

BDP

Geoenvironmental and Geotechnical Interpretative Report

Stage 2a

Project Oak, Fallowfield, Manchester

10th August 2015



Results emerge
when local knowledge
intersects with
global expertise

Document Verification

Page 1 of 1

Job title:

Project Oak, Fallowfield, Manchester

Job number

02428AA

Document title

Geoenvironmental and Geotechnical Interpretative
Report Stage 2a

File reference

Document ref

UMRF-COF-XX-XX-RP-Y-00001 (Coffey Ref: 02428AA_R_002A_MJW-Stage 2a)

Issue No	Date	Filename	02428AA_R_001F_MJW-GIR		
1	03/06/15	Description	1 st Issue		
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2	10/08/15	Filename	02428AA_R_002A_MJW-Stage 2a		
		Description	Address BDP comments on 10 June 2015.		
			Prepared by	Checked by	Approved by
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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 comprising of 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 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 was provided by BDP and takes into account for the on-going investigation.
- 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, under the instruction and part-time supervision of Coffey. Details are provided in this report.
- Stage 2b – Principal Ground Investigation – This detailed investigation will be carried out at later date once the results of the Stage 2a investigation are known and evaluated.

This interpretative report presents the findings of the Stage 2a 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 - Geo-Environmental Desk Study Report (Ref. 2) provided by BDP, together with factual information from the ground investigation (Ref.3).

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 PRELIMINARY GROUND INVESTIGATION (STAGE 2A)

2.1 Site Work

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

The ground investigation comprised 2 No. windowless sample holes (WS01-3/1B and WS01/2) and 13 no. cable percussive boreholes (BH01-5/1A, BH01-3/1B & BH01-5/2) 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, a programme of ground gas and groundwater level monitoring was undertaken during the week commencing 20 April 2015; this was programmed to comprise 4 visits at weekly intervals. Monitoring rounds 1 (21 April 2015), 2 (6 May 2015), 3 (14 May 2015) and 4 (22 May 2015) have been completed to date.

The investigation of the mounded vegetated area on eastern side of the Phase 1B area was not undertaken during Stage 2a as it is understood from anecdotal evidence that asbestos containing material (ACM) is present within this area. This mounded area will be 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. 3).

2.2 Laboratory testing

2.2.1 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;
- 5 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.

2.2.2 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).

3 THE SITE

3.1 Site Description

A site walkover was carried out on 30 March 2015 to determine suitable locations for exploratory holes, and the site description is based on observations made during this visit. 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 the 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 4) had been demolished between 1986 and 2002.

3.3 Geology

3.3.1 Published information

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

- British Geological Survey 1:50,000 Scale Geological Sheet 85 – Manchester (solid) (Ref.4)
- British Geological Survey 1:63,360 Scale Geological Sheet 85 – Manchester (drift) (Ref. 5)
- British Geological Survey 1:10,560 Scale Geological Sheet SJ 89 SE (solid and drift) (Ref. 6)
- Memoire for the Geology of Manchester and the South-East Lancashire Coalfield (Ref. 7)

Figure 4 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 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 Phase 2 area, Gore Brook located 400m north of 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. 20).

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 Report (Ref. 3).

3.7 Radon

According the BRE publication BR211, Report: Guidance on Protective Measures for New Dwellings (England and Wales) 2007 (Ref. 8), 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 site 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 ground investigation are summarised in Table 1. The exploratory hole location plan and geological sections are presented in Figures 2 and 3, respectively.

Table 1: Summary of ground conditions

Stratum	Description	Depth to Base (m bgl)	
		Min.	Max.
Topsoil / Hardstanding	Topsoil / Tarmacadam	0	0.3
Made Ground	Mainly sand and gravel including sandstone, ash, clinker, and brick with pockets of clay.	0.4	2.2 (former pond to 3.3m)
Glacial Till	Soft to firm slightly sandy CLAY with occasional gravel	1.0	2.3
	Firm to Stiff slightly sandy CLAY with occasional gravel.	2.1	4.6
Upper Weathered Sandstone (not recorded in places)	Fine to medium SAND	2.7	4.8
Weathered Sandstone / Mudstone	Extremely weak Sandstone (recovered as sand) was encountered over the majority of the site.	Top at 1.85m (Base not proven)	Top at 4.8m (Base not proven)
Note: On the eastern side of Phase 1A area, weathered mudstone (extremely weak mudstone) was encountered from depths between 6.2m and 7.5m (base of mudstone not proven).			

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 reduced level (m bgl) are presented on Figure 5.

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 2.2m depth. The Made Ground generally comprised sand and gravel comprising siltstone, sandstone, quartz, ash, clinker and brick, occasionally within layers of clay. The Made Ground included wood in BH02/1B.

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

Results of particle size distribution tests are presented in Geotechnical Factual Report (Ref. 3).

SPT 'N' values for the Made Ground are presented in Table 2 and graphically on Figure 5.

Table 2: Soil data for Made Ground

Test parameter	Unit	Range	Average	Figure
SPT 'N' value	N/A	2 to 15	8	Fig 5

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 6). The moisture content of the clay was recorded at between 11% and 23%.

The Made Ground was very variable and is not considered a suitable founding material for the design of foundations (see Section 9).

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 2.1m and 4.6m (i.e. base of Glacial Till). The thickness of Glacial Till varies between 0.75m and 3m.

The Glacial Till (cohesive) stratum generally comprised soft becoming firm to stiff slightly sandy slightly gravelly clay. The firm to stiff clay was encountered typically at depths of between 1.5m and 2m, up to 3.3m depths where the Made Ground was found to be deeper.

There was a layer of sand between 1.6m and 2.1m bgl encountered in the Glacial Till in Borehole BH01/1B.

Results of particle size distribution tests are presented in Geotechnical Factual Report (Ref. 3).

SPT 'N' values for Glacial Till are presented in Table 3 and graphically on Figure 5.

Table 3: SPT data for Glacial Till

Test parameter	Unit	Range	Average	Figure
SPT 'N' value	N/A	12 to >50 (refusal)	30	Fig 5

Index testing classified the cohesive material as generally low to intermediate plasticity clay (Figure 6). The moisture content of the clay was recorded at between 12% and 29%. Values of undrained cohesion (C_u) from 88kPa to 273kPa (i.e. stiff to very stiff) were recorded from four triaxial tests. The moisture content range is indicative of a similarly wide range of undrained shear strength when compared with average plastic and liquid limits. Coefficients of volume compressibility test results at the in-situ stress range between 0.19m²/MN and 0.41m²/MN which is medium to high compressibility.

Characteristic SPT values of 10 at 1m and 20 at 2m depth are considered appropriate in the Glacial Till. Published correlations of SPT 'N' value with undrained shear strength, C_u , (Ref. 9) indicate preliminary design values of 50kPa at 1.2m and 100kPa at 2m would be appropriate. This would correspond to typical allowable bearing capacities of 100kPa at 1m depth and 200kPa at 2m depth, albeit a slightly more cautious value should be taken at this stage, due to the limited number of exploratory holes carried out for the Stage 2a investigation.

