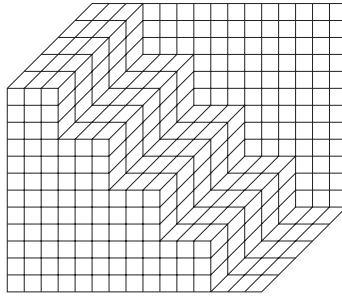




Buro Happold

021706 Kirkby Redevelopment
Geoenvironmental and Geotechnical
Interpretative Report: Phase 1
Ground Investigation (GDO 205
Landfill)

November 2007

Revision 00

Revision	Description	Issued by	Date	Checked
00	For comment	PH		GG/KL

\\srv-zeus\Project Filing\021706 Kirkby Regeneration\F09 Geotechnical & Site
Investigation\Reports\Interpretative Phase 1\071112 PH 021706 Kirkby GE_Interp_Phase1 GI 00.doc

This report has been prepared for the sole benefit, use and information of Tesco Stores Ltd for the purposes set out in the report or instructions commissioning it. The liability of Buro Happold Limited in respect of the information contained in the report will not extend to any third party.

author **Paul Hazlehurst**

signature



date **12 November 2007**

approved **Kenny Lyons/Gary Graveling**

signature



date **22 November 2007**

Contents

Executive Summary

1	Introduction	7
2	Phase 1 (GDO 205 Landfill) Ground Investigation	9
3	Ground Conditions Encountered	11
4	Site Monitoring and Laboratory Testing	16
5	Soil data assessment - contaminant source characterisation	19
6	Soil leachability and Groundwater data assessment - contam source characterisation	28
7	Data assessment - Ground Gas	41
8	Contaminated land risk assessment	44
9	Remedial Options Appraisal	56
10	Waste Management	67
11	Geotechnical Considerations	72
12	Conclusions and recommendations	74

Figures

Appendix A – Current Masterplan

Appendix B – Pelorus Geophysical Survey Resistivity Sections

Appendix C – Soil Analytical Data

Appendix D – Soil Leachate Analytical Data

Appendix E – Water Analytical Data

Appendix F – Ground gas Data

Appendix G – CIRIA C659 Guidance

Appendix H – CIRIA C552 Guidance

Appendix I – Hazardous Waste Assessment

Appendix J – Waste Acceptance Criteria Assessment

Executive Summary

The Kirkby Redevelopment site is located in Kirkby Town Centre, Knowsley. The approximate Ordnance Survey (OS) National Grid Reference (NGR) for the centre of the site is 341090 mE, 398360 mN.

The current development proposal for the Kirkby Redevelopment masterplan site consists of demolition of existing commercial, residential and school buildings and construction of a major new football stadium, a number of retail units and office and residential uses. An architects drawing of the masterplan is included as Appendix A.

This report is based upon an exploratory level Phase 1 ground investigation which was undertaken within a specific area of the masterplan site, see Figure 2. This report is intended to provide a Generic Quantitative Risk Assessment in general accordance with CLR11 – 'Model Procedures for the Management of Land Contamination', Environment Agency (UK), September 2004¹. In addition due to the significant pollutant linkages identified in this Risk Assessment, this report also contains a Remedial Options Appraisal following CLR11. This report is also intended to provide an assessment of geotechnical issues associated with the proposed development.

The following reports which should be read in conjunction with this report;

- Buro Happold Ground Engineering 'Site Appraisal Report' Kirkby Redevelopment (Revision Final) job no: 021706, December 2006; and
- Soil Mechanics Factual Report on Ground Investigation, Kirkby Redevelopment Phase 1 Ground Investigation (GDO 205 landfill area) Report No. F7023, (Final) September 2007 (referred to in this report as 'Soil Mechanics Phase 1 Factual Report');
- AES Kirkby Regeneration Phase 1, August 2007 (referred to in this report as 'AES Phase 1 Factual Report'); and
- Pelorus Surveys Kirkby Redevelopment Geophysical Survey Report No. L7033, June 2007 (referred to in this report as 'Pelorus Geophysical Report').

The investigation has generally proven the following ground profile; Made Ground 'Type 1'(imported natural arisings from construction of Mersey Tunnel together with some construction/demolition materials), Made Ground Type 2 (early-1960s municipal refuse contaminated soils), Natural Drift Deposits (localised Glacial

¹ CLR11, Model Procedures for the Management of Land Contamination, Environment Agency, September 2004.

Deposits and Alluvium), overlying Sherwood Sandstone bedrock. The Sherwood Sandstone is designated a major aquifer by the Environment Agency and is largely unconfined due to historical extraction of superficial (drift) deposits, prior to landfilling activity.

A number of pollutant linkages have been identified as being of unacceptable risk; including pollution of Kirkby Brook and the major aquifer, ground gas migration into proposed onsite and existing offsite structures, and risks to human health from contact with landfill materials, gas/vapours and asbestos. To mitigate these risks the preferred remediation scheme includes the following elements;

- Controlled waters (Kirkby Brook and Major Aquifer): Reduce infiltration by hardstanding/capping to reduce contaminant leaching. Installation of Permeable Reactive Barrier (PRB) system along Kirkby Brook. Possible drawdown and regulation of groundwater levels via pumping system. Appropriate site management during enabling works including bunds, stockpile covers, wheel washes, daily cover, monitoring etc. Post construction long-term groundwater and surface water level and quality monitoring;
- Human health: – Appropriate PPE and working practices during enabling works/construction. Permanent works - capping/hardstanding to break pathway between ground contaminants and end users.
- Ground gas: During enabling works/ground improvement construct and maintain site perimeter gravel trench with membrane on outer wall to mitigate risk of gas migration offsite. For permanent works (stadium) active venting system and gas membrane (current design subject to ongoing gas monitoring). Post construction monitoring of protection system and site perimeter concentrations/flows to validate performance.

The proposed development will require a significant programme of earthworks within the Phase 1 ground investigation area. It is proposed to reuse the Made Ground Type 1 materials on site as fill pending regulatory approval. A quantity of material will not be suitable for re-use on site and will require off-site disposal to landfill.

In order to provide a consistent suitable engineered material to support the football pitch, car parks and access roads, dynamic compaction of the landfill materials is proposed. Long term creep of the landfill materials due to decay of the degradable fill constituents shall be controlled by the use of geotextiles and granular blanket placed over treated areas. To support the stadium and other structures in areas of deep fill, pile foundations will be required.

1 Introduction

1.1 Scope

The Kirkby Redevelopment site is located in Kirkby Town Centre, Knowsley. The approximate Ordnance Survey (OS) National Grid Reference (NGR) for the centre of the site is 341090 mE, 398360 mN.

The site location is shown in Figure 1.

The current development proposal for the Kirkby Redevelopment masterplan site consists of demolition of existing commercial, residential and school buildings and construction of a major new football stadium, a number of retail units and office and residential uses. An architects drawing of the masterplan is included as Appendix A.

This report is based upon a exploratory level Phase 1 ground investigation which was undertaken within a specific area of the masterplan site, delineated in Figure 2. Access to the remainder of the masterplan site was not possible at the time of the Phase 1 ground investigation and investigations in these areas will be reported upon at a later date and the results will be added to this report in due course.

This report is intended to provide a Generic Quantitative Risk Assessment in general accordance with CLR11 – ‘Model Procedures for the Management of Land Contamination’, Environment Agency (UK), September 2004². In addition due to the significant pollutant linkages identified in this Risk Assessment, this report also contains a Remedial Options Appraisal following CLR11. This report is also intended to provide an assessment of geotechnical issues associated with the proposed development.

1.2 Existing Information and Reporting

The design of the Phase 1 ground investigation was based upon the known site history, the results of previous studies and investigations and the masterplan current at that time.

The following reports include relevant information and should be read in conjunction with this report:

- Buro Happold Ground Engineering ‘Site Appraisal Report’ Kirkby Redevelopment (Revision Final) job no: 021706, December 2006; and
- Buro Happold Ground Engineering ‘Interim Report’ Kirkby Redevelopment (Revision 00) job no: 021706, June 2007.

² CLR11, Model Procedures for the Management of Land Contamination, Environment Agency, September 2004.

1.3 Existing Conceptual Site Model

The reader is referred to the Buro Happold Site Appraisal Report which includes details on site history, geology, hydrogeology, hydrology, environmental setting as well as a Preliminary Conceptual Site Model for the Kirkby Redevelopment masterplan site (though excluding the land north of Cherryfield Drive).

The majority of the area investigated in the Phase 1 ground investigation is public open space, comprising a series of grassed mounds and areas of woodland. The approximate elevation of the highest mound is 29 m AOD. Kirkby Brook is present to the west of these mounds, with the stream channel at an approximate elevation of 15 m AOD. The area can be accessed via a track leading from Bewley Drive.

A recent aerial photograph of the Phase 1 investigation area together with photos of relevant site features is included as Figure 3.

1.4 Limitations and Exceptions

The spacing of the exploratory holes and the sampling and analysis plan for this investigation is considered to have provided a reasonable level of certainty about the ground conditions. Constraints on the locations of intrusive ground investigations were imposed due to the nature of the existing site. In particular no intrusive investigations were permitted in areas of existing tree cover to prevent environmental damage; furthermore access to certain areas of the site by ground investigation plant was not possible due to steep slopes.

It is important to recognise that contamination can be both widespread and relatively localised, depending upon its source and nature etc. No investigation, however comprehensive can be expected to determine absolutely the nature and extent of all the contamination which could be present on any site. There will always be an element of uncertainty about the ground conditions including contamination. The potential for undetected contamination on the site must therefore be taken into account with respect to future development activities, for example, in the design of the remedial strategy, health and safety planning, financial planning/financial risk management and while below ground works are undertaken during the construction phase and in the future.

1.5 Site Ownership

At the time of writing it is understood the Phase 1 ground investigation area is owned by Knowsley Metropolitan Borough Council (KMBC).

