

**PHASE 2
GEOTECHNICAL AND GEO-ENVIRONMENTAL
SITE INVESTIGATION**

PHASE 2 SITE, BARNBURGH LANE, GOLDTHORPE

FOR

GLEESON DEVELOPMENTS LTD



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1.0 EXECUTIVE SUMMARY

1. The site is located to the south of the current Gleeson Developments Ltd housing development on Barnburgh Lane, Goldthorpe and comprises an agricultural field of approximately 1.9 hectares. It is centred on National Grid Reference SE 467 036. With the exception of a mine shaft, there are no recorded previous developments. The boundaries are marked by intermittent hawthorn hedges, mixed trees and low wooden post fencing.
2. Generally ground conditions comprise clay topsoil over soft to firm, quickly becoming firm to stiff brown or mottled clay with rare gravel and cobbles of sandstone and mudstone. This is underlain by mudstone, coal and sandstone. Groundwater can be expected at shallow depth.
3. The Shafton coal seam (1.6 m thick) has been worked and is present between around 4 and 15 m bgl. Drilling and grouting will be required at 2 m intervals where the thickness of cover is less than 4 times seam thickness. 3 m grout hole spacing may be used elsewhere. At least 1 mine shaft is present on site. Other unexpected shafts may also be present.
4. Piled foundations are required in plots to the south of the site. Reinforced thickened strip and trench fill footings are considered appropriate elsewhere. A minimum thickness of 450 mm will be required where grout hole spacing is at 2 m intervals. The thickness can be reduced to 300 mm where the grout hole spacing is at 3 m intervals. Heave precautions are required where plots are within influencing distance of existing or proposed trees.
5. Superstructure precautions of masonry reinforcement will be required.
6. Precast concrete floors with an underlying minimum 150 mm ventilated void and suitably resistant fully sealed gas membrane are required (i.e. Amber 1 gas precautions).
7. No radon precautions are required.
8. There may be strong bedrock in localised areas.
9. Superstructure precautions will be required for the proposed development where the depth to the base of the Shafton seam is less than 11 m.
10. No significant risk is considered to be posed to construction workers, site visitors or future residents from exposure or interaction with the topsoil and natural ground. Topsoil is considered suitable for reuse, subject to regulatory approval. No remedial measures are considered to be required.

11. A Design Sulphate Class of DS-1 AC-1 should be used in the natural ground. DS-2 AC-2 sulphate precautions should be allowed for if any made ground is encountered on site.
12. The above conclusions must be agreed with the regulators prior to commencing works on site.

2.0 INTRODUCTION

2.1 Terms of Reference

This report presents the findings of a geotechnical and geo-environmental site investigation carried out by Eastwood and Partners (Consulting Engineers) Ltd for, and on the instructions of, Gleeson Developments Ltd. Any other parties using the information in this report do so at their own risk and any duty of care is excluded.

2.2 Context

A desk study has been previously undertaken across this site and the site to the north, and a summary is included as part of this report. Eastwood and Partners have previously undertaken a site investigation report for the adjacent land to the north of site, referenced 34041/005 in September 2011. No site investigations are known to have taken place on this site.

2.3 Aims and Objectives

The aims and objectives of this investigation were as follows.

- To review previous Phase 1 report and examine published documentation to derive an outline conceptual model identifying potential contaminants, pathways and receptors, as well as possible linkages between these;
- Refine the conceptual model through ground investigation and chemical testing of soils;
- Carry out tiered risk assessment to establish the likely risks to future receptors, involving the use of generic assessment criteria and where unacceptable risks are identified, site specific assessment criteria within a detailed quantitative risk assessment;
- Identify feasible remediation options if unacceptable risks are highlighted;
- Develop an appropriate remediation strategy where remediation is required; and
- Detail the ground conditions and their geotechnical properties, enabling outline foundation proposals to be made for the proposed residential development.

2.4 Scope of Investigation

This document constitutes the findings of Phase 2 investigation. This part of the investigation consisted of intrusive works and laboratory analysis. The findings were used to test the conceptual model and produce a refined risk assessment.

