                                 | 730,000                    |                        |
| pH                            | <5 - 10> units                                       |                                        |                            | Professional judgement |
| Naphthalene                   | 2.3                                                  | 2.3                                    | 190                        | S4UL                   |
| Acenaphthylene                | 170                                                  | 2,900                                  | 83,000                     |                        |
| Acenaphthene                  | 210                                                  | 3,000                                  | 84,000                     |                        |
| Fluorene                      | 170                                                  | 2,800                                  | 63,000                     |                        |
| Phenanthrene                  | 95                                                   | 1,300                                  | 22,000                     |                        |
| Anthracene                    | 2,400                                                | 31,000                                 | 520,000                    |                        |
| Fluoranthene                  | 280                                                  | 1,500                                  | 23,000                     |                        |
| Pyrene                        | 620                                                  | 3,700                                  | 54,000                     |                        |
| Benzo(a)anthracene            | 7.2                                                  | 11                                     | 170                        |                        |
| Chrysene                      | 15                                                   | 30                                     | 350                        |                        |
| Benzo(b)fluoranthene          | 2.6                                                  | 3.9                                    | 44                         |                        |
| Benzo(k)fluoranthene          | 77                                                   | 110                                    | 1,200                      |                        |
| Benzo(a)pyrene                | 2.2                                                  | 3.2                                    | 35                         |                        |
| Indeno(1,2,3-cd)pyrene        | 27                                                   | 45                                     | 500                        |                        |
| Dibenzo(a,h)anthracene        | 0.24                                                 | 0.31                                   | 3.5                        | S4UL                   |
| Benzo(ghi)perylene            | 320                                                  | 360                                    | 3,900                      |                        |
| TPH Aliphatic C5-C6           | 42                                                   | 42                                     | 3,200                      |                        |
| TPH Aliphatic C6-C8           | 100                                                  | 100                                    | 7,800                      |                        |
| TPH Aliphatic C8-C10          | 27                                                   | 27                                     | 2,000                      |                        |
| TPH Aliphatic C10-C12         | 130                                                  | 130                                    | 9,700                      |                        |
| TPH Aliphatic C12-C16         | 1,100                                                | 1,100                                  | 59,000                     |                        |
| TPH Aliphatic C16-C35         | 65,000                                               | 65,000                                 | 1,600,000                  |                        |
| TPH Aliphatic C35-C44         | 65,000                                               | 65,000                                 | 1,600,000                  |                        |

| ANALYSIS             | GENERIC ASSESSMENT CRITERIA<br>(mg/kg unless stated) |                                  |                         | SOURCE                   |
|----------------------|------------------------------------------------------|----------------------------------|-------------------------|--------------------------|
|                      | RESIDENTIAL WITH PLANT UPTAKE                        | RESIDENTIAL WITHOUT PLANT UPTAKE | COMMERCIAL / INDUSTRIAL |                          |
| TPH Aromatic C5-C7   | 70                                                   | 370                              | 26,000                  |                          |
| TPH Aromatic C7-C8   | 130                                                  | 860                              | 56,000                  |                          |
| TPH Aromatic C8-C10  | 34                                                   | 47                               | 3,500                   |                          |
| TPH Aromatic C10-C12 | 74                                                   | 250                              | 16,000                  |                          |
| TPH Aromatic C12-C16 | 140                                                  | 1,800                            | 36,000                  |                          |
| TPH Aromatic C16-C21 | 260                                                  | 1,900                            | 28,000                  |                          |
| TPH Aromatic C21-C35 | 1,100                                                | 1,900                            | 28,000                  |                          |
| TPH Aromatic C35-C44 | 1,100                                                | 1,900                            | 28,000                  |                          |
| Benzene              | 0.87                                                 | 3.3                              | 98                      | C4SL                     |
| Toluene              | 130                                                  | 880                              | 56,000                  | S4UL                     |
| Ethylbenzene         | 47                                                   | 83                               | 5,700                   | EIC / AGS / CL: AIRE GAC |
| Xylene <sup>^</sup>  | 56                                                   | 79                               | 5,900                   |                          |
| MTBE                 | 49                                                   | 73                               | 7,900                   |                          |

Notes:

\* The S4UL for methyl mercury has been adopted as the worst case mercury compound as generally there is no desk study evidence to suggest the potential for elemental mercury on the majority of sites.

<sup>^</sup> The lowest S4UL of either p-xylene, o-xylene or m-xylene has been adopted for each land use as a conservative measure.