2 Phase 1 (GDO 205 Landfill) Ground Investigation

2.1 Site Works

The ground investigation was designed by Buro Happold to obtain both geotechnical and geoenvironmental information on the GDO 205 landfill area. Soil Mechanics (Deeside) were appointed principal contractor for the intrusive investigation. Site works were carried out between 23rd April and 25th May 2007 and comprised the following scope:

- 15 No. machine excavated trial pits excavated using a JCB 3CX;
- 17 No. boreholes constructed using cable percussive techniques (15 No. continued by rotary coring);
- 6 No. handheld windowless sampler holes;
- Installation of 15 No. wells for groundwater and gas monitoring;
- Soil logging and sampling for both geoenvironmental and geotechnical purposes;
- Screening of soil samples using a portable Flame Ionisation Detector (FID) calibrated for methane; and
- Geophysical resistivity survey carried out by Pelorus Surveys(4 no. survey lines).

The locations of the exploratory holes are shown on Figure 4.

All logging and soil sampling was undertaken by a Soil Mechanics site engineer, under supervision of Buro Happold. The ground conditions encountered in all exploratory holes were logged in accordance with BS 5930:1999.

Appropriate methods of sample collection and preservation together with procedures to avoid cross-contamination were followed as recommended in BS5930:1999 and BS10175:2001. Soil and water samples for contamination purposes were collected from site by daily courier and sent to UKAS-accredited testing laboratory Analytical and Environmental Services (AES) for subsequent analysis.

To mitigate potential environmental and human health risks during ground investigation works procedures were adopted following Environment Agency 'R & D Technical Report P5-065/TR' (Steeds et al, 2000), and Soil Mechanics 'Project (Health and Safety) Plan: Kirkby Redevelopment Ground Investigation'(16 April 2007), with salient points summarized below;

- Trial pit arisings stockpiled separately and pits backfilled to reform original ground profile in layers, particularly where potentially contaminated material is encountered underlying other materials;
- Use of visqueen and plywood boards at exploratory positions to contain potentially contaminated soil arisings and prevent runoff into Kirkby Brook; and

- Borehole design to minimise risk of creating preferential pathways for contaminants principally:
 - Large diameter borehole casing maintained within top of weathered Sherwood Sandstone stratum sealing off potential contaminants in overlying fill materials, hole progressed in smaller diameter 'clean' casing;
 - Response zones designed to screen either Made Ground or natural ground, not a combination, to prevent risk of creating preferential pathways between fill materials and underlying natural strata;
 - No nested installations to prevent risk of creating preferential pathways between fill materials and underlying natural strata;
 - Bentonite seal between top of Sherwood Sandstone response zones and the base of fill materials to prevent risk of creating preferential pathway deeper into the underlying natural strata; and
 - Flush lockable stopcock covers to prevent well pollution from surface sources.

Full results of the ground investigation are included in the following reports which should be read in conjunction with this report;

- Soil Mechanics Factual Report on Ground Investigation, Kirkby Redevelopment Phase 1 Ground Investigation (GDO 205 landfill area) Report No. F7023, (Final) September 2007 (referred to in this report as 'Soil Mechanics Phase 1 Factual Report');
- AES Kirkby Regeneration Phase 1, August 2007 (referred to in this report as 'AES Phase 1 Factual Report'); and
- Pelorus Surveys Kirkby Redevelopment Geophysical Survey Report No. L7033, June 2007 (referred to in this report as 'Pelorus Geophysical Report').

3 Ground Conditions Encountered

3.1 Grass overlying topsoil

Grass overlying topsoil is present across the GDO 205 landfill area. The topsoil is typically 0.10m in thickness across the majority of the 'mounded' landfilled area, though is locally present in greater thicknesses adjacent to Kirkby Brook.

3.2 Made Ground

Made Ground was proven to a maximum proven thickness of 12.30m in BH1010. Generally, the thickest deposits of Made Ground were found in areas of existing high topography. Based on the materials encountered during the ground investigation, the Made Ground has been characterized into two types for the purposes of this report, described below in Table 3.1.

Table 3.1 – Types of Made Ground

Material	Location	Generalized Description
Made Ground 'Type 1'	Generally site wide below topsoil.	Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, and concrete. Rare wood, metal. Rare cement bound asbestos. Origin: Imported natural arisings from construction of Mersey Tunnel together with some construction/demolition materials.
Made Ground 'Type 2'	Generally below Made Ground Type 1.	Typically damp, dark brown/black sandy gravelly clay matrix, with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Generally strong organic odour. Frequent asbestos. Origin: Early 1960s municipal refuse disposal

Site observations indicated possible asbestos containing materials (ACM) were present in the Made Ground consisting principally of cement-bound pipe and insulation board. Samples were taken for subsequent laboratory verification and identification (refer Section 5.3.2).

Dates obtained from newspaper fragments within the Made Ground Type 2 material are summarized below;

- TP1005 at approx. 3.50m BGL: 1963;
- TP1007 at approx. 0.90m BGL: 1964;
- TP1008 at approx. 2.80m BGL: 1964;
- TP1013 at approx. 2.60 – 3.10 m BGL: 1960 & 1964; and
- BH1010 at approx. 11.00m BGL: 1961

The Made Ground lateral extents can be described as follows;

- To the west: Made Ground Type 1 and Type 2 materials becoming absent at base of western flank of 'mounds' adjacent to Kirkby Brook;
- To the south: Made Ground Type 1 and Type 2 becoming absent at base of southern flank of landfill 'mounds' adjacent to Bewley Road;
- To the east: It is known from previous ground investigations (refer Buro Happold Site Appraisal Report) that Made Ground extends further east of the recorded eastern boundary of the GDO 205 landfill (defined by the access track extending north from Bewley Road). Extent will confirmed by further investigation when access to this area obtained; and
- To the north: It is known from previous ground investigations (refer Buro Happold Site Appraisal report) that Made Ground is present north of the recorded northern boundary of the GDO 205 landfill underlying Knowsley Community College.

3.3 Natural Drift Deposits

Natural drift deposits were encountered in selected exploratory holes, with details provided in Table 3.2 overleaf.

Table 3.2 – Types of Natural Drift deposits encountered.

Material	Location	Generalized Description
Alluvium <i>(associated with Kirkby Brook):</i>	BH1013, BH1014, BH1015, TP1010, TP1011, TP1012	Interbedded soft brown sandy clay/silt and loose brown sand and gravel
Glacial Deposits Granular <i>(Glacial Sand and Gravel or Shirdley Hill Sand):</i>	BH1004, BH1008, BH1017, TP1014, TP1015	Yellow/brown slightly silty slightly gravelly coarse sand.
Glacial Deposits Cohesive <i>(Glacial Boulder Clay)</i>	BH1001, BH1002, BH1003, TP1004	Stiff brown sandy gravelly clay, gravel of mixed lithologies.

3.4 Solid Geology - Sherwood Sandstone

The bedrock underlying the site is Sherwood Sandstone of Permo-trassic age comprising red/brown sandstone and rare mudstone. The base of this stratum was not proven in any of the exploratory holes, though reference to the published geology (Buro Happold Site Appraisal Report) indicates this stratum continues to significant depth (>100m). There is typically 1 – 2 m of ‘weathered’ rock (recoverable by cable percussion boring techniques) overlying competent rock.

3.5 Groundwater

Complete records of groundwater entries are recorded on the exploratory logs included within the Soil Mechanics Phase 1 Factual Report. A summary of conditions encountered is provided below;

- Made Ground: – Typically minor seepages were encountered occasionally in boreholes and trial pits, predominantly within the Made Ground Type 2 materials;
- Natural Drift Deposits: Seepages in boreholes and trial pits were encountered within the Alluvium adjacent to Kirkby Brook generally coincident with stream water level;

- Sherwood Sandstone: Groundwater strikes within the Sherwood Sandstone were recorded in selected boreholes, typically within the top 1-3m; and
- Surface: A localized area of groundwater emergence at ground level was identified during ground investigation works on site, subsequently this area was investigated by handheld windowless sampler techniques (refer location WS1004 on Figure 4). The emergence was observed on a number of occasions during site works and described as slightly odorous with a multicoloured surface sheen, with flow rates estimated to be $< 1 \text{ ml/s}^{-1}$ from visual assessment. The location was coincident with a historic meander of Kirkby Brook (refer Figure 4), and the water discolouration was attributed to high iron content resulting from leachate break-out.

3.6 Stability of excavations

The machine dug trial pits were generally progressed to the full reach of the excavator (~4.50m BGL) with the following exceptions;

- TP1002: Groundwater ingress at 3.60m BGL causing instability, unable to progress pit (in Made Ground Type 2);
- TP1007: Concrete lintel obstruction encountered at 3.80m BGL, unable to progress pit (in Made Ground Type 2);
- TP1008: Car tyres encountered at 3.50m BGL, unable to progress pit (in Made Ground Type 2);
- TP1010: Collapse of saturated alluvium material below groundwater table at 3.00m BGL (in Alluvium);
- TP1011: Collapse of saturated alluvium material below groundwater table at 3.60m BGL (in Alluvium);
- TP1012: Collapse of saturated alluvium material below groundwater table at 2.60m BGL (in Alluvium);
- TP1013: Poor stability of fill at 3.10m BGL (in Made Ground Type 2); and
- TP1015: Poor stability and collapse at 4.00m BGL (in Glacial Deposits Granular).

3.7 FID screening results

Soil samples were screened on site using a portable Flame Ionisation Detector (FID) calibrated for methane. Full results are included in the Soil Mechanics Phase 1 Factual Report. Characteristic FID results for the various strata encountered during the ground investigation are summarized below:-

- Made Ground Type 1: Typically between 0 – 100 ppm;
- Made Ground Type 2: Typically between 100 – 3000 ppm; and
- Natural stratum: Typically between 0 – 20 ppm.

A maximum reading of 9000 ppm was recorded in BH1012 for a sample of Made Ground Type 2 at 1.50 m BGL. Plots of FID results for selected boreholes and trial pits are included as Figure 5.

