

BDP

Geoenvironmental and Geotechnical Interpretative Report

Stage 2b

Project Oak, Fallowfield, Manchester

4th September 2015



Results emerge
when local knowledge
intersects with
global expertise

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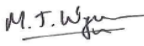
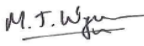
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1 INTRODUCTION

1.1 Background

This geo-environmental and geotechnical interpretative report relates to the proposed redevelopment of Fallowfield Residential Campus, off Moseley Road in Fallowfield, Manchester. The National Grid Reference of the site is 385790E, 394180N. The location of the site is shown on Figure 1.

The proposed site is split into the following three areas (as show in Figure 2) with current description:

- Phase 1A - Sports field on eastern side, mounded vegetated area on western side with works compound area and car park in the north-west corner.
- Phase 1B - Mainly 4 storey student accommodation buildings surrounded by hardstanding and landscaping.
- Phase 2 - Variety of buildings associated with student accommodation including tower block on the north-west side surrounded by hardstanding and landscaping.

The proposed development of the site comprises demolition of the existing buildings and redevelopment of new student accommodation including between 1 and 6 storey buildings which may be framed in either steel or reinforced concrete, or load bearing masonry construction. Column and wall loads are to be confirmed at a later date. The boundaries of the proposed development site are shown on Figure 2.

Coffey Geotechnics Ltd (Coffey) was appointed by Building Design Partnership (BDP) to specify and arrange an intrusive ground investigation based on BDP's 'Scope of Works' dated 2 February 2015 (Ref. 1). Coffey's proposals for the works dated 25 March 2015 were accepted by BDP on 26 March 2015.

The works comprise of a three staged approach:

- Stage 1 - Desk Study carried out by others and outside Coffey's scope of works. The desk study information, Geo-Environmental Desk Study Report (Ref. 2), was provided by BDP and was taken into account in Stage 2a and 2b investigations.
- Stage 2a – Preliminary Ground Investigation - Limited number of boreholes and windowless sampling with associated in-situ and laboratory testing has been carried out by Geotechnics Ltd (Geotechnics), under the instruction and part-time supervision of Coffey. Details are provided in Coffey's Interpretative Report (Ref. 3) and Geotechnics' Factual Report (Ref. 4).
- Stage 2b – Principal Ground Investigation – Additional number of boreholes, windowless sampling and trial pits with associated in-situ and laboratory testing has been carried out by Geotechnics, under the instruction and part-time supervision of Coffey. Details are provided in this report and Geotechnics' Factual Report (Ref. 5).

This interpretative report presents the findings of the Stage 2a and 2b ground investigation following completion of exploratory holes, groundwater / ground gas monitoring and geotechnical and geoenvironmental laboratory testing. This report uses desk study information from the Stage 1, together with factual information from the Stage 2a and 2b ground investigations (Refs. 4 & 5).

This report presents a summary of the ground conditions encountered and provides initial geotechnical advice relating to foundations for the new development. It also provides guidance on possible

environmental and human health risks based on the ground conditions observed in the exploratory holes, in relation to the existing site and proposed development.

2 GROUND INVESTIGATION (STAGE 2A & 2B)

2.1 Nomenclature

The ground investigations for each stage are discussed below. We note that the convention adopted in borehole naming is to number exploratory holes sequentially for each stage, followed by stage number 1A, 1B or 2 as appropriate. For example WE03/1B is the third window sample hole in Stage 1B.

2.2 Site Work

Stage 2a Investigation

The preliminary ground investigation (Stage 2a) was undertaken between 1 and 23 April 2015 by Geotechnics with part time supervision by Coffey.

The Stage 2a ground investigation comprised 2 No. windowless sample holes (WS03/1B and WS01/2) and 13 no. cable percussive boreholes (BH01-05/1A, BH01-03/1B & BH01-05/2) with in-situ standard penetration testing (SPTs) and representative soil sampling during hole formation at the site on the locations shown on Figure 2.

In addition, 13 No. in-situ falling head permeability tests were undertaken in the boreholes at various depths to provide information to assess the potential for soakaways on the site.

Groundwater and gas monitoring installations were constructed in 8 No. boreholes on their completion (double instruments in four boreholes). Following exploratory hole formation, 4 sets of ground gas and groundwater level monitoring was undertaken for Stage 2a: Monitoring rounds 1 (21 April 2015), 2 (6 May 2015), 3 (14 May 2015) and 4 (22 May 2015).

The investigation of the mounded vegetated area on western side of the Phase 1A area was not undertaken during Stage 2a as it was understood from anecdotal evidence that asbestos containing material (ACM) was potentially present within this area. This mounded area was investigated during Stage 2b.

The exploratory hole records, laboratory test results and results from the gas and groundwater monitoring are presented in Geotechnics' Ground Investigation Factual Report (Ref. 4).

Stage 2b Investigation

The principal ground investigation (Stage 2b) was undertaken between 27 May and 22 June 2015 by Geotechnics Limited with part time supervision by Coffey.

Stage 2b ground investigation comprised:

- 34 No. cable percussive boreholes (BH05-18/1A, BH04-14/1B, BH06-22/2 & BHA1-A3);
- 12 No. boreholes were extended by rotary technique through the base of cased cable percussion boreholes;
- 22 No. trial pits (TP01-05/1A, TP01-06/1B, TP01-06/2 & TPA1-A5); and
- 10 No. windowless sample holes (WS04-06/1B and WS02-08/2).

Representative soil sampling collected during hole formation and in-situ standard penetration testing (SPTs) were carried in boreholes and windowless samples. The locations of exploratory holes are shown on Figure 2.

In addition, 17 No. in-situ CBR (TRL Probe) tests were undertaken in the trial pits at between 0.4m and 0.5m to provide information for the pavement design on the site.

As additional 4 No. groundwater and gas monitoring installations were constructed in boreholes on their completion. A further two sets of ground gas and groundwater level monitoring was undertaken for Stage 2b: Monitoring rounds 5 (25 June 2015) & 6 (27 July 2015).

The investigation included five trial pits (TPA1-A5) and four boreholes (BHA1- A3 & A3A) in the mounded vegetated area on western side of the Phase 1A area undertaken during Stage 2b. It is understood from anecdotal evidence that asbestos containing material (ACM) may be present within this area. Geotechnics' safety procedures were followed for investigating ground that potentially has ACM.

The exploratory hole records, laboratory test results and results from the gas and groundwater monitoring are presented in Geotechnics' Ground Investigation Factual Report (Ref. 5).

2.3 Laboratory testing

2.3.1 Stage 2a Geotechnical testing

Geotechnical laboratory testing was scheduled on soil samples obtained and included:

- 15 No. natural moisture content;
- 14 No. liquid and plastic limits;
- 8 No. particle size distribution;
- 3 No. oedometer tests for compressibility;
- 4 No. single stage quick undrained triaxial tests for undrained shear strength;
- 6 No. BRE SD-1 suite for assessment of concrete in aggressive ground in the brownfield environment (Water soluble sulphate, Acid soluble sulphate, Total sulphur, pH); and
- 5 no. soil organic matter content.

2.3.2 Stage 2b Geotechnical testing

Geotechnical laboratory testing was scheduled on soil samples obtained and included:

- 20 No. natural moisture content;
- 20 No. liquid and plastic limits;
- 3 No. oedometer tests for compressibility;
- 6 No. single stage quick undrained triaxial tests for undrained shear strength;
- 35 No. Point Load Strength on rock;
- 8 No. Unconfined Compressive Strength (UCS) on rock; and

- 19 No. BRE SD-1 suite for assessment of concrete in aggressive ground in the brownfield environment (Water soluble sulphate, Acid soluble sulphate, Total sulphur, pH).

2.3.3 Stage 2a Chemical testing

Chemical laboratory testing was scheduled on 7 No. soil samples and included:

- Asbestos screening
- Metals suite (Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead, Selenium and Zinc)
- Inorganics (Boron, Cyanide, Phenol)
- Polycyclic Aromatic Hydrocarbons (PAH,16 speciated)
- Benzene, Toluene, Ethylbenzene, m/p-xylene, o-xylene (BTEX)
- Total Petroleum Hydrocarbons (TPHs)

Speciated TPHs and quantitative testing for asbestos were scheduled on selected samples (two for each test suite).

2.3.4 Stage 2b Chemical testing

Chemical laboratory testing was scheduled on 18 No. soil samples and included:

- Asbestos screening
- Metals suite (Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead, Selenium and Zinc)
- Inorganics (Boron, Cyanide, Phenol)
- Polycyclic Aromatic Hydrocarbons (PAH,16 speciated)
- Benzene, Toluene, Ethylbenzene, m/p-xylene, o-xylene (BTEX)
- Total Petroleum Hydrocarbons (TPHs)
- Soil organic matter content.

Speciated TPHs, PCBs and quantitative testing for asbestos were scheduled on selected samples.

2.3.5 Groundwater testing

Chemical laboratory testing was scheduled on 3 no. water samples from BH02/1A, BH05/1A & BH08/1A and included:

- Metals suite (As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn, V, Be, Ba)
- Water soluble sulphate
- pH
- PAH (16 speciated)
- BTEX
- Speciated TPH

3 THE SITE

3.1 Site Description

A site walkover was carried out prior to commencing Stage 2a and 2b investigations and the site description is based on observations made during these visits. The site is split into three phases for reference: Phase 1A, 1B and 2, as shown in Figure 2. The site is located in Fallowfield, at the University of Manchester campus which includes student accommodation and sports facilities. The camp is bounded by Moseley Road to the south and Wilmslow Road to the west, fields to the east and a residential area to the north. In terms of topography the site generally falls from 44mAOD on the northern side to 40mAOD on the southern side.

Phase 1A

The Phase 1A area, approximately 2.8Ha, is generally rectangular and 220m by 110m with additional rectangular extensions in the north-west corner (0.4Ha). The area consists of a sports field on the eastern side, mounded vegetated area on the western side and a works compound area / car park in the north-west corner.

The sports field comprises a level grassed area surrounded by a boundary fence. On the eastern side, the sports field continues beyond the Phase 1A boundary. It is understood this adjacent sport area is not owned by the university.

The mounded vegetated area on the eastern side is about 110m length by 60m wide, and rises up to about 3.5m higher than surrounding ground level in the centre. It is covered with trees, about 10 to 15 years old, to provide an area of woodland. Anecdotal evidence indicates the mound may include demolition materials from the former athletic and cycling stadium which may contain asbestos.

Stuart Mallinson (Outdoor duty manager / grounds-person) has worked at the Armitage for a very considerable period and he described the mounded area as including asbestos containing material (ACM) which originated from a structure associated with the former Reg Harris cycle stadium. Stuart described his recollection of seeing asbestos sheets being buried in this location; apparently the sheets were marked up with 'do not drill' warnings and they had been painted with black bituminous paint, also he described the earthworks operation to infill this mounded area, which apparently contains numerous concrete blocks from the former cycle stadium, being conducted with a series of fire hoses spraying water over the operation – presumably as a means of dust suppression.

The compound area in the north-west corner contains a workshop, steel lockups, skips and space to park maintenance vans.

Phase 1B

The Phase 1B area, approximately 2.8Ha, is a generally rectangular parcel of land, 185m by 150m. In this area are many 4 storey buildings used for university accommodation including: Chestnut Court, Holly Court, Maple Court, Sycamore Court and Beech Court. There are also other 1 to 4 storey buildings including Oak House and warden's accommodation. The buildings are surrounded by hardstanding and landscaping including open grass space and mature trees around the perimeter.

Phase 2

The Phase 2 area, approximately 3.4Ha, is a generally rectangular parcel of land, 215m by 160m. There are a variety of buildings associated with student accommodation including a tower block on the

north-west side. Also in this area are 4 storey buildings used for university accommodation (Tree Court) and the Lime Building which houses the estate management facilities. The buildings are surrounded by hardstanding and landscaping including open grass space and mature trees around the perimeter.

3.2 Site History

The site history was outlined in the Geo-Environmental Study Report (Ref. 2) and more detail can be found in that report.

In summary, in the mid-19th Century the site was mostly undeveloped. There are two ponds shown in the north east corner of the Phase 1A area and a pond in Phase 2 (at the location where the Beech Court building presently exists). Buildings and roads were constructed in the area of Phase 1B and Phase 2 by 1892. The 'Manchester athletics ground' stadium was built on the western side of Phase 1A by 1905. The Phase 1B and Phase 2 areas were redeveloped between 1965 and 1974, with the 1974 map showing some of the present student accommodation buildings. The 1986 map shows the remaining student buildings as generally seen during the site walkover. The stadium (former location shown in Figure 5) had been demolished between 1986 and 2002.

3.3 Geology

3.3.1 Published information

The following publications of the British Geological Survey (BGS) were examined with reference to the geology underlying the site:

- British Geological Survey 1:50,000 Scale Geological Sheet 85 – Manchester (solid) (Ref.6)
- British Geological Survey 1:63,360 Scale Geological Sheet 85 – Manchester (drift) (Ref. 7)
- British Geological Survey 1:10,560 Scale Geological Sheet SJ 89 SE (solid and drift) (Ref. 8)
- Memoire for the Geology of Manchester and the South-East Lancashire Coalfield (Ref. 9)

Figure 5 shows the 1:10,560 Scale geology plan of the site.

The geological data show that the natural drift underlying the site is Glacial Till (formerly referred to as Boulder Clay); this is predominantly cohesive material but may include and/or conceal granular glacial horizons.

The solid geology beneath (most of) the site is shown to be the Chester Pebble Beds Formation (formerly Pebble Beds) of the Triassic Sherwood Sandstone Group (formerly Bunter Sandstone). The Chester Pebble Beds Formation is described on the BGS website as fine to coarse sandstone, commonly pebbly, with conglomerates and sporadic siltstone, cross-stratified.

There is a conjectured major northeast-southwest trending geological fault, with a down-throw to the north west, which is indicated to be approximately 120m to the eastern margin of the site. To the west of this fault, strata of the older (Triassic) Collyhurst Sandstone Formation are depicted.

3.3.2 Mineral Extraction

The Geo-Environmental Desk Study Report (Ref. 2) indicates that the site does not lie within an area, or within 500m of an area, affected by coal mining. The report concluded that there is minimal risk to the development from coal mining activities.

Similarly, the desk study report did not identify any brine extraction areas, recorded mines or quarries within 500m of the site.

3.3.3 Intrusive Ground Investigation

Boreholes undertaken during the ground investigation show the following general ground profile:

- Made Ground
- Glacial Till (predominantly cohesive)
- Upper weathered Sandstone (sand)
- Extremely weak Sandstone / Mudstone

These materials are discussed in detail in Section 4 of this report.

3.4 Hydrogeology

Details of hydrogeological information are given in the Geo-Environmental Desk Study Report (Ref. 2). A summary of this information is presented below:

The hydrogeology of the site is likely to be characterised by a principal aquifer within the Chester Pebble Bed Formation, overlain by unproductive strata of the glacial till unit.

- Principal Aquifer: Layers of rock or drift deposits that have high intergranular and/or fracture permeability (usually provide a high level of water storage). They may support water supply and/or river base flow on a strategic scale.
- Unproductive strata: Low permeability with negligible significance for water supply or river base flow.

The site is situated within an EA Source Protection Zone 3 or the “Total Catchment” which is defined as the area around the source within which all groundwater recharge is presumed to be discharged at the source.

Three licensed groundwater abstractions have been identified within 2km of the site, none of which are public water supply boreholes.

3.5 Hydrology

Details of the local hydrology have been obtained via inspection of topographical maps and through the information database as provided in the Geo-Environmental Desk Study Report (Ref. 2).

The nearest known / recorded surface watercourses to the site is either Platt Brook located 500m north of the Phase 2 area, Gore Brook located 400m north of the Phase 2 area or Cringle Brook located 200m to 400m south of the Phase 1B. There is a historical feature (a military defence fortification

originally about 9.7km long and created between the 5th and 11th century AD called “Nico Ditch” that is 170m north west of Phase 2 area. Parts of Nico Ditch are protected as a Scheduled Ancient Monument.

A preliminary flood risk assessment was carried out for the Geo-Environmental Desk Study Report (Ref. 2). The indicative floodplain map for the area prepared by the EA shows that the site lies outside of the designated floodplain. Nonetheless, owing to the size and nature of the development the desk study advises that a flood risk assessment will be required.

3.6 Unexploded Ordnance Risk Assessment

A Preliminary Unexploded Ordnance (UXO) Risk Assessment for the subject site by 6 Alpha Associates Ltd is presented in the Geo-Environmental Desk Study Report (Ref. 2).

This document concludes that the UXO probability assessment has a rating of 3, indicating a medium possibility of a UXO encounter.

A summary of the risk assessment and conclusion of the desk study is reproduced below:

- During WWII, the site is situated with Manchester County Borough, which was subject of 26 high explosive (HE) bomb strikes per 1000 acres, a relatively low level of bombing density;
- A tramway depot, a goods yard and a railway station were located in the vicinity of the site and were likely to be considered secondary bombing targets;
- Air Raid Precaution (ARP) records show 2 HE bombs struck the site. Additional, 2 bombs were recorded within 20m of the site boundary;
- A heavy anti-aircraft (HAA) battery was located within the site's boundary, which may have been considered a bombing target and therefore may be a potential source for UXO contamination; and
- Given that the site was occupied by a HAA gun site (a potential source for UXO contamination) and 2 HE bomb strikes were recorded within the site, the report suggests that further action is warranted to address the potential for UXO encounter.

Based on the above information the threat potential has been classified by 6 Alpha as medium risk, a UXO probability assessment rating of 3. Consequential to this and in accordance with CIRIA C681 Chapter 5 on managing UXO risks, 6 Alpha recommends that the next stage in the risk management framework is a Detailed UXO Threat and Risk Assessment. A detailed UXO threat and risk assessment for the redevelopment of the site would involve undertaking a preliminary risk assessment by an UXO specialist to determine if any specific risk mitigation measures are required for such redevelopment activities. Further details can be found in CIRIA C681 (Ref. 10).

As part of the detailed UXO threat and risk assessment for ground investigation, geophysical methods were used to investigate all exploratory hole locations for UXO prior to carrying out the intrusive works. More details are given in Geotechnics Ground Investigation Factual Reports (Refs. 4 & 5).

3.7 Radon

According the BRE publication BR211, Report: Guidance on Protective Measures for New Dwellings (England and Wales) 2007 (Ref. 11), the site does not lie in an area where protective measures against radon gas are required.

3.8 Japanese Knotweed

Japanese knotweed is present on the site. Locations of the Japanese Knotweed, based on a visual inspection by Japanese Knotweed Solutions, are shown on Dwg. No. JK15-0868-003 Rev A dated 15 April 2015. This drawing was provided by BDP in an email on 5 May 2015.

4 DESCRIPTION OF MATERIALS

4.1 General

Descriptions of the materials encountered during the Stage 2a & 2b ground investigation are summarised in Table 1. The exploratory hole location plan and geological sections are presented in Figures 2 to 4.

Table 1: Summary of ground conditions

Stratum	Description	Depth to Base (m bgl)	
		Min.	Max.
Topsoil / Hardstanding	Topsoil / Tarmacadam	0	0.35
Made Ground	Mainly sand and gravel including sandstone, ash, clinker, and brick with pockets of clay.	0.2	3.1 (former pond - 3.3m) (mounded area - 4.4m)
Glacial Till (absent in three locations where Made Ground is deeper)	Generally, soft to firm becoming stiff slightly sandy CLAY with occasional gravel	1.2	4.6
Upper Weathered Sandstone (not recorded in places)	Fine to medium SAND	1.4	6.5
Weathered Sandstone	Extremely weak Sandstone (recovered as sand) was encountered over the majority of the site.	Top at 1.3m (Base not proven)	Top at 4.8m (Base not proven)
Note: On the western side of Phase 1A, there is a mounded area with Made Ground stockpiled up to about 4m to 5m height. On the eastern side of Phase 1A area, weathered mudstone / sandstone layers were encountered below the Glacial Till.			

Findings are generally in accordance with published geology. Each material type encountered is discussed below.

The geotechnical test results are presented using the following abbreviations:

SPT = Standard Penetration Test 'N' value

SPT data for each strata encountered plotted against depth (metres below ground level) are presented on Figure 6.

4.2 Topsoil / Hardstanding

The fieldwork encountered topsoil / tarmacadam surfacing to depths of 0.3m.

4.3 Made Ground

The fieldwork encountered Made Ground generally up to 3.1m depth. The Made Ground generally comprised sand and gravel comprising siltstone, sandstone, quartz, ash, clinker and brick, occasionally within layers of clay.