<sup>§</sup> S4UL for Chromium III adopted, as in the absence of Chromium VI it is likely that all of the chromium will be in this form as these are the two most common and stable forms of chromium in the soil environment.

Where no GAC is available, any concentrations exceeding the laboratory limit of detection are identified and discussed in more detail.

#### Water Environment - Soil Generic Assessment Criteria

There are no UK published Generic Assessment Criteria for soil test results in respect of the risk to the water environment and therefore risk estimation is on the basis of the professional judgement and experience of BRD to employ values that are a reasonable concentration above which concern for water resources is valid.

The Total PAH GAC employed is the sum of the 16No. priority PAH compounds regularly tested for in contaminated land analysis (i.e. US EPA 16PAHs). BRD employ a soil screening based upon the total PAH limit for 'inert waste' of 100mg/kg. The rationale is based on PAHs are recognised to be generally of low solubility and the risk to the water environment is correspondingly low.

In respect of Total Petroleum Hydrocarbons, BRD employ a value of 500 mg/kg as a screening value in comparison to the sum of the component aliphatic and aromatic TPH carbon bands. The employed soil screening value is based upon:

- In common with some other consultants, the professional judgement and experience of BRD suggests that this value is a reasonable concentration above which concern for water resources is valid. The rationale is based on the fact that lower concentrations of fuel based contaminants are more likely to naturally degrade than migrate any great distance.
- BRD is aware of regional Environment Agency groundwater and contaminated land teams historically employing 500 mg/kg as a screening value for considering whether or not TPH could represent a risk to water resources.
- The value mirrors the mineral oil Waste Acceptance Criteria limits for what is considered 'inert waste'.

Should elevated contaminants that pose a potential risk to the water environment be identified then site specific assessment criteria should be developed.

#### Building Materials and Services - Soil Generic Assessment Criteria

Some hydrocarbon compounds are known to both attack and permeate through certain plastic pipe materials, with the primary concern being the degradation and tainting of water supplies. The UK Water Industry Research (UKWIR) has therefore produced a document 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites' (ref. 10/WM/03/21) that specifies threshold criteria for the adoption of 'standard' polythene (PE) or PVC pipes, protective barrier pipe and ductile iron/steel/copper pipes.

The UKWIR threshold assessment criteria from Table 3.1 of this document for standard PE pipes have been employed. It should be noted that the approach taken by UKWIR is very conservative, and both the document and research are flawed. However, it is these values that are being using to specify water pipe materials and therefore it is appropriate to consider them.

The UKWIR guidance is particularly flawed in respect of the chemical analysis it expects as it seeks a limit of detection that is generally below limits that are reasonable or commonly employed in contaminated land assessment. The UKWIR seeks that where a substance is below the limit of detection it should be taken as being present at half this concentration. For the larger suite of chemicals where the limit is against a sum of compounds, this approach would mean that a sample of virgin sub-soil from a greenfield site with absolutely no contamination would actually fail the criteria for using standard PE pipes. To avoid this situation, BRD have adopted the approach of summing only those compounds detected above their respective limits of detection.

In terms of building materials, the primary concern is in respect of concrete as certain commonly occurring natural ground conditions can adversely impact on buried concrete as discussed in 'Special digest 1:2005 Concrete in aggressive ground', BRE, 2005.

| ANALYSIS                                                                          | GENERIC ASSESSMENT CRITERIA | SOURCE                                          |
|-----------------------------------------------------------------------------------|-----------------------------|-------------------------------------------------|
| pH                                                                                | <5.5                        | BRE Special Digest 1:2005                       |
| Sulphate (w/s)                                                                    | 500 mg/l                    | BRE Special Digest 1:2005                       |
| Sum of any VOC above detection limits                                             | 0.5 mg/kg                   | Relevant compounds adapted from UKWIR Table 3.1 |
| Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits | 2 mg/kg                     |                                                 |
| Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits      | 10 mg/kg                    |                                                 |
| Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits      | 500 mg/kg                   |                                                 |
| Sum of BTEX + MTBE above detection limits                                         | 0.1 mg/kg                   |                                                 |
| Phenols                                                                           | 2 mg/kg                     |                                                 |
| Cresols and chlorinated phenols                                                   | 2 mg/kg                     |                                                 |
| Naphthalene                                                                       | 0.5 mg/kg                   |                                                 |
| Benzo(a)pyrene                                                                    | 0.5 mg/kg                   |                                                 |

## RISK ESTIMATION - GROUNDWATER

The initial assessment of the contamination risk to groundwater is by comparing dissolved groundwater concentrations with screening values (GAC) that are protective of groundwater resources.