The intrusive works comprised trial pits and boreholes which were excavated to enable:

- Examination of the upper few metres of ground in order to provide in situ description of soils, including any localised lateral and vertical changes in soil conditions and strengths;
- Assessment of any contamination identified using visual and olfactory methods;
- Collection of samples for chemical and geotechnical testing.

2.5 Limitations of Investigation

This report is based on the assumption that the site will be developed with residential properties of conventional construction, associated hard standing and soft landscaped areas. It is assumed that existing ground levels will not alter significantly. If this is not the case, then the advice given in this report may not be appropriate.

Where assessments of site areas affected in particular ways are given, these are approximate. All information, comments and opinions given in this report are based on the ground conditions encountered during the site work, on the results of laboratory testing carried out as part of the investigation and information gained from the desk study. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata and water conditions between or below investigation points. It should be noted that groundwater and gas levels vary due to seasonal or other effects, and may at times differ from those measured during the investigation.

This report was prepared for the sole and exclusive use of Gleeson Developments Ltd in response to particular instructions. Any other parties using the information contained in this report, unless given prior written approval to do so, do so at their own risk, and any duty of care to those parties is excluded.

3.0 SUMMARY OF PHASE 1 REPORT

The Phase 1 report covered this site and the site to the north, which is currently being developed by Gleeson Developments Ltd. Information provided has been obtained from the original Envirocheck Report and updated where appropriate.

3.1 Site Description

The site comprises a field located to the south of the Gleeson Developments site on Barnburgh Lane, to the east of Goldthorpe. The site has an area of approximately 1.9 hectares, and is centred on National Grid Reference SE 467 036 (446646, 403624). The site slopes to the south-east with a level difference of approximately 3 m from the northern hedge-line to the southern boundary.

The site is bordered by a housing development site off Barnburgh Lane to the north (Gleeson Homes Regeneration Phase 1), a track to the east and fields to the south and south west. The boundaries are marked by low hawthorn hedges with intermittent elder and sycamore trees and wooden post fencing to the north, east and south. A drainage system is present to the west boundary. One backfilled mine shaft is known to be present on site adjacent to the hedgerow in the north-east corner.

The appended 'Exploratory Hole Location Plan', drawing number, 34041/013A indicates the approximate location of the described features.

3.2 Site and Surrounding Area History

The earliest map reviewed, dated 1851, shows the site to comprise an agricultural field. There are no significant changes to the present day with the exception of a footpath shown to cross the field in a north-east to south-west direction from 1961 onwards. The footpath is no-longer visible on site.

The 1854 map shows the surrounding area to be agricultural with Barnburgh Lane and Engine Lane present. Engine House is shown beyond Engine Lane to the east of the site. The village of Goldthorpe is 500 m west of the site. There is a small pond shown beyond the boundary to the south east of the site and West Moor Dyke is shown 250 m east of the site. The Engine House has been demolished by 1894.

Major residential development occurred around Goldthorpe and up to the north eastern site boundary by 1931. Allotment gardens are shown beyond the road to the north of the site and the railway 100 m north of the site is operational as Dearne Valley Railway. Two collieries have been constructed, Goldthorpe colliery 175 m north of the site and Barnburgh Main Colliery 1 km east of

the site. By 1976 the land to the north and east of the Goldthorpe Colliery is shown as active workings and two fields, 250 m south west of the site are shown as a tip.

The only changes to present day are the closure and demolition of the collieries and dismantling of the nearest railway by 2000.

3.3 Geology

The Geological Map sheet 275 SE (1:10,560) shows the solid geology beneath the site to be mudstone and shales of the Carboniferous Middle Coal Measures. No superficial deposits are indicated over the site. There is a fault shown 100 m to the east of the site. The strata are estimated to dip at approximately 3° to the north east.

The shallowest named coal seam underlying the site is the Shafton Coal, which is estimated to lie beneath the site at approximately between 4 and 15 m. The next stratigraphical seam lies at significant depth beneath the Shafton Coal.