The mounded area on the western side of Phase 1A contains Made Ground stockpiled up to about 4m to 5m high (i.e. 4.4m in TPA2). Ground conditions encountered in this area are described in Section 6.

There is a deeper area of very soft to soft peaty clay in BH05/1A. This clay has organic odours and contains fragments of wood. This is believed to be in the location of a former pond (as indicated from the historical maps).

A summary of the Made Ground thickness is given in Table 2 below.

Table 2: Summary of Made Ground Thicknesses

Area	Thickness of Made Ground (in metres)			Comment
	Minimum	Maximum	Average	
Phase 1A (excluding mounded area)	0.35	3.1	0.8	Possible backfilled pond to 3.3m (BH05/1A). Deeper Made Ground in BH18/1A to 3.1m.
Mounded Area	1.5	4.4	2.9	
Phase 1B	0.35	2.6	1.2	Deeper Made Ground to 2.6m in BH12/1B
Phase 2	0.2	2.7	0.8	Deeper Made Ground to 2.7m in WS06/2

Results of particle size distribution tests are presented in the Geotechnical Factual Reports (Ref. 4 and 5).

SPT 'N' values for the Made Ground are presented in Table 3 and graphically on Figure 6.

Table 3: SPT data for Made Ground

Test parameter	Unit	Range	Average	Figure
SPT 'N' value	N/A	0 to 50	15	Fig 6

The SPT 'N' value of 4 at 2m depth was measured in peaty clay in BH05/1A. The moisture content result from a sample of this material recorded 59%.

Index testing classified the cohesive Made Ground as generally intermediate plasticity clay (Figure 7). The moisture content of the clay was recorded in four samples at between 15% and 28%.

The Made Ground is very variable and is not considered a suitable founding material for the design of foundations (see Section 11.3).

A characteristic unit weight of 18 kN/m³ for Made Ground would be considered suitable for use in the foundation design. No allowable bearing capacity value is given for the Made Ground, as it is not advisable or recommended for structural foundations to bear onto such strata directly.

4.4 Glacial Till

The fieldwork encountered natural Glacial Till beneath the Made Ground to depths between 1.2m and 4.6m (i.e. base of Glacial Till). The thickness of Glacial Till varies between 0.6m and 3.65m, but is absent in three boreholes where the Made Ground is deeper / sandstone shallower.

The Glacial Till (cohesive) stratum generally comprised soft becoming firm to stiff slightly sandy slightly gravelly clay. The stiff clay was encountered typically at depths of about 2m below ground level, where the Glacial Till was present to this depth.

There was a layer of sand between 1.0m and 1.6m bgl encountered in the Glacial Till in Borehole BH01/1B.

Results of particle size distribution tests are presented in the Geotechnical Factual Reports (Ref. 4 and 5).

SPT 'N' values for Glacial Till are presented in Table 4 and graphically on Figure 6.

Table 4: SPT data for Glacial Till

Test parameter	Unit	Range	Average	Figure
SPT 'N' value	N/A	4 to >50 (refusal)	23	Fig 6

Index testing classified the cohesive material as generally low to intermediate plasticity clay (Figure 7). The testing recorded values of liquid limit between 29% and 50%, the average of twenty data points being 37%. The plastic limit is between 12% and 25%, with an average of 17% and the plasticity index (PI) averaged at 21% (ranging from 14% to 25%). The moisture content of the clay was recorded at between 12% and 28%, averaging 18%. The moisture content range is generally slightly less than the plasticity index of the clay indicating stiff clay.

The Modified Plasticity Index (I'_p) (defined as the plasticity Index of the soil multiplied by the percentage of particles less than 425 μ m) ranges from 12 to 24, averaging 18 from 25 No. results, which we consider a reasonably representative spread of data. The glacial clays can be classified as being of "low" volume change potential.

Values of undrained cohesion (C_u) from 42kPa to 273kPa (i.e. firm to very stiff) were recorded from ten triaxial tests. The equivalent undrained shear strength of the soil can be derived by empirical relationship with SPT results (Ref. 12). Using $f_1 = 5.2$ based on average plasticity index of 21%, Figure 8 shows the undrained shear strengths with depth, derived from SPTs together with triaxial test results.

Oedometer tests were carried out on six undisturbed samples of clay from depths between 1.2m and 2.2m. These recorded values of coefficient of volume compressibility (m_v) between 0.09 m²/MN and 0.41 m²/MN at the in-situ stress range. The average value was 0.20 m²/MN, higher than the typical value of m_v of 0.10 m²/MN for glacial clay from the north west of England. The disturbance to the oedometer test samples results may be the cause of the higher m_v than anticipated.

Characteristic C_u design values of 50kPa at 1.2m and 100kPa at 2m are considered appropriate. This would correspond to typical allowable bearing capacities of 100kPa at 1m depth and 200kPa at 2m depth, albeit the ground investigation showed slight variations across the site which should be taken into account in the design.

The bulk density of four samples measured between 2.02Mg/m³ and 2.34Mg/m³, averaging 2.14Mg/m³. A characteristic unit weight of 21kN/m³ for Glacial Till would be suitable for use in the design, based on typical values.

4.5 Upper Weathered Sandstone

The fieldwork encountered the top of upper weathered sandstone (sand) at depths from 1.2m to 4.6m, up to 2.6m thickness. No sand was recorded in some of the exploratory holes (i.e. Glacial Till recorded directly over sandstone). The upper weathered sandstone is described in the exploratory logs as red clayey sand.

SPT values in the upper weathered sandstone were generally over 50 (i.e. refused in the sand). Accordingly the SPT values for these tests have been determined by extrapolation for full test depth (i.e. 300mm). SPT 'N' values for the upper weathered sandstone are presented in Table 5 and graphically on Figure 6.

Table 5: SPT data for Upper Weathered Sandstone

Test parameter	Unit	Range	Average	Figure
SPT 'N' value	N/A	21 to 500 (extrapolated)	145	Fig 6

Results of particle size distribution tests are presented in the Geotechnical Factual Reports (Ref. 4 and 5).

Published correlations of SPT 'N' value with effective angle of shear resistance (Ref. 13) indicate a characteristic value of about 40° would be suitable for use in the design. The allowable bearing value of the material will be at least 500kPa.

A characteristic unit weight of 20kN/m³ for upper weathered sandstone would be suitable for use in the design.

4.6 Bedrock (Weathered Sandstone / Mudstone)

The fieldwork encountered weathered sandstone from depths between 1.3m and 6.5m below ground level over the majority of the site. (Note, completely weathered sandstone (sand) was encountered above where the weathered sandstone was found to be deeper.) The base of the sandstone layer was not proven. The sandstone layer is generally described in the exploratory logs as extremely weak sandstone recovered as sand.

On the eastern side of Phase 1A, nine boreholes (BH04/1A, BH05/1A, BH10-15/1A) encountered weathered mudstone, generally interbedded within layers of weathered sandstone. Boreholes BH04/1A and BH05/1A encountered sand (assumed to be upper weathered sandstone) interlayered with stiff clay (completely weathered mudstone), before proving extremely weak to weak mudstone at depths of 6.2m (BH05/1A) and 7.5m (BH04/1A). The other seven boreholes encountered the top of mudstone between 3.5m and 4.1m bgl.

In the Phase 1B area, there were layers of extremely weak mudstone recorded within the sandstone (0.2m layer at 4.7m depth in BH12/1B, 0.1m layer in Borehole BH04/1B at 6.29m, and 0.25m layer in BH05/1B at 8.15m depth).

The description 'extremely weak sandstone / mudstone' is not a standard term; however, based on the standard rock strength term 'very weak' (Ref 14), the unconfined compressive strength (UCS) of the layer is inferred as less than 1MPa.

In situ Testing

SPT 'N' values for sandstone / mudstone are presented graphically on Figure 6. The majority of SPT results refused, i.e. $N > 50$. Accordingly the SPT values for these tests have been determined by extrapolation for full test depth (i.e. 300mm). The completely weathered mudstone, very stiff clay, had a slightly lower SPT 'N' value of 44.

Table: SPT data for Weathered Sandstone / Mudstone

Rock Type	Test Parameter	Range	Average	Figure
Sandstone	SPT 'N' value	27 to 750 (extrapolated)	303	Fig 6
Mudstone	SPT 'N' value	18 to 300 (extrapolated)	128	Fig 6

An equivalent UCS values for the rock based on average SPT 'N' value is 3MPa for the sandstone and 1.3MPa for mudstone (Ref. 12).

Laboratory Testing on Rock Cores

The cable percussive boreholes generally refused at the top of the rock. Twelve selected boreholes (four in each phase area of the site) were continued by rotary drilling technique at least 4m into rock. Rock core were taken from each hole and laboratory testing undertaken on selected rock samples.

Seven unconfined compression strength (UCS) tests were carried out on the rock cores. The results of six tests on the sandstone provided unconfined compressive strengths ranging between 5 MN/m² (weak) and 54 MN/m² (strong) and one test on mudstone measured the UCS as 5.2 MN/m² (weak).

Point load tests (axial and diametral) were also carried out on the rock cores recovered from this investigation. Point load test results (IS_{50}) were converted to equivalent unconfined compressive strength (UCS) values using a conversion factor of 24 (Ref. 15). The equivalent UCS values range from 0.05MPa to 10.4MPa (average of 2.0MPa) for sandstone and 0.1MPa to 7.2MPa (average of 1.7MPa) for mudstone. These results are predicably lower than the UCS test results as poor quality of core recovery meant that UCS testing could only be tested on limited length of core, presumably that with higher strength. There was no significant difference between axial and diametral point load test results.

Design Parameters

For the completely weathered mudstone, very stiff clay, with SPT 'N' value of 44, a characteristic undrained shear strength of 150kPa would be considered appropriate. The allowable bearing value of the material will be 300kPa.

On review of the in-situ test and laboratory data, unconfined compressive strengths of 1 MN/m² and 3 MN/m² are considered appropriate for foundation design purposes in the mudstone and sandstone, respectively.

A characteristic unit weight of 22kN/m³ / 23kN/m³ for sandstone / mudstone, respectively, would be suitable for use in the design, based on typical values.

4.7 Groundwater

Groundwater entries were recorded in the exploratory holes during hole formation at depths of 0.8m to 1.5m bgl (in the Made Ground).

Groundwater installations across the site showed groundwater levels between 0.51m and 1.94m below ground level in the Made Ground. In the deeper installations with response zones in sandstone, the groundwater levels were measured at 2.15m and 8.44m bgl during hole formation, with one installation recorded as dry. These water levels in the deeper installations were only just above the base of the standpipes and it is expected water may have seeped into the installation from above the response zone and become trapped at the base of the pipe.

It is inferred that groundwater is perched locally at shallow depths at the site within the Made Ground, overlying the more impermeable strata of the Glacial Till.

The Chester Pebble Bed Formation is a Principal Aquifer and hence will also be water-bearing but the groundwater level is expected to be below the depth of the present investigation.

5 SOIL: GEO-ENVIRONMENTAL ASSESSMENT

5.1 Soil Generic Quantitative Risk Assessment (GQRA)

A comparison of soil chemical concentrations with published guidance levels has been undertaken to give an indication of the contamination potential of the Made Ground and natural soils encountered on the site. Details on laboratory testing suites are provided in Section 2.2.

The proposed end use of the site is for a residential development with areas of car park and surface yard hardstanding. The data have been compared against Generic Assessment Criteria (GAC) derived for a residential land use scenario to provide a conservative initial assessment of the data to establish what determinands exceed their respective GAC. Details of the GAC used in this assessment and the risk assessment process are presented in Appendix A.

The chemical test results are presented in full in the Geotechnical Factual Reports (Ref. 4 & 5); the results are compared with their respective GAC concentrations, where such exist, on the summary tables presented in Appendix B.

This assessment excludes the mounded area on the western side of Phase 1A which is reported separately in Section 6.

5.2 Soil Organic Matter Content

An assessment of Soil Organic Matter Content (SOM) has been made to allow the determination of the appropriate GAC thresholds to use in the risk assessment. (Note: 6% SOM is the highest SOM content available for any GAC; other bands are 2.5% and 1%. Lower values have more stringent GAC thresholds). Five SOM test has been carried out on the samples obtained. The result received recorded a range of values of <0.2% to 35.2%. A representative value of 1% SOM has been selected for GAC criteria.

5.3 Asbestos

Nineteen samples obtained from the boreholes and window samples were tested to check for the presence of asbestos. This included two samples from Trial Pits TP04/1B at 0.35m and TP06/1B at 0.6m containing fragments identified by Geotechnics as possible asbestos during the fieldworks.

Chrysotile asbestos was recorded in three of 17 No. samples from Boreholes BH02/1A and BH05/1A at 1m depth and BH06/1A at 0.2m depth. A summary table of results is presented in Appendix B and should be referenced with the exploratory hole location plan Figure 2. The fragments identified by Geotechnics from Trial Pits TP04/1B and TP06/1B were also confirmed to be Chrysotile asbestos.

Quantification tests were scheduled for the 3 No. samples from Boreholes BH02/1A and BH05/1A at 1m depth and BH06/1A at 0.2m depth. The results of these tests showed that there is 1.888% by mass in Sample BH06/1A at 0.2m but less than 0.001% by mass of asbestos fibres in two samples: BH02/1A and BH05/1A at 1m depth.

With regard to asbestos, it is recommended that the localised presence of asbestos within the Made Ground at the site should be documented within all required Health & Safety (CDM or Contractor's) risk assessments required for construction work including the pre-construction information pack for tenderers.

The risk of chronic exposure to asbestos should be managed by the adoption of good general working practices (during all ground-works) such as dust suppression, use of standard PPE and good standards of hygiene, together with guidance and direction from a suitably qualified and experienced asbestos specialist.

Any Made Ground containing asbestos which is to be taken off site may need to be treated and would require disposal at a suitable licenced landfill site.

In terms of post-construction site use, near-surface soils in the landscaped/soft-standing parts of the site need to be devoid of asbestos. This can be addressed by ensuring that the upper 600mm of all such areas consist of cover soils that are uncontaminated, and in particular are devoid of asbestos.

5.4 PCB

One samples WS05/1B at 0.85m depth from the windowless sample hole nearest to the sub-station in Phase 1B area was tested for PCBs (7 Congeners). The PCB results were all less than the detection limit of 5µg/kg.

5.5 Made Ground

Nineteen samples of Made Ground were tested from exploratory holes: sixteen samples for general suite of specialist chemical testing and three samples for hydrocarbons. Concentrations of potential contaminants were generally found to be below their respective detection limits and/or the GAC for residential end use in all samples of Made Ground tested except for following:

- Arsenic exceeded in three of sixteen samples (up to 60.1mg/kg, GAC: 32mg/kg)
- Mercury exceeded in two of sixteen samples (up to 7.3mg/kg, GAC: 1mg/kg)
- Naphthalene exceeded in five of nineteen samples (up to 87.4mg/kg, GAC 1.5mg/kg)
- Phenanthrene exceeded in two of nineteen samples (up to 365.1mg/kg, GAC 92mg/kg)
- Fluoranthene exceeded in one of nineteen samples (492mg/kg, GAC 260mg/kg)
- Benzo[a]anthracene exceeded in twelve of nineteen samples (up to 213.1mg/kg, GAC: 3.1mg/kg)
- Chrysene exceeded in ten of nineteen samples (up to 258.9mg/kg, 6mg/kg)
- Benzo[b]fluoranthene exceeded in nine of nineteen samples (up to 273mg/kg, GAC: 5.6mg/kg)
- Benzo[k]fluoranthene exceeded in seven of nineteen samples (up to 106.3mg/kg, GAC: 8.5mg/kg)
- Benzo[a]pyrene exceeded in fifteen of nineteen samples (up to 239.6mg/kg, GAC: 0.83mg/kg)
- Indeno[123-cd]pyrene exceeded in nine of nineteen samples (up to 150.9mg/kg; GAC:3.2mg/kg)
- Dibenzo[ah]anthracene exceeded in seven of nineteen samples (up to 17.9mg/kg; GAC:0.76mg/kg)
- Benzo[ghi]perylene exceeded in one of nineteen samples (134.7mg/kg, GAC 44mg/kg)
- Aromatics EC >12-16 exceeded in three of seventeen samples (789mg/kg, GAC 140mg/kg)
- Aromatics EC >16-21 exceeded in six of seventeen samples (6795mg/kg, GAC 250mg/kg)
- Aromatics EC >21-35 exceeded in five of seventeen samples (7465mg/kg, GAC 890mg/kg)

The arsenic and mercury values are considered slight exceedences. The TPHs and PAHs exceedences results are indicative of coal tar PAHs and trace degraded diesel, possible tarmac/bitumen. The sample, WS05/2 at 0.5m, with highest PAHs was sampled from a stratum containing 'hardened tar'. The testing laboratory have visually examined the Sample BH15/1A at 0.2m and BH20/2 at 0.2m and

state that “there are possible tarmac like fragments present in both the samples.” Other samples with main TPHs and PAHs exceedences were taken from a stratum of Made Ground with black ash and clinker at or near the depth of 0.2m. It is expected that fragments of asphalt / tarmac are present within the Made Ground which are likely to be the source of the TPHs and PAHs exceedences. Given that the site is to be used as student accommodations with mainly landscape areas rather than garden areas for children the risk of the exceedences to end users would be lower than assumed in the development of the GACs.

5.6 Natural Ground

Four samples of natural ground were tested from windowless samples and boreholes during the recent investigation. Concentrations of potential contaminants were found to be below their respective detection limits and/or the GAC for residential end use in all samples

5.7 Conclusions

The main risk to end users is considered to be the asbestos in the Made Ground. This can be addressed by ensuring that the upper 600mm of all such areas consists of cover soils that are uncontaminated, and in particular are devoid of asbestos.

The main risk to site / construction workers is also considered to be inhaling of the air-borne asbestos from disturbed Made Ground containing ACM. This can be address by taking appropriate precautions such as damping down ground to reduce air-borne fibres, wearing appropriate breathing apparatus and provision of appropriate training/guidance, PPE and welfare facilities during the works.

6 MOUNDED AREA: GEO-ENVIRONMENTAL ASSESSMENT

6.1 General

There is a mounded vegetated area on the western side of the Phase 1A area. It is understood from anecdotal evidence that this mounded area may have some buried asbestos containing material (ACM). Details regarding the anecdotal evidence are given in Section 3.1.

Geotechnics have carried out five trial pits (TPA1-A5) and four boreholes (BHA1-A3 & BHA3A) in this area. Borehole BHA3 refused at 1.5m depth in Made Ground (expected concrete obstruction) and a further borehole was carried out at a new location (BHA3A). The locations of exploratory holes are shown on Figure 2.

It is understood that the mound of material is proposed to be removed off site prior to the development. It is expected any building in this area will be constructed with ground levels at about 45m AOD (i.e. consistent with the ground levels either side of the mound).

6.2 Findings from Ground Investigation

Trial Pits TPA1 and TPA5 on the northern side of the mounded area encountered concrete obstructions at 2.2m depth (JCB excavator was struggling to excavate through the material at this depth). TPA1 was progressed a further 0.3m, to 2.5m depth, before a small fragment of asbestos was identified by the asbestos appointed person. Similarly, in TPA5, a small fragment of asbestos was also encountered at 2.2m by the asbestos appointed person. The trial pits were terminated once asbestos was encountered in accordance with Geotechnics' safety policy.

The other trial pits and boreholes elsewhere, with the exception of Borehole BHA3, encountered between 2m and 4.4m of Made Ground before proving the natural ground (i.e. firm glacial clay). The boreholes proved sandstone below firm becoming stiff clay. The Made Ground generally consisted of soft to firm sandy gravelly clay including occasional bricks, concrete boulders, glass, etc. There were pockets of ash / clinker material within the Made Ground.

6.3 Asbestos Test Results

Coffey scheduled 14 No. samples for asbestos screening. The results are summarised in Table 6 below.

The asbestos screen confirmed the two small fragments of asbestos identified in TPA1 at 2.5m and TPA5 at 2.2m were Chrysotile type asbestos (white asbestos). Twelve other samples were randomly selected and screened for asbestos. Two of twelve samples identified fibre bundles of Chrysotile type asbestos (white asbestos).

Quantification tests were scheduled for the samples TPA3/1.5m and TPA3/3.9m with asbestos. These tests showed that there is 0.005% of ACM by mass in Sample TPA3/3.9m and no quantifiable amounts of asbestos were present (i.e. <0.001% by mass) in Sample TPA3/1.5m.