The bulk density of four samples measured between 2.03Mg/m³ and 2.22Mg/m³, averaging 2.16Mg/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 2.1m to 4.6m, up to 1m thickness. No sand was recorded in some of boreholes and windowless samples (i.e. glacial till recorded over sandstone in other exploratory holes). The upper weathered sandstone is described in the exploratory logs as red clayey sand.

SPT 'N' values for the upper weathered sandstone are presented in Table 4 and graphically on Figure 5.

Table 4: SPT data for Upper Weathered Sandstone

Test parameter	Unit	Range	Figure
SPT 'N' value	N/A	44 to >50 (refusal)	Fig 5

Results of particle size distribution tests are presented in Geotechnical Factual Report (Ref. 3).

SPT values in the Glacial Till give values of 44 and over. Published correlations of SPT 'N' value with effective angle of shear resistance (Ref. 9) indicate a characteristic value of about 40° would be suitable for use in the preliminary design. The presumed net bearing value of the Sandstone will be at least 300kPa. The given bearing capacity will be reviewed as part of the Stage 2b investigation, when the data on rock core samples is available.

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

4.6 Bedrock (Weathered Sandstone / Mudstone)

The fieldwork encountered weathered sandstone from depths between 1.85m and 4.8m below ground level over the majority of the site. 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, two boreholes (BH04/1A and BH05/1A) encountered sand (assumed to be upper weathered sandstone) interlayered with stiff clay (completely weathered mudstone), before the holes stopped in extremely weak to weak mudstone.

The description 'extremely weak sandstone / mudstone' is not a standard term; however, based on the standard rock strength term 'very weak' (Ref 10), the unconfined compressive strength (UCS) of the layer is inferred as less than 1.25MPa.

Based on the (weathered) nature of the lithology of this layer as encountered in exploratory holes, we consider it to be more appropriate to give soil parameters to the strata than rock strength characteristics.

SPT 'N' values for sandstone / mudstone are presented graphically on Figure 5. All SPT results refused i.e. $N > 50$. Note, the SPT 'N' value in the completely weathered mudstone is 44.

For the completely weathered mudstone, very stiff clay, with SPT 'N' Value of 44, a characteristic undrained shear strength of 150kPa and would be considered appropriate.

For the weathered mudstone, extremely weak mudstone, with SPT 'N' Value of over 50, a design undrained shear strength value of 300kPa and effective angle of frictional resistance (ϕ') of 28° would be considered appropriate (Ref. 11 & 12).

For the sandstone, an effective angle of frictional resistance (ϕ') design value of $\phi' = 42^\circ$ is considered appropriate (Ref. 11 & 12).

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

The rock parameters should be considered preliminary and reviewed when rock cores are taken for examination and testing for Stage 2B.

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 1.74m 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 5.81m bgl, 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 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 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 Report (Ref. 3); the results are compared with their respective GAC concentrations, where such exist, on the summary tables presented in Appendix B.

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%). Five SOM test has been carried out on the samples obtained. The result received recorded a values of <0.2% (twice), 0.8%, 1.1% and 35.2%. A representative value of 6% SOM has been selected for GAC criteria.

5.3 Asbestos

Seven samples obtained from the boreholes and window samples were tested to check for the presence of asbestos. Chrysotile asbestos was recorded in 2 no. samples from Boreholes BH05/1A and BH02/1A at 1m depth. A summary table of results is in Appendix B and should be referenced with the exploratory hole location plan Figure 2.

Quantification tests have been scheduled for the samples with asbestos. These tests showed that there is less than 0.001% by mass of asbestos fibres in these two samples.

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.

The mounded vegetated area on eastern side of Phase 1A area is understood from anecdotal evidence to potentially contain asbestos material. Note, Chrysotile asbestos found in Borehole BH02/1A at the edge of this area supports this. It is anticipated that redevelopment will require this material in the mound to be sent for disposal off site at a suitable landfill. Further investigation should be carried out

confirm the presence or otherwise of asbestos containing material (ACM) which will need to be treated and taken off site to 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 Made Ground

Four samples of Made Ground were tested from windowless samples and boreholes during the recent investigation. 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 Sample BH02/1A only (33.4mg/kg, GAC: 32mg/kg)
- Naphthalene exceed in three of four samples (up to 45.1mg/kg, GAC 1.5mg/kg)
- Phenanthrene exceed in two of four samples (up to 217.5mg/kg, GAC 92mg/kg)
- Benzo[a]anthracene exceeded in all four samples (up to 65.2mg/kg, GAC: 3.1mg/kg)
- Chrysene exceeded in all four samples (up to 91.9mg/kg, 3.1mg/kg)
- Benzo[b]fluoranthene in all four samples (up to 80.8mg/kg, GAC: 5.6mg/kg)
- Benzo[k]fluoranthene in all four samples (up to 28.4mg/kg, GAC: 8.5mg/kg)
- Benzo[a]pyrene in all four samples (up to 71.2mg/kg, GAC: 0.83mg/kg)
- Indeno[123-cd]pyrene in all four samples (up to 44.5mg/kg; GAC:3.2mg/kg)
- Dibenzo[ah]anthracene in all four samples (up to 7.2mg/kg; GAC:0.76mg/kg)

There are no GAC for total petroleum hydrocarbons (TPH) and this initial screen did not speciate the hydrocarbons tested. The most stringent GAC for speciated hydrocarbons was selected for comparison against the concentrations of TPH encountered, as a worst case (Aliphatic C8-C10, GAC 110mg/kg for SOM 6%). Concentrations above the detection limit were encountered in three samples of Made Ground encountered. TPH concentrations range from 3441mg/kg to 6361mg/kg. All concentrations encountered were above the GAC selected.

Speciated TPH testing was carried out on the two selected samples (BH03/1B at 1m and BH05/1A at 1m) with highest TPH concentrations. These speciated TPH results were below their respective detection limits and/or the GAC for residential end use except for the following:

- Aromatics EC >C12-C16 in Sample BH05/1A (185mg/kg; GAC: 140mg/kg)
- Aromatics EC >C12-C16 in the two samples (up to 1156mg/kg; GAC: 250mg/kg)
- Aromatics EC >C21-C35 in the two samples (up to 3075mg/kg; GAC: 890mg/kg)

The arsenic values are considered slight exceedences. The samples with TPHs and PAH exceedences are taken from a stratum of made ground with black ash and clinker at or near that depth. It is expected that fragments of asphalt / tarmac are present within the made ground which are likely to be the source of the TPH and PAH 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.