3.4 Hydrogeology

3.4.1 Groundwater Vulnerability

The Envirocheck Report indicated the site to overlie a Secondary A Aquifer. These are rocks classified as permeable layers capable of supporting water supplied at a local rather than strategic scale and form an important base flow to rivers.

3.4.2 Groundwater Abstractions

The Envirocheck report indicates there are no water abstractions within 500 m of the site boundary.

3.5 Hydrology

The nearest surface water feature is a drain which runs along the western boundary into a marshland in the adjacent southern field. The drain enters into Far Moor Dyke approximately 400 m downstream, south of the site. The Envirocheck map also indicates two small ponds to be adjacent to the south-east corner of the site. Information provided by the Envirocheck Report shows that the site is not within a flood plain.

3.6 Mining

The shallowest significant coal seam is the Shafton Coal, which lies from approximately 4 m bgl in the south-west. Along the north eastern site boundary, the grouting works encountered worked coal from around 13 to 16 m bgl. This seam outcrops approximately 700 m south-west of

the site and is recorded as 1.6 m in total thickness in Goldthorpe Colliery, 450 m north of the site. The Goldthorpe Colliery mine shafts were sunk to the Shafton Coal Seam.

A Coal Authority Report obtained states that the site is within the likely zone of influence on the surface from workings in five seams of coal at shallow to 670 m, last worked in 1982. The report states reserves of coal exist beneath the site which could be worked at some point in the future. However the site is not within an area where opencast workings have or are currently being undertaken or where a license to remove or otherwise work coal using underground methods has been granted.

There is one recorded mine entry within the site. The mineshaft (ref: 446403-021) is present on the eastern boundary approximately 15 m south from the north-east corner. It has been back-filled to an unknown specification and its approximate position is shown on the 'Exploratory Hole Location Plan', drawing number 34041/013. We understand the shaft was grouted as part of the grouting works on the site to the north.

3.7 Ground Gas

Information contained within the Envirocheck Report indicates historic landfill site, Marsh Tip, is present adjacent to the south-west boundary of the site. The license for this was held by South Yorkshire County Council. The tip inputted between 1970 and 1979 and deposited waste included inert, industrial, commercial, household waste and liquid sludge.

It is almost certain that the Shafton seam has been worked at shallow depth below the site. There is therefore the possibility of mine gas migrating to the surface.

Information provided within the Envirocheck Report states that no radon precautions will be required for residential development on this site.

4.0 OUTLINE CONCEPTUAL MODEL

The site is considered for development with residential dwellings, including private gardens and areas of associated soft landscaping and hardstanding. The following table details the possible sources and associated contaminants of concern, pathways and receptors, which are potentially present on site.

Source	Pathway	Target
Naturally elevated levels of metals and PAHs in the natural ground.	Ingestion, inhalation, direct contact	Site workers, future residents and visitors
	Migration through ground	Secondary A aquifer
Elevated levels of metals and PAHs in topsoil present on the site.	Ingestion, inhalation, direct contact	Site workers, future residents and visitors
	Migration through ground	Secondary A aquifer
Ground and Mine Gas	Inhalation	Future Residents

5.0 GROUND INVESTIGATION

5.1 Site Works

We visited site on 25 September 2014 and excavated ten trial pits (EP1 to EP10) across the southern field. These reached depths of between 2.2 m and 3.3 m below ground level and were positioned to provide representative coverage of the site. Trial pits were terminated upon reaching hard strata in the natural ground where further progression was not possible.

Eight boreholes, RO201 to RO208 were drilled between 24 and 26 September 2014 to between 11 and 18 m bgl.

Copies of the trial pit and borehole logs are presented in Appendix 2, and their approximate locations are plotted on the 'Exploratory Hole Location Plan', drawing number 34041/013A in Appendix 1.

5.2 Laboratory Testing

Three samples of clay were despatched for geotechnical testing in order to determine the natural moisture content and plasticity index of the natural ground. The geotechnical results are present in Appendix 3 and discussed in Section 7.0.