Sampling and testing of Borehole BH02/1A for the Stage 2a investigation identified fibre bundles of Chrysotile asbestos at 1m depth. The borehole is located at the edge of the mounded area. However, further tests showed that no quantifiable amounts of asbestos were present (i.e. <0.001 mass %).

Table 6: Asbestos Screen Results

Exploratory Hole Ref.	Depth	Screening Result	Asbestos Type	Quantification Results
TPA1	0.5m	NAD	NAD	Not tested
TPA1	2.5m	Asbestos cement	Chrysotile	Not tested
TPA2	0.5m	NAD	NAD	Not tested
TPA2	1.5m	NAD	NAD	Not tested
TPA2	4.3m	NAD	NAD	Not tested
TPA3	0.5m	NAD	NAD	Not tested
TPA3	1.5m	Fibre Bundles	Chrysotile	<0.001 mass %
TPA3	3.5m	NAD	NAD	Not tested
TPA3	3.9m	Fibre Bundles	Chrysotile	0.005 mass %
TPA4	0.25m	NAD	NAD	Not tested
TPA4	2.0m	NAD	NAD	Not tested
TPA4	3.0m	NAD	NAD	Not tested
TPA5	1.5m	NAD	NAD	Not tested
TPA5	2.2m	Asbestos cement	Chrysotile	Not tested

NAD – No asbestos detected

6.4 Chemical Testing Results

Six samples of Made Ground from the mounded area were tested from trial pits. The results are compared with their respective GAC concentrations (see Section 5.1), where such exist, on the summary tables presented in Appendix B. Concentrations of potential contaminants were generally found to be below their respective detection limits and/or the GAC for residential end use (1% SOM) in all samples of Made Ground tested except for following:

- Arsenic exceeded in one sample (33.8mg/kg, GAC: 32mg/kg)
- Lead exceeded in one sample (1579mg/kg, GAC: 450mg/kg)
- Naphthalene exceeded in one sample (2.89mg/kg, GAC 1.5mg/kg)
- Benzo[a]anthracene exceeded in all six samples (up to 7.2mg/kg, GAC: 3.1mg/kg)
- Chrysene exceeded in two samples (up to 8.1mg/kg, 3.1mg/kg)
- Benzo[b]fluoranthene exceeded in two samples (up to 9.6mg/kg, GAC: 5.6mg/kg)
- Benzo[a]pyrene exceeded in all six samples (up to 8.7mg/kg, GAC: 0.83mg/kg)
- Indeno[123-cd]pyrene exceeded in two samples (up to 5.1mg/kg; GAC:3.2mg/kg)
- Dibenzo[ah]anthracene exceeded in one sample (up to 0.78mg/kg; GAC:0.76mg/kg)
- Aromatics EC >16-21 exceeded in three samples (473mg/kg, GAC 250mg/kg)
- Aromatics EC >21-35 exceeded in one sample (990mg/kg, GAC 890mg/kg)

The arsenic and lead values are considered slight exceedences. The TPHs and PAHs exceedences results are indicative of trace elements of coal tar PAHs and trace degraded diesel, possible tarmac/bitumen.

6.5 Assessment and Recommendations

The asbestos screening shows that asbestos containing material (ACM) is present within the mounded area.

The fragments of asbestos containing material (ACM) found in TPA1 and TPA5 on the northern side of the mounded area indicate there is possibly further ACM buried below the concrete obstruction encountered at 2.2m depth. This would be consistent with anecdotal evidence by Stuart Mallinson (Outdoor duty manager / groundsperson) recollection of seeing asbestos sheets being buried the mound; with numerous concrete blocks from the former cycle stadium.

Other ACM was possibly mixed in the Made Ground along with other former building materials (i.e. bricks and concrete) which may be present at or near the surface.

Investigations to date have proven the presence of at least some ACM and tend to confirm the anecdotal reports of buried ACM from the former stadium. These investigations should be considered preliminary. The investigations to date have not been sufficiently extensive to representatively characterise or accurately delineate the areal extents of ACM within the mounded area, and it is recommended that a precautionary approach be adopted, including appropriate notification to future tenderers of the potential risks from ACM in this area and as required under the CDM Regulations 2015. It is anticipated that further more detailed intrusive investigation will be required, either before tender on behalf of the client or post tender by the successful Principal Contractor.

If the ground is disturbed, there is a possibility of releasing asbestos fibres into the atmosphere which will pose a health risk to humans. Where the specialist knotweed contractors need to disturb the ground (for examples to remove rhizomes) it is recommended as above that a precautionary approach be adopted and that all asbestos risks are assessed and suitable precautions such as spraying the ground and air with water to reduce the risk of airborne dust and wearing appropriate face protection should be considered, also potentially working under the supervision of a suitably qualified asbestos appointed person.

It is anticipated that redevelopment will require this material in the mound to be disposed off site at a suitable licensed landfill. ACM may require pre-treatment before disposal. Any remaining near-surface soils with ACM in landscaped/soft-standing should be addressed by ensuring that the upper 600mm of all such areas consist of cover soils that are uncontaminated, and devoid of asbestos.

7 WATER: GEO-ENVIRONMENTAL ASSESSMENT

7.1 Groundwater GQRA

Groundwater chemical testing was undertaken from samples collected on 25th June 2015.

The groundwater test results were directly compared to the UK Drinking Water Standards (UK DWS) initially. Where UK DWS are not available, the groundwater determinand concentrations have been compared to the Environment Agency's Environmental Quality Standards (EQS), which are derived for the protection of aquatic life.

Screening tables are presented in Appendix C, for determinands with threshold values.

7.2 Summary of Groundwater Chemical Test Results

During this visit on 25th June 2015, groundwater samples were taken, after well development, from Boreholes BH02/1A, BH05/1A and BH08/1A. Note, the other borehole installations were sampled during this site visit but insufficient groundwater could be collected for chemical testing. The findings and results of the laboratory testing are presented in Appendix C. Exceedences of the water quality standards are listed below:

- Lead was detected in BH05/1A at concentrations of 0.011mg/l, which is in slight exceedance of the UK DWS for Lead which is 0.01 mg/l. This concentration is within the EA EQS range of value of 4-20µg/l (dependent on the hardness) and is unlikely to represent a significant pollution risk at this site.
- Nickel was detected in BH02/1A at a concentration of 0.027mg/l, which is in slight exceedance of the UK DWS for Nickel of 0.02 mg/l. This concentration is below the EA EQS value of 50-200µg/l (dependent on the hardness) and is unlikely to represent a significant pollution risk at this site.
- Various types of PAH were detected in BH02/1A and BH05/1A during the groundwater monitoring at total PAH concentrations of 0.0061 mg/l and <0.0002 mg/l, respectively. Speciated PAH, Benzo[a]pyrene was detected in BH02/1A at concentration of 0.0008mg/l exceed the DWS of 0.00001 mg/l. Benzo[a]pyrene measured in BH05/1A was less than detection but the detection limit is above the DWS. It is possible that some PAHs in the soils have leached into the groundwater. However, the PAH values measured in the groundwater samples are considered low and are not likely to pose significant risks for the purposes of this development.

7.3 Conclusions

There were slightly elevated levels of lead, nickel and PAHs measured in the groundwater samples which are in exceedance of the UK DWS. However, the concentrations are considered relatively low and are not likely to pose significant risks for the purposes of this development.

8 GROUND GAS RISK ASSESSMENT

The ground gas assessment is carried out in accordance with the recently published BS 8485:2015, 'Code of Practice for the Design of Protective Measures for Methane and carbon dioxide ground gases for new buildings' (Ref. 16).

The desk study (Ref. 2) reported that

"There are no records of landfill sites (former or current) within 250m of the site (i.e. within the planning consultation zone). Furthermore, there are no records of landfills within a 0.5km radius of the site. However, the site and surrounding areas have a long history of development therefore the presence of made ground and materials used as fill to raise levels are likely to be present both on and off-site."

There were also some former ponds shown on the historical maps in the Phase 1A area. Backfilled ponds may be a potential source of ground gas.

Based solely on knowledge of the potential gas sources (Made Ground and backfilled ponds) it is anticipated that the site will be a very low or low hazard potential site (CS1 or CS2).

The ground model considered appropriate for the gas risk assessment is presented in Table 7, based on the information from the ground investigation.

Table 7: Ground Model for Gas Risk Assessment

Strata	Approx. Thickness	Gas Source	Gas Investigation Data
Made Ground: - General - Backfilled Pond	Up to 3.1m Up to 3.3m	S1 S2	Gas Monitoring Gas Monitoring
Glacial Till - Clays	0 to 3.65m	-	-
Weathered Sandstone / Mudstone	Not proven.	-	-

The ground investigation included installation of 16 No. combined gas and groundwater monitoring standpipes. Gas monitoring including methane and carbon dioxide concentrations and standpipe emission flow rates was undertaken on six occasions with two at less than 1000mb pressure. From the ground gas monitoring results, the maximum recorded values are given in Table 8 below (combined from different monitoring rounds).

Table 8: Summary of Gas Monitoring Results

	Units	Detection Limit	Maximum Measured Value	Comment
Methane	% v/v	0.1	2.4	BH05/1A - 5.5m on 6 May 2015
Carbon Dioxide	% v/v	0.1	11	BH05/1A - 5.5m on 6 May 2015
Ground Gas Flow	l/hr	0.1	5**	BH05/1A - 5.5m on 27 July 2015
Hydrogen Sulphide	ppm	1	<1	

** Reading from BH05/1A of 43.2l/hr and BH02/1A up to 30l/s not considered representative (see below).

The ground gas flow in Borehole BH05/1A 5.5m was first measured on 6 May. At this time, the groundwater level was at 0.62m bgl, which is relatively high. It is expected the high ground gas flow of 43.2l/hr measured on 6 May was the result of pressure built up in the installation from the groundwater recharge (after the borehole was constructed and not from gas generation). This was the first time the borehole was monitored and any built up of pressure from groundwater recharge would not have escaped from the sealed installation. The flow rate is not considered representative.

The flow rates measured from BH02/1A - 5.9m were inconsistent, varying between less than 30l/hr inflow to 30l/hr outflow and the hazardous gas flow rate from this installation is not considered representative. From the flow rate measurement in BH10/2 on 27 July 2015, -30l/hr is also considered not representative.

The maximum implied Characteristic Gas Situation (CS) was calculated in accordance with BS 8485:2015 (Ref. 16) and presented in Table 9 below.

Table 9: Maximum Implied Characteristic Gas Situation

Flow Rate q l/h	C _{hg} CH ₄ %	C _{hg} CO ₂ %	Q _{hg} CH ₄ (C _{hg} × q) l/hr	Q _{hg} CO ₂ (C _{hg} × q) l/hr	Implied CH ₄ CS (Table 2, Ref. 16)	Implied CO ₂ CS (Table 2, Ref. 16)
5	2.4	11	0.12	0.55	2	2
-9.5	2.4	11	-0.23*	-1.05*	-	-

* Results based on negative flow (suction) for comparison.

From these results, the maximum individual hazardous gas flow rate (Q_{hg} value) for the site is 0.55 l/hr carbon dioxide in BH05/1A 5.5m (5 l/hr on 27 July 2015 and a maximum carbon dioxide concentration of 11% v/v). Borehole BH05/1A contained organic odours and fragments of wood, possibly the former pond area. Elsewhere on site, the maximum individual hazardous gas flow rate (Q_{hg} value) is 0.09 l/hr carbon dioxide (2.2 l/hr in BH2/2 on 14 May 2015 and a maximum carbon dioxide concentration of 4.2% v/v in BH2/1A on 14 May 2015).

With reference to Table 2 in BS 8485:2015 (Ref. 16), based on the combination of worst case gas concentrations and flows, the site is classified as Characteristic Gas Situation (CS) 2, "low risk", in terms of its hazardous ground gas regime. This is consistent with the potential gas sources (Made Ground and backfilled ponds) identified in the desk study and ground investigation.

An assessment of the individual hazardous gas flow rate for different site areas indicated the following:

- Phase 1A – Maximum category CS 2 (based on ground gas flow in Borehole BH05/1A 5.5m)
- Phase 1B – Maximum category CS 1
- Phase 2 – Maximum category CS 1 (although a former pond existed in this area, no individual gas readings indicated flow rate or concentrations above CS 1).

We therefore recommend that the above zoned approach is adopted for categorisation of this site.

CS1 does not require gas protection measures according to BS 8485:2015. CS2 in Phase 1A requires ground gas protection measures for the proposed new development. For example, 'Type B' building for public use with multiple occupancy would need a minimum gas protection score of 3.5 for CS2 in accordance with BS 8485:2015. This may be achieved by the application of combinations of the following in the building design: a ground bearing slab with nominal mesh reinforcement scores 0.5, a suitably installed gas resistance membrane scores 2 and a passive sub floor dispersal layer with good performance scores 1.5.

An alternative strategy to gas protection measures in the Phase 1A area could be to delineate then excavate the material in the location of the backfilled ponds in Phase 1A and replace with inert material, followed by a new gas installation borehole and monitoring to assess whether the gas concentration and flow rates reduce.

9 CONCEPTUAL SITE MODEL

The Conceptual Site Model (CSM) has been established based on the findings of the ground investigation and gas and groundwater monitoring results. Sources identified are based on the results of this investigation and Desk Study report (Ref. 2).

In summary, sources comprise:

- Elevated arsenic, lead, mercury, TPHs and PAHs in the Made Ground
- Slightly elevated lead, nickel and PAHs in the groundwater
- Asbestos containing Chrysotile material in Made Ground
- Japanese Knotweed on the site
- Unexploded Ordnance (UXO) threat
- Hazardous ground gases
- There may be localised contamination in Made Ground at other locations

The potential pathways at the site include:

- Air and gas flow
- Dermal contact, ingestion and inhalation
- Infiltration and runoff
- Groundwater flow
- Pathways via buried pipes such as redundant drainage

Receptors considered include:

- Construction and maintenance workers
- Current and future site users (university users and maintenance staff)
- Groundwater and surface water

10 GEO-ENVIRONMENTAL RISK ASSESSMENT

10.1 Summary of risk assessment

A geo-environmental risk assessment for the site is outlined below in the context of the findings of the investigation and the potential pollutant linkages identified in the CSM.

In brief, the geo-environmental risk assessment considers the various potential pollutant linkages identified in the CSM and qualitatively determines a level of risk (based on the classification of the magnitude of the potential consequence of the risk occurring and the magnitude of the probability of the risk occurring). The risk assessment highlights areas which warrant either further investigation to prove and validate the level of risk, or remedial action. Where information is of insufficient detail or incomplete, risks may be identified as moderate/high and then reduced as necessary after further information is gathered.

Table 10 below provides a description of the resultant risk levels.

Table 10 – Risk Definitions

Risk Term	Description
VERY HIGH	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	Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
MODERATE	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	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.
VERY LOW	The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor

Taken from NHBC & Environment Agency (2008) 'Guidance for the Safe Development of Housing on Land Affected by Contamination', R&D 66:2008 Vol. 1.

The outcome of the risk assessment below, considering the site in its present state and the proposed end use, to the environment and human health would be generally LOW with a MODERATE / HIGH risk to construction workers from ground gas and asbestos in soils.

10.2 Risk Assessment

The outcome of the risk assessment for the subject site in relation to the proposed development is summarised on the following table.

Table 11 – Summary of Risk Assessment (Risk Rating)

Receptor	Pathway	Source		
		Asbestos (primarily in Made Ground)	Metals, TPHs and PAH in soils	Hazardous ground gas (elevated carbon dioxide and methane)
Human Health - construction and maintenance workers	Direct contact in open ground	N/A	LOW	N/A
	Ingestion in open ground	N/A	LOW	N/A
	Inhalation of gases/vapours/dust	HIGH / MODERATE	N/A	MODERATE
Human Health - development users	Direct contact in open ground	N/A	LOW	N/A
	Ingestion in open ground	N/A	LOW	N/A
	Inhalation of gases/vapours/dust	HIGH / MODERATE	N/A	MODERATE
	Explosion of gas	N/A	N/A	MODERATE
Groundwater	Leaching and/or percolation	N/A	LOW	N/A
	Off-site migration	N/A	LOW	N/A
Surface water	Off-site migration	N/A	LOW	N/A

The risks above are generally considered LOW, with a MODERATE to HIGH risk to human health based on ground gas and asbestos encountered in soils.

The site is within a Source Protection Zone III (outer source protection zone). However, based on the limited amount of perched shallow groundwater above relatively impermeable clay layer of Glacial Till, risk to the local abstraction points from this site is considered to be low.

The presence of Japanese Knotweed on the site has been confirmed. This should be treated and removed from site in accordance with statutory / Environment Agency guidelines.

As indicated in Section 6, the mounded vegetated area on eastern side of Phase 1A area has been proven to contain asbestos material (ACM). It is anticipated that redevelopment will require this material in the mound to be disposed off site at a suitable licensed landfill. ACM may require pre-treatment before disposal.

Any near-surface soils with ACM in landscaped/soft-standing should be addressed by ensuring that the upper 600mm of all such areas consist of cover soils that are uncontaminated, and devoid of asbestos.

As indicated in Section 8, the ground gas monitoring results and risk assessment has indicated potential moderate risk to (unprotected) development users from ground gas in part of the site. Protection measures should be assumed necessary at this stage for the Phase 1A area. The Phase 1B and 2 areas do not require gas protection measures.

11 GEOTECHNICAL CONSIDERATIONS

11.1 Proposed Development

Based on the information provided by BDP, the proposed redevelopment of new student accommodation comprises between 1 and 6 storey buildings which may be framed in either steel or reinforced concrete, or load bearing masonry construction. Preliminary loads and design building layout plans for the proposed development have not been provided.

11.2 Ground Model

The following table presents generalised ground model and geotechnical parameter values proposed for preliminary foundation design, based on the information from the geotechnical investigation. The ground conditions do vary across the site which needs to be considered for the detailed design. The site has been divided into two (see Table 12) to reflect the two representative ground models. The dividing line between the two areas is shown in cross section on Figure 3, cross sections 1 and 2.

Table 12: Ground Model

Lithology (Phase 1B, 2 and western side of Phase 1A)	Depth (m bgl)	Ground Parameters			
		Unit Weight, γ (kN/m ³)	ϕ' (°)	c' (kPa)	c _u (kPa)
Made Ground	0m to 1m	18	N/A	N/A	N/A
Glacial Till – Soft to firm	1m to 2m	21	N/A	N/A	50
Glacial Till – Firm to Stiff	2m to 3m	21	N/A	N/A	100
Sand	3m to 4m	20	40	0	N/A
Sandstone	Below 4m	22	UCS = 3 MPa		
Eastern side of Phase 1A					
Very Stiff Clay	4 to 7m	22	28	0	150
Mudstone	Below 7m	23	UCS = 1 MPa		
On the eastern side of Phase 1A, layers of sand /very stiff clay over weathered mudstone were encountered in place of the sandstone. Weathered mudstone encountered at about 6m to 8m depth.					

Groundwater is assumed below the anticipated depth of foundations (i.e. below 8m bgl) expect for perched water in the Made Ground from 0.5mbgl.

11.3 Foundation Options

The following foundation design recommendations are based on the general ground conditions and the ground model described above. The feasibility of the different foundation types will ultimately depend on the building loadings and specific ground conditions at the location.

For existing trees and new trees within influencing distance of structures the foundations details should be developed to be according to NHBC Guidance or otherwise accepted good practice such as installation of cut off trenches / root barriers. Further details are given below for the different options considered.

11.3.1 Shallow Foundations

Made Ground is unsuitable for the support of any major structure owing to the risk of excessive total and/or differential settlements resulting from the loading of such strata.

It is considered that relatively-shallow spread/trench-fill foundations may be feasible for the proposed redevelopment but would need to be taken through any soft to firm clays into the underlying stiff glacial clays, dense sand or weathered sandstone strata. The design of such foundations at typically 2m depth should have an allowable bearing capacity of 200kPa. It is recommended the foundations spanning across different strata are suitably reinforced to cope with any differential settlement effects.

Foundations founded directly onto the dense sand / weathered sandstone would typically have an allowable bearing capacity of at least 500kPa. However, it would be prudent to assume an allowable bearing capacity of 300kPa to allow for the presence of weathered mudstone layers (very stiff clays) beneath this natural stratum.