The reference source for the target concentrations is generally the EA's Environmental Quality Standards (EQS) (accessed July 2018: <http://evidence.environment-agency.gov.uk/ChemicalStandards/report.aspx?cid=17>), the Water Supply (Water Quality) Regulations 2016 and the DW1/DW2 criteria from the Surface Water (Abstraction for drinking water)(classification) Regulations 1996. The target concentrations are outlined in the table below. The 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies'. CL:AIRE, 2017 has also been used as reference source for the values.

| ANALYSIS                       | GENERIC ASSESSMENT CRITERIA (GAC) | SOURCE                                                                              |
|--------------------------------|-----------------------------------|-------------------------------------------------------------------------------------|
| Arsenic                        | 50 µg/l                           | DW1 & EQS                                                                           |
| Cadmium                        | 5 µg/l                            | EQS                                                                                 |
| Chromium (total)               | 50 µg/l                           | DW2 & EQS                                                                           |
| Copper                         | 50 µg/l                           | DW1                                                                                 |
| Nickel                         | 20 µg/l                           | EQS                                                                                 |
| Lead                           | 50 µg/l                           | DW1                                                                                 |
| Mercury                        | 1 µg/l                            | WSR                                                                                 |
| Selenium                       | 10 µg/l                           | WSR                                                                                 |
| Zinc                           | 5 mg/l                            | DW2                                                                                 |
| Cyanide                        | 50 µg/l                           | WSR                                                                                 |
| pH                             | 6 to 9 units                      | EQS                                                                                 |
| Benzene                        | 10 µg/l                           | EQS                                                                                 |
| Toluene                        | 74 µg/l                           | EQS                                                                                 |
| Ethylbenzene                   | 300 µg/l                          | WHO guideline                                                                       |
| Xylene                         | 30 µg/l                           | EQS                                                                                 |
| Methyl tert-butyl ether (MTBE) | 15 µg/l                           | Taste and odour threshold.                                                          |
| Naphthalene                    | 2 µg/l                            | EQS                                                                                 |
| Benzo(a)pyrene                 | 0.0017 µg/l                       | EQS - Less than Limit of Detection (LOD)                                            |
| Total PAH                      | 0.2 µg/l                          | DW1                                                                                 |
| TPH Aliphatic C5-C6            | 15,000 µg/l                       | World Health Organization (WHO) guide values for TPHCWG fractions in drinking water |
| TPH Aliphatic C6-C8            | 15,000 µg/l                       |                                                                                     |
| TPH Aliphatic C8-C10           | 300 µg/l                          |                                                                                     |
| TPH Aliphatic C10-C12          | 300 µg/l                          |                                                                                     |
| TPH Aliphatic C12-C16          | 300 µg/l                          |                                                                                     |
| TPH Aromatic C5-C7             | 10 µg/l                           |                                                                                     |
| TPH Aromatic C7-C8             | 700 µg/l                          |                                                                                     |
| TPH Aromatic C8-C10            | 300 µg/l                          |                                                                                     |
| TPH Aromatic C10-C12           | 90 µg/l                           |                                                                                     |
| TPH Aromatic C12-C16           | 90 µg/l                           |                                                                                     |
| TPH Aromatic C16-C21           | 90 µg/l                           |                                                                                     |
| TPH Aromatic C21-C35           | 90 µg/l                           |                                                                                     |

There are no available generic assessment criteria for some of the analytical parameters which have been scheduled, for example hexavalent chromium, and some VOC compounds. These parameters will be assessed based on professional judgement should they exceed the limit of detection.

## **RISK ESTIMATION - GROUND GAS**

### Introduction

*A variety of potentially hazardous gases occur naturally in the ground environment. Microbial decay of organic matter under anaerobic conditions and geological processes can lead to the generation of Methane and Carbon Dioxide, but can also include traces gases such as Hydrogen sulphide and Carbon monoxide.*

*Methane is a colourless and odourless gas that has the hazardous properties of being flammable and, at certain air/Methane mixtures, explosive. Methane has a low toxicity, but can be a simple asphyxiant due to the displacement of oxygen.*

*Carbon Dioxide is a colourless, odourless and non-combustible gas that has the hazardous property of being a highly toxic chemical. At concentrations of 3% by volume, shortness of breath and headaches will occur becoming acute by 6%. At levels of above 10% by volume headache, visual distortion, tremors and rapid loss of consciousness occur. Concentrations of Carbon Dioxide above 22% by volume are likely to be fatal. The effects of Carbon Dioxide poisoning are made more severe if there is accompanying reduction in oxygen concentrations.*