Eight samples of topsoil and four of natural clay were despatched for chemical testing. Soil samples were taken in 500g plastic tubs and 100 ml amber glass jars and analysed at Chemtest Laboratories, Newmarket using MCERTs accredited methodologies where available. The chemical results, Chemtest Report 14-10977 are presented in Appendix 3 and discussed in Section 8.0.

6.0 GROUND CONDITIONS

6.1 Surface Covering

The site has a covering of grass over topsoil approximately 0.3 m thick. The topsoil was found to comprise slightly sandy clay with frequent rootlets.

6.2 Made Ground

A thin localised band of reworked mudstone around 150 mm thick was present beneath the topsoil in the north-east corner of the site in EP8, extending to around 0.6 m bgl. Natural ground was encountered below.

Sandstone blocks were encountered in EP5 between 0.8 and 1.3 m bgl held amongst natural sandy clay deposits. This was limited to the north pit face only. An additional excavation within this area was carried out and found no further evidence of any made ground. The deposits of sandstone are considered to be localised.

6.3 Natural Ground

The upper 1 m or so of natural ground comprised soft to firm rapidly becoming firm and stiff brown or mottled orange and grey clay with local sandy lenses overlying weak to strong mudstone and shale at depth.

6.4 Groundwater

Running groundwater was encountered in three trial pits (EP1, EP2 and EP10) from 2.0 m to 2.2 m bgl. This is within or just above the mudstone in the three southernmost pits along the western site boundary. No groundwater was recorded within the boreholes.

6.5 Obstructions

A dry terracotta land drain was encountered in EP1 at 0.45 m bgl. No other obstructions were encountered in any of the exploratory holes, except for strong bedrock in localised areas.

6.6 Evidence of Contamination

Visual or olfactory evidence of possible contamination was not identified in any of the exploratory holes.

7.0 GEOTECHNICAL APPRAISAL

7.1 Mining

From the boreholes drilled on site and those previously drilled beyond the north eastern site boundary, it appears that the depth to the base of the Shafton coal seam is about 5 m in the south-west corner, 10 m in the south-east corner, 12.5 m in the north-west corner and 15 m in the north-east corner.

Shallow intact coal was present in RO201 and RO202 along the south boundary of site. The coal was present at depths between 4.10 and 9.50 m bgl.

The rotary boreholes drilled on site indicate 1.10 m to 1.70 m of broken ground or voids to be present within boreholes positions RO204 in the east and RO206 to RO208 in the north and west of site. The broken ground was present at depths of between 7.80 and 11.50 m bgl.

In RO203, the coal appears to be absent and so is assumed to be worked. The 300 mm coal thickness is assumed to be another lower minor coal seam. The coal seam depth in BH208 appears inconsistent with adjoining boreholes drilling on Phase 1 to the northern boundary.

The coal seam thickness found varied from 1.0 to 1.5 m in the three boreholes where it was found. However on the drilling for grouting on Phase 1, the coal seam thickness was found to be generally 1.5 or 1.6 m, which correlates with the 1.6 m found in Goldthorpe Colliery nearby. A 1.6 m extraction thickness has therefore been assumed for the design of mining precautions.

The presence of broken ground and intermittent intact coal within the boreholes is evidence to previous shallow coal mining of the Shafton coal seam. It should be considered the seam has been worked beneath the whole of site.

Grouting of a shallow coal seam is normally recommended where the depth from the bottom of the foundations to the top of the coal seam is less than 10 times the extracted seam thickness. Where there is less than 4 times the seam thickness, it is considered necessary to use a spacing of grout holes to 2 m. Elsewhere 3.0 m spacing can be adopted. The approximate extent of grout hole spacing is presented on drawing 34041/013.

Using an extraction thickness of 1.6 m and assuming that the underside of the footings are, conservatively 1.5 m below ground level, the depth from ground level to the underside to the coal seam would have to be more than 20 m of competent cover for grouting to be considered unnecessary. The site will therefore require ground stability improvement via grouting works

beneath proposed housing and roadworks prior to construction. It is not considered to be standard practise to grout beneath proposed gardens and driveways and may not be economically viable.