Minimum foundation depth should be 0.75m below ground level for cohesive formations, due to the potential for shrinkage / swelling of cohesive soils and the effects of adjacent trees, subject to local building authority guidance. The glacial clays (including most Made Ground) can be classified as being of "low" volume change potential. There are some existing trees on and within influencing distance of the site, some of which may require felling and removal, and the presence of these trees will need to be taken into account in determination of appropriate foundation depths, heave precautions, and need or otherwise for suspended floor slabs.

It is recommended that the location of any proposed new tree planting is greater than 0.5 x mature tree height away from any building footprint. Alternatively, an appropriately designed root barrier system may be constructed around any new building to provide protection from roots of newly planted trees.

Phase 1A Area

The development on the existing rugby pitch is generally expected to be suitable for shallow foundations. The exploratory holes show stiff clay at generally 1.5m to 2m bgl., locally deeper (i.e. at 2.9m bgl. at BH10/1A). Borehole BH05/1A identified soft clays to 3.3m bgl which is believed to be from a former pond in the north-west corner of the site. Piled foundation would be expected to be more economical over soft ground in this corner of the site.

The exploratory holes show stiff clay at generally 2m bgl in the car park and compound in the north of the Phase 1A area (north of mounded area). Deeper areas of fill may be expected such as 3.1m depth of Made Ground in BH18/1A. Shallow foundations are expected to be suitable bearing on stiff clay, taken locally deeper though any Made Ground.

Mounded Area in Phase 1A

Given the mound material will be disposed off site leaving the proposed redevelopment to be constructed at ground levels of about 45m AOD (i.e. consistent with the ground levels either side of the mound), a competent bearing stratum of stiff clay / sand is anticipated at a depth of typically 2.3m (42.7m AOD).

Phase 1B Area

The exploratory holes showed that a suitable founding stratum for shallow foundation is generally about 2m bgl. Deeper areas of Made Ground, such as in Borehole BH12/1B to 2.6m bgl and that associated with previous and existing development, should be expected in this area. A suitable founding stratum for shallow foundation in this area is expected to be a combination of stiff clay, dense sand and sandstone. Sandstone can be found at shallow depth (i.e. less than 2m) in the north of the Phase 1B area.

Phase 2 Area

A suitable founding stratum for shallow foundation is generally at about 2m bgl. Deeper areas of Made Ground may be expected in this area, such as found at 2.7m depth of Made Ground in WS06/2 and that associated with previous and existing development. The suitable founding strata will generally be stiff clay with dense sand / sandstone in the southern part of the Phase 2 area.

11.3.2 Piled Foundations

Piled foundations into bedrock are also feasible for the proposed buildings and may in fact be necessary depending on the structural loads to be accommodated.

Small displacement piles, such as circular steel tubes, are ideally suited to piling in the weak rock with its design and installation advantages. However, load carrying capacity would be limited by the driveability and thereby diameter of the piles. Limitations of driven piles would include noise and vibration effects, together with possible heave effects.

It is possible to install significant rock sockets with replacement techniques (Bored or Continuous Flight Auger (CFA)), particular when using modern high torque piling rigs. The feasible construction depth of the CFA piles into bedrock will depend on the rock strength and piling equipment used. Discussion with specialist piling contractors is required to ensure the piling type and rig are suitable for the ground conditions. Note that whilst the rock is generally described as extremely weak to weak sandstone and mudstone, some layers of medium strong to strong sandstone were encountered during the investigation.

Preliminary calculations for allowable capacities of single CFA piles (or conventional bored piles) are presented in Table 13 below. There is relatively a thin layer of Glacial Till above the rock and therefore the piles will need to be socketed into the sandstone / mudstone before the piles achieve any significant load capacity.

Table 13: Summary of preliminary allowable pile capacities for a single CFA pile

Preliminary Allowable Pile Capacities (kN)				
Pile Length (m)	End bearing Stratum	Pile Diameter (mm)		
		300	450	600
1	Made Ground	N/A	N/A	N/A
2		N/A	N/A	N/A
3	Glacial Till	50	100	160
4	Sand	250	500	900
6 (Min. 2m rock socket)	Extremely weak sandstone	500	900	1,350
8 (Min. 4m rock socket)		700*	1,450	2,100
* About the structural capacity of the pile.				

For example a working load of 900kN could be carried by 450mm diameter CFA piles installed to a minimum of 6m depth, socketed a minimum 2m in competent sandstone rock. It is noted that the capacities given in the table are for single piles and for a detailed pile design group effects will have to be considered.

For piles socketed into the mudstone on the eastern side of Phase 1A area, it is anticipated that the piles may need to be about 4m longer to achieve similar pile capacities to piles socketed into the sandstone.

It is considered essential / good practice to carry out static load testing to confirm the pile loads in the sandstone / mudstone. The ground investigation identified occasional layers of mudstone within the sandstone. For design pile socketed in sandstone, as well as pile load testing, adequate construction quality control is required, i.e. an observational approach of an experienced geotechnical engineer examining pile arising together with monitoring of CFA pile torques, to confirm that the pile is socketed into an adequate depth of competent sandstone to achieve the required load capacities.

For piled foundations within the influence of existing trees, heave precautions for pile and beam foundations should include a 50mm void or equivalent compressible material below all ground beams and suitable embedment of pile tension reinforcement between beams and piles. Alternative to this approach, a cut off trench / root barrier could be utilised to stabilise the moisture content of the ground below the building. The timing of the root barrier installation would need to be sufficiently early to allow the moisture content below the building to achieve a stable ambient status, thus mitigating the effect of subsequent ground heave on slabs / foundations. Further specialist Arboriculture input is required for this.

The above assessment methodology is presented as follows.

For the assessment of CFA piles in cohesive materials, an adhesion factor (α) is considered to vary according to the undrained shear strength for bored piles in Glacial Till stratum. The suggested values from CIRIA C504 (Ref. 17) were generally adopted.

For concrete CFA piles in granular soils, relative earth pressure coefficient $K_s = 0.3$ for CFA piles in dense sand (Ref. 18), and an interface friction coefficient of $\tan \delta = 1.0 * \tan \phi'$ may be used for cast in-

situ concrete and sand (Table 4.11 in Ref. 18). The average unit shaft friction and base resistance were limited to a value of 100kN/m² and 15,000kN/m², respectively.

Skin friction and negative skin friction from Made Ground layer (up to 3.0m depth) was ignored in this design.

A factor of safety of 2.5 was applied to limit total settlement to within 10mm, subject to more detailed settlement calculations which would be required at detailed design stage.

The site area is underlain by bedrock designated as a Principal Aquifer and the groundwater protection zone map identifies that the site is located in a Source Protection Zone III area. Piling may provide a more direct route for potentially contaminated groundwater entering the aquifer. However, on the basis of the site history, current features and observations made during the site inspection, gross/site-wide mobile ground contamination sources are considered unlikely to exist.

11.3.3 Ground Improvement

An alternative foundation solution for lighter foundation loadings that may be considered for the support of the proposed buildings could comprise shallow reinforced foundations (i.e. raft) on ground subjected to improvement by Rapid Impact Compaction or vibro stone columns. Rapid Impact Compaction would be suitable for densification of granular Made Ground. Vibro concrete / stone columns would transfer the load through weaker ground into the more competent strata at depth. The suitability of vibro concrete / stone columns in relatively shallow strata would need to be considered. There may be also noise and vibration issues using ground improvement near existing developments. The use of ground improvement should be discussed with ground improvement specialist contractors. Vibro stone columns would also need to be agreed with the Environment Agency as they may create a direct pathway for any potentially contaminated groundwater in the Made Ground to flow through the glacial till and into the Principal Aquifer beneath. On review, given the above issues and the presence of a competent load bearing strata at 2m depth for lighter foundation loading, ground improvement is not recommended for the site,

11.4 Ground Floor Slab Construction

Made Ground to depths up to 3.1m was encountered in places. It is assumed the maximum load applied to the ground floor will be 5kN/m².

Ground bearing floor slabs may be suitable where there is a limited thickness of reasonable competent Made Ground. Ground bearing floor slabs may be suitable in some areas of Phase 1A.

For deeper areas of Made Ground with a relative uniform thickness, reinforced concrete ground-bearing floor slabs could be adopted if ground improvement were carried out. Alternatively, suspended floor slabs may be adopted. Suspended floor slabs would be recommended for any proposed building in the north-west corner of Phase 1A over the former pond area.

Formation soils for ground bearing slabs should be carefully inspected and any soft spots or deleterious material removed and replaced with suitable compacted granular material. The sub-grade below the ground bearing slabs should be proof-rolled prior to construction (i.e. eight passes of a vibrating roller with a mass per metre width over 3600kg).

The design of ground bearing floor slabs can be based on C&CA publication (Ref. 19) with a CBR design value of less than 10%, or other appropriate guidance. Any excavations below the floor slabs

should be backfilled and compacted in layers in accordance with the Specification for Highway Works Series 600 "Earthworks" (Ref. 20).

For buildings within the influence of existing trees, suspended floor slabs with an appropriate void space, or compressible material beneath the slab, to accommodation against potential heave should be used where heave can occur within the area bounded by the foundations. Similar to Section 11.3.2 a root barrier system could be adopted to stabilise the moisture content of the ground beneath the building, after allowing sufficient period after the barrier is installed for the ground to reach a stable ambient moisture content before the ground floor slab is installed.

11.5 New Hardstanding Pavement Construction

Sixteen TRL Probe Tests have been carried out in the trial pits at depths between 0.45m and 0.5m across the site to assess appropriate CBR values for pavement design. A summary of correlated CBR values determined from the TRL Probe Test results is presented in Table 14 below and Appendix D.

Table 14: Summary of CBR Results

Stratum Type	No of Tests	Minimum CBR Value (%)	Maximum CBR Value (%)	Average
Made Ground - Fine Grained	5	5	10	7
Made Ground - Coarse Grained	2	55	55	55
Glacial Till - Clays	9	4	16	9

At this stage it is assumed for pavement design that subgrade foundation level will be at about 0.45m below the existing ground in either Made Ground or firm Glacial Till with mid-range PI of about 20. An estimated long term CBR value based on TRRL Report LR1132 (Ref. 21) is 4%. This is based on a thin layer of construction with a high water table (i.e. the foundation may be wetted with groundwater during its design life).

An indicative design CBR value of 4% may be assumed at this stage for the design of new pavement, based on the estimated value above and the lower bound TRL probe test results. The formation level should be inspected and any soft spots replaced with suitably compacted granular fill.

When the location of proposed access roads and formation levels are known, further in-situ CBR testing should be carried out to confirm suitable CBR values for the pavement design.

11.6 Excavations

Excavation is required for the removal of existing foundations and for foundations to the proposed building. The Made Ground layer at this site is likely to require temporary support or battered slopes during excavation as they are unlikely to remain stable in the short term. The Principal Contractor will need to conduct appropriate assessment of risks to determine safe methods of working.

Groundwater control may be required in excavations deeper than around 0.5m. A perched water table is anticipated across the site in the Made Ground above the glacial clays. Monitoring showed groundwater levels up to a depth of 0.5m below ground level. Dewatering is not anticipated to be

required, but there may be a need for localised sump drainage. Details will depend on the foundation scheme to be developed. Any excavations that require groundwater control should be appropriately designed such that piping or failure of the base of excavation due to water pressure does not occur.

Removal and disposal of what is likely to be contaminated material should also be considered. Waste Acceptance Criteria (WAC) testing will likely be required by any proposed landfill and should be undertaken at the time of construction works.

11.7 Aggressivity Towards Concrete

Testing to determine the aggressivity of the ground towards concrete was undertaken on soil and groundwater samples in accordance with the Building Research Establishment Special Digest 1 (Ref. 22). The results are presented in Appendix E.

Sulphates present in the ground can attack and degrade concrete. Additionally, sulphates can be formed by disturbance of certain minerals, such as pyrite, during construction. Concrete can be designed to resist such attack in accordance with the guidance in BRE Special Digest 1:2005 'Concrete in Aggressive Ground'. Disturbance of the ground would include activities such as near-surface excavation, as proposed at this site for ground-works, including the foundation construction.

Table 15 gives a summary of soil test results. Three groundwater samples were tests for sulphate and pH. These recorded a maximum sulphate content of 83mg/l and a lowest pH value of 7.54.

The site was assessed on the basis of being a 'brownfield location' in accordance with BRE guidelines. Groundwater was considered to be mobile for this assessment due to the granular nature of the near surface stratum (Made Ground) and groundwater regime at the site.

Table 15: Summary of concentrations measured in soils for materials assessment

Determinand	Soil		Characteristic Value
	Min Value	Max Value	
pH	5.79	9.22	6.51*
Water Soluble Sulphate	10 mg/l	1372 mg/l	1372mg/l**
Acid Soluble Sulphate	<0.01%	0.37%	0.37%**
Total Sulphur	<0.01%	0.16%	0.16%**
Total Potential Sulphate	<0.03%	0.48%	0.48%**

* Average of lowest 20% of results

** Highest result

The results correspond with a Design Sulphate Class and ACEC Class of DS-2 and AC-2 respectively, assuming ground disturbance will occur during construction, e.g. during excavation for construction of foundations as well as for new underground services/utilities.

11.8 Soakaways

During Stage 2a, falling head permeability tests were carried out to evaluate the potential for soakaways. Equivalent infiltration rates have been calculated from the falling head test permeability test which are presented in Appendix F. The use of soakaways on the site has been considered and it is concluded that the site is not suitable for soakaways.

The Made Ground will not be suitable for soakaways for a number of reasons including that it contains a perched water table and has limited volume capacity, possibly resulting in flooding of the site.

The Glacial Till is predominately clay. Infiltration rates range between 3.6×10^{-7} and $4.4 \times 10^{-7} \text{ m}^3/\text{m}^2/\text{s}$ and this stratum is assessed as not suitable for soakaways.

The upper weathered sandstone is fine to coarse sand. Infiltration rates range between 1.44×10^{-6} and $1.2 \times 10^{-5} \text{ m}^3/\text{m}^2/\text{s}$. The range of infiltration rates is poor to moderately poor in terms for providing a soakaway medium. The thickness of the sand is variable and found to be absent in some parts of the site.

The infiltration rates in the weathered sandstone range from 2×10^{-5} to $7 \times 10^{-5} \text{ m}^3/\text{m}^2/\text{s}$. The range of infiltration rates are moderately poor in terms for providing a soakaway medium, especially considering the depth of overburden needed to be excavated before encountering the sandstone.

Any soakaway in the sand / weathered sandstone would need to be excavated below the perched water table and through the glacial till. This would create construction and environmental issues, especially as the sandstone is a Principal Aquifer. Therefore, soakaways are not considered suitable in these strata.

12 CONCLUSIONS

The following conclusions are presented based on the findings of the Stage 2a and 2b ground investigation fieldwork and laboratory testing:

1. The site consists of three areas: Phase 1A, 1B and 2. It is proposed to redevelop the site with new student accommodation facilities.
2. Stage 2a and 2b ground investigations comprising 47 No. cable percussive boreholes, (twelve of which were extended by rotary technique), 22 No. trial pits and 12 No. windowless sampling holes with in-situ and laboratory geotechnical and chemical testing were carried out on the proposed site.
3. Ground conditions encountered during the borehole investigation at the site comprised generally Made Ground over natural Glacial Till underlain by sand becoming extremely weak Sandstone. Mudstone was encountered on the eastern side of the Phase 1A area, in place of the sandstone.
4. Groundwater entries were recorded in the exploratory holes (during hole formation and in installations) up to depths of 0.5mbgl. This is considered to be a perched water table in the Made Ground above the Glacial Till.
5. Chemical testing was undertaken on soil samples and compared to published Generic Assessment Criteria (GAC) for residential land use. The range of contaminants identified from the test results received included elevated metals, TPHs and PAHs in samples of Made Ground. The metals, TPHs and PAHs are likely due to the ash, clinker, and tarmac / bitumen fragments in the Made Ground.
6. Chemical testing was undertaken on samples of groundwater and compared to published Generic Assessment Criteria (GAC). The range of contaminants identified from the test results received included slightly elevated lead, nickel and PAHs in the samples.
7. It is understood that the mounded vegetated area on western side of the Phase 1A area will be removed off site prior to the development. Investigations to date have proven the presence of at least some ACM and tend to confirm the anecdotal reports of buried ACM from the former stadium. It is anticipated that further more detailed intrusive investigation will be required, either before tender on behalf of the client or post tender by the successful Principal Contractor.
8. Elsewhere on the site asbestos was identified in three soil samples in Phase 1A, and fragments of ACM were identified in trial pits in Phase 1B. In terms of post-construction site use, near-surface soils in the landscaped/soft-standing parts of the site need to be devoid of asbestos (i.e. by the application of 600mm thick uncontaminated cover soil).
9. Ground gas with elevated levels of methane and carbon dioxide was recorded in some boreholes on the site. The sources of gas are believed to be deeper areas of Made Ground and backfilled former ponds. A gas risk assessment has been carried out with reference to BS 8485:2015 and ground gas protection measures for Characteristic Gas Situation 2, "low risk", are considered appropriate for proposed new development in Phase 1A of the site. An alternative to gas protection measures could be to excavate the material in the location of the backfilled ponds in Phase 1A and replace with inert material, followed by a new gas installation borehole and monitoring to assess whether the gas concentration and flow rates reduce.

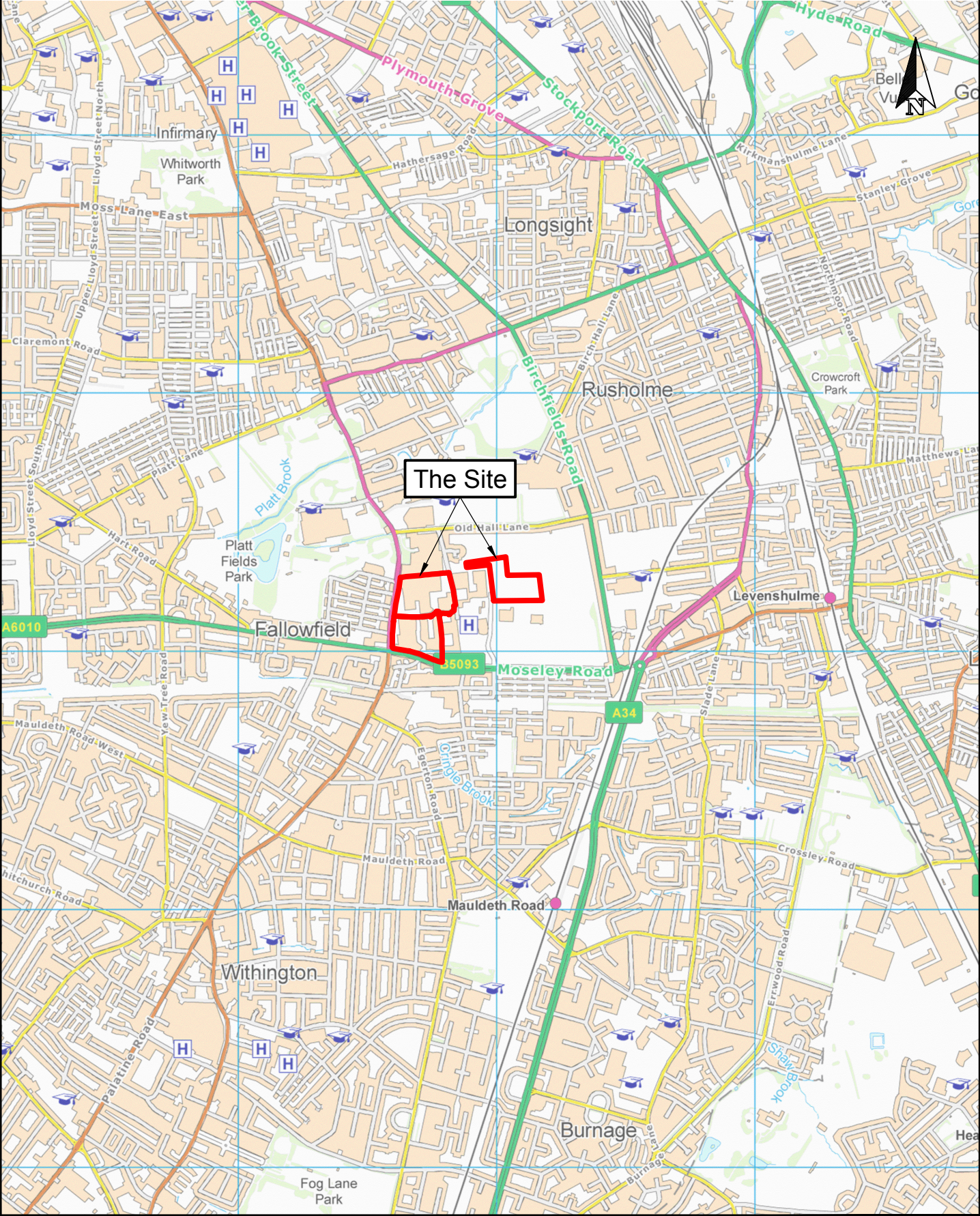
Phase 1B and Phase 2 are considered to be represented by CS1, which does not require gas protection measures.