5.5 Natural Ground

Three 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

5.6 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 GROUND GAS RISK ASSESSMENT

From the initial ground gas monitoring results (3 visits to date), the maximum recorded values are given in Table 5 below. From these results, the maximum individual hazardous gas flow rate (Qhg value) for the site is 475.2 l/hr carbon dioxide in BH05/1A 5.5m on 6 May 2015. Borehole BH05/1A contained organic odours and fragments of wood, possibly the former pond area. Note, the other individual hazardous gas flow rate (Qhg value) were all less than 0.39 l/hr, except for one value in BH02/1A 5.9m on 14 May 2015 of 126 l/hr carbon dioxide. The flow rates measured from BH02/1A 5.9m were very sporadic varying between less than 30l/hr inflow to 30l/hr outflow and the hazardous gas flow rate from this installation is not considered representative.

Table 5: 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	5	11	BH05/1A 5.5m on 6 May 2015
Ground Gas Flow	l/hr	0.1	43.2	BH05/1A 5.5m on 6 May 2015
Hydrogen Sulphide	ppm	1	<1	

These initial results have been considered with reference to BS8485:2007, 'Code of Practice for the Characterization and Remediation from Ground Gas in Affected Developments' (Ref. 13). With reference to Table 1 of the above document, the site is provisionally indicated to classify as Characteristic Gas Situation (CGS) 6, "very high risk" for Phase 1A area possibly due to the former pond area and CGS 2, "low risk" for Phases 1B and 2, in terms of its hazardous ground gas regime.

The ground gas flow measured in Borehole BH05/1A 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. Further gas monitoring will indicate if the high gas flow result in BH05/1A installation on 6 May is representative or produced by the recharge of groundwater in the installation. The high CSC risk rating of Phase 1A area is based on the one reading on 6 May 2015. It is expected that the total volume of gas generation of the former organic material in the pond is relatively low and as such would not warrant such a high CSC risk rating. It is recommended that further ground gas monitoring and assessment should be carried out in the Phase 1A area before finalising the suitable Characteristic Gas Situation classification.

At this stage, ground gas protection measures are indicated to be required for the new development. Further ground gas monitoring and assessment should be carried out before confirming the type of gas protection measures required.

7 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, TPHs and PAHs in the Made Ground.
- Asbestos containing material, including Chrysotile fibres, in Made Ground.
- Japanese Knotweed on the site.
- Unexploded Ordnance (UXO) threat.
- Hazardous ground gases.
- Contamination in groundwater.
- 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

8 GEO-ENVIRONMENTAL RISK ASSESSMENT

8.1 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 6 below provides a description of the resultant risk levels.

Table 6 – 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 'Guidance for the Safe Development of Housing on Land Affected by Contamination (R&D 66:2008 Vol 1 (NHBC Environment Agency/CIEH))'.

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.

8.2 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 7 – Summary of Risk Assessment (Risk Rating)

Receptor	Pathway	Source		
		Asbestos (primarily in Made Ground)	Arsenic, 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 / HIGH
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 / HIGH
	Explosion of gas	N/A	N/A	MODERATE / HIGH
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 limited amount of perch shallow groundwater above relatively impermeable clay layer of glacial till, risk to the local abstraction points from this site is considered to be low based on the current information.

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 5, the mounded vegetated area on eastern side of Phase 1A area is understood to potentially contain asbestos material (ACM). It is anticipated that redevelopment will require this material in the mound to be disposed off site at a suitable landfill. 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.

As indicated in Section 6, the ground gas monitoring results and risk assessment has indicated potential significant risk to (unprotected) development users from ground gas. Protection measures should be assumed necessary at this stage.

9 GEOTECHNICAL CONSIDERATIONS

9.1 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 for the proposed development have not been provided.

9.2 Ground Model

The following table presents representative ground models and geotechnical parameter values for preliminary design for the foundations based on the information available to date.

Table 8: Ground Model

Lithology	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	42	0	N/A
Eastern side of Phase 1A					
Very Stiff Clay	4 to 7m	22	28	0	150
Mudstone	Below 7m	23	28	0	300
On the eastern side of Phase 1A, layers of sand /very stiff clay over weathered mudstone was 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 table water in the made ground from 0.5mbgl.

9.3 Foundation Options

Preliminary foundation design recommendations follow based on the ground model described above. The feasibility of the different foundation types will ultimately depend on the building loadings. Once more information is available regarding the Stage 2B investigation and loading requirements of the building, the foundation recommendation can be refined to provide an optimum solution.

9.3.1 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 "competent" Glacial Till stratum (encountered upper horizon from depths of 1.7m to 3.3m). At typically 2m depth, the design of such foundations could be based on a presumed net bearing value of about 150kPa. The bearing capacity for shallow foundation will be assessed further for Stage 2b when additional ground investigation data becomes available.

In some areas the sandstone will be encountered below 3m depth and it would be feasible to construct spread/trench-fill foundations directly onto the sandstone with a presumed net bearing value of at least 300kPa.

9.3.2 Piled Foundations

Piled foundation to the bedrock is also feasible for the support of the proposed buildings. 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. This has implications on the piling option which may provide a more direct route for potentially contaminated groundwater entering the aquifer. 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. Accordingly, groundwater remediation is not anticipated to be required for the proposed development. This needs to be confirmed by further assessment during the Stage 2B investigation.

If the test results confirm that the site is on land affected by contamination and where spread foundations are not possible and there is no alternative to piling, continuous flight augured (CFA) piles probably pose the least risk of groundwater pollution. Based on NC/99/73 (Ref 14), for contaminated sites, CFA piles are generally preferred over driven pre-cast concrete piles as they do not provide an easy path for surface water to reach the lower strata.

Preliminary calculations for allowable capacities of single CFA piles are presented in Table 9 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 before the piles achieve any significant load capacity. The load capacities should be considered preliminary at this stage and will be reviewed when more detailed information on the rock is obtained during the Stage 2B investigation.

Table 9: 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	Extremely weak sandstone	400	900	1600
8		500	1050	1850
10		550*	1100	1900
* At about the structural capacity of the pile.				

For example a working load of 500kN could be carried by 300mm diameter CFA piles installed to a minimum of 8m depth, socketed 4m in 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 would need to be about 4m longer to achieve similar pile capacities to piles socketed into the sandstone.

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 C5044. (Ref. 15) were generally adopted.

For concrete CFA piles in granular soils (assuming extremely weak sandstone as granular soils), relative earth pressure coefficient $K_s = 0.3$ for CFA piles in dense sand / sandstone (Ref. 16), 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. 16). The average unit shaft friction and base resistance was 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 feasible construction depth of the CFA piles into bedrock will depend on the rock strength and CFA piling equipment used. Stage 2b ground investigation includes rotary boreholes to assess the rock strength and further commentary will be provided in Stage 2b interpretative report on the above.

9.3.3 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. Vibrostone 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. However, 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,

9.4 Ground Floor Slab Construction

Made Ground to depths up to 2.2m 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 slabs may be adopted.

Formation 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 proofed-roller 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. 18) 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. 19).

The ground floor slab construction should be reviewed as part of the Stage 2b investigation when further information on the ground conditions is obtained.