3.8 Geophysical Resistivity Survey

A geophysical survey utilising electrical resistivity techniques was undertaken by Pelorus Surveys between 17 – 19 April 2007. Full details of the techniques used, results and interpretation of data are provided in the Pelorus Report which should be read in conjunction with this report. Cross sections from this report are included as Appendix B.

Ground cross sections based on the Soil Mechanics exploratory logs are included as Figure 6.

Outputs from the 12D software used to model the proposed site earthworks exercise are included as Figure 7 to enable site ground conditions to be illustrated in addition to Figure 6.

4 Site Monitoring and Laboratory Testing

4.1 Site Monitoring

A programme of site monitoring consisting of the following elements has been undertaken:

- 4 No. site monitoring visits undertaken between 6 June and 4 July 2007 by AES laboratory;
- Groundwater level monitoring of all installations;
- Groundwater sampling in selected installations following procedures outlined in BS ISO 5667-18:2001 including use of dedicated Waterra tubing in each installations and purging of 3 well volumes prior to sampling, with subsequent laboratory analysis;
- Surface water sampling of Kirkby Brook (upstream, adjacent to and downstream of the landfill) with subsequent laboratory analysis;
- Ground gas monitoring of selected installations following best practice procedures outlined in CIRIA C659:2006; and
- Ground gas sampling in selected installations with subsequent laboratory analysis.

Full results of the site monitoring are included in the AES Phase 1 Factual Report.

Groundwater levels and variations as recorded during the monitoring period are presented on the ground cross sections included as Figure 6. It should be noted the first 3 No. monitoring visits were undertaken after a period of dry weather, whereas the 4th monitoring visit (04/07/2007) followed a period of sustained heavy rainfall in July 2007.

It should be noted further site monitoring will be undertaken in addition to that reported within this report, in order to further characterise groundwater, surface water and ground gas conditions.

4.2 Groundwater Regime

Intrusive investigations and monitoring results show the 'main' groundwater table underlying the site lies within the Sherwood Sandstone. The aquifer is largely unconfined due to historical extraction of superficial (drift) deposits (refer Buro Happold Site Appraisal Report for further details).

Discussions with the Environment Agency indicate the regional hydraulic gradient within the Sherwood Sandstone aquifer is east to west. Investigation and monitoring results have generally validated this gradient within the area investigated. The elevation of the top of the Sherwood Sandstone is seen to decrease generally in a westward direction towards Kirkby Brook (refer cross sections in Figure 6).

Interpolation of the sandstone rock head elevation indicates it is present at shallow depth or even directly underlying the channel bed of Kirkby Brook. Supporting evidence for this is provided by the red/brown colour of the channel bed which matches the colour of the Sherwood Sandstone; in addition an outcrop of sandstone is visible outcropping in the bank of the Brook directly south of Bewley Road. Based on the groundwater within the Sherwood Sandstone aquifer is considered to be in hydraulic continuity with Kirkby Brook surface water.

The localised groundwater flow regime underlying the site is considered to be controlled by an infilled former valley feature that runs approximately east-west and extends eastwards under the All Saints school playing fields (refer Figure 7 and Buro Happold Site Appraisal report). This channel was subsequently infilled, including Made Ground Type 2 materials. Groundwater within this channel feature may be present above rockhead lying within the landfilled materials.

From a site walkover an emergence of groundwater/landfill leachate was identified in the bank of Kirkby Brook at the location of WS1004 (refer Figure 4). It should be noted this location is coincident with an area where previously the channel of Kirkby Brook extended significantly further east (into the present day landfill) as identified on historical Ordnance Survey maps. It is considered this area is now discharging the majority of the groundwater which is flowing through the former valley feature as well as the main landfill. Along the majority of the remainder of the eastern bank of Kirkby Brook north of WS1004, a small retaining wall is visible, which may be masking the flow of groundwater/leachate into the Brook, or inhibiting and diverting flow southwards to the vicinity of WS1004.

4.3 Laboratory Testing for Contamination Purposes

Representative soil, water and gas samples were selected for laboratory analysis to characterise the different material types encountered during the ground investigation and assess risks to human health and controlled waters. Laboratory testing was carried out by UKAS-accredited laboratory AES. A summary of the laboratory testing undertaken is provided in Table 4.1 below.

Table 4.1 – Number of samples analysed and Suites of analysis: Contamination

Suite	Soil	Soil Leachate	Water	Gas
'General' Suite	66	48	43	7
WAC Suite	49	-	-	-
TPHCWG	13	3	12	-
VOCs Suite	14	8	12	-
SVOCs Suite	6	4	12	-
Natural Attenuation Indicators Suite	-	10	12	-

Full results are included in the AES Phase 1 Factual Report.

Analytical suites were selected based on the findings of the Site Appraisal Report (Buro Happold, 2006), site observations, ambiguous contaminants typically found on brownfield sites and also the requirements of the current waste classification regime (specifically Waste Acceptance Criteria). Duplicate groundwater and surface water samples were collected and analysed for quality assurance purposes.

4.4 Laboratory Testing for Geotechnical Purposes

Representative soil and rock core sub-samples were selected for geotechnical laboratory testing which was carried out by Soil Mechanics. A summary of the testing carried out is provided in Table 4.2 below.

Table 4.2 – Number of samples analysed and Suites of analysis: Geotechnical

Test	Soil	Rock
Moisture Content	30	-
Atterberg Limit	30	-
Particle Size Distribution	56	-
pH, Water soluble sulphate, carbonate, chloride	9	-
California Bearing Ratio	4	-
Dry density/Moisture Content	17	-
Moisture Condition Value	6	-
Permeability in a triaxial cell	13	-
Uniaxial Compressive Strength	-	10
Point Load	-	124

Full results are included in the Soil Mechanics Phase 1 Factual Report.

5 Soil data assessment - contaminant source characterisation

5.1 Approach

The current land use of the former GDO 205 landfill area is public open space. An assessment of soil contaminant concentrations in relation to the current condition will be carried out to assess potential risks to human receptors using the site, principally recreational users and children attending a secondary school in the local area.

Due to existing topography, site redevelopment will require a cut and fill exercise to create a level platform. An assessment of soil contaminant concentrations in relation to the enabling works/construction phase condition will be carried out to assess potential risks to human receptors using the site, principally construction workers.

The proposed development within the former GDO 205 landfill area comprises a football stadium and surrounding hardstanding areas, and as such does not readily fit within one of the CLEA 'standard' land use scenarios (namely commercial/industrial, residential without plant uptake, residential with plant uptake). It is considered however that the commercial/industrial land use scenario most closely fits the proposed development.

The analytical data derived from the Phase 1 ground investigation has been put into context by comparison with screening values for residential with plant uptake, residential without plant uptake and commercial/industrial land use scenarios. Criteria used in this assessment are summarized in the following paragraphs;

- Soil Guideline Values (SGVs), published by DEFRA/Environment Agency which are available for a limited number of determinands and land uses.
- Human health threshold values (Generic Assessment Criteria) for Polycyclic Aromatic Hydrocarbons (PAHs) and Total Petroleum Hydrocarbons (TPH) in soils have been derived by Buro Happold using the CLEA UK (beta version) risk assessment model. Criteria for benzo(a)pyrene and naphthalene were derived using toxicological data from the TOX reports published by the Environment Agency. For TPH, criteria were derived for the various carbon bands for both aliphatic and aromatic hydrocarbons, adopting the toxicological values reported in the EA publication "The UK approach for evaluating human health risks from petroleum hydrocarbons in soils".

- Generic Assessment Criteria (GAC) derived by Land Quality Management Ltd (LQM)³ have been used for VOCs/SVOCs where possible.
- The phytotoxic metals copper and zinc have been screened against Dutch Intervention Values for eco-toxic risk due to the lack of authoritative current UK guidance.

For determinands where no appropriate criteria exists the laboratories limit of detection has been used as an initial screen of the dataset.

5.1.1 Division relevant to receptor

The analytical data has been assessed with respect to:

- Chronic risks to human health;
- Acute risks to human health;
- Risks to *flora*;
- Risks to buildings/ structures; and
- Risks to controlled waters are considered in Section 7.

5.1.2 Division relevant to source material

The analytical data has been characterised with respect to the different soil types encountered; principally:

- Made Ground Type 1;
- Made Ground Type 2; and
- Natural Drift Deposits (including Alluvium, Glacial Deposits Granular and Glacial Deposits Cohesive).

The soil testing data together with their relevant screening criteria is included as Appendix C.

5.2 Chronic risks to human health

5.2.1 Made Ground Type 1

A total of 39 No. samples of Made Ground Type 1 were analysed for a suite of inorganic and organic determinands with results screened against thresholds outlined in Section 5.1. Determinands showing one or more exceedance of a relevant threshold value have been subjected to a statistical analysis following CLR7 summarised in Table 5.1.

³ Generic Assessment Criteria for Human Health Risk Assessment, Land Quality Management Ltd, November 2007.

Certain determinands, predominantly organic contaminants including petroleum hydrocarbons and VOCs/SVOCs are not usually subjected to statistical analysis (i.e. calculation of “average” or US95 value) as analysis has often been carried out on a judgemental basis (contamination suspected from visual/olfactory evidence). “Averaging” of such data can therefore disguise the true distribution and magnitude of this contamination which may be present in localised areas (“hot spots”) across a site..

Table 5.1 –Made Ground Type 1 Determinands showing exceedances of thresholds

Determinand	No of samples	SGV (No of samples exceeding SGV)			Max	Min	US95 (exc. Outlier)	Outliers
		Residential with plant uptake	Residential without plant uptake	Commercial industrial				
Cadmium (mg/kg)	39	1 (1)	30 (0)	1400 (0)	9.3	<0.2	0.94 (0.377)	9.3 in BH1011 (0.5m)
Nickel (mg/kg)	39	50 (2)	75 (2)	5000 (0)	200	10	42.4 (33.6)	200 in BH1011(0.5m)
Benzo(a)pyrene (mg/kg)	39	1.2* (7)	1.4* (6)	31*(0)	5.2	<0.1	1.00	-

*Generic Assessment Criteria

A single sample recorded an elevated cadmium concentration of 9.3 mg/kg (BH1011 @ 0.5m) which has been indicated to be a statistical outlier. The US95 after removal of this outlier is below the residential with plant uptake SGV.