10. The excavated material on the site would generally be expected to be classified as non-hazardous, except for material containing quantifiable amounts of asbestos which will classify as hazardous waste. WAC testing may need to be carried out at the construction stage on the particular materials to be disposed.
11. Using the information obtained from the ground investigation, a ground model has been developed. Foundation design recommendations are provided based on this ground model. The ground conditions do vary across the site which needs to be considered for the detailed design.
12. Shallow spread foundations through any Made Ground and soft to firm clays founded on stiff clay, dense sand and sandstone could be feasible for the proposed redevelopment dependent upon the proposed loadings. The preliminary design of such foundations should be based on an allowable bearing value of 200kPa, at typically 2m depth, locally deeper.
13. Ground improvement by vibro-compaction is not likely to be viable for the proposed redevelopment at the site because of the limited depth of competent bearing stratum and nature of proposed development.
14. Piled foundations into bedrock are also feasible for the proposed buildings and may in fact be necessary depending on the structural loads to be accommodated. CFA piles are recommended with the piles socketed into the sandstone / mudstone. Indicative pile capacities are summarised in Section 11.3, to be confirmed by pile load testing.
15. There is generally perched groundwater in the Made Ground above the Glacial Till clay. Groundwater control may be required in excavations deeper than 0.5m below ground level. It is anticipated that there may be a need for localised sump drainage. Details will depend on the foundation scheme to be developed.
16. The Made Ground at this site is likely to require temporary support during excavation for new foundations or to remove the foundations of buildings to be demolished as they are unlikely to remain stable in the short term.
17. Preliminary UXO risk assessment has identified that a moderate risk exists. This was addressed for the Ground Investigation and a more detailed UXO risk assessment is required prior to any construction works.
18. The Geo-Environmental Desk Study Report provided to Coffey advises that a flood risk assessment will be required, owing to the size and nature of the development. We understand this is being addressed by others.
19. Design Sulphate Class and ACEC Class of DS-2 and AC-2 should be adopted, assuming ground disturbance will occur during construction, e.g. during excavation for construction of foundations as well as for new underground services/utilities.
20. For pavement design, an indicative design CBR value of 4% may be assumed at this stage. When the location of proposed access roads and formation levels are known, further in-situ CBR testing should be carried out to confirm suitable CBR values for the pavement design.
21. Soakaways are not considered suitable for the redevelopment of the site.

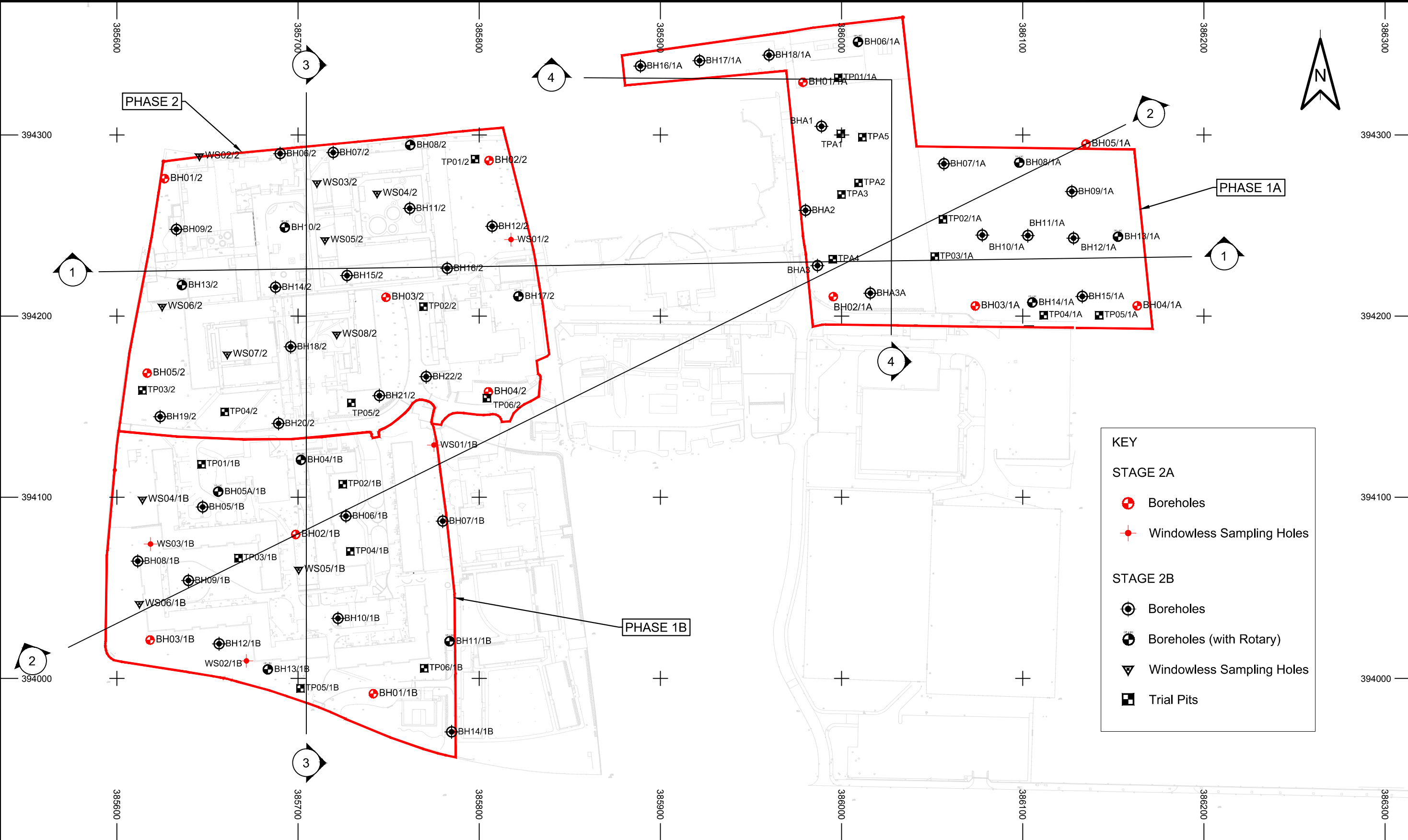
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Figures



drawn	SN/MJW		client:	BDP	
date	MAY 2015		project:	PROJECT OAK, FALLOWFIELD, MANCHESTER	
scale	1:20 000		title:	SITE LOCATION PLAN	
original size	A4		project no:	02428AA	fig no: Figure 1



KEY

STAGE 2A

Boreholes

Windowless Sampling Holes

STAGE 2B

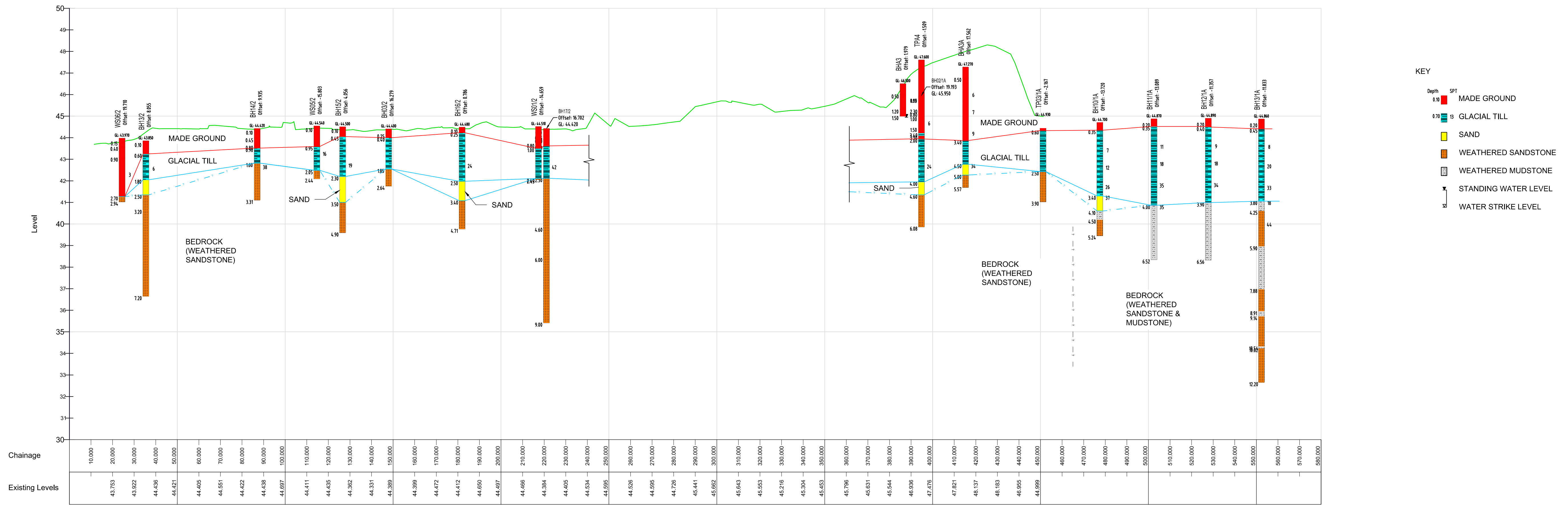
Boreholes

Boreholes (with Rotary)

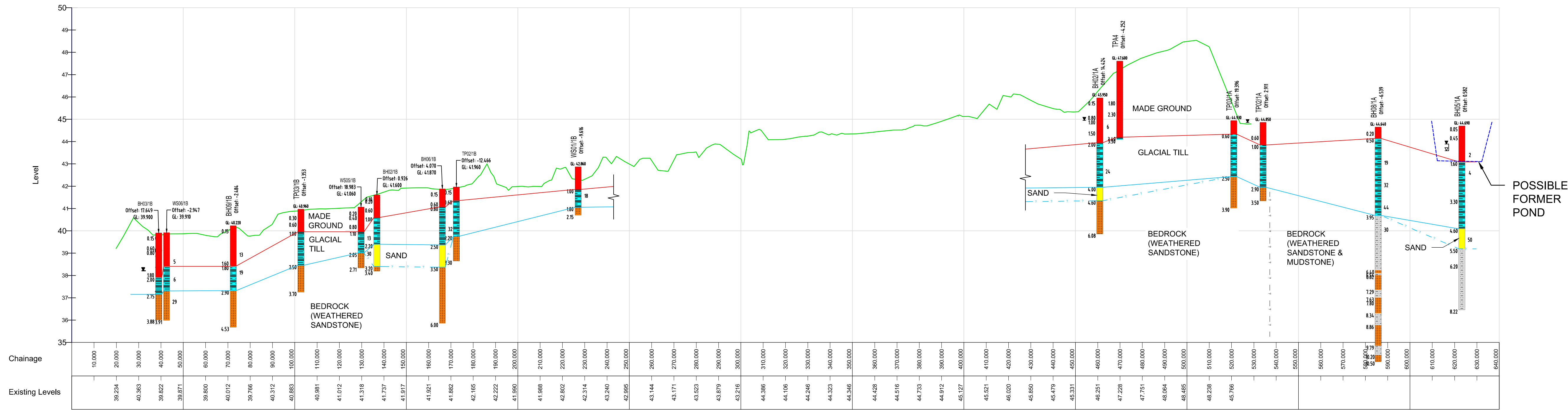
Windowless Sampling Holes

Trial Pits

Notes: 1. Do not scale from this drawing. 2. All dimensions are in metres unless otherwise stated. 3. Reference drawing: 12650A-MASTER.dwg (Topographical Survey by SURVEY SYSTEMS - February 2014) 4. Exploratory hole locations provided by Geotechnics in AGS format.	drawn	MN	coffey	client: BDP	
	date	27/07/2015		project: PROJECT OAK GROUND INVESTIGATION - STAGE 2B	
	scale	1 : 2,000		title: EXPLORATORY HOLE LOCATION PLAN	
	original size	A3		project no: 02428AA	fig no: FIGURE 2

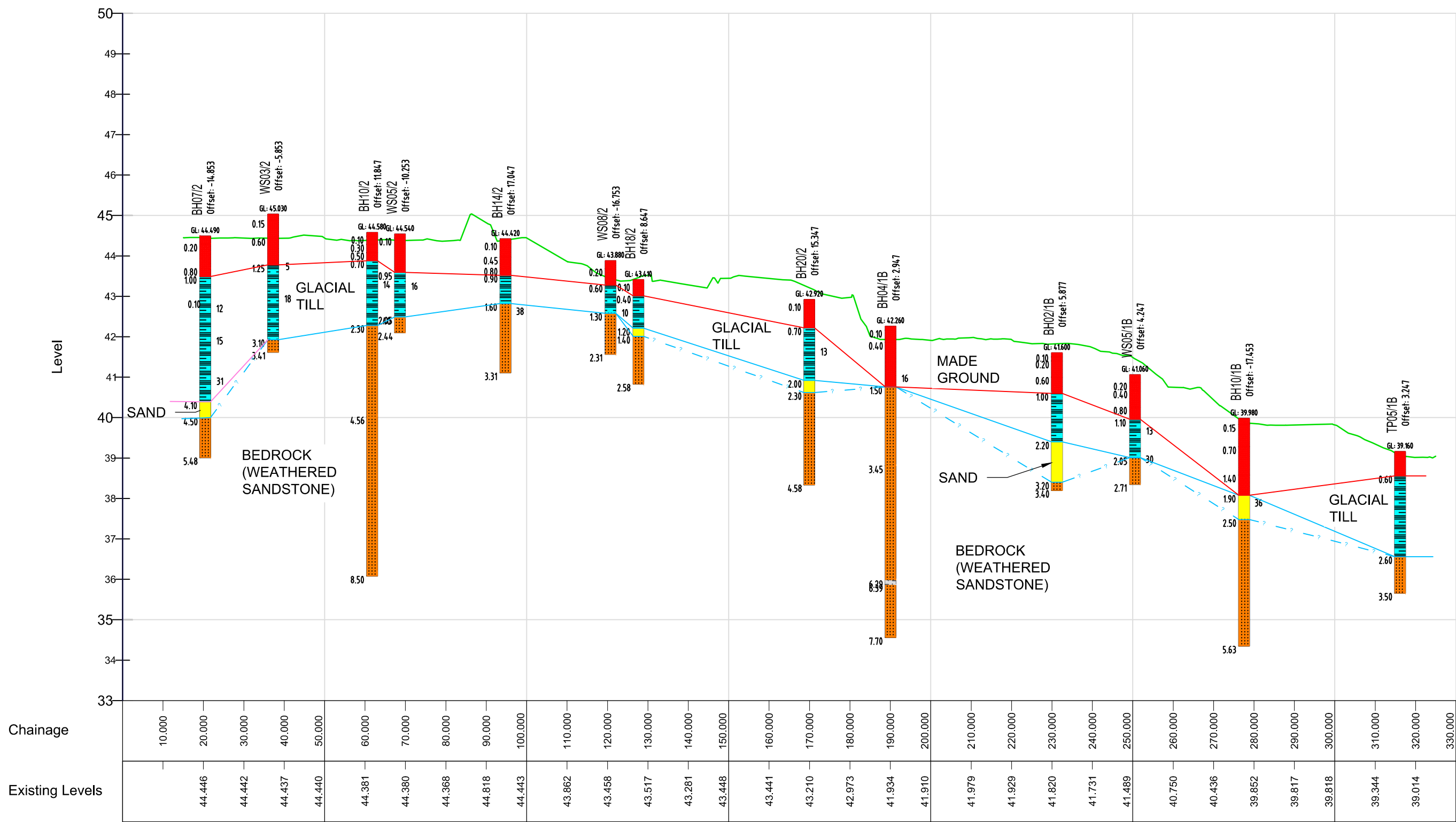


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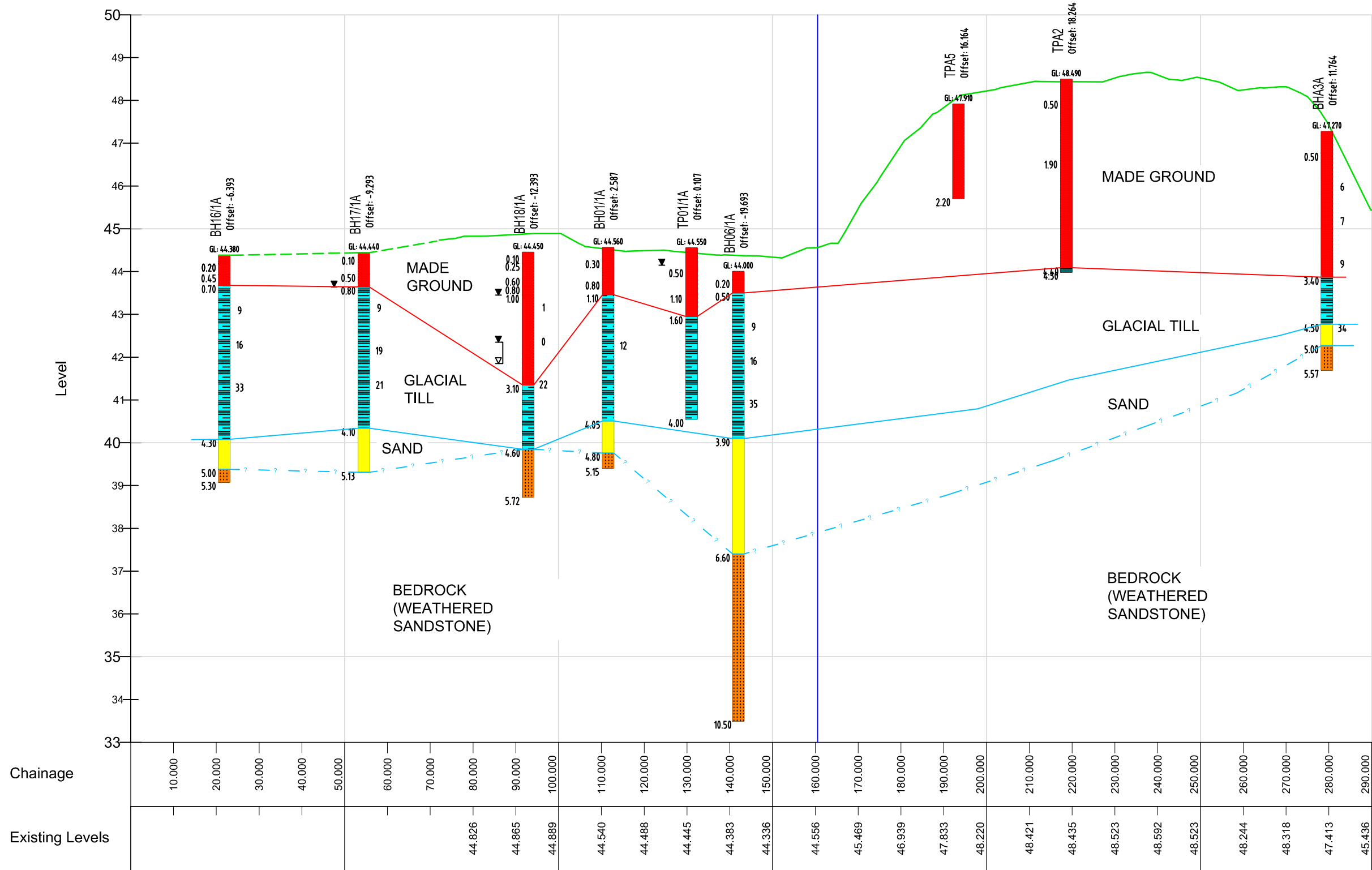


SECTION 2
SCALE: H 1:1000,V 1:100.