9.5 New Hardstanding Pavement Construction

At this stage, an indicative design CBR value of about 2% should be assumed for the design of new pavement hardstanding areas of the development on the basis that the pavement areas are to be founded on made ground / glacial till. This will be reassessed once in-situ TRL probe tests are carried out during the Stage 2B investigation.

9.6 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.

Groundwater control is likely to be required in excavations deeper than around 0.5m. 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.

9.7 Aggressivity Towards Concrete

Testing to determine the aggressivity of the ground towards concrete was undertaken on soil samples in accordance with the Building Research Establishment Special Digest 1 (Ref. 17).

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 prevent this 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 10 gives a summary of soil test results. 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.

Soil samples tested were taken from depths of between 0.3m and 6.5m below ground level from both Made Ground and natural soils.

Table 10: Summary of concentrations measured in soils for materials assessment

Determinand	Soil		Characteristic Value
	Min Value	Max Value	
pH	7.8	9.0	7.8*
Water Soluble Sulphate	10 mg/l	1323 mg/l	1323mg/l**
Acid Soluble Sulphate	<0.005%	0.27%	0.27%**
Total Sulphur	<0.01%	0.10%	0.10%**
Total Potential Sulphate	<0.03%	0.30%	0.30%**

* Lowest result

** 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.

9.8 Soakaways

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 C. 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 to 4.4 x 10⁻⁷m³/m²/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} to $1.2 \times 10^{-5} \text{m}^3/\text{m}^2/\text{s}$. The range of infiltration rates are 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 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 that the depth of overburden needed to be excavated before encountering the sandstone.

Any soakaway in the sand / weathered sandstone would need to 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.

10 CONCLUSIONS

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

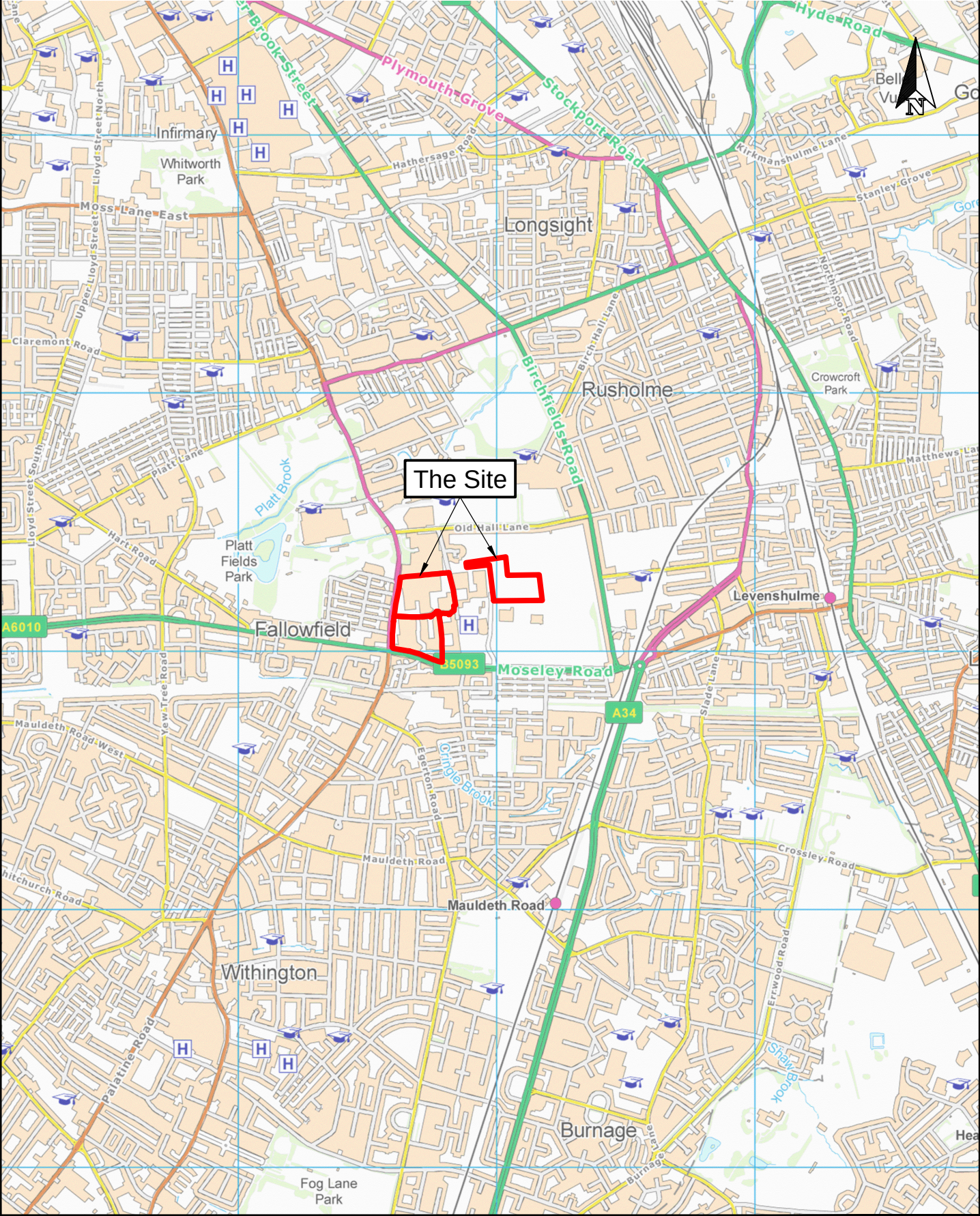
1. The site consists of three areas: Phase 1A, 1B and 2. It is proposed to redevelop the site with new student accommodation facilities.
2. A ground investigation comprising 13 no. cable percussive boreholes and 2 no. windowless sampling holes with in-situ and laboratory geotechnical and chemical testing was 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 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 samples from the Made Ground and compared to published Generic Assessment Criteria (GAC) for residential land use. The range of contaminants identified from the test results received included elevated arsenic, TPHs and PAH in samples of Made Ground. The arsenic, TPHs and PAH is likely due to the ash and clinker content in the Made Ground.
6. Asbestos was encountered in two soil samples in Phase 1A with quantifiable amounts of Chrysotile. There is also anecdotal evidence that the mound on the western side of Phase 1A may contain asbestos (also demolition waste from the former stadium). The risk of chronic exposure to asbestos is to be managed by the adoption of good general working practices (during all ground-works) together with guidance and direction from a suitably qualified and experienced asbestos specialist. The mounded area will be investigated further in the Stage 2B Investigation.
7. Ground gas with elevated levels of methane and carbon dioxide was recorded in one borehole, BH05/1A on 6 May 2015. This borehole recorded peaty clay with fragments of wood and organic odours up to 3.3m depth. It is inferred that this is the area of a former pond. At this stage, ground gas protection measures are indicated to be required for the new development. Further ground gas monitoring and assessment is to be carried out (as part of the Stage 2A investigation) before confirming the type of gas protection measures required.
8. The excavated material on the site would generally be expected to be classified as non-hazardous, except for material containing 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.
9. Using the information obtained from the ground investigation, a preliminary ground model has been developed. A preliminary foundation assessment and design was carried out based on this ground model.