The US95 value for nickel is below the residential with plant uptake SGV. One sample has been identified as an outlier with a nickel concentration approximately 4 times higher than the residential with plant uptake SGV.

The maximum benzo(a)pyrene concentration of 5.2mg/kg is approximately 4 times higher than the residential with plant uptake SGV though is 6 times lower than the commercial/industrial SGV. The US95 is lower than the residential with plant uptake SGV.

In addition to the determinands listed in Table 5.1 a single sample showed an exceedance of a screening value for PCBs (where the screening value adopted was the limit of detection). This result of 41 µg/kg is approximately 2 times the laboratory limit of detection of 20µg/kg.

5.2.2 Made Ground Type 2

A total of 23 No. samples of Made Ground Type 2 were analysed for a suite of inorganic and organic determinands with results screened against thresholds outlined in Section 5.1. Determinands showing one or

more exceedance of a relevant threshold value have been subjected to a statistical analysis following CLR7, summarised in Table 5.2 below.

Table 5.2 –Made Ground Type 2: Determinands showing exceedances of thresholds

Determinand	No of samples	SGV (No of samples exceeding SGV)			Max	Min	US95 (exc. Outlier)	Outliers
		Residential with plant uptake	Residential without plant uptake	Commercial industrial				
Arsenic (mg/kg)	23	20 (9)	20 (9)	500 (0)	140	7.9	40.6 (31.8)	140 in BH1011 (3m)
Cadmium (mg/kg)	23	2 (5)	30 (0)	1400 (0)	11	<0.2	2.46	-
Lead (mg/kg)	23	450 (1)	450 (1)	750 (1)	910	30	210	-
Nickel (mg/kg)	23	50 (7)	75 (2)	5000 (0)	160	23	59.4 (50.3)	160 in BH1011 (3m)
Benzo(a)pyrene (mg/kg)	23	1.2*(5)	1.4*(5)	31*(0)	12	<0.1	2.40	-

* Generic Assessment Criteria

A single statistical outlier in the arsenic dataset is indicated, however this outlier is approximately 3 ½ times lower than the commercial/industrial SGV. The US95 with the outlier removed is less than 2 times higher than the residential without plant uptake SGV.

The US95 for cadmium is slightly higher than the residential with plant uptake SGV (assuming a pH of 7) though is approximately 12 times lower than the residential without plant uptake SGV.

A maximum lead concentration of 910 mg/kg is not indicated to be a statistical outlier. The US95 value is approximately 2 times lower than the residential with plant uptake SGV.

The US95 for nickel is higher than the residential with plant uptake SGV though lower than the residential without plant uptake SGV. A single outlier is identified within the dataset which is approximately 2 times greater than the residential without plant uptake SGV. It is noted that this outlier was found in the same exploratory hole as the outlier in the Made Ground Type 1 results though at a greater depth below ground level.

The US95 value for benzo(a)pyrene is less than 2 times higher than the residential without plant uptake Generic Assessment Criteria however significantly below the commercial/industrial GAC. It is noted that the maximum

PAH (USEPA 16) concentration of 233.17 mg/kg is recorded in BH1016 @8.00m which also contains the maximum benzo(a)pyrene concentration of 12 mg/kg

In addition to the determinands listed in Table 5.2 above, a single sample of Made Ground Type 2 showed a slight exceedance of the residential with plant uptake GAC for cresols (BH1001 @ 5.00m). This result is however 2 orders of magnitude below the residential without plant uptake GAC.

In the PCB dataset 5 No. samples were recorded above the limit of detection of 20µg/kg, with a maximum result of 460 µg/kg (BH1006 @ 10.00m). The same sample also shows the only exceedance of the residential without plant uptake GAC for xylenes, though this result is over an order of magnitude lower than the commercial/industrial SGV.

Of the 18 No. samples analysed for Total Petroleum Hydrocarbons, 4 No. exceed the screening value of 1000mg/kg. Samples subjected for further TPHCWG testing show that the majority of the hydrocarbons producing the elevated TPH results are generally 'heavy end' aliphatics in the carbon range C21 – C35. It should be noted TPHCWG carbon banding results do not exceed any threshold criteria.

Of the 4 No. samples of Made Ground Type 2 submitted for a VOCs suite, all determinands recorded below limits of detection for all 4 No. samples, with the exception of bis(2-ethylhexyl)phthalate (BH1006@6.00m, BH1016@8.00m) and Di-n-Butylphthalate (BH1006 @ 6.00m). These results however were less than an order of magnitude above the laboratory limit of detection.

Results for samples submitted for a sVOC suite were generally below limits of detection, though certain determinands were shown to be slightly elevated. The maximum individual SVOC concentration was 420 µg/kg for both 1,3,5-Trimethylbenzene and Isopropylbenzene in TP1007 @ 3.50m.

5.2.3 Natural Drift Deposits

A total of 4 No. samples of natural drift deposits were analysed for a suite of inorganic and organic determinands primarily to characterise the 'background' levels of determinands present in the underlying natural soils. No determinands showed exceedances of relevant threshold values.

5.2.4 Indicator parameters

An assessment of selected parameters has been undertaken to characterise the different materials encountered during the ground investigation. For each selected parameter, the averages of the Made Ground Type 1, Made Ground Type 2 and Natural Drift deposits datasets have been calculated and are summarised in Table 5.3 below (results below limit of detection are assumed to be equal to limit of detection for this assessment).

Table 5.3 – Soil Indicator Parameters

Indicator Parameter	Natural Drift Deposits Average (4 No. samples)	Made Ground Type 1 Average (39 No. samples)	Approx. ratio Made Ground Type 1/Natural Drift	Made Ground Type 2 Average (23 No. samples)	Approx. ratio Made Ground Type 2/Natural Drift
pH	7.4	8.2	1.1	8.2	1.1
Moisture Content at 30 degrees (%)	18.1	13.4	0.7	22.7	1.3
Loss on Ignition (%)	2	2.9	1.5	8.2	4.1
Organic Carbon (%)	0.7	0.9	1.3	2.6	3.7
Organic Matter (%)	1.2	1.5	1.3	4.5	3.8
Sulphur (mg/kg)	211.8	516.6	2.4	3011.3	14.2
Ammonia (mg/kg)	<3	16.7	5.6	138.3	46
Sulphate (Total, mg/kg)	316.7	666.1	2.1	2927.4	9.2
Sulphate (Extractable, mg/l)	47.3	155.5	3.3	793	16.7

Table 5.3 above generally shows that the Made Ground Type 2 materials are more organic-rich than the Made Ground Type 1 materials in agreement with the findings of intrusive investigations and log descriptions. Ammonia concentrations are on average approximately 8 times higher in the Made Ground Type 2 than the Made Ground Type 1 and 46 times higher than the Natural Drift deposits. Sulphur and sulphate (total and extractable) concentrations are also shown to be elevated in the Made Ground Type 2 materials relative to both the Made Ground Type 1 and Natural Drift deposits.

5.3 Acute Risks to Human Health

5.3.1 Soil concentrations

There are no guidance values for assessing acute risk related to soil contamination. Because such risks are associated with short term exposure, consideration is required of maximum concentrations (and not the “average” concentration which is relevant to chronic, or long term risk).

The maximum concentrations of lead, petroleum hydrocarbons, cresols and VOCs/SVOCs in Made Ground Type 2 samples may be considered to represent an acute risk to human health.

5.3.2 Asbestos

Site observations indicated possible asbestos containing materials (ACM) in the Made Ground, consisting of cement-bound pipe and insulation board. Asbestos screening was undertaken on all soil samples during AES laboratory testing as part of the Soils General suite. It should be noted in line with the laboratories health and safety procedures no further testing was undertaken on soil samples in which ACM were identified. Results of the asbestos testing are summarized in Table 5.4 below.

Table 5.4 – Asbestos identified in soil samples

Material	Total number of samples screened for ACM	Number of samples where ACM identified	Chrysotile(white asbestos) present	Amosite (brown asbestos present)
Made Ground Type 1	42	3	BH1001@2.00m BH1006@2.00m BH1013@0.50m	
Made Ground Type 2	33	10	TP1001@1.50m TP1001@3.00m TP1003@4.00m TP1005@3.50m TP1006@3.90m TP1007@1.00m TP1008@2.20m TP1008@3.20m BH1001@6.00m,	TP1003@4.00m TP1006@3.90m BH1010@12.00m
Natural Drift Deposits	4	0	-	-

Generally the most hazardous form of asbestos with respect to human health is blue asbestos (crocidolite), followed by brown asbestos (amosite) and white asbestos (chrysotile). Reference to Table 5.4 above indicates the majority of the ACM identified during the AES laboratory testing is the lower risk chrysotile (white) asbestos. This is in general agreement with the site observations of cement-based products. No crocidolite (blue asbestos) was identified during laboratory testing.

5.3.3 Unexploded Ordnance

The Buro Happold Ground Engineering Site Appraisal Report identified a risk of unexploded ordnance being present on site. However, no evidence of ordnance, military waste or odours of marzipan typically characteristic of explosive materials were recorded during the ground investigation. Although considered low risk, a watching brief for evidence of ordnance is recommended during all enabling works/construction phase excavations on site.

5.4 Risks to *Flora*

Phytotoxic effects with respect to *flora* have been assessed by statistical evaluation of the datasets of the phytotoxic elements copper and zinc. Results are summarized in Table 5.5 below.