Grout holes should be spaced at 2 m intervals for the proposed development where the depth from finished ground level to the base of the seam is less than 9.5 m. This depth would have to be increased if the footing depth will exceed 1.5 m from finished ground level. The approximate extent of this is shown on drawing 34041/13A.

One recorded mine shaft (ref: 446403-021) is present in the north-east corner of the development site. We understand the shaft was grouted during the grouting of the phase to the north of the site. Capping of the mine shaft will be required. The current proposed development layout does not show any development over the mineshaft.

It is possible that other unrecorded shafts may be present on site, and care should be taken accordingly. During the topsoil surface strip of the site, inspection of the ground surface should be undertaken for the potential of further mine shafts. Where a mine shaft is suspected, documented evidence via photographs, further inspection and reporting will be required.

7.2 Foundations

Three samples of the natural clay were tested to assess the volume change potential. The modified plasticity indices recorded were 16, 29 and 30%. These results equate to low and medium volume change potential in accordance with NHBC Standards. It would be prudent to use the medium volume change potential classification for foundation design.

The unconfined compressive strength of the natural clay ranges from 50 kN/m² to 100 kN/m² in the upper 1 m or so and was found to increase rapidly with depth providing unconfined compressive strengths in the region of 150 to 300 kN/m². An allowable bearing pressure of 125 kN/m² should be used for foundation design within the clay.

Shallow coal workings are present, and drilling and grouting will be required. Suitable foundations for the majority of the site are considered to be reinforced thickened strip or trench fill footings taken through any made or soft ground and into the firm to stiff natural clay at 900 mm depth from original or finished ground level, whichever is lowest.

Foundations within influence of trees or hedgerows will need to be deepened in accordance with the NHBC guidance. Where foundations are deepened over 1500 mm due to trees, heave precautions will be required.

Where the depth to the coal is very shallow and the seam has been worked, collapse and distortion of the strata immediately above the coal may make it unsuitable as a founding material. This could occur where the depth to the top of the coal seam from ground level is less than about 4.5 m. Therefore where the seam is expected to have been worked and where the depth to the base of the seam is less than 6.0 m, pile foundations should be adopted and founded below the base of the coal. This is likely to only affect a few plots. The approximate extent of this is shown on drawing 34041/13A.

In the zone where a 2 m grout hole spacing is required, there is a risk of localised weakness in the ground at foundation level. The footing should therefore be at least 450 mm thick and reinforced with a layer of B785 mesh top and bottom. In the area of the site where 3 m grout hole spacing is used, the footing should be 300 mm thick and reinforced top and bottom with one layer of B785 mesh.

7.3 Superstructure Precautions

Superstructure precautions will be required for the proposed development where the depth to the base of the Shafton seam is less than 11 m. This should comprise proprietary stainless steel in the masonry reinforcement, two courses above ground floor windows and two courses below the upper storey windows in the inner leaf and outer leaf of external and party walls. The reinforcement should have a grid area of at least 20 mm² and be laid in accordance with the manufacturer's recommendations.

7.4 Ground Slabs

Due to the expected gassing regime of the site, precast concrete floors with an underlying minimum 150 mm ventilated void will be required. A suitably resistant, fully sealed gas membrane will also be required.

7.5 Road Works

A CBR value of at least 2% may be appropriate for road design however there may be softer areas present, particularly in the south and during wetter times of the year. The ground should be assumed to be frost susceptible. It is recommended that CBR tests are undertaken along any proposed roads prior to construction so that more accurate CBR values can be obtained.

7.6 Excavation Problems

Excavation of the natural ground can generally be anticipated to be relatively stable however there may be the potential for side instability and collapse in deeper trenches within the clay where the depth to the worked coal is very shallow. There may be strong bedrock in localised areas.

Support will be required in accordance with current Health & Safety Regulations wherever access is required to trenches deeper than 1.2 m or less where there is risk of collapse.