*Hydrogen sulphide is a colourless and flammable gas that has an odour of rotten eggs. It is important that the sense of smell is over powered at higher concentrations. The gas is toxic and can be an asphyxiant.*

*Carbon monoxide is a colourless, odourless and explosive gas in air mixtures that has the hazardous property of being a highly toxic chemical.*

*Radon is a naturally occurring colourless and odourless gas that is radioactive. It is formed by the radioactive decay of radium which in turn is derived from the radioactive decay of uranium, both of which are minerals that can be found in many soil types. Whilst it is recognised that the air inside every building contains radon, some buildings built in certain defined areas of the country might have unacceptably high concentrations and require special precautions to be taken. The maps contained within BRE211:2023 'Radon: guidance on protective measures for new buildings' identify areas where no radon protection measures are necessary or where higher concentrations are present that either basic or full radon protection measures are required to be fitted to all new buildings, extensions or refurbishments.*

### Basis of Gas Assessment

*In order to classify the level of risk and need, if any, for gas protection measures at a site with the potential for a gas problem, consideration of each of the following is necessary:*

- *The source of the gas.*
- *The generation potential of the gas.*
- *The location of the source and the geological setting.*
- *Boreholes flow rate and estimated surface emission rate.*
- *The nature of the proposed development.*
- *Confidence in the knowledge of the gas regime.*

*The gas assessment is made with reference to 'C665 - Assessing risks posed by hazardous ground gases to buildings', Construction Industry Research and Information Association (CIRIA), 2007 and 'BS8485:2015 - Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' BSi 2015.*

## Gas Screening Value

The methods within CIRIA C665 and BS8485 both use the gas concentrations together with the borehole flow rates to define a characteristic situation for a site based on the limiting borehole gas volume flow for Methane and Carbon Dioxide. This limiting borehole gas volume flow is called the Gas Screening Value (GSV) and is expressed below:

$$\text{Gas Screening Value (l / hr)} = \text{borehole flow rate (l/hr)} \times \text{gas concentration (fraction)}$$

The calculation of GSV is completed for both Methane and Carbon Dioxide and then the 'worse case' maximum values are used in the assessment. The assessment is to determine the gas regime at the site is dependent upon the nature of the development.

## Characteristic Gas Situation

The characteristic situation for many sites is determined from evaluation of the Gas Screening Value derived against the criteria in the following table.

| Characteristic situation | Hazard potential      | Gas Screening Value (CH <sub>4</sub> or CO <sub>2</sub> l/hr) | Additional factors                                                                                             |
|--------------------------|-----------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| CS1                      | Very low risk         | <0.07                                                         | Typically Methane ≤1% and/or Carbon Dioxide ≤5%. Otherwise consider an increase to characteristic situation 2. |
| CS2                      | Low risk              | 0.07 to <0.7                                                  | Borehole air flow rate not to exceed 70 l/hr. Otherwise consider an increase to characteristic situation 3.    |
| CS3                      | Moderate risk         | 0.7 to <3.5                                                   | -                                                                                                              |
| CS4                      | Moderate to high risk | 3.5 to <15                                                    | -                                                                                                              |
| CS5                      | High risk             | 15 to <70                                                     | -                                                                                                              |
| CS6                      | Very high risk        | >70                                                           | -                                                                                                              |

## Low rise housing with gardens - NHBC 'Traffic Lights'

The NHBC model for low rise housing development considered a typical residential house with a ground floor area of 64m<sup>2</sup>, suspended floor and ventilated sub-floor void of height 150mm. Where the proposed development of a site is consistent with this model, the NHBC traffic light situation of the site is determined from evaluation of the Gas Screening Value against the criteria in the following table.

| Traffic Lights | Methane                            |                            | Carbon Dioxide                     |                            |
|----------------|------------------------------------|----------------------------|------------------------------------|----------------------------|
|                | Typical maximum concentrations (%) | Gas Screening Value (l/hr) | Typical maximum concentrations (%) | Gas Screening Value (l/hr) |
| Green          | ≤1                                 | ≤0.16                      | ≤5                                 | ≤0.78                      |
| Amber 1        | 1 > to ≤5                          | >0.16 to ≤0.63             | >5 to ≤10                          | >0.78 to ≤1.56             |
| Amber 2        | 5 > to ≤20                         | >0.63 to ≤1.56             | >10 to ≤30                         | >1.56 to ≤3.13             |
| Red            | >20                                | >1.56                      | >30                                | >3.13                      |