Table 5.5 – Phytotoxicity assessment

Material	Determinand	No of samples	Dutch Intervention Value (DIV)	Max	Min	US95 (exc. Outliers)	Outliers
Made Ground Type 1	Copper (mg/kg)	39	190 (1)	290	8.2	59 (47.4)	290 in BH1016 (5m)
	Zinc (mg/kg)	39	720 (0)	540	24	133	-
Made Ground Type 2	Copper (mg/kg)	23	190 (13)	1300	22	538	-
	Zinc (mg/kg)	23	720 (3)	8700	60	1420 (579)	8700 in BH1012 ((5m)

Results for the Made Ground Type 1 samples shows no exceedances of the DIV for zinc, and 1 No. exceedance for copper which is indicated to be a statistical outlier.

Results for the Made Ground Type 2 samples show over 50% of samples exceed the DIV for copper, with the US95 value being approximately 3 times higher than the DIV. No statistical outliers are indicated. In the zinc dataset 3 No. exceedances of the DIV are present with 1 No. indicated to be a statistical outlier. The recalculated US95 after removal of this outlier is less than the zinc DIV.

It should be noted none of the 4 No. samples of Natural Drift deposits recorded copper or zinc concentrations above the relevant DIV.

5.5 Risks to buildings/structures

An assessment of the risk to buried concrete and other building materials from ground contamination is presented in Section 6.4.

6 Soil leachability and Groundwater data assessment - contaminant source characterisation

6.1 Approach

Potential risks to controlled waters have been assessed by examining soil leachability data as well as groundwater data from the site. For the initial data assessment the principal thresholds adopted were UK Drinking Water Standards (DWS) and Freshwater Environmental Quality Standards (EQSs) derived under the requirements of the EC Dangerous Substances Directive). EQSs have been selected, where necessary, to be protective of *Cyprinid* fish and hardness-dependent EQSs selected to reflect the hardness of the Kirkby Brook surface water.

6.2 Leachability Data

Soil leachability testing has been undertaken on representative samples following guidance within Environment Agency (2006) Remedial Targets Methodology, specifically:

- BSEN 12457 Part 3 (Two Stage Test using a liquid to solid ratio of 2:1 in the first stage and a liquid to solid ratio of 8:1 in the second stage. (The combined result in mg/kg 10:1 is used in evaluating Waste Acceptance Criteria in Section 10.); and
- BSEN 12457 Part 2 (One Stage Test using a liquid to solid ratio of 10:1.

Where 2:1 and 8:1 results are available for a sample the higher result of the two is used (which is generally the 2:1 result) in the following assessment.

6.2.1 Division relevant to source material

The soil leachability data have been divided in accordance with the divisions used in Section 7 as follows:

- Made Ground Type 1;
- Made Ground Type 2; and
- Natural Drift Deposits (including Alluvium, Glacial Deposits Granular and Glacial Deposits Cohesive).

The soil leachate testing data together with their relevant screening criteria is included as Appendix D.

6.2.2 Made Ground Type 1

Determinands with one or more exceedance of relevant screening criteria are summarized in Table 6.1 below.

Table 6.1 – Made Ground Type 1

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Conductivity (uS/cm)	28	-	2,500 (1)	3,300	71
Fluoride (mg/l)	28	-	1.5 (2)	2.1	<0.2
Ammonia (mg/l as N)	28	0.015 (8)	-	17	<0.2
Sulphate (mg/l)	28	400 (1)	250 (4)	650	6
Antimony (mg/l)	28	-	0.005 (10)	0.019	0.001
Arsenic (mg/l)	28	0.05 (0)	0.01 (2)	0.013	0.00025
Cadmium (mg/l)	28	0.005 (5)	0.005 (5)	0.059	<0.0002
Lead (mg/l)	28	0.25 (0)	0.025 (6)	0.25	<0.002
Nickel(mg/l)	28	0.2 (0)	0.02 (1)	0.083	<0.0004
Selenium (mg/l)	28	-	0.01 (1)	0.021	<0.0001
PAH Drinking Water	29	-	0.1 (3)	0.84	<0.04
Benzo(a)pyrene	29	-	0.01 (8)	0.2	<0.01

In general based on the testing undertaken soil leachability of the Made Ground Type 1 materials appears to be limited. It is noted approximately 10% of samples exceed the UK 'Drinking Water 4' Standard, although benzo(a)pyrene (not included in the Drinking Water 4 list) exceeds its UK Drinking Water Standard in approximately 25% of all samples.

6.2.2.1 Made Ground Type 2

Determinands with one or more exceedance of relevant screening criteria are summarized in Table 6.2 below.

Table 6.2 – Made Ground Type 2

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Conductivity (uS/cm)	17	-	2,500 (4)	3,100	180
Fluoride (mg/l)	17	-	1.5 (2)	2.9	<0.2
Ammonia (mg/l as N)	17	0.015 (17)	-	130	<0.2
Cyanide (mg/l)	17	-	0.05 (1)	0.13	<0.02
Sulphate (mg/l)	17	400 (10)	250 (13)	2100	8.9
Antimony (mg/l)	17	-	0.005 (15)	0.049	0.0016
Arsenic (mg/l)	17	0.05 (1)	0.01 (9)	0.079	0.00082
Boron (mg/l)	17	2 (3)	1 (10)	8.5	<0.04
Cadmium (mg/l)	17	0.005 (6)	0.005 (6)	0.051	<0.0002
Chromium (mg/l)	17	0.25 (0)	0.05 (1)	0.076	<0.0003
Copper (mg/l)	17	-	2 (1)	2.7	<0.002
Lead (mg/l)	17	0.25 (0)	0.025 (2)	0.25	<0.002
Mercury (mg/l)	17	0.001 (1)	0.001 (1)	0.016	<0.00008
Nickel(mg/l)	17	0.2 (0)	0.02 (10)	0.17	0.0018
Nitrite (mg/l as N)	8	-	0.03 (2)	1.6	<0.011
Iron Dissolved (mg/l)	8	1 (1)	0.2 (1)	9.7	0.004
Manganese Dissolved (mg/l)	8	-	0.05 (7)	4	0.029
PAH Drinking Water 4	17	-	0.1 (2)	0.215	<0.04
Benzo(a)pyrene	17	-	0.01 (6)	1.5	<0.01

Table 6.2 shows that soil leachability of the Made Ground Type 2 samples is generally more elevated than for the Made Ground Type 1 samples. Exceedances of screening criteria are present in greater than 50% of samples for the following determinands; ammonia, arsenic, sulphate, antimony, boron, nickel, manganese (dissolved).

6.2.3 Natural Drift Deposits

Determinands with one or more exceedance of relevant screening criteria are summarized in Table 6.3 below.

Table 6.3 – Natural Drift Deposits

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Ammonia (mg/l as N)	3	0.015 (1)	-	0.37	<0.2
Antimony (mg/l)	3	-	0.005 (1)	0.02	0.00096
Arsenic (mg/l)	3	0.05 (0)	0.01 (1)	0.019	0.0018
Cadmium (mg/l)	3	0.005 (2)	0.005 (2)	0.0097	<0.0002
Lead (mg/l)	3	0.25 (0)	0.025 (2)	0.06	<0.002
Nickel(mg/l)	3	0.2 (0)	0.02 (1)	0.035	0.0047

Leachable concentrations within the natural ground samples are in general not elevated, with occasional minor exceedances of the relevant screening criteria.

6.2.4 Indicator parameters

An assessment of 'indicator' parameters has been undertaken to characterise the different materials encountered during the ground investigation. For each selected parameter, the averages of the datasets for the Made Ground Type 1, Made Ground Type 2 and Natural Drift deposits results has been taken and is summarised in Table 6.4 below. It is noted results below limit of detection are assumed to be equal to limit of detection for this assessment.

Table 6.4 –Indicator parameters for leachate results

Indicator Parameter	Natural Drift Deposits Average (4 No. samples)	Made Ground Type 1 Average (39 No. samples)	Approx. ratio Made Ground Type 1/Natural Drift	Made Ground Type 2 Average (23 No. samples)	Approx. ratio Made Ground Type 2/Natural Drift
Conductivity (uS/cm)	174.3	316.4	1.8	1068.8	6.1
Total Dissolved Solids @105 degrees (mg/l)	299	208.8	0.7	985.9	3.3
Chemical Oxygen Demand (mg/l)	33.7	22.5	0.7	80.1	2.4
Total Organic Carbon (mg/l)	15.6	13.4	0.9	32.4	2.1
Dissolved Organic Carbon (mg/l)	1.2	1.5	1.25	30.9	25.75
Ammonia (mg/kg)	0.23	0.8	3.5	25	108.7

The comparison above indicates that the Made Ground Type 1 material appears to have similar leachability properties to the 'background' natural stratum. The Made Ground Type 2 results are however highly elevated compared to the natural background, particularly so for leachable dissolved organic carbon and ammonia.

6.3 Water Results

Groundwater and surface water results have been assessed against screening criteria, primarily the UK Drinking Water Standards and Freshwater Environmental Quality Standards upon consideration of the high controlled waters sensitivity of the site. EQSs have been selected where necessary to be protective of *Cyprinid* fish and hardness-related EQS have been adjusted to reflect the hardness of the Kirkby Brook surface receptor ascertained by laboratory testing.

6.3.1 Division relevant to waterbody

The groundwater data has been assessed on the basis of which stratum water samples were sampled from. Surface water results are considered separately. The different aquifers/water bodies to be considered are summarized below;

- Made Ground Type 1;
- Made Ground Type 2.;
- Natural Drift Deposits between landfill and Kirkby Brook;
- Sherwood Sandstone; and
- Kirkby Brook.

The water testing data together with their relevant screening criteria is included as Appendix E. Duplicate samples were taken for analysis and comparison of results generally indicate good precision. Furthermore conductivity readings taken on site during sampling agree well with laboratory conductivity results indicating samples have not deteriorated significantly between sampling and analysis.

6.3.2 Made Ground Type 1

Standpipe installations in BH1002, BH1007, BH1 and BH2 have response zones within the Made Ground Type 1 material. Groundwater samples were obtained from BH1002 (2 No. occasions), BH1 (2 No. occasions) and BH1007 (1 No. occasion). A sufficient sample could not be obtained from BH2 on both sampling visits. Determinands exceeding their screening criteria in one or more samples are summarized in Table 6.5 below.