10. Shallow spread foundations through any Made Ground and soft to firm clays founded on “competent” Glacial Till (encountered at depths of between 1.3m and 3.3m) could be feasible for the proposed redevelopment dependent upon the proposed loadings. The preliminary design of such foundations should be based on a presumed net bearing value of about 150kPa, at typically 2m depth. In some areas sandstone is found at a shallow depth (i.e. <3m), and a presumed net bearing value of at least 300kPa would be appropriate for shallow foundations on sandstone.
11. 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.
12. The site area is underlain by bedrock designated as a Principal Aquifer and located in a Source Protection Zone III area. If the ground investigation confirms that the site is on land affected by contamination and where spread foundations are not possible and there is no alternative to piling, continuous flight augured (CFA) piles probably pose the least risk of groundwater pollution. Indicative pile capacities are summarised in Section 9.3.
13. Once more information is available from the Stage 2B investigation and regarding the loading requirements of the building the foundation details can be refined to provide an optimum design solution.
14. 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.
15. 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.
16. 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.
17. 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.
18. Design Sulphate Class and ASEC 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.
19. Soakaways are not considered suitable for the redevelopment of the site.

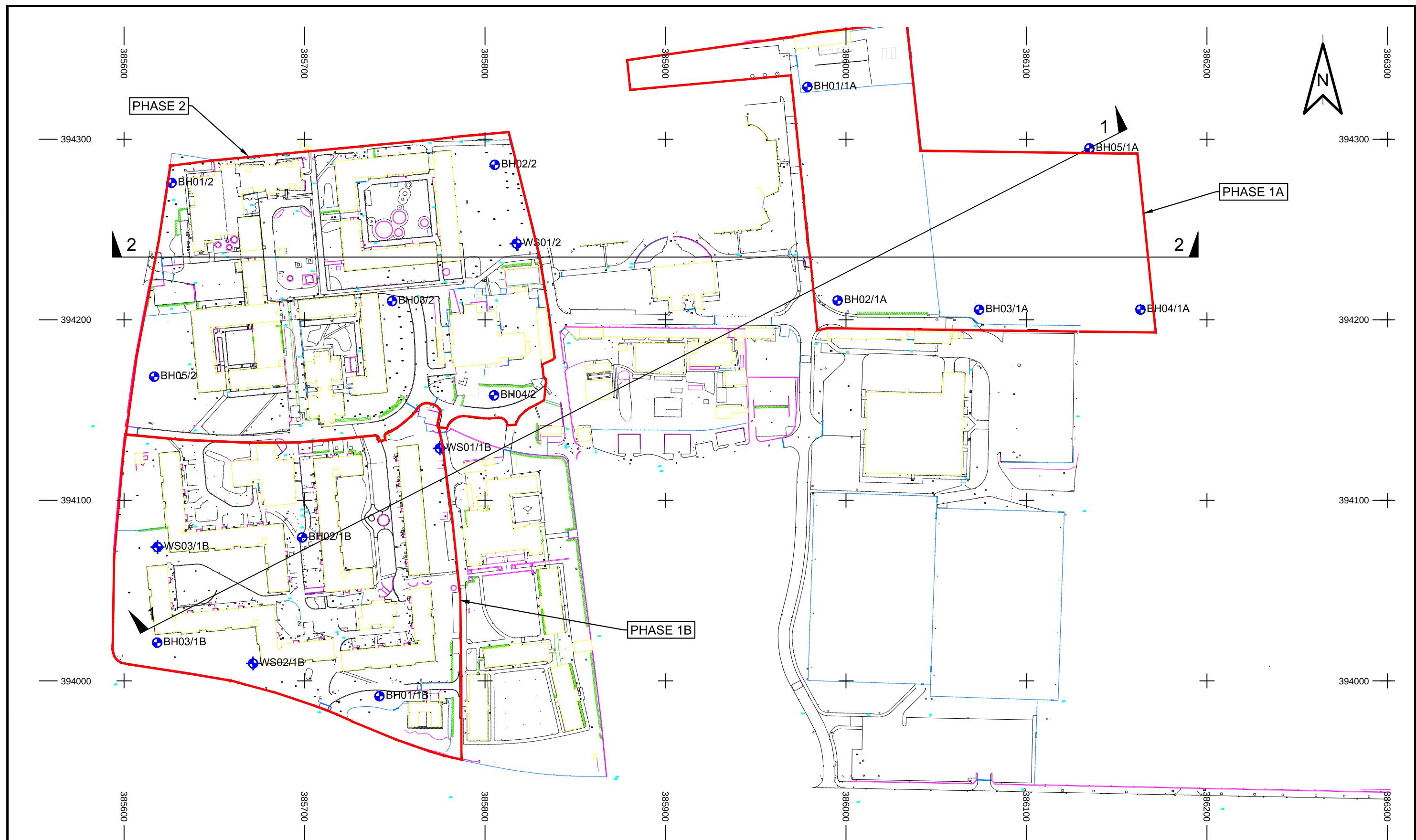
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6. British Geological Survey 1:10,560 Scale Geological Sheet SJ 89 SE (solid and drift)
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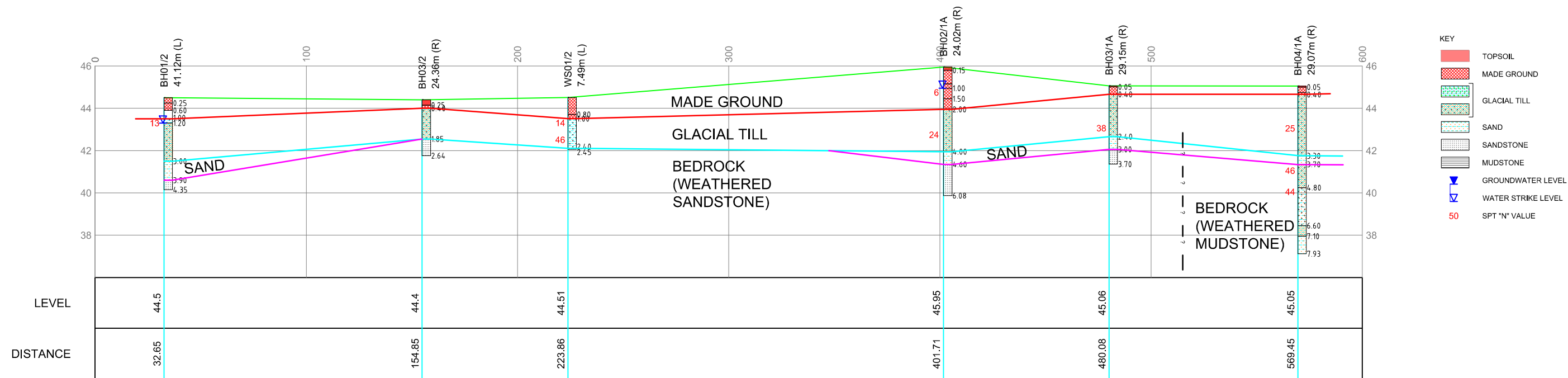
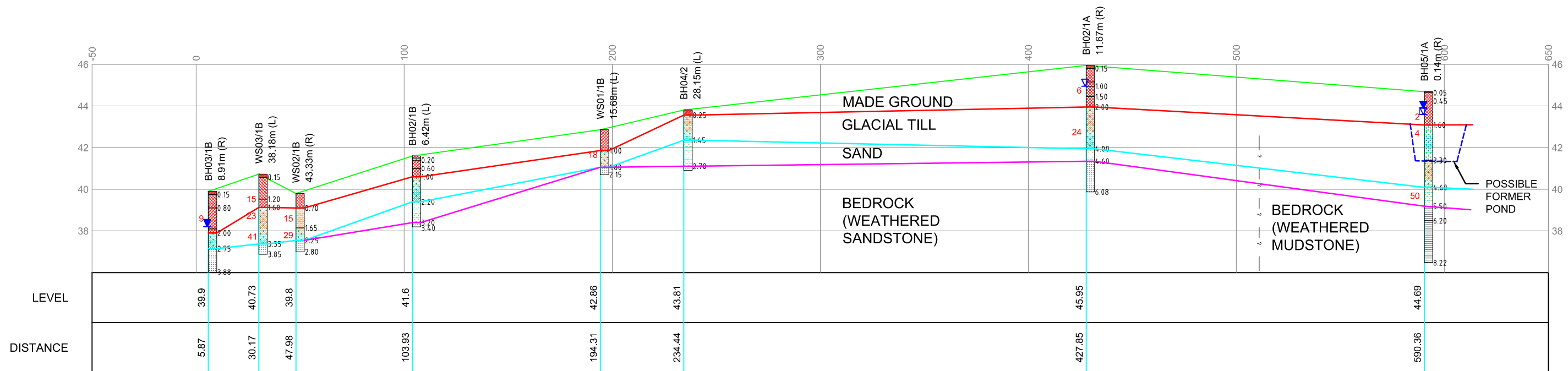
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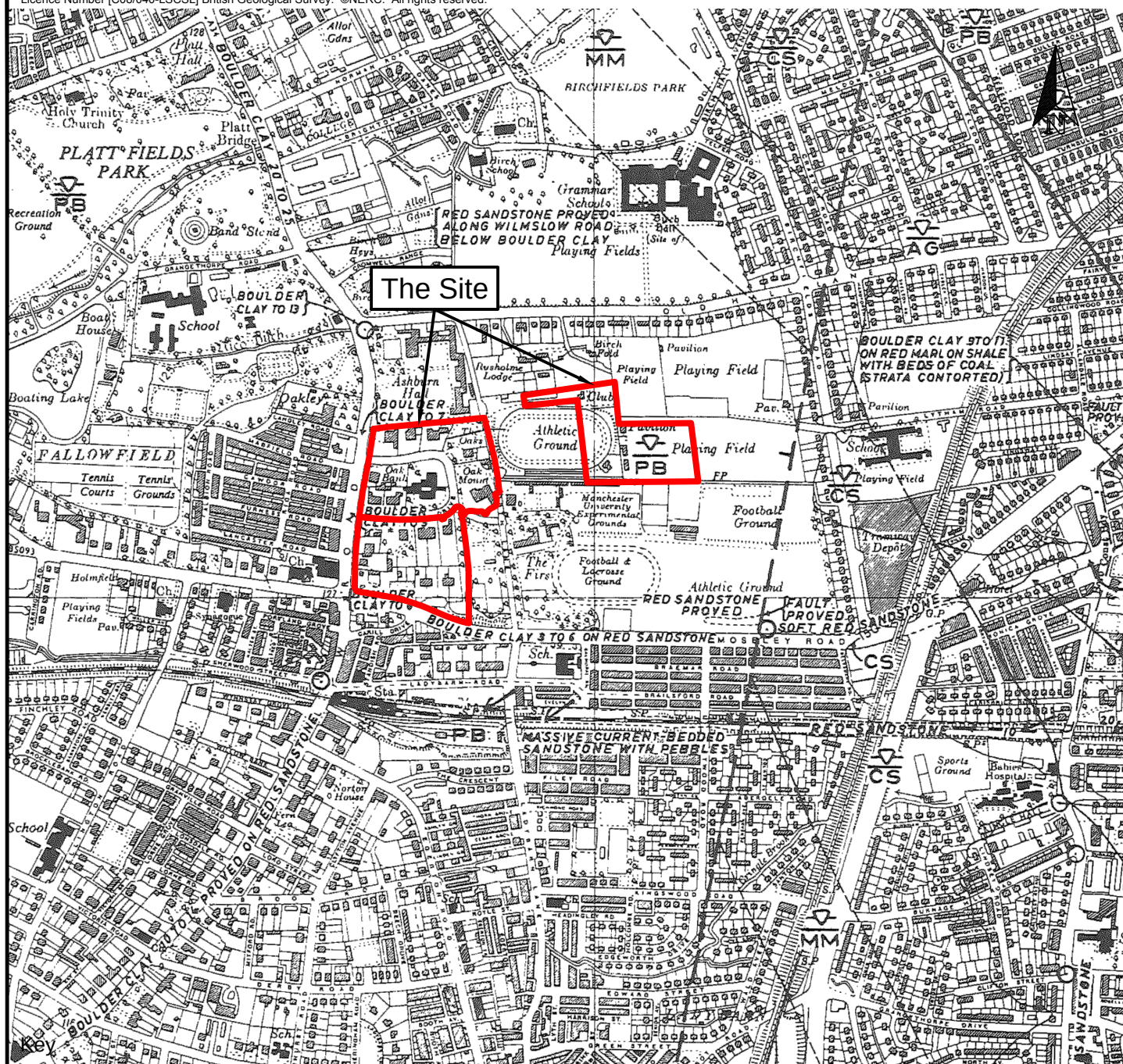
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date	MAY 2015		project:	PROJECT OAK, FALLOWFIELD, MANCHESTER	
scale	1:20 000		title:	SITE LOCATION PLAN	
original size	A4		project no:	02428AA	fig no: Figure 1



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)	drawn	MN		client: BDP	
	date	26/05/2015		project: PROJECT OAK STAGE 2A GI	
	scale	1 : 2,000		title: EXPLORATORY HOLE LOCATION PLAN	
	original size	A3		project no: 02428AA	fig no: 2