7.7 Surface Water Drainage

The natural clay and underlying mudstone will not be suitable for soakaway drainage. Additionally, the water table beneath site is relatively shallow.

7.8 Obstructions

Significant obstructions are not expected on the site although some locally strong sandstone may be encountered at shallow depth.

8.0 REFINEMENT OF OUTLINE CONCEPTUAL MODEL

8.1 Source Characterisation

An outline conceptual model, detailing the possible sources and associated contaminants of concern, potential pathways and receptors is shown in Section 4.0.

This section of the report documents the works undertaken to obtain information to test and refine this model enabling a risk assessment to be produced and, where significant risks are expected, remediation recommendations.

8.2 Ground Conditions

The site was covered with topsoil approximately 0.3 m thick. The natural ground comprises firm to stiff brown or mottled grey and orange clay over mudstone and shale. There is no reason to suspect that the materials recorded on site, being natural, will contain any specific contaminants although elevated concentrations of common contaminants such as heavy metals and sulphates may be encountered due to the presence of pyrite. Polycyclic Aromatic Hydrocarbons (PAHs), such as benzo(a)pyrene, may also be elevated due to the atmospheric fallout of these derived from the combustion of fossil fuels and natural background levels.

8.3 Unexpected Contamination

No visual or olfactory observations of unexpected contamination were noted.

8.4 Chemical Testing

Eight samples of topsoil and four of natural clay were sent for testing. Each of the samples was analysed for the suite of contaminants listed below.

Contaminant Type	Actual Contaminants
Metals/Metalloids	Arsenic, cadmium, chromium, lead, mercury, nickel, copper, selenium and zinc
pH	pH
PAHs	Speciated PAH

In addition to the above testing the samples of clay were analysed for water soluble sulphate, acid soluble sulphate and sulphur.

Testing was undertaken by Chemtest, using MCERTs accredited methodologies, where available.

8.5 Assessment Criteria

The proposed development of the site is to be residential properties with associated gardens. Tables detailing the relevant assessment concentrations used are included in Appendix 3.

8.6 Chemical Test Results

Some preliminary risk assessment is undertaken in this section of the report where determinants can be readily discounted.

8.6.1 Metals/Metalloids

No metals were found to exceed their relevant assessment concentrations within the topsoil or natural ground on site.

8.6.2 Polycyclic Aromatic Hydrocarbons (PAHs)

No PAHs were found to exceed their relevant assessment concentrations within the topsoil or natural ground on site.

8.6.3 Sulphates

In accordance with BRE Special Digest 1, the site comes under the classification of 'Greenfield'. The four samples of natural ground were tested for total sulphate and sulphur. The results record a maximum total potential sulphate as 0.09%. The upper limit of the Design Sulphate Class 1 is 0.24%. The concentrations of water soluble sulphate were a maximum of 29 mg/l compared with the upper limit of Design Sulphate Class 1 of 500 mg/l. pH values ranged between 7.0 and 7.5.

8.7 Significant Pollutant Linkages

No pollutant linkages have been identified after the intrusive investigation.

9.0 RISK ASSESSMENT

9.1 Human Health – Construction Workers

No significant risks are considered to be posed to site construction workers from exposure and interaction with the topsoil or natural ground.

Normal site precautions such as wearing gloves and washing hands prior to eating should be sufficient to mitigate against any potential unexpected contamination. There is the possibility that, as with any site, areas of unexpected contamination may be encountered during construction works. If any unusual, brightly coloured, ashy or particularly odorous material are encountered it should be brought to the attention of the site staff and investigated.

9.2 Human Health – Future Site Users

No concentrations of the tested determinands were found to exceed their respective residential assessment values. There are no significant risk considered to be posed to future residents and visitors from interaction with the topsoil and natural ground on site. Remedial measures are not considered necessary for the materials on site.

The topsoil and natural clay material may be considered suitable for reuse in a residential development, subject to regulatory approval.

9.3 Plants

No significant risk is considered to be posed to plants from the topsoil and natural ground.