Table 6.5 – Made Ground Type 1 Groundwater Exceedances

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Biological Oxygen Demand (mg/l)	5		7* (4) (*criteria from Surface Water Directive)	58	5
Ammonia as N (mg/l)	5	0.015 (5)	-	24	0.44
Antimony (mg/l)	5	-	0.005 (2)	0.0056	<0.002
Nickel (mg/l)	5	0.2 (0)	0.02 (2)	0.032	0.01
Phenol (ug/l)	5	30 (0)	0.5 (3)	2.5	<0.5
PAH Drinking Water 4 (ug/l)	5	-	0.1 (3)	1.084	<0.01
Benzo(a)pyrene (ug/l)	5	-	0.01 (4)	0.13	<0.01

The groundwater results and exceedances of the screening criteria will be evaluated as part of the risk assessment presented in Section 8.

6.3.3 Made Ground Type 2

Standpipe installations in BH1005, BH1006, BH1009, BH1012 and BH1016 have response zones within the Made Ground Type 2 material. Groundwater samples of sufficient volume for analysis were obtained from BH1005 on 2 occasions and BH1009 on 1 occasion, with a second sample from BH1009 obtained on the second monitoring visit sufficient in volume only to complete PAH analysis. Sufficient samples could not be obtained from the other borehole installations on both sampling visits. In addition to the above a sample was

obtained during the site works from an inflow into TP1002 which occurred within the Made Ground Type 2 material. Determinands exceeding their screening criteria in one or more samples are summarized in Table 6.6 below.

Table 6.6 – Made Ground Type 2 Groundwater Exceedances

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Biological Oxygen Demand (mg/l)	3	-	7* (3) (*criteria from Surface Water Directive)	51	30
Ammonia as N (mg/l)	4	0.015 (4)	-	66	1.3
Arsenic (mg/l)	4	0.05 (0)	0.01 (1)	0.036	0.0048
Chromium(mg/l)	4	0.25 (0)	0.5 (1)	0.082	0.00078
Nickel (mg/l)	4	0.2 (0)	0.02 (2)	0.032	0.01
Lead (mg/l)	4	0.25 (1)	0.025 (1)	3.4	<0.002
Boron (mg/l)	4	2 (1)	1 (1)	3.7	0.47
Phenol (ug/l)	4	30 (1)	0.5 (1)	236.3	<0.5
PAH Drinking Water 4 (ug/l)	5	-	0.1 (2)	0.235	<0.04
Benzo(a)pyrene (ug/l)	5	-	0.01 (4)	0.06	<0.01

The groundwater results and exceedances of the screening criteria will be evaluated as part of the risk assessment presented in Section 8.

6.3.4 Natural Drift Deposits

Standpipe installations in BH1004, BH1008, BH1013, WS1004, WS1005 and WS1006 have response zones within the Natural Drift deposits located between the area of the former landfill and Kirkby Brook.

Determinands exceeding their screening criteria in one or more samples are summarized in Table 6.7 below.

Table 6.7 – Natural Drift Deposits Groundwater Exceedances

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Biological Oxygen Demand (mg/l)	18	-	7* (8) (*criteria from Surface Water Directive)	450	1
Ammonia as N (mg/l)	18	0.015 (18)	-	78	0.56
Mercury (mg/l)	18	0.001 (1)	0.001 (1)	0.0019	<0.00008
Nickel (mg/l)	18	0.2 (0)	0.02 (3)	0.024	0.0024
Boron (mg/l)	18	2 (12)	1 (16)	10	0.076
Phenol (ug/l)	18	30 (0)	0.5 (12)	10.1	<0.5
PAH Drinking Water 4 (ug/l)	15	-	0.1 (2)	0.273	<0.04
Benzo(a)pyrene (ug/l)	15	-	0.01 (3)	0.08	<0.01

In addition to the determinands listed in Table 6.7 above, 2 No. determinands in the SVOC suite (bis(2-ethylhexyl)phthalate in 1 out of 2 No. samples and di-n-Butylphthalate in 1 out of 2 No. samples) were identified above the laboratory limit of detection (lod), though the maximum exceedance was no more than one order of magnitude. One determinand in the VOC suite (chlorobenzene, 1 out of 2 No. samples) was identified above the laboratory lod though the exceedance was less than one order of magnitude.

The groundwater results and exceedances of the screening criteria will be evaluated as part of the risk assessment presented in Section 8.

6.3.5 Sherwood Sandstone

Installations in BH1001, BH1003, BH1010, BH1011, BH1017 have response zones within the Sherwood Sandstone stratum and all underlie the area of historical landfilling. Determinands exceeding their screening criteria in one or more samples are summarized in Table 6.8 below.

Table 6.8 – Sherwood Sandstone Groundwater Exceedances

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Biological Oxygen Demand (mg/l)	10	-	7* (1) (*criteria from Surface Water Directive)	10	2
Ammonia as N (mg/l)	10	0.015 (8)	-	29	<0.2
Chloride (mg/l)	10	250 (2)	250 (2)	330	20
Manganese Dissolved (mg/l)	4	-	0.05 (4)	10	2.6
Barium (mg/l)	10	-	1 (2)	1.2	0.099
Nickel (mg/l)	10	0.2 (0)	0.02 (2)	0.1	0.00096
Phenol (ug/l)	10	30 (0)	0.5 (2)	2.12	<0.5
PAH Drinking Water 4 (ug/l)	10	-	0.1 (1)	0.572	<0.04
Benzo(a)pyrene (ug/l)	10	-	0.01 (3)	0.2	<0.01

In addition to the determinands listed in Table 6.8 above, 1 out of 4 No. samples identified Extractable TPH (aromatic >C16-C21) though less than one order of magnitude above the lod. Furthermore 3 No. determinands in the sVOC suite were identified above lod (bis(2-ethylhexyl)phthalate in 4 out of 4 No. samples, di-n-Butylphthalate in 4 out of 4 No. samples, diethylphthalate in 1 out of 4 No. samples), though the maximum exceedance was no more than one order of magnitude. In the VOC suite 3 No. determinands were identified above lod (benzene in 2 out of 4 No. samples, chlorobenzene in 4 out of 4 No. samples, 1-4 dichlorobenzene in 2 out of 4 No. samples). Exceedances were no more than one order of magnitude with the exception of 2 No. elevated results for chlorobenzene from groundwater in BH1001 (maximum result 430 µg/l compared to lod of 1 µg/l).

The groundwater results and exceedances of the screening criteria will be evaluated as part of the risk assessment presented in Section 8.

6.3.6 Surface Water (Kirkby Brook)

Water samples were obtained from Kirkby Brook during the site monitoring at 3 no. sampling points; KB1 (upstream of site west of Valley Road), KB2 (adjacent to location of WS1004) and KB3 (downstream of site south of Bewley Road). Refer to the exploratory plan included as Figure 4 for locations. Water samples were collected from all 3 no. points on 2 no. separate monitoring visits. In addition data on pH, hardness, BOD, ammonia and nitrate was obtained from the Environment Agency website for the upstream and downstream stretches of Kirkby Brook.

Determinands exceeding their screening criteria in one or more samples are summarized in Table 6.9 below.

Table 6.9 – Kirkby Brook Surface Water Exceedances

Determinand	No of samples	Screening Criteria		Max	Min
		Environmental Quality Standard (EQS)	UK Drinking Water Standard (DWS)		
Ammonia as N (mg/l)	8 (inc 2 averages of EA data)	0.015 (8)	-	23	0.482
Nitrite (mg/l as N)	6	-	0.03* (6) *converted from NO ₂	0.31	0.17
Nitrate (mg/l as N)	8 (inc 2 averages of EA data)	-	11* (2) *converted from NO ₃	23.86	0.66
Iron Dissolved (mg/l)	6	1 (0)	0.2 (6)	0.42	0.22
Phenol (ug/l)	6	30 (0)	0.5 (3)	0.81	<0.5

In addition to the determinands listed in Table 6.9 above, a number of results for TPHCWG, sVOCs and VOCs were above the laboratory lod, which are summarised below:

- Extractable TPH aromatic >C12-C16: 2 out of 6 No. samples, less than one order of magnitude >lod;
- Extractable TPH aromatic >C16-C21: 1 out of 6 No. samples, less than one order of magnitude >lod;
- bis(2-ethylhexyl)phthalate: 6 out of 6 No. samples less than one order of magnitude >lod;
- Di-n-Butylphthalate: 5 out of 6 No. samples up to 1.5 orders of magnitude >lod;
- 1,2-Dichlorobenzene: 2 out of 6 No. samples, up to 2 orders of magnitude >lod;

- Meta + Para Xylene: 2 out of 6 No. samples, less than one order of magnitude > lod;
- Trichloroethene: 3 out of 6 No. samples, less than one order of magnitude > lod;
- 1,2-Dibromoethane: 3 out of 6 No. samples less than one order of magnitude > lod;
- Chlorobenzene: 3 out of 6 No. samples, less than 2 orders of magnitude > lod; and
- Tetrachloroethene: 2 out of 6 No. samples, less than one order of magnitude > lod.

The groundwater results and exceedances of the screening criteria will be evaluated as part of the risk assessment presented in Section 8.

6.4 Risks to Buildings/Services

6.4.1 Buried Concrete

The soil and groundwater testing results from AES have been assessed to ascertain potential detrimental effects on buried concrete by aggressive ground, following BRE Special Digest 1⁴. The results of this assessment, following the procedures outlined in Section C5 of this document, are summarised as follows;

C5.1 Step 1(a) Soil Samples

The results of sulphate testing (2:1 water/soil extract) have been assessed. Due to the differing characteristics of the materials encountered during the ground investigation the datasets for Made Ground Type 1, Made Ground Type 2 and Natural Drift Deposits have been assessed separately in Table 6.10.