Notes: 1. Do not scale from this drawing. 2. All dimensions are in metres unless otherwise stated. 3. Borehole ground levels were estimated based on drawing 12650A-MASTER.dwg (Topographical Survey by SURVEY SYSTEMS - February 2014)	drawn	MN		client: BDP	
	date	26/05/2015		project: PROJECT OAK STAGE 2A GI	
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	original size	A3		project no: 02428AA	fig no: 3



DRIFT

SOLID

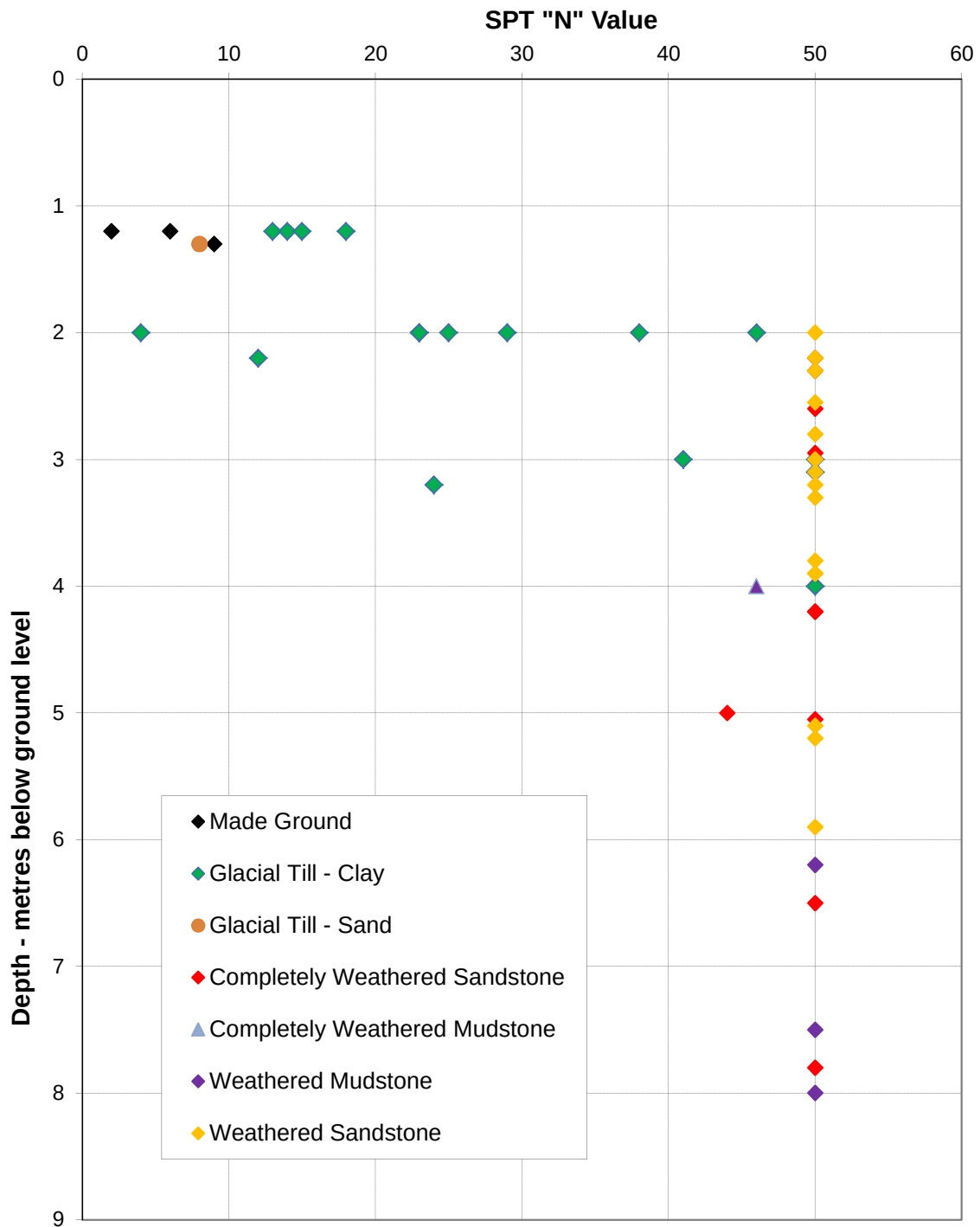
	Alluvium
	First Terrace
	Second Terrace
	Fluvio-Glacial Gravel
	Glacial Sand and Gravel
	Boulder Clay

UMS	Upper Mottled Sandstone
PB	Bunter Pebble Beds
MM	Manchester Marls with Stockport Conglomerate
CS	Collyhurst Sandstone
AG	Ardwick Group