Notes: 1. Do not scale from this drawing. 2. All dimensions are in metres unless otherwise stated.								drawn	MN	 UK offices: Harrington Manchester Reading Website T (+44) (0) 1423 878 130 F (+44) (0) 1423 878 131 T (+44) (0) 161 499 6800 F (+44) (0) 161 499 6802 T (+44) (0) 1189 560 0660 F (+44) (0) 1189 576 006 www.coffey.com Coffey Geotechnics Limited Registered Office: 1 Northfield Road, Reading, Berkshire RG1 8AH United Kingdom Registered in England No 06328315	client:	BDP					
							checked	MJW	project:		PROJECT OAK GROUND INVESTIGATION - STAGE 2B						
							approved	MJW									
							date	12/8/2015				title:	GEOLOGICAL CROSS-SECTIONS (1 OF 2)				
							scale	AS SHOWN									
												project no:	02428AA	fig no:	FIGURE 3	rev:	
	rev no	revision note			date	checked	approved	original size	A1								



SECTION 3
SCALE: H 1:1000,V 1:100.



SECTION 4
SCALE: H 1:1000,V 1:100.

- Notes:
- Do not scale from this drawing.
 - All dimensions are in metres unless otherwise stated.

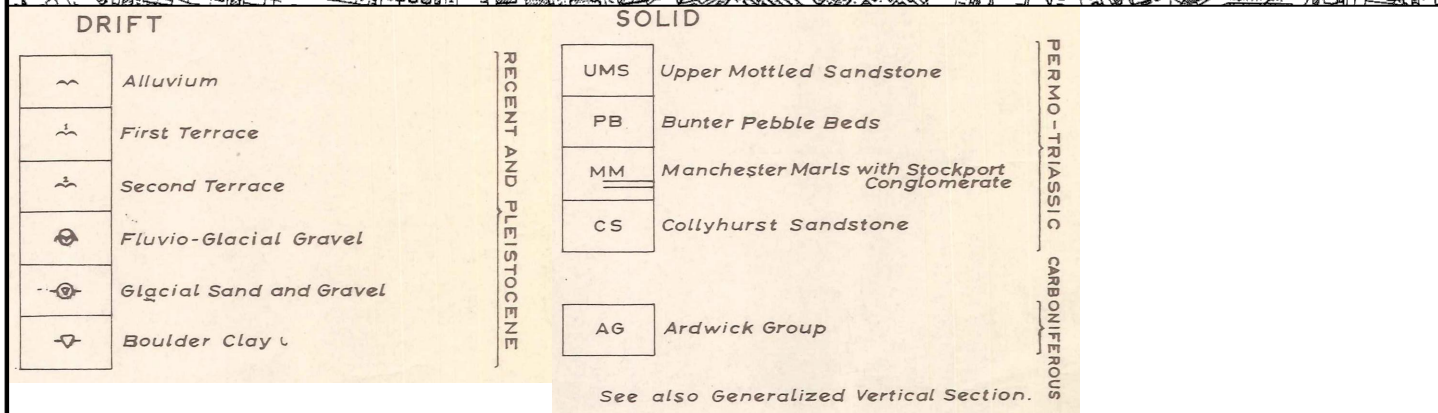
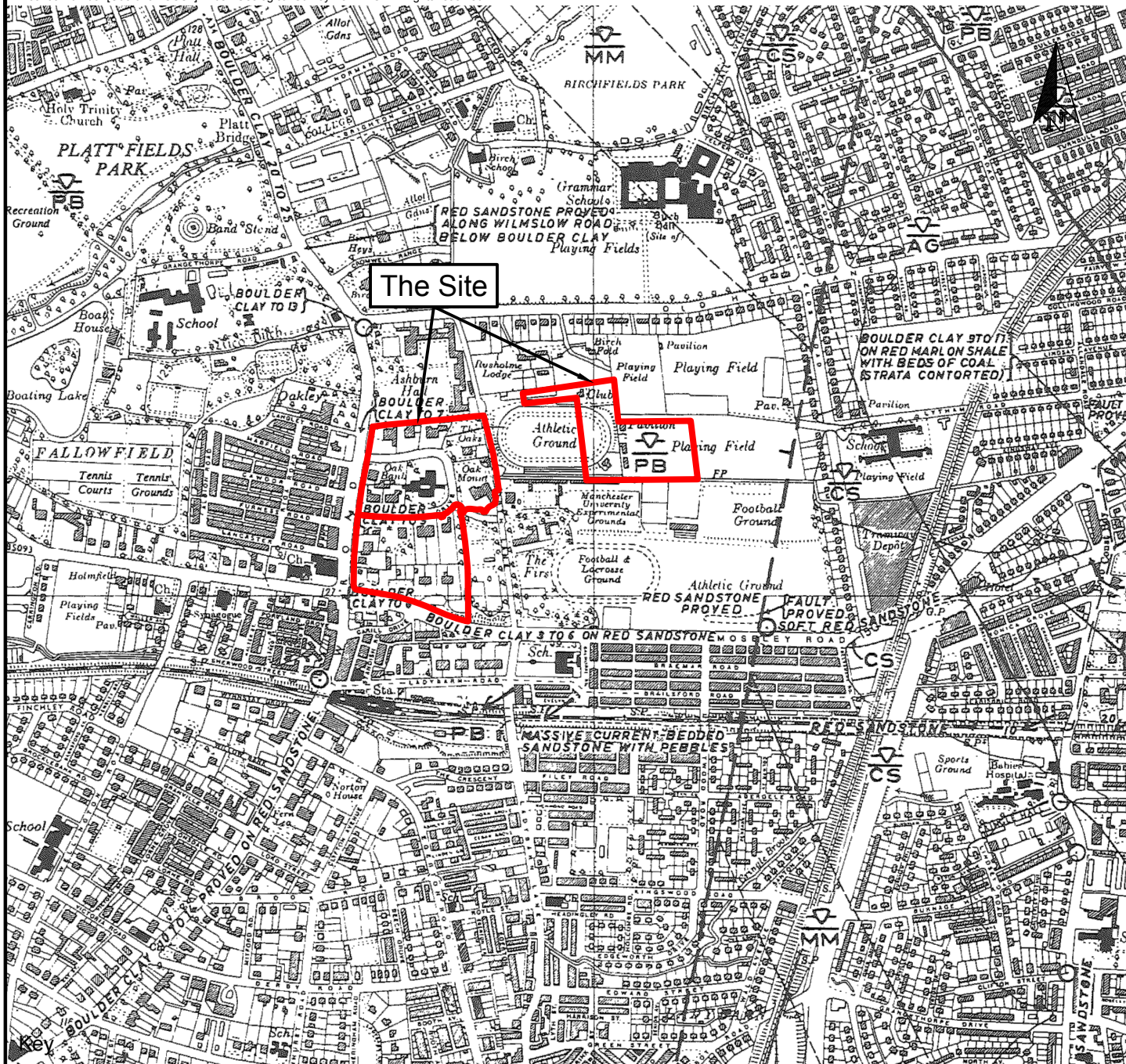
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							checked	MJW
							approved	MJW
							date	12/8/2015
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rev no	revision note					date	checked	approved
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coffey

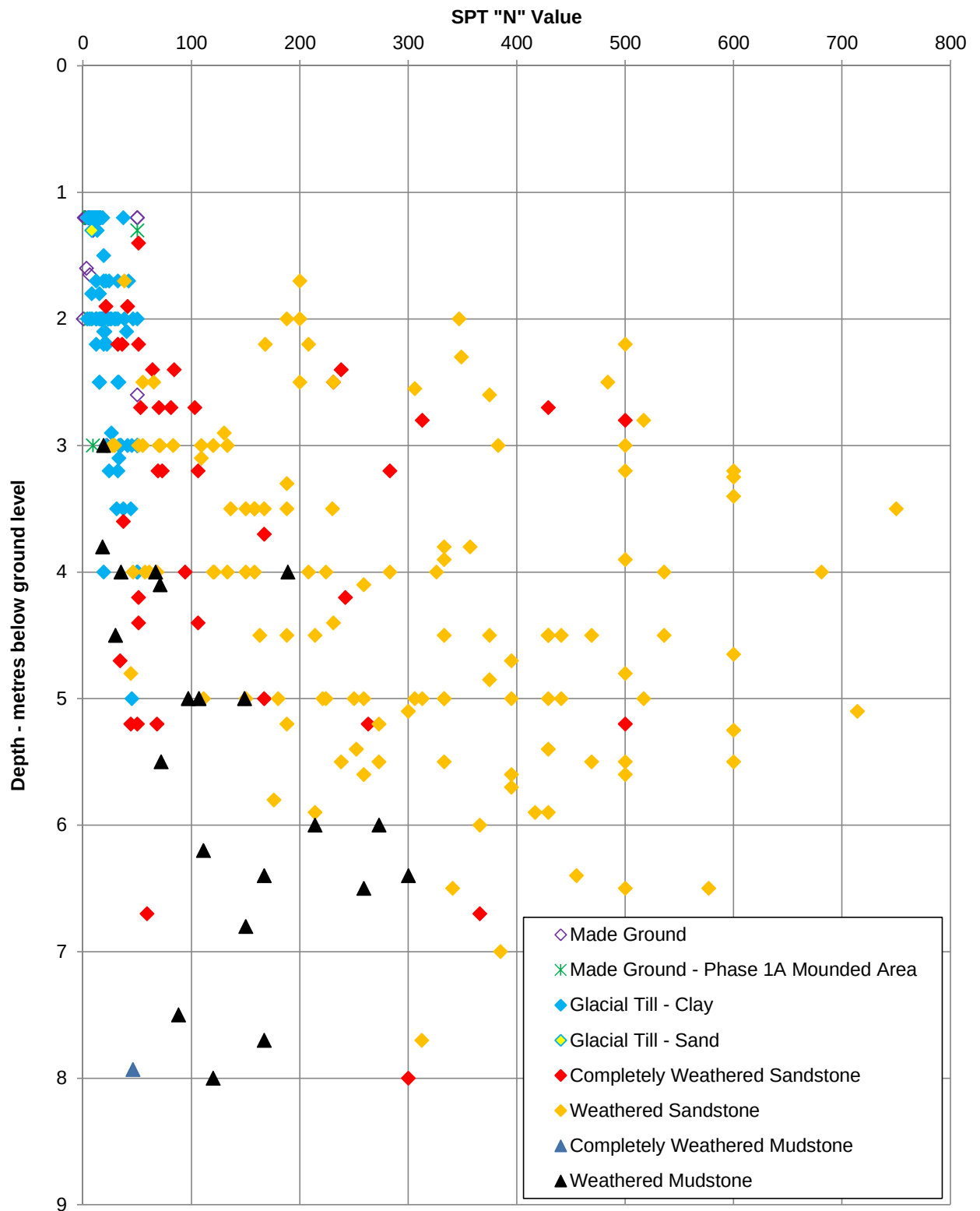
UK offices:
Harrington
Manchester
Reading
Website
www.coffey.com

Registered Office: 1 Northfield Road, Reading, Berkshire RG1 8AH United Kingdom
Registered in England No 06328315

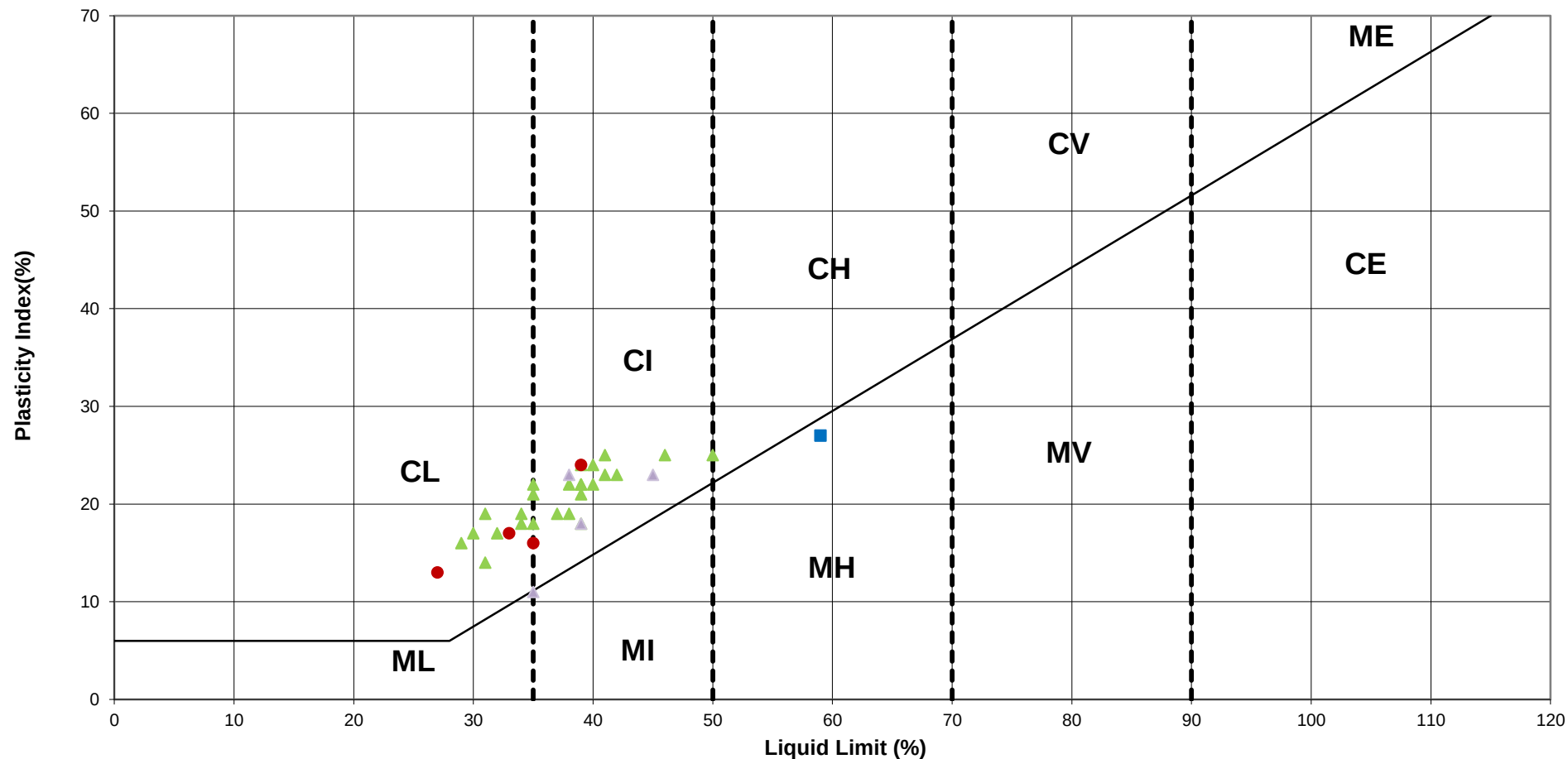
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project:	PROJECT OAK GROUND INVESTIGATION - STAGE 2B		
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project no:	02428AA	fig no:	FIGURE 4
rev:			



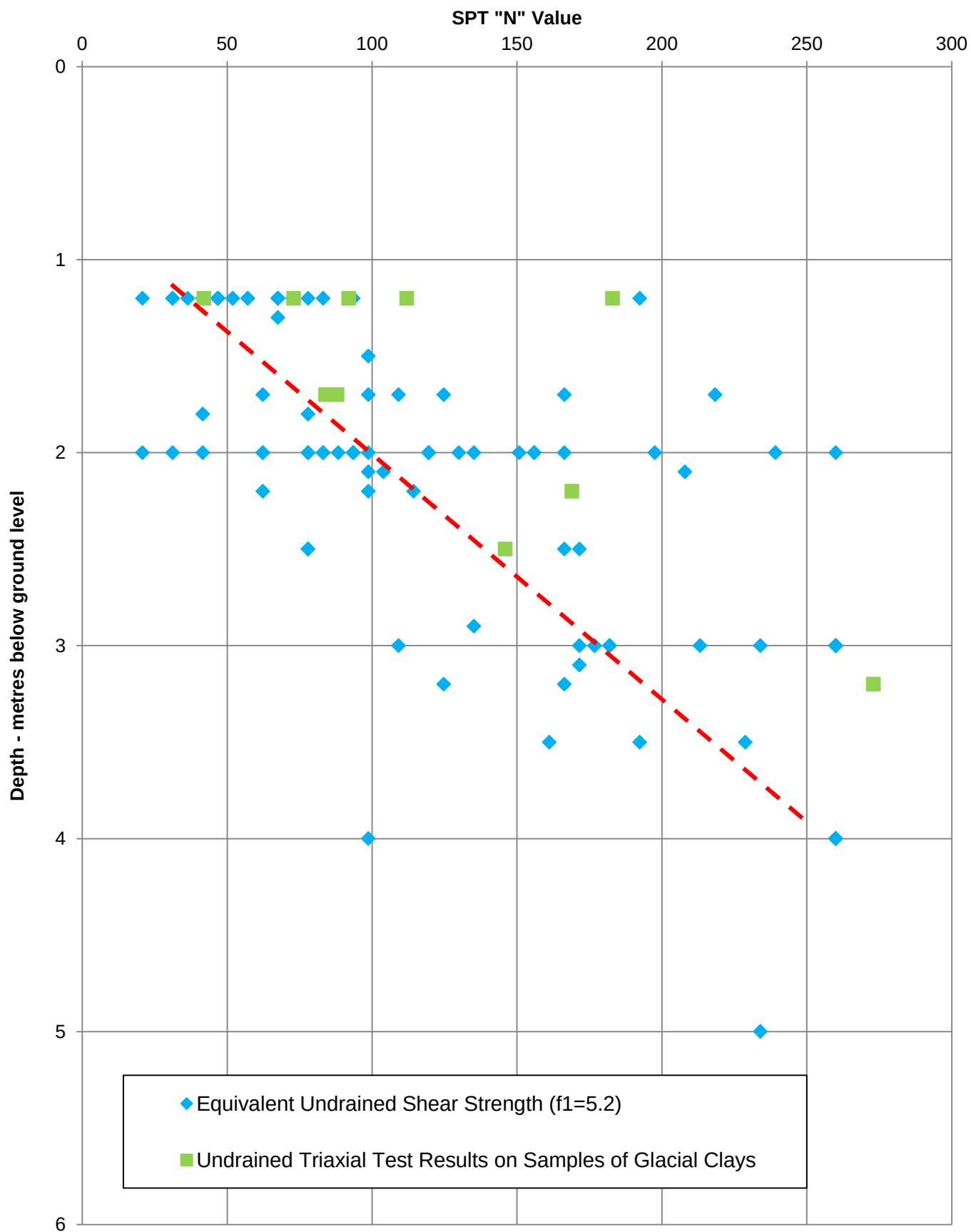
drawn	SN / MJW		client:	BDP	
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original size	A4		project no:	02428AA	fig no: Figure 5



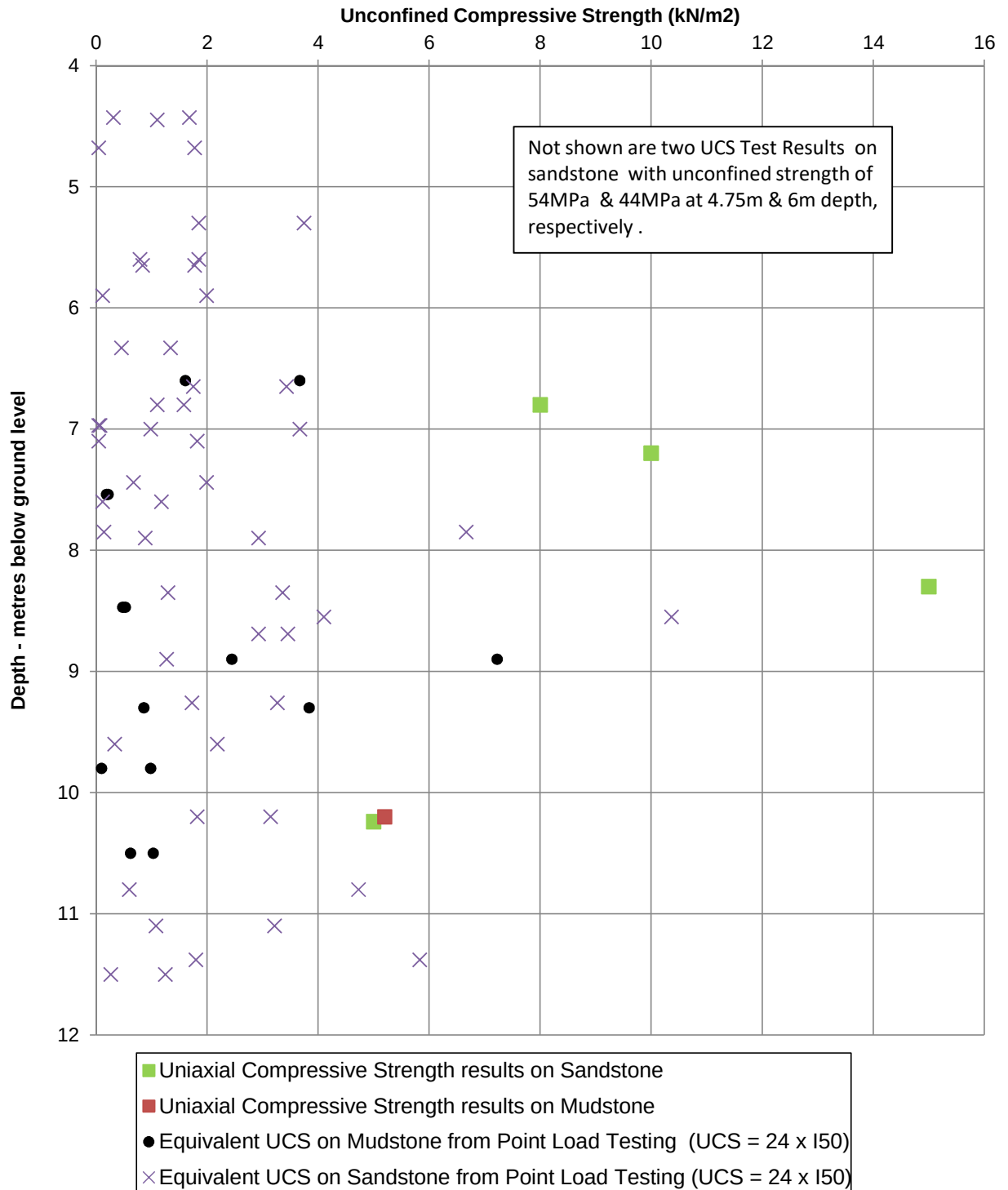
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original size	A4		project no:	02428AA	figure no:	6



drawn	MJW		client:	BDP		
approved	MJW		project:	PROJECT OAK GROUND INVESTIGATION STAGE 2B		
date	21/08/2015					
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original size	A4		project no:	02428AA	figure no:	7



drawn	MJW		client:	BDP		
approved	MJW		project:	PROJECT OAK		
date	21/08/2015			GROUND INVESTIGATION		
scale	N.A.		title:	Cu Value vs Depth		
original size	A4		project no:	02428AA	figure no:	8



drawn	MJW		client:	BDP		
approved	MJW		project:	PROJECT OAK		
date	04/09/2015			GROUND INVESTIGATION		
scale	N.A.		title:	UCS Value vs Depth		
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Appendix A

Generic Assessment Criteria

F GENERIC ASSESSMENT CRITERIA

F1 Background

Where land has been affected by contamination it may present a risk to a range of receptors including humans, ecosystems, water quality and property. The Environment Agency Report 'Model Procedures for the Management of Land Contamination, CLR11' provides the technical framework for applying a risk management process when dealing with contaminated land risk. The process involves identifying, making decisions on, and taking appropriate actions to deal with land contamination in a way that is consistent with UK government policies and legislation. The technical approach in CLR11 is designed to be applicable to a range of non-regulatory and regulatory contexts including the redevelopment of land under the planning regime.