Table 6.10 – Summary of water soluble sulphate results

Stratum	Number of results	Maximum result (mg/l)	Recommended Approach	Characteristic value for stratum (mg/l)
Made Ground Type 1	39	700	Mean of highest 20% of results, rounded to nearest 100mg/l	500
Made Ground Type 2	23	2500	Mean of highest 20% of results, rounded to nearest 100mg/l	1900
Natural Drift Deposits	4	160	Highest result	160

C5.1 Step 1(b) Groundwater Samples

⁴ BRE (2005). *Concrete in aggressive ground*. Building Research Establishment, Special Digest 1:2005, Third Edition.

The highest determined sulphate concentration of the samples (rounded to 100mg/l) has been adopted as recommended in BRE SD1:2005. Of the 37 No. groundwater results the maximum sulphate concentration is 160mg/l (rounded to 200mg/l).

C5.1 Step 2

The site is considered to be a 'brownfield location' due to historical deposition of waste and as such results have been compared to Table C2 of BRE SD1:2005:

- The Made Ground Type 1 characteristic value of 500mg/l corresponds to the boundary between 'DS-1' (<500mg/l) and 'DS-2' (500-1500mg/l);
- The Made Ground Type 2 characteristic value of 1900mg/l corresponds to 'DS-3' (1600-3000mg/l);
- The Natural Drift Deposits characteristic value of 160mg/l corresponds to 'DS-1' (<500mg/l); and
- The groundwater characteristic value of 160mg/l corresponds to 'DS-1' (<400mg/l).

C5.1 Step 3

Representative Design Sulphate Class' for each stratum have been selected based on the above results:

- Made Ground Type 1: 'DS-2';
- Made Ground Type 2 'DS-3'; and
- Natural Drift Deposits characteristic 'DS-1'.

C5.1 Step 4

Based on a consideration of the groundwater conditions encountered during the ground investigation, the site has been characterised for the purposes of BRE SD1:2005 as containing 'mobile' groundwater, based on the groundwater seepages encountered in various boreholes and trial pits and the hydraulic gradient from east to west across the site towards Kirkby Brook.

Of the 65 No. soil pH results (all stratum), no results were lower than pH 6.5 which is the limit below which pH should be considered to pose to risk to buried concrete following BRE SD1:2005.

Of the 37 No. groundwater pH results no results were lower than pH 6.5 which is the limit below which pH should be considered to pose to risk to buried concrete following BRE SD1:2005.

C5.1 Step 5

The Aggressive Chemical Environment for Concrete (ACEC) classification for each stratum have been selected based on the above results based on BRE SD1:2005:

- Made Ground Type 1: 'AC-2';

- Made Ground Type 2: 'AC-3'; and
- Natural Drift Deposits: 'AC-1'.

Notwithstanding the above assessment, the impact of direct contact with contaminated groundwater/landfill leachate should be considered when specifying concrete in addition to the soil pH and sulphate concentrations used in the above assessment. A higher concrete class affording a greater level of protection may be required than that based solely on the foregoing assessment. Any concrete class should take into account the potential for future leachate production, however unlikely, and likely leachate pH etc – e.g. burst water main/sewer etc.

6.4.1.1 Buried Infrastructure

Chemical attack and permeation through buried plastic services is typically limited to organic contaminants. Consideration is required of both soil concentrations and groundwater concentrations, which have the potential to permeate into certain types of plastic supply pipes and contaminate water supplies including those for public consumption. Elevated concentration of several determinands including phenols, sulphates and hydrocarbons were identified by laboratory testing which are considered to pose a risk to buried infrastructure.

7 Data assessment - Ground Gas

7.1 Programme

Ground gas monitoring was undertaken by AES at 16 No. locations across the site during 4 No. monitoring visits between 6 June - 4 July 2007. Atmospheric pressure readings were recorded on all visits. Gas samples were collected during the monitoring visit on 14 June 2007, and scheduled for laboratory analysis to confirm the readings recorded on site following the receipt of field gas monitoring results. Further gas monitoring is being undertaken at the site the results of which will be reported when available.

The ground gas results are presented in Appendix F of this report. Full results can be found in the AES Phase 1 Factual Report

7.2 Data

Table 7.1 summarises the ground gas data recorded for boreholes installed within each of the strata monitored.

Table 7.1 – Summary of ground gas data

Strata	Methane (%)	Carbon Dioxide(%)	Flows (l/hr)	Characteristic Situation (CIRIA C659:2006)
Made Ground Type 1	Average 13.24% (Average excluding BH1002 results 0.77%{	Average 9.14%	Maximum flow 0.2 l/h	4/19 No. results CS1 15/19 No. results CS2
Made Ground Type 2	Average 65.20%	Average 19.37%	Maximum flow 0.8 l/h	19/19 No. results CS2
Natural Drift Deposits/Sherwood Sandstone	All results <0.5%	Average 2.03%	Maximum flow 0.3 l/h	17/20 No. CS1 3/20 No. CS2

During the monitoring round carried out 14 June 2007, 7 No. gas samples were collected from the following borehole installations; BH1002, BH1005, BH1006, BH1007, BH1009, BH1012, BH1016. Samples were scheduled for an analytical suite including methane, carbon dioxide, hydrogen sulphide and VOCs including BTEX. Full results of the laboratory analysis are included in the AES Phase 1 Factual Report. A comparison of the laboratory results with field monitoring results (methane, carbon dioxide and oxygen) is included in Appendix F. On average laboratory results for methane were 7.47% lower than the equivalent field reading, laboratory results for carbon dioxide were 3.50% lower than the equivalent field reading, and laboratory results for oxygen were 0.55% higher than the equivalent field reading. The differences observed are inferred to

represent a degree of sample loss which may have occurred during sample transport or handling, however in general the laboratory testing validates the gas concentrations monitored during the field visits.

7.2.1 Made Ground Type 1

Concentrations of methane were typically low in all installations monitoring this stratum, with the exception of BH1002 which recorded consistently elevated methane concentrations (maximum over monitoring period 73.80%). Carbon dioxide concentrations were generally slightly elevated and again were highest in BH1002. BH1002 also showed elevated FID results (maximum 1000 ppm) during site screening, though no municipal waste/organic content is recorded in the borehole log within this stratum. It is considered likely the concentrations observed are a result of gas migration from biodegradable components within Made Ground Type 2 materials proven in the vicinity of this borehole. Flow rates were consistently low in Made Ground Type 1 installations.

7.2.2 Made Ground Type 2

This stratum is typified by highly elevated methane concentrations (maximum 87.8%) and carbon dioxide concentrations (maximum 29.40%). The elevated concentrations correlate with elevated on site FID results on samples within this stratum. Flow rates were however consistently low in Made Ground Type 2 installations. The biodegradable component of this stratum is considered to be the source of the gas recorded within this stratum. Laboratory analysis for VOCs and hydrogen sulphide on samples from BH1005, BH1006, BH1009, BH1012 and BH1016 returned results generally below limits of detection.

7.2.3 Natural Drift Deposits/Sherwood Sandstone

Concentrations of carbon dioxide were generally low within the installations, although slightly elevated concentrations of carbon dioxide were recorded in BH1004 (5.1%) and BH1014 (5.5%). Methane concentrations were recorded below limits of detection on all occasions, furthermore FID results on samples from these installations are generally at trace levels. Flow rates are consistently low.

7.3 Assessment

The ground gas data has been assessed with reference to CIRIA report C659⁵. Consideration is therefore given to both methane and carbon dioxide concentrations as well as emission (flow) rates. The Gas Screening Value (GSV) is defined as the product of gas concentration multiplied by flow rate. The GSV is then considered with other parameters/ limiting conditions to define a Characteristic Situation (CS). The CS in turn identifies the need for and scope of any necessary gas protection measures (refer Appendix G).

⁵ Assessing risks posed by hazardous ground gases to buildings, CIRIA Report C659, December 2006.

Evaluation of individual monitoring results indicates that the maximum Characteristic Situation observed is CS2. The combined maximum individual methane and carbon dioxide concentrations and flow rates within the whole dataset (a 'worse case' assessment) produces a CS3 condition (low end of CS3 range).

Based on the foregoing, and with reference to Table 8.6 of CIRIA C659 (included as Appendix H), a typical recommended scope of protective measures for an 'office/commercial/industrial' development for CS3 is all joints and penetrations sealed and a minimum 2000 g/reinforced gas proof membrane and passively ventilated underfloor sub-space or positively pressurised underfloor sub-space.

It should be highlighted that the concentrations of methane and carbon dioxide are highly elevated, and in addition although gas flow rates have been found to be generally low (<1 litre/hour) more data is required to obtain more confidence in this assumption, particularly during periods of low and failing pressure which typically cause an increase in ground gas flow rates. It is possible that the ground gas regime (particularly flow rates) may worsen (flow rates increase) during development of the site due to ground disturbance and loading. Design to a higher CS (possibly CS4 or CS5) may be required dependent on the findings of further monitoring data, risk assessment and regulatory review.

7.4 Radon

With reference to the Health Protection Agency (HPA)/ British Geological Survey (BGS) Indicative Atlas of Radon in England and Wales (2007), the site is located in an area where less than 1% of homes are above the Action Level for radon affected areas, as such no radon protective measures are necessary in the construction of new dwellings, extensions or where change of use includes places where people sleep.

8 Contaminated land risk assessment

8.1 General approach

In the UK, the assessment of risk from contamination follows the source-pathway-target approach. If one of these three elements is absent it is considered that there is no risk of harm. If, however, there is considered to be a linkage between any given source and any given target/receptor then a risk-based approach is used to assess the significance or impact of any such linkage.

Source – The contaminants that have the potential to negatively affect human health and/or the health of the environment (i.e. the hazard).

Pathway – The potential route by which a receptor may come into contact with the source.

Receptor – The specific group of human beings or aspect of the environment (e.g. controlled waters) that could be affected by the source.

Risks are defined as the probability of an event occurring combined with the severity of the consequence of that event occurring. Particularly, to assess the risk to site end users posed by any given source, the sensitivity of each receptor is considered. For example, the concentration of contamination acceptable at a site to be developed as a residential property with a garden used to grow vegetables and accessible to young children is set lower than that for a commercial site where soil is exposed in minor areas of landscaping and the only long-term users of the site are adults. Similarly, a site overlying a major aquifer supplying potable water to a large population will be considered more stringently than a site overlying an impermeable geology with only minor seepages of groundwater.