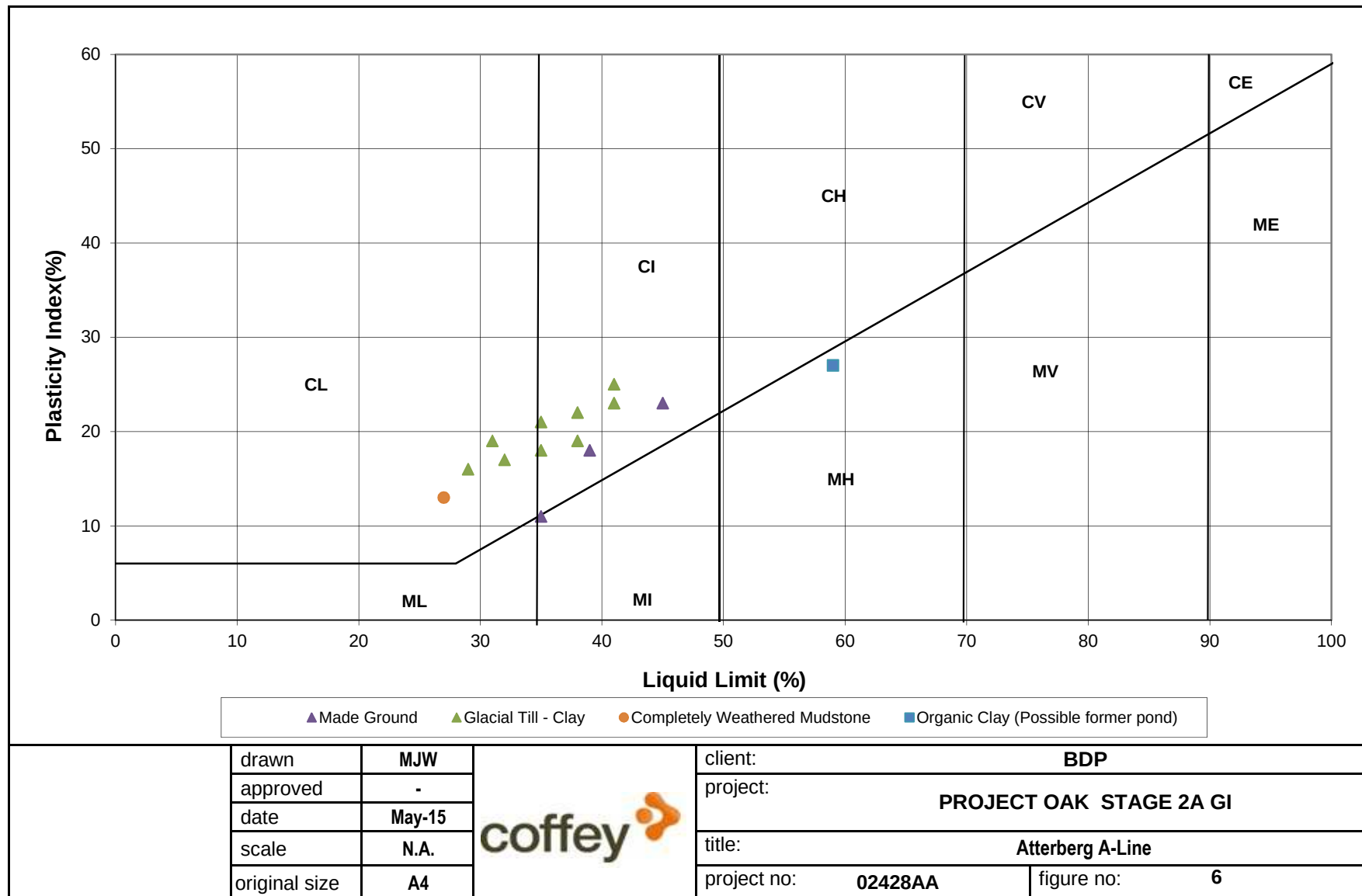
PERMO-TRIASSIC CARBONIFEROUS

See also Generalized Vertical Section.

drawn	SN / MJW		client:	BDP
date	MAY 2015		project:	PROJECT OAK, FALLOWFIELD, MANCHESTER
scale	1:10 560		title:	SITE GEOLOGY PLAN
original size	A4		project no:	02428AA
			fig no:	Figure 4



drawn	MJW	<div>coffey</div>	client: <div>BDP</div>	
approved	-		project: <div>PROJECT OAK STAGE 2A GI</div>	
date	May-15		title: <div>SPT "N" Value vs Depth below ground level</div>	
scale	N.A.		project no: <div>02428AA</div> figure no: <div>5</div>	
original size	A4			



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 and Groundwater Screening Tables

GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA) - SOILS

Site: Project Oak
Project No.: 02428AA
Client: BDP
Sample Collection Date: May-15
Assessment Scenario: RESIDENTIAL

Data Source:
SGVs (2009): Derived by the Environment Agency using the CLEA 1.04
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_002A_RDB- Project Oak-Tier 4 RA.xls

INORGANICS & METALS

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	BH05/1A	BH02/1A	BH03/1B	BH05/2	BH02/2	WS01/1B	BH01/1A
			1.0m	1.00m	1.00m	1.00m	1.00m	1.00m	1.00m
			MG	MG	MG	MG	Clay	Clay	Clay
Arsenic	32	1	21	33.4	7	6.1	7.4	8.3	13.6
Cadmium	10	0	0.1	0.3	0.8	<0.1	<0.1	<0.1	0.1
Chromium III	3000	0	18.2	27.7	32.3	32.8	42.9	40.3	25.8
Copper	2330	0	116	105	57	10	21	22	38
Lead	450	0	293	164	87	27	12	14	84
Mercury - Elemental	1	0	1	0.1	<0.1	<0.1	<0.1	<0.1	0.9
Nickel	130	0	31.2	44.5	36.5	10.6	24	19.5	20
Selenium	350	0	<1	<1	<1	1	<1	<1	<1
Zinc	3750	0	151	156	93	45	53	53	58
Cyanide - Total	No Criteria	0	<0.5	1	1.7	1	<0.5	<0.5	6.9
Boron	291	0	0.7	0.9	0.2	0.4	0.4	0.4	1.9

ORGANICS

Determinand	SGV/GAC (mg/kg)	No. of Samples Above the SGV/GAC	BH05/1A	BH02/1A	BH03/1B	BH05/2	BH02/2	WS01/1B	BH01/1A
			1.0m	1.00m	1.00m	1.00m	1.00m	1.00m	1.00m
			1.0m	1.00m	1.00m	1.00m	1.00m	1.00m	1.00m
Naphthalene	1.5	2	45.08	9.02	0.92	<0.04	<0.04	<0.04	0.11
Acenaphthylene	170	0	7.14	4.64	4.3	<0.03	<0.03	<0.03	<0.03
Acenaphthene	210	0	38.47	11.36	4.6	<0.05	<0.05	<0.05	<0.05
Fluorene	160	0	37.61	12.07	4.59	<0.04	<0.04	<0.04	0.05
Phenanthrene	92	1	217.53	89.67	60.01	<0.03	<0.03	<0.03	0.4
Anthracene	2300	0	44.49	21.65	19.85	<0.04	<0.04	<0.04	0.1
Fluoranthene	260	0	180.32	105.56	135.38	<0.03	<0.03	<0.03	0.56
Pyrene	560	0	173.35	97	113.12	<0.03	<0.03	<0.03	0.58
Benzo[a]anthracene	3.1	3	65.17	34.15	58.22	<0.06	<0.06	<0.06	0.33
Chrysene	6	3	91.9	45.78	64.45	<0.02	<0.02	<0.02	0.37
Benzo[b]fluoranthene	5.6	3	72.96	43.04	80.76	<0.05	<0.05	<0.05	0.32
Benzo[k]fluoranthene	8.5	3	28.38	16.74	31.4	<0.02	<0.02	<0.02	0.13
Benzo[a]pyrene	0.83	3	69.93	41.21	71.18	<0.04	<0.04	<0.04	0.31
Indeno[123-cd]pyrene	3.2	3	32.01	24.61	44.45	<0.04	<0.04	<0.04	0.16
Dibenzo[ah]anthracene	0.76	3	7.18	3.44	7.13	<0.04	<0.04	<0.04	<0.04
Benzo[ghi]perylene	44	0	37.81	18.65	39.68	<0.04	<0.04	<0.04	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	<0.005	<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	<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				
Aromatics EC >10-12	69	0	16.7		3.2				
Aliphatics EC >12-16	740	0	<4		6				
Aromatics EC >12-16	140	1	185		81				
Aliphatics EC >16-35	45000	0	29		184				
Aromatics EC >16-21	250	2	1156		1141				
Aromatics EC >21-35	890	2	2556		3075				
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	<7		13				
Aromatics EC >7-8 (toluene)	120	0	<0.1		<0.1				
Aromatics EC >35-44	890	0	256		369				
Total PAH	No Criteria	0	1149.3	578.6	740	<0.6	<0.6	<0.6	3.6
Total EPH (C8-C40)			7148	3441	6381	<30	100	<30	270
Asbestos screen			Chrysotile	Chrysotile	NAD	NAD	NAD	NAD	NAD
Asbestos Level			Quantifiable	Quantifiable	None	None	None	None	None
SOM			1.1				<0.2		35.2

Appendix C

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