The model procedures include a tiered approach to deal with risk. The first tier includes an evaluation of pollutant linkages using generic assessment criteria in order to assess whether contamination presents an unacceptable level of risk.

Published Generic Assessment Criteria (GACs) are available from a number of sources. The Environment Agency has published generic assessment criteria in the form of Soil Guideline Values for eleven contaminants. For derivation of generic assessment criteria for other contaminants, the Environment Agency has made available the modelling software 'CLEA version 1.06'. The software is based on the CLEA model. The CLEA model uses generic assumptions about the fate and transport of chemicals in the environment and a generic conceptual model for site condition and human behaviour to estimate exposure thresholds.

The CLEA software, (including previous versions of the programme), has been used by the Chartered Institute of Environmental Health (CIEH) in partnership with Land Quality Management (LQM) to derive generic assessment criteria for a range of compounds for which Soil Guideline Values do not exist. This information has been complimented by derivation of further generic assessment criteria by the Environmental Industries Commission (EIC) in collaboration with CL:AIRE and the Association of Geotechnical and Geoenvironmental Specialists (AGS).

The Human Health Risk Assessment presented in this report compares contamination concentrations with published generic assessment criteria.

F2 CLEA Model (Soil)

The CLEA model uses generic assumptions about the fate and transport of chemicals in the environment and a generic conceptual model for site conditions and human behaviour to estimate child and adult exposures to soil contaminants for those potentially living, working, and/or playing on contaminated sites over long time periods. These modelled exposure limits are compared to established Health Criteria Values (HCVs). DEFRA state that the HCVs are set levels of minimal or tolerable risk for long-term human exposure to chemicals in soil. They represent a baseline and health protective position to minimise risks of significant harm.

The aim of the CLEA model is to estimate human exposure to chemicals in soil in terms comparable with relevant HCVs including the Tolerable Daily Intake and the Index Dose. Exposure is defined as contact between a chemical and the external surfaces of the human body (IPCS, 2005).

The CLEA model estimates the Average Daily Exposure (ADE) to a contaminant in soil via the following pathways:

- By ingestion through the mouth (as intake);
- By inhalation through the nose and mouth (as intake);
- By absorption through the skin (as uptake).

Environment Agency Soil Guideline Values

The Environment Agency Soil Guideline Values are set at the soil concentration where the Average Daily Exposure from soil sources by a particular pathway equals the Health Criteria Value.

For many substances, exposure by all pathways may contribute to the same toxic effect and therefore the overall exposure could be more than the Health Criteria Value. To combat this, the SGV is set so that the total risk from exposure via all pathways is mathematically no greater than the risk by any single pathway.

The Soil Guideline Values have been calculated by the Environment Agency as 'trigger values' which indicate that soil concentrations above this level may pose a possibility of significant harm to human health. However, they do not automatically represent an unacceptable intake in the context of part 2A of the Environmental Protection Act 1990. They can only be used for human receptors and to assess risks from long term exposure to chemical contamination in soil.

Where a representative contaminant concentration in the soil is at or below the GAC it can be assumed that it is very unlikely to pose a "significant possibility of significant harm" (Defra, 2012).

Where a representative contaminant concentration in the soil exceeds the GAC, there are three possibilities in terms of determining significant possibility of significant harm under Part 2A (Defra, 2008):

- the possibility of significant harm is negligible (for a range of reasons).
- There may be a "non-significant" possibility of significant harm.
- There may be a significant possibility of significant harm.

If the concentration is above the GAC then a more detailed evaluation of human health risks will usually need to be conducted.

LQM/CIEH Generic Assessment Criteria Second Edition

The LQM/CIEH Generic Assessment Criteria (GAC) have been derived using the CLEA v1.06 model released in 2011 for soil contaminants for which there are no Environment Agency Soil Guideline Values. Input parameters have been drawn from Environment Agency documents or where none exist, from other reliable sources in accordance with relevant Environment Agency guidance.

EIC/AGS/CL:AIRE Generic Assessment Criteria

The EIC/AGS/CL:AIRE GAC have been derived using CLEA version 1.06 for a number of land use scenarios: residential with consumption of home-grown produce; residential without consumption of home-grown produce; allotments and commercial land use. Each scenario has GAC derived for three soil organic matter (SOM) contents; 1%, 2.5% and 6%.

US EPA Regional Screening Level Generic Assessment Criteria

Where UK published GACs are not available, reference may be made to the US Environmental Protection Agency (EPA) Regional Screening Levels (RSLs). It is noted that the US EPA values have no standing in the UK. However, if required for reference purposes Coffey compare US EPA RSLs against the individual laboratory results. Where recorded concentrations are less than one order of magnitude below the US EPA RSL, Coffey considers the determinand is unlikely to present a significant risk to human health.

Where the chemical concentrations encountered on site have not exceeded the laboratory method detection limit (LOD), GACs have not been calculated.

F3 Leachate and Groundwater

The available leachate and groundwater results have been directly compared to the UK Drinking Water Standards (UK DWS) initially. Where UK DWs are not available, the groundwater and leachate concentrations have been compared to the Environment Agency's Environmental Quality Standards (EQS), which are derived for the protection of aquatic life.

Comparison is also made with the River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010.

Where a determinand is present at a concentration below the criteria, the determinand is considered not to represent a risk to controlled waters. Where a determinand is present at a concentration above the corresponding criteria, the determinand may represent a risk to controlled waters. This screening process informs the Generic Quantitative Risk Assessment (GQRA) for groundwater.

Appendix B

Soil Screening Tables

GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA) - SOILS

Site: Project Oak
 Project No.: 02428AA
 Client: BDP

Data Source:
SGVs (2009): Derived by the Environment Agency using the CLEA 1.04



Assessment Scenario: RESIDENTIAL

FOR MOUNDED AREA

GAC (2009): Derived by the LQM/CIEH GAC for Human Health Risk Assessment, 2nd Edition) or by CL:AIRE (The Soil Generic Assessment Criteria for Human Health Risk Assessment, published 2009).

INORGANICS & METALS

Document Ref: 02428AA_X_002C_MJW- Project Oak-Stable 2b.xls

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)						
			TPA1	TPA2	TPA2	TPA4	TPA5	TPA3	
			0.5m	0.5m	4.3m	0.25m	1.5m	1.5m	
			MG	MG	MG	MG	MG	MG	
Arsenic	32	1	2.9	10.1	28.9	16.2	33.8	16.8	
Cadmium	10	0	4.8	<0.1	<0.1	<0.1	<0.1	0.5	
Chromium III	3000	0	37	75	77	69.8	74.2	21.8	
Copper	2330	0	27	26	249	45	256	71	
Lead	450	1	26	37	1579	70	148	143	
Mercury - Elemental	1	0	<0.1	0.1	0.3	0.1	0.2	0.2	
Nickel	130	0	23.2	37.5	55.5	33.8	47.6	28.3	
Selenium	350	0	<1	<1	<1	<1	<1	<1	
Zinc	3750	0	39	76	403	76	130	120	
Cyanide - Total	No Criteria	0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Boron	291	0	0.3	0.9	1.3	0.8	1.3	1.2	

ORGANICS

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)						
			TPA1	TPA2	TPA2	TPA4	TPA5	TPA3	
			0.5m	0.5m	4.3m	0.25m	1.5m	1.5m	
Naphthalene	1.5	1	0.83	0.42	0.15	0.23	0.32	2.89	
Acenaphthylene	170	0	0.34	0.83	0.05	0.3	0.16	1.62	
Acenaphthene	210	0	2.24	0.72	0.62	0.97	0.9	1.28	
Fluorene	160	0	1.77	1.1	0.81	0.65	0.66	2.67	
Phenanthrene	92	0	15.47	9.37	8.83	8.62	7.89	14.75	
Anthracene	2300	0	3.47	2.17	1.59	2.14	1.83	3.61	
Fluoranthene	260	0	19.35	9.63	7.62	14.14	9.69	12.07	
Pyrene	560	0	16.56	8.79	6.12	12.61	8.6	11.54	
Benzo[a]anthracene	3.1	6	7.21	4.54	3.69	7.08	3.46	4.56	
Chrysene	6	2	8.07	4.32	3.53	6.1	3.99	4.99	
Benzo[b]fluoranthene	5.6	2	9.63	4.49	4.1	7.39	4.5	5.03	
Benzo[k]fluoranthene	8.5	0	3.74	1.74	1.6	2.88	1.75	1.96	
Benzo[a]pyrene	0.83	6	8.65	4.29	3.18	6.52	3.98	5.21	
Indeno[123-cd]pyrene	3.2	2	5.07	2.3	1.69	3.86	2.46	2.69	
Dibenzo[ah]anthracene	0.76	1	0.78	0.4	0.38	0.37	0.31	0.45	
Benzo[ghi]perylene	44	0	4.95	2.42	1.64	3.75	2.55	2.74	
Benzene	0.33	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Toluene	610	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Ethylbenzene	350	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
p-xylene	240	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
o-xylene	250	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Methyl tertiary butyl ether (MTBE)	49	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Phenol	210	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Aliphatics EC 5-6	30	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >6-8	73	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >8-10	19	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >10-12	93	0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Aliphatics EC >12-16	740	0	<4	<4	<4	<4	<4	<4	
Aliphatics EC >16-35	45000	0	38	<26	105	81	<26	<19	
Aromatics EC 5-7 (benzene)	65	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aromatics EC >7-8 (toluene)	120	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aromatics EC >8-10	27	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
Aromatics EC >10-12	69	0	<0.2	<0.2	8.9	5	27	0.4	
Aromatics EC >12-16	140	0	15	8	83	46	106	14	
Aromatics EC >16-21	250	3	141	49	473	264	283	108	
Aromatics EC >21-35	890	1	376	122	990	575	420	296	
Total PAH	No Criteria	0	108.1	57.5	45.6	77.6	53.1	78.1	
Organic Matter			2.5	4.1	9.9	12.1	21.4	-	

GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA) - SOILS

Site: Project Oak
 Project No.: 02428AA
 Client: BDP

Assessment Scenario: RESIDENTIAL

FOR PHASE 1A

INORGANICS & METALS

Data Source:
SGVs (2009): Derived by the Environment Agency using the CLEA
GAC (2009): Derived by the LQM/CIEH GAC for Human Health Risk Assessment, 2nd Edition) or by CL:AIRE (The Soil Generic Assessment Criteria for Human Health Risk Assessment, published 2009).

Document Ref: 02428AA_X_002C_MJW- Project Oak-Stable 2b.xls

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)						
			BH05/1A	BH02/1A	BH06/1A	BH15/1A	BH07/1A	BH17/1A	BH01/1A
			1.0m	1.00m	0.2m	0.2m	0.2m	0.5m	1.00m
			MG	MG	MG	MG	MG	MG	CLAY
Arsenic	32	2	21	33.4	31.1	18.5	60.1	16.9	13.6
Cadmium	10	0	0.1	0.3	0.3	0.2	<0.1	0.2	0.1
Chromium III	3000	0	18.2	27.7	18	79.1	99.2	69.3	25.8
Copper	2330	0	116	105	106	79	124	65	38
Lead	450	0	293	164	120	129	240	114	84
Mercury - Elemental	1	1	1	0.1	7.3	0.4	0.4	0.4	0.9
Nickel	130	0	31.2	44.5	55.4	22.6	46.8	31.3	20
Selenium	350	0	<1	<1	1	1	2	1	<1
Zinc	3750	0	151	156	82	95	110	96	58
Cyanide - Total	No Criteria	0	<0.5	1	<0.5	<0.5	<0.5	<0.5	6.9
Boron	291	0	0.7	0.9	1.4	0.7	0.7	1.1	1.9

ORGANICS

SOM (%)	1	Soil Concentration (mg/kg)							
Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	BH05/1A	BH02/1A	BH06/1A	BH15/1A	BH07/1A	BH17/1A	BH01/1A
			1.0m	1.00m	0.2m	0.2m	0.2m	0.5m	1.00m
Naphthalene	1.5	3	45.08	9.02	0.28	4.36	0.7	0.68	0.11
Acenaphthylene	170	0	7.14	4.64	0.32	1.17	0.44	0.69	<0.03
Acenaphthene	210	0	38.47	11.36	0.95	15.02	1.18	1.75	<0.05
Fluorene	160	0	37.61	12.07	0.68	8.09	0.94	1.57	0.05
Phenanthrene	92	1	217.53	89.67	7.1	76.47	8.1	13.32	0.4
Anthracene	2300	0	44.49	21.65	1.42	14.24	1.65	2.79	0.1
Fluoranthene	260	0	180.32	105.56	8.97	76.28	10.89	14.35	0.56
Pyrene	560	0	173.35	97	8.37	67.94	11.01	14.17	0.58
Benzo[a]anthracene	3.1	6	65.17	34.15	4.09	28.11	5.76	7.02	0.33
Chrysene	6	5	91.9	45.78	4.43	35.93	6.04	7.78	0.37
Benzo[b]fluoranthene	5.6	4	72.96	43.04	3.58	29.51	5.28	6.49	0.32
Benzo[k]fluoranthene	8.5	3	28.38	16.74	1.38	11.47	2.05	2.53	0.13
Benzo[a]pyrene	0.83	6	69.93	41.21	3.39	25.67	4.89	6	0.31
Indeno[123-cd]pyrene	3.2	4	32.01	24.61	1.78	12.95	2.71	3.28	0.16
Dibenzo[ah]anthracene	0.76	3	7.18	3.44	0.25	2.66	0.58	0.55	<0.04
Benzo[ghi]perylene	44	0	37.81	18.65	1.74	14.39	2.81	3.46	0.16
Benzene	0.33	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007
Toluene	610	0	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	0.026
Ethylbenzene	350	0	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005
p-xylene	240	0	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	0.012
o-xylene	250	0	0.016	0.009	<0.0005	<0.005	<0.005	<0.005	<0.005
Methyl tertiary butyl ether (MTBE)	49	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenol	210	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aliphatics EC >10-12	93	0	<0.2		<0.2	<0.2	<0.2	<0.2	
Aromatics EC >10-12	69	0	16.7		0.4	1	0.3	0.5	
Aliphatics EC >12-16	740	0	<4		<4	<4	<4	<4	
Aromatics EC >12-16	140	1	185		24	30	23	18	
Aliphatics EC >16-35	45000	0	29		<17	<14	<14	<14	
Aromatics EC >16-21	250	2	1156		154	268	150	126	
Aromatics EC >21-35	890	1	2556		332	647	367	270	
Aliphatics EC 5-6	30	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >6-8	73	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >35-44	45000	0	<7						
Aromatics EC >7-8 (toluene)	120	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aromatics EC >35-44	890	0	256						
Total PAH	No Criteria	0	1149.3	578.6	48.7	424.3	65	86.4	3.6
Total EPH (C8-C40)			7148	3441					270
Asbestos screen			Chrysotile	Chrysotile	Chrysotile	NAD	NAD	NAD	NAD
Asbestos Level			Quantifiable	Quantifiable	Quantifiable	None 9	None 18.8	None 7.2	None
Organic Matter									
SOM				1.1					35.2

GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA) - SOILS

Site: Project Oak
 Project No.: 02428AA
 Client: BDP

Data Source:
SGVs (2009): Derived by the Environment Agency using the CLEA

GAC (2009): Derived by the LQM/CIEH GAC for Human Health Risk Assessment, 2nd Edition) or by CL:AIRE (The Soil Generic Assessment Criteria for Human Health Risk Assessment, published 2009).

Assessment Scenario: RESIDENTIAL

FOR PHASE 1A (CONT.)

INORGANICS & METALS

Document Ref: 02428AA_X_002C_MJW- Project Oak-Stable 2b.xls

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)					
			BH16/1A	BH16/1A				
			2m	0.5m				
			CLAY	MG				
Arsenic	32	0						
Cadmium	10	0						
Chromium III	3000	0						
Copper	2330	0						
Lead	450	0						
Mercury - Elemental	1	0						
Nickel	130	0						
Selenium	350	0						
Zinc	3750	0						
Cyanide - Total	No Criteria	0						
Boron	291	0						

ORGANICS

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)					
			BH16/1A	BH16/1A				
			2m	0.5m				
Naphthalene	1.5	0	<0.04	0.61				
Acenaphthylene	170	0	<0.03	0.39				
Acenaphthene	210	0	<0.05	0.72				
Fluorene	160	0	<0.04	0.65				
Phenanthrene	92	0	<0.03	5.76				
Anthracene	2300	0	<0.04	1.37				
Fluoranthene	260	0	<0.03	9.1				
Pyrene	560	0	<0.03	8.58				
Benzo[a]anthracene	3.1	1	<0.06	4.83				
Chrysene	6	0	<0.02	4.77				
Benzo[b]fluoranthene	5.6	0	<0.05	4.44				
Benzo[k]fluoranthene	8.5	0	<0.02	1.72				
Benzo[a]pyrene	0.83	1	<0.04	4.56				
Indeno[123-cd]pyrene	3.2	0	<0.04	2.46				
Dibenzo[ah]anthracene	0.76	0	<0.04	0.51				
Benzo[ghi]perylene	44	0		2.54				
Benzene	0.33	0	<0.005	<0.005				
Toluene	610	0	<0.005	<0.005				
Ethylbenzene	350	0	<0.005	<0.005				
p-xylene	240	0	<0.005	<0.005				
o-xylene	250	0	<0.005	<0.005				
Methyl tertiary butyl ether (MTBE)	49	0	<0.005	<0.005				
Phenol	210	0						
Aliphatics EC >10-12	93	0	<0.2	<0.2				
Aromatics EC >10-12	69	0	<0.2	<0.2				
Aliphatics EC >12-16	740	0	<4	<4				
Aromatics EC >12-16	140	0	<4	7				
Aliphatics EC >16-35	45000	0	<14	<14				
Aromatics EC >16-21	250	0	<7	68				
Aromatics EC >21-35	890	0	<7	207				
Aliphatics EC 5-6	30	0	<0.1	<0.1				
Aliphatics EC >6-8	73	0	<0.1	<0.1				
Aliphatics EC >35-44	45000	0						
Aromatics EC >7-8 (toluene)	120	0	<0.1	<0.1				
Aromatics EC >35-44	890	0						
Total PAH	No Criteria	0	<0.6	53				

Total EPH (C8-C40)

Asbestos screen

Asbestos Level

Organic Matter

SOM



GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA) - SOILS

Site: Project Oak
 Project No.: 02428AA
 Client: BDP

Data Source:
SGVs (2009): Derived by the Environment Agency using the CLEA 1.04

Assessment Scenario: RESIDENTIAL

GAC (2009): Derived by the LQM/CIEH GAC for Human Health Risk Assessment, 2nd Edition) or by CL:AIRE (The Soil Generic Assessment Criteria for Human Health Risk Assessment, published 2009).