9.4 Controlled Waters

No significant risk is considered to be posed to nearby water courses from the natural materials on site.

9.5 Ground Gas

The Envirocheck Report states that no radon precautions will be required for residential development on this site.

The Envirocheck Report indicates a historic landfill site, Marsh Tip, is adjacent to the south-west boundary of the site. The license for this was held by South Yorkshire County Council. The tip accepted waste between 1970 and 1979 and included inert, industrial, commercial, household waste and liquid sludge.

The Shafton coal seam has been worked at shallow depth below the site. There is therefore the possibility of mine gas migrating to the surface.

It is unlikely that the adjacent landfill is still gassing 35 years after its closure. We have discussed this landfill with Barnsley MBC. Whilst they did monitor it early on, they do not have any recent data. This would indicate that the council is not particularly concerned with its gassing state. Barnsley MBC also expects the landfill is relatively thin, as the levels in this area are relatively flat, indicating that a significant thickness of made ground is not expected.

Gas monitoring took place for the site to the north, with three wells installed along this site's northern boundary. Over 4 monitoring visits, no flow was recorded and no methane. Carbon dioxide concentrations up to 1.7% were noted alongside normal oxygen concentrations. The site was classified as 'Green' in accordance with CIRIA C665. However, these wells lie around 150 m from this site's south-western corner and the boundary of the historic landfill.

The site's ground conditions comprise predominantly clay over mudstone. Groundwater was noted within a number of trial pits within the upper 2 m, and there are main drains and ditches to the south of the site, indicating that ground is generally shallow in this area. The relatively impermeable ground conditions and shallow groundwater table are expected to hinder significant ground gas migration from the landfill.

Based on the relatively impermeable ground conditions, shallow groundwater and since the landfill is at least 35 years old, we would consider Amber 1 gas precautions are sufficient for the proposed development. These precautions will comprise a suitably resistant gas membrane, fully sealed, and lapped across wall cavities and service entries. A precast concrete floor with an underlying minimum 150 mm ventilated void will also be required.

9.6 Sulphate Attack of Buried Concrete

On the basis of the chemical test results, the natural ground would be assigned a Design Sulphate Class of DS-1 and ACEC class of AC-1.

Should evidence of any made ground be encountered, allowance should be made for Design Sulphate Class of DS-2 and ACEC class of AC-2 sulphate precautions.

10.0 RECOMMENDATIONS

1. The Shafton coal seam has been worked. Drilling and grouting will be required at 2 m intervals where the thickness of cover is less than 4 times seam thickness. 3 m grout hole spacing may be used elsewhere. At least 1 mine shaft is present on site. Other unexpected shafts may also be present.
2. Piled foundations are required in plots to the south of the site. Reinforced thickened strip and trench fill footings are considered appropriate elsewhere. A minimum thickness of 450 mm will be required where grout hole spacing is at 2 m intervals. The thickness can be reduced to 300 mm where the grout hole spacing is at 3 m intervals. Heave precautions are required where plots are within influencing distance of existing or proposed trees.
3. Superstructure precautions of masonry reinforcement will be required.
4. Precast concrete floors with an underlying minimum 150 mm ventilated void and suitably resistant fully sealed gas membrane are required (i.e. Amber 1 gas precautions).
5. No radon precautions are required.
6. No significant risk is considered to be posed to construction workers, site visitors or future residents from exposure or interaction with the topsoil and natural ground. Topsoil is considered suitable for reuse, subject to regulatory approval. No remedial measures are considered to be required.
7. A Design Sulphate Class of DS-1 AC-1 should be used in the natural ground. DS-2 AC-2 sulphate precautions should be allowed for if any made ground is encountered on site.
8. There is the possibility that, as with any site, areas of significant unexpected contaminated materials may be encountered during construction works. If any unusual, brightly coloured, ashy or particularly odorous material are encountered it should be brought to the attention of the site staff and investigated.
9. The conclusions made in this report in relation to contamination are subject to agreement by the approving bodies such as the NHBC.