FOR PHASE 1B

INORGANICS & METALS

Document Ref: 02428AA_X_002C_MJW- Project Oak-Stable 2b.xls

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	BH03/1B	WS01/1B	TP03/1B	TP04/1B	TP05/1B	TP01/1B	
			1.00m	1.00m	0.75m	0.25m	0.5m	0.25m	
			MG	Clay	MG	MG	MG	MG	
Arsenic	32	0	7	8.3	27.6	10.6	9.8	9.1	
Cadmium	10	0	0.8	<0.1	0.5	0.2	<0.1	0.3	
Chromium III	3000	0	32.3	40.3	64.7	70.8	101.9	77.5	
Copper	2330	0	57	22	1055	46	10	22	
Lead	450	0	87	14	259	125	39	93	
Mercury - Elemental	1	1	<0.1	<0.1	6.8	0.5	<0.1	0.1	
Nickel	130	0	36.5	19.5	36	14.5	19.3	18.9	
Selenium	350	0	<1	<1	<1	1	1	<1	
Zinc	3750	0	93	53	161	111	57	85	
Cyanide - Total	No Criteria	0	1.7	<0.5	<0.5	<0.5	<0.5	2.6	
Boron	291	0	0.2	0.4	0.6	0.7	0.5	0.6	

ORGANICS

SOM (%)		1							
Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	BH03/1B	WS01/1B	TP03/1B	TP04/1B	TP05/1B	TP01/1B	
			1.00m	1.00m	0.75m	0.25m	0.5m	0.25m	
Naphthalene	1.5	0	0.92	<0.04	1.01	0.21	0.07	0.34	
Acenaphthylene	170	0	4.3	<0.03	1.81	0.14	0.06	0.67	
Acenaphthene	210	0	4.6	<0.05	5.6	0.28	0.17	0.77	
Fluorene	160	0	4.59	<0.04	5.75	0.25	0.13	0.9	
Phenanthrene	92	0	60.01	<0.03	77.04	2.55	1.44	10.93	
Anthracene	2300	0	19.85	<0.04	30.24	0.58	0.27	3.25	
Fluoranthene	260	0	135.38	<0.03	177.41	3.31	1.84	19.41	
Pyrene	560	0	113.12	<0.03	144.48	3.02	1.82	17.23	
Benzo[a]anthracene	3.1	3	58.22	<0.06	46.52	1.05	0.8	7.06	
Chrysene	6	3	64.45	<0.02	56.59	1.55	1.01	7.62	
Benzo[b]fluoranthene	5.6	3	80.76	<0.05	56.71	1.67	0.95	8.7	
Benzo[k]fluoranthene	8.5	2	31.4	<0.02	22.05	0.65	0.37	3.39	
Benzo[a]pyrene	0.83	5	71.18	<0.04	52	1.46	0.97	8.81	
Indeno[123-cd]pyrene	3.2	3	44.45	<0.04	27.31	0.75	0.47	4.65	
Dibenzo[ah]anthracene	0.76	2	7.13	<0.04	3.15	0.16	0.08	0.37	
Benzo[ghi]perylene	44	0	39.68	<0.04	26.14	0.8	0.53	3.8	
Benzene	0.33	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Toluene	610	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Ethylbenzene	350	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
p-xylene	240	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
o-xylene	250	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Methyl tertiary butyl ether (MTBE)	49	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Phenol	210	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Aliphatics EC 5-6	30	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >6-8	73	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >8-10	19	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aliphatics EC >10-12	93	0	<0.2		2.6	<0.2	<0.2	<0.2	
Aliphatics EC >12-16	740	0	6		28	<4	<7	<4	
Aliphatics EC >16-35	45000	0	184		157	<37	<26	<33	
Aromatics EC 5-7 (benzene)	65	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aromatics EC >7-8 (toluene)	120	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aromatics EC >8-10	27	0	<0.1		<0.1	<0.1	<0.1	<0.1	
Aromatics EC >10-12	69	0	3.2		23.5	<0.2	<0.2	<0.2	
Aromatics EC >12-16	140	1	81		789	<4	<4	7	
Aromatics EC >16-21	250	2	1141		6795	39	29	28	
Aromatics EC >21-35	890	2	3075		7465	163	94	96	
Aromatics EC >35-44	890	0	369						
Total PAH	No Criteria	0	740	<0.6	733.8	18.4	11	97.9	
Total EPH (C8-C40)			6381	<30					
Asbestos screen			NAD	NAD	NAD	NAD	NAD	NAD	
Asbestos Level			None	None	None	None	None	None	
Organic Matter					2420.00%	7.5	1.8		



GENERIC QUANTITATIVE RISK ASSESSMENT (GORA) - SOILS

Site: Project Oak
Project No.: 02428AA
Client: BDP

Assessment Scenario: RESIDENTIAL

FOR PHASE C

INORGANICS & METALS

Data Source:

SGVs (2009): Derived by the Environment Agency using the CLEA

GAC (2009): Derived by the LQM/CIEH GAC for Human Health Risk Assessment, 2nd Edition) or by CL:AIRE (The Soil Generic Assessment Criteria for Human Health Risk Assessment, published 2009).

Document Ref: 02428AA_X_002C_MJW- Project Oak-Stable 2b.xls

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)							
			BH05/2	BH02/2	BH07/2	BH20/2	TP02/2	WS05/2	BH17/2	WS02/2
			1.00m	1.00m	0.5m	0.2m	0.3m	0.5m	0.5m	0.5m
			MG	Clay	MG	MG	MG	MG	MG	MG
Arsenic	32	1	6.1	7.4	20.4	34.2	8.7	11.7		
Cadmium	10	0	<0.1	<0.1	0.5	0.7	<0.1	<0.1		
Chromium III	3000	0	32.8	42.9	109.6	78.3	96.4	102		
Copper	2330	0	10	21	44	87	19	99		
Lead	450	0	27	12	279	156	46	108		
Mercury - Elemental	1	0	<0.1	<0.1	0.4	0.7	0.2	0.1		
Nickel	130	0	10.6	24	27.2	33.1	16.4	44.4		
Selenium	350	0	1	<1	<1	<1	2	3		
Zinc	3750	0	45	53	120	152	58	105		
Cyanide - Total	No Criteria	0	1	<0.5	1	2	<0.5	<0.5		
Boron	291	0	0.4	0.4	1.9	2.4	0.7	2.1		

ORGANICS

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	Soil Concentration (mg/kg)							
			BH05/2	BH02/2	BH07/2	BH20/2	TP02/2	WS05/2	BH17/2	WS02/2
			1.00m	1.00m	0.5m	0.2m	0.3m	0.5m	0.5m	0.5m
Naphthalene	1.5	2	<0.04	<0.04	<0.04	12.99	<0.04	87.37	0.06	0.24
Acenaphthylene	170	0	<0.03	<0.03	0.06	6.85	<0.03	33.44	0.04	0.13
Acenaphthene	210	0	<0.05	<0.05	<0.05	9.16	<0.05	46.65	0.07	0.25
Fluorene	160	0	<0.04	<0.04	0.05	12.35	<0.04	54.4	<0.04	0.21
Phenanthrene	92	1	<0.03	<0.03	0.57	82.58	0.31	365.11	0.32	1.13
Anthracene	2300	0	<0.04	<0.04	0.14	17.79	0.07	88.38	0.05	0.28
Fluoranthene	260	1	<0.03	<0.03	0.97	73.75	0.49	492.05	0.51	1.63
Pyrene	560	0	<0.03	<0.03	0.91	70.69	0.45	459.62	0.58	1.48
Benzo[a]anthracene	3.1	2	<0.06	<0.06	0.45	28.67	0.26	213.14	0.38	0.61
Chrysene	6	2	<0.02	<0.02	0.52	35.38	0.29	258.93	0.46	0.83
Benzo[b]fluoranthene	5.6	2	<0.05	<0.05	0.51	32.16	0.25	273.43	0.58	0.71
Benzo[k]fluoranthene	8.5	2	<0.02	<0.02	0.2	12.51	0.1	106.33	0.23	0.28
Benzo[a]pyrene	0.83	3	<0.04	<0.04	0.49	32.7	0.25	239.65	0.74	0.87
Indeno[123-cd]pyrene	3.2	2	<0.04	<0.04	0.25	16.46	0.13	150.93	0.27	0.32
Dibenzo[ah]anthracene	0.76	2	<0.04	<0.04	0.05	3.03	<0.04	17.94	<0.04	0.05
Benzo[ghi]perylene	44	1	<0.04	<0.04	0.24	16.56	0.13	134.71	0.32	0.29
Benzene	0.33	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Toluene	610	0	<0.005	<0.005	<0.005	<0.005	<0.005	23	<0.005	<0.005
Ethylbenzene	350	0	<0.005	<0.005	<0.005	<0.005	<0.005	11	<0.005	<0.005
p-xylene	240	0	<0.005	<0.005	<0.005	<0.005	<0.005	61	<0.005	<0.005
o-xylene	250	0	<0.005	<0.005	<0.005	<0.005	<0.005	96	<0.005	<0.005
Methyl tertiary butyl ether (MTBE)	49	0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenol	210	0	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.005	<0.005
Aliphatics EC 5-6	30	0			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatics EC >6-8	73	0			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatics EC >8-10	19	0			<0.1	<0.1	<0.1	0.3	<0.1	<0.1
Aliphatics EC >10-12	93	0			<0.2	<0.2	<0.2	7.7	<0.2	<0.2
Aliphatics EC >12-16	740	0			12	<4	<4	47	<4	<4
Aliphatics EC >16-35	45000	0			40	54	<14	194	<25	<14
Aromatics EC 5-7 (benzene)	65	0			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aromatics EC >7-8 (toluene)	120	0			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aromatics EC >8-10	27	0			<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Aromatics EC >10-12	69	0			<0.2	9.2	<0.2	51.2	<0.2	<0.2
Aromatics EC >12-16	140	1			<4	101	<4	390	<4	<4
Aromatics EC >16-21	250	2			18	513	<7	2300	<7	10
Aromatics EC >21-35	890	2			102	999	<7	4969	58	56
Total PAH	No Criteria	0	<0.6	<0.6	5.4	463.6	2.7	3022.1	4.6	9.3
Total EPH (C8-C40)			<30	100						
Asbestos screen			NAD	NAD	NAD	NAD	NAD	NAD		
Asbestos Level			None	None	None	None	None	None		
SOM				<0.2						
Organic Matter					5.1	21.5	2.2	7.7		

Appendix C

Groundwater Screening Tables

Site: Project Oak
Project No.: 02428AA
Client: BDP
Sample Collection Date: 25/06/2015

1 - UK Drinking Water Standards (UK DWS)
2 - Environmental Quality Standards Freshwater (EQS FW)
3 - World Health Organisation (WHO)

[illegible]

Appendix D

Summary of CRB Test Results

Summary of CBR Test Results (measured using TRL Probe in Trial Pits)

Made Ground - Fine Grained

Date of Test	Exploratory Hole Ref.	Depth to Top of Test (m)	CBR (%)	General Description of Material (from Trial Pit Logs)
12/06/2015	TP01/1A	0.59	7.8	Made Ground - Sand / Clay
12/06/2015	TP02/1A	0.6	4.55	Possible Made Ground - Firm to stiff clay
10/06/2015	TP05/1A	0.765	6.8	Made Ground - Firm Clay
16/06/2015	TP01/1B	0.5	5.75	Made Ground - Firm Clay
17/06/2015	TP02/2	0.54	9.5	Made Ground - Firm to stiff clay
Minimum			5	
Maximum			10	
Average			7	

Made Ground - Course Grained

Date of Test	Exploratory Hole Ref.	Depth to Top of Test (m)	CBR (%)	General Description of Material (from Trial Pit Logs)
15/06/2015	TP03/1B	0.505	55.1	Made Ground - Sand
15/06/2015	TP04/1B	0.51	55.1	Made Ground - Sand
Minimum			55	
Maximum			55	
Average			55	

Glacial Till - Clays

Date of Test	Exploratory Hole Ref.	Depth to Top of Test (m)	CBR (%)	General Description of Material (from Trial Pit Logs)
12/06/2015	TP03/1A	0.57	4.35	Firm to stiff CLAY
10/06/2015	TP04/1A	0.635	11.35	Firm becoming stiff CLAY
16/06/2015	TP02/1B	0.45	14.7	Firm CLAY
15/06/2015	TP05/1B	0.52	6.7	Soft to firm CLAY
17/06/2015	TP01/2	0.825	8.3	Stiff CLAY (Glacial Till)
16/06/2015	TP03/2	0.45	15.8	Firm to stiff CLAY
16/06/2015	TP04/2	0.51	7	Firm to stiff CLAY
17/06/2015	TP05/2	0.635	7.4	Firm CLAY
17/06/2015	TP06/2	0.52	5.4	Stiff CLAY
Minimum			4	
Maximum			16	
Average			9	

Notes

1. In-situ CBR test using TRL Probe carried out in Trial Pits at depths of about 0.45m.
2. Full details of individual results are given in Geotechnics Factual Report for Stage 2b.
3. CBR Values calculated using correlation in Highways Agency Interim Advice Note 73/06.
4. CBR Values reported above are 50% percentile of CBR reported by Geotechnics in the upper 500mm, ignore the first value.

Appendix E

Chemical Test Results for Assessment of Aggressivity towards Concrete

CHEMICAL TEST RESULTS FOR ASSESSMENT OF AGGRESSIVITY TOWARD CONCRETE

Site: Project Oak
Project No.: 02428AA
Client: BDP
Samples: Soil



Areas	Exploratory Holes	Depth m	Sulphur %	Total Sulphate (BRE) %	Sulphate as SO4 (2:1 Ext) g/l	pH	Soil Type
Phase 1A	BH01/1A	0.3	0.08	0.09	0.152	8.76	Made Ground
	BH06/1A	0.5	0.02	0.02	0.0304	5.79	Made Ground
	BH14/1A	0.2	0.03	0.03	0.0093	7.03	Made Ground
	BH08/1A	0.2	0.03	0.04	0.0212	5.85	Made Ground
	BH18/1A	0.6	0.14	0.15	0.3819	7.71	Made Ground
Phase 1A - Mound Area							
	TPA1	1.5	0.11	0.05	0.0917	7.87	Made Ground
	TPA2	4.3	0.1	0.09	0.2235	7.65	Made Ground
	TPA3	3.9	0.11	0.1	0.3129	7.37	Made Ground
Phase 1B							
	WS04/1B	0.65	0.04	0.05	0.024	8.45	Made Ground
	WS06/1B	0.6	0.02	0.04	0.0217	8.56	Made Ground
	TP02/1B	0.25	0.03	0.04	0.0112	8.08	Made Ground
	TP01/1B	0.25	0.05	0.13	0.2001	8.47	Made Ground
	TP03/1B	0.5	0.02	0.05	0.0164	8.46	Made Ground
	TP04/1B	0.5	0.16	0.37	1.3723	7.91	Made Ground
	TP05/1B	0.25	0.03	0.03	0.0331	8.33	Made Ground
Phase 2							
	TP03/2	0.55	0.04	0.03	0.037	8.75	Made Ground
	TP05/2	0.25	0.03	0.04	0.5915	8.54	Made Ground
	TP02/2	0.3	0.02	0.03	0.0022	7.39	Made Ground
	BH10/2	0.2	<0.01	<0.01	0.0045	9.22	Made Ground
	BH08/2	0.5	0.06	0.08	0.0404	8.51	Made Ground
Maximum			0.16	0.37	1.3723	9.22	
Minimum			0.02	0.02	0.0022	5.79	

Areas	Exploratory Holes	Depth m	Sulphur %	Total Sulphate (BRE) %	Sulphate as SO4 (2:1 Ext) g/l	pH	Soil Geology
Natural							
	BH04/1A	6.5	<0.01	0.01	0.0102	8.61	Weathered Sandstone
	BH02/1A	3.2	<0.01	0.01	0.0225	7.81	Glacial Till
	BH01/2	2.5	0.1	0.27	1.3235	8.49	Glacial Till
	BH02/2	3.5	<0.01	<0.01	0.0225	9.01	Weathered Sandstone
Maximum			<0.01	0.2679	1.3235	9.01	
Minimum			<0.01	0.0065	0.0102	7.81	

Notes

Stage 2a results

CHEMICAL TEST RESULTS FOR ASSESSMENT OF AGGRESSIVITY TOWARD CONCRETE

Site: Project Oak
Project No.: 02428AA
Client: BDP
Samples: Groundwater



Areas	Exploratory Holes	Depth m	Sulphate mg/l	pH			Sample Type
Phase 1A	BH02/1A	1.33	73.38	7.54			Groundwater
	Bh05/1A	0.93	7.54	6.74			Groundwater
	BH08/1A	2.3m	82.97	7.32			Groundwater
Maximum			82.97	7.54			
Minimum			7.54	6.74			

Appendix F

Equivalent Infiltration Rates from Borehole Falling Head Permeability Tests

Calculating Equivalent Infiltration Rate

Assumptions

1. Glacial Clay is impermeable during the period of the test, except for the tests in the material.
2. No groundwater table in the sand / sandstone below glacial till at shallow depth.
3. The infiltration calculations ignore the effect of the head of water.

Borehole Test No. Test Strata	Units	BH01/1A 1 Sand	BH02/1A 2 Sand	BH1/1A 3 Sand	BH02/1B 4 GT-Clay	BH03/1B 5 MG-Clay	WS01/1B 6 Sandstone	WS02/1B 7 Sandstone	WS03/1B 8 Sandstone	BH01/2 9 GT-Clay	BH02/2 10 GT-Clay	BH03/2 11 GT-Clay	BH04/2 12 Sand	BH05/2 13 Sandstone
Depth of casing bgl	m	1.3	1.7	1.5	1.2	2.2	2.15	2.45	3.85	1.8	1.8	1.25	1.8	1.5
Depth of "impermeable" strata bgl	m	4.05	4	2.1										2
Depth of borehole bgl	m	4.2	4.2	2.3	2.2	2.8	2.15	2.45	3.85	3	3.3	1.8	2.5	2.1
Diameter of borehole	m	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15
Depth of water at start of test bgl	m	2	0.86	2	1	0.57	1	0.76	1.6	1.2	2	2	2	2
Depth of water at end of test bgl	m	2.171	1.2	2.276	1.018	0.8	1.09	0.89	1.66	1.22	2.057	2.025	2.085	2.187
Duration of test	mins	60	60	60	30	30	30	30	30	60	60	60	50	60
Estimated Groundwater level	m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Height of "permeable" strata above base for test	m	0.15	0.2	0.2	1	0.6	0	0	0	1.2	1.5	0.55	0.7	0.1
Outflow Volume during test	m ³	0.003	0.006	0.005	0.000	0.004	0.001	0.001	0.000	0.000	0.001	0.000	0.002	0.003
Mean surface area which outflow occurs	m ²	0.088	0.112	0.112	0.489	0.300	0.008	0.008	0.008	0.583	0.725	0.277	0.348	0.065
Soil Infiltration rate	m/s	9.5E-06	1.49E-05	1.21E-05	3.61E-07	7.52E-06	0.00005	7.22E-05	3.33E-05	1.68E-07	3.86E-07	4.43E-07	1.44E-06	1.42E-05

Note

GT - Glacial Till

MG - Made Ground