8.2 Conceptual Site Model

The potential risks posed to human health and the environment by ground contamination at this site have been evaluated using a generic quantitative risk assessment which incorporates the 'source-pathway-receptor' identification and assessment methodology in accordance with CLR 11⁶. The risk assessment process therefore involves the identification of each site specific source based on both desk based and chemical information obtained from the site investigation together with identification of each relevant exposure pathway and each potential receptor. The potential risks to the receptor are then assessed by considering the potential effect of the source on the receptor as well as the likelihood of a pathway linking the two, i.e. a pollutant linkage as discussed above (refer Appendix H).

⁶ Model Procedures for the Management of Land Contamination, Environment Agency, September 2004.

8.2.1 Potential Sources

Based on the desk based and site investigation data obtained to date, the potential sources of contamination that may reasonably affect receptors on the site are summarised in Table 8.1 below.

Table 8.1: Principal Sources of Contamination

Potential Source(s)	Potential Contaminants of Concern/Comments
Made Ground Type 1 (majority of site)	<u>Soil</u>: < 20% nickel and B(a)P results > residential w/out plant uptake criteria. Low average and max concentrations of inorganics and organics. 3/42 samples contained chrysolite asbestos. <5% copper results >DIV. <u>Leachability</u>: <40% ammonia, antimony, lead, B(a)P results >DWS/EQS. Low leachability. <u>Gas potential</u>: Occasional elevated CO₂ and CH₄, gas flow < 1.0 l/h. Typically CS₂. Log descriptions and soil testing indicates low organic content/gas generation potential.
Made Ground Type 2 (majority of site)	<u>Soil</u>: < 50% arsenic, nickel, B(a)P results > residential w/out plant uptake criteria. 1 No. lead result > commercial/industrial criteria (910mg/kg). Locally elevated heavy-end aliphatic hydrocarbons, PCBs, SVOCs, VOCs. 9/33 samples contained chrysolite asbestos, 3/33 contained amosite asbestos. >50% copper results >DIV, plus 1 No. zinc hotspot of 8700mg/kg. Elevated organic matter, sulphur (x14 above natural background), sulphate (x9), ammonia (x16). <u>Leachability</u>: > 50% sulphate, antimony, boron, arsenic, nickel, manganese, ammonia results >DWS/EQS. Elevated conductivity (x6 above natural background), dissolved organic carbon (x26), ammonia (x109). <u>Gas potential</u>: Consistently high concentrations of CO₂ (average 19.37%) and CH₄ (average 65.26%). Gas flow < 1.0 l/h. Individual results CS₂, maximum concentration and flow (worse case) CS₃. High gas generation potential due to domestic waste component and elevated soil organic matter.
Contaminants in solution/landfill leachate	<u>Water samples from Made Ground Type 1 and Type 2</u>: > 40% BOD, ammonia, phenol, PAHs results >DWS/EQS. Locally highly elevated concentrations, including lead 3.4 mg/kg, 236.3 mg/l phenol. <u>Water samples from natural drift deposits (between landfill and Brook)</u>: > 40%

Potential Source(s)	Potential Contaminants of Concern/Comments
	ammonia, boron, phenol > DWS/EQS. Highly elevated concentrations from WS1004-WS1006 installations correlate with leachate emergence identified on site at this locality. Max. ammonia in WS1004 78 mg/l as N, conductivity in WS1004 consistently >2000 us/cm. 1 No. sample WS1006 COD 17,000 mg/l, BOD 450 mg/l. Occasional VOCs/SVOCs. <u>Water samples from Sherwood Sandstone:</u> > 50% ammonia, manganese results > DWS/EQS. Occasional VOCs/SVOCs. Conductivity (typically 1000 us/cm), BOD (<10 mg/l) and COD all low relative to Made Ground and WS1004-WS1006 water samples. <u>Water samples from Kirkby Brook:</u> Low relative conductivity (<600 us/cm) and BOD (<10mg/l). >50% ammonia, nitrite, iron, phenol results >DWS/EQS, plus locally elevated TPH, VOCs, SVOCs. No obvious deterioration in water quality between upstream/adjacent/downstream sampling points, including no noticeable increase in conductivity, COD, BOD, DOC, TOC, ammonia.

8.2.2 Potential Receptors and Pathways

Site specific pathway receptor linkages have been identified (Table 8.2 below) with respect to the sources outlined above with respect to the anticipated current, construction phase and future uses of the site.

Table 8.2 – Receptors & Pathways

Receptor	Pathway
Current site users (recreational users, children attending local secondary school)	Direct contact and dermal uptake, soil ingestion, gas and vapour inhalation (outdoor air)
Enabling works and construction phase workers.	Direct contact and dermal uptake, soil and dust ingestion including asbestos fibres, gas and vapour inhalation.
Site end users (football stadium maintenance workers, football players, stadium visitors)	Direct contact and dermal uptake, soil and dust ingestion including asbestos fibres, gas and vapour inhalation. Ingestion of contaminated water supplies.
Offsite users (principally Knowsley Community College and local residents)	Soil and dust ingestion during enabling works/construction including asbestos fibres, gas and vapour inhalation, ingestion of contaminated water supplies.
Kirkby Brook	Leaching and groundwater transport/surface runoff
Sherwood Sandstone Major Aquifer	Leaching and groundwater transport.
<i>Flora</i>	Direct contact and up-take <i>via</i> root system.
On site structures (including water supply pipes)	Direct contact/ permeation of plastic pipe work by contaminants in soil and leachate.
Offsite structures (including water supply pipes)	Direct contact/ permeation of plastic pipe work by contaminants in leachate.

A Conceptual Site Model for the existing condition showing ground conditions and potential sources, pathways and receptors is included as Figure 8.

A Conceptual Site Model for the proposed development condition is included as Figure 9.

8.3 Risk Assessment

The details of the Generic Quantitative Risk Assessment are presented in Tables 8.3 (existing site condition), 8.4 (enabling works/construction phase condition), and 8.5 (proposed site condition). It should be noted this risk assessment has been completed without consideration of potential remedial measures however does assume use of standard site health and safety procedures and appropriate personal protective equipment (PPE) and site management practices (stockpile management, surface drainage etc). A summary of key details with respect to the existing, construction phase and proposed development conditions is provided below prior to the risk assessment:

- (a) Existing condition: Public open space, grass and tree cover with footpaths;
- (b) Enabling works/construction phase: Significant cut and fill to construct platforms, realignment of Kirkby Brook; and
- (c) Proposed development: Football stadium including basement under western stand, with car parking and access roads.

Table 8.3 - Generic Quantitative Risk Assessment: Existing site condition

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
Made Ground Type 1	Majority of site	Locally elevated heavy metals, B(a)P	Existing site users	Dermal uptake, soil and dust ingestion.	Medium	Unlikely	Low	Period of exposure unlikely to be prolonged. Existing grass and tree cover restrict soil dust generation. No ground disturbance in existing condition.
			Offsite users	Dust ingestion/inhalation	Minor	Unlikely	Very Low	Existing grass and tree cover restrict soil dust generation. No ground disturbance in existing condition.
		Asbestos	Existing site users	Soil dust/fibre inhalation	Severe	Unlikely	Moderate/Low	Only minor quantity of cement bound chrysotile identified by testing. No ground disturbance occurring in existing condition.
			Offsite users					
		Methane, carbon dioxide.	Existing site users	Outdoor vapour/gas inhalation	Medium	Unlikely	Low	Locally elevated CO2 and CH4 concentrations in Made Ground Type 1, however trace gases below LoD and gas flow rates <1 l/h. Minimal organic component. No known evidence/records/complaints of odours by site users or offsite users/residents. Gas protection measures known to be incorporated into adjacent residential development to SE (Whinberry Drive).
			Offsite structures	Migration into and build up/possible explosion in occupied buildings	Severe	Unlikely	Moderate/low	
Made Ground Type 2	Majority of site	Leachable contaminants including heavy metals, organics	Sherwood Sandstone Major Aquifer	Leaching of contaminants and groundwater transport.	Medium	Unlikely	Low	Low leachability generally. Minimal groundwater encountered in this stratum during GI.
			Kirkby Brook					
		Phytotoxic metals	Flora	Direct contact, up-take via root system	Mild	Unlikely	Very Low	<5% copper results >DIV. Site walkover indicates no evidence of grass dieback, discolouration etc, flora onsite apparently healthy.
		Elevated heavy metals, B(a)P, hydrocarbons, SVOCs, VOCs, ammonia, sulphate.	Existing site users	Dermal uptake, soil and dust ingestion.	Medium	Unlikely	Low	Period of exposure unlikely to be prolonged. No ground disturbance in existing condition, Type 2 generally encountered at depth
			Offsite users	Dust ingestion/inhalation	Minor	Unlikely	Very Low	Existing grass and tree cover restrict soil dust generation. No ground disturbance in existing condition.
		Asbestos	Existing site users	Soil dust/fibre inhalation	Severe	Unlikely	Moderate/Low	Abundant chrysotile and amosite identified by testing. No ground disturbance occurring in existing condition.
			Offsite users					
		Methane, carbon dioxide.	Existing site users	Outdoor vapour/gas inhalation	Medium	Low likelihood	Moderate/low	Abundant organic component in stratum. Highly elevated CH4 and CO2 concentrations, though gas flow rates <1 l/h. Low permeability overlying 'cap' of Made Ground Type 1 considered to be minimising emissions. No known evidence/records/complaints of odours by site users or offsite users/residents. Gas protection measures known to be incorporated into adjacent residential development to SE (Whinberry Drive).
			Offsite structures	Migration into and build up/possible explosion in occupied buildings	Severe	Low likelihood		

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
		Leachable contaminants including heavy metals, organics, ammonia, sulphate	Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport.	Medium	High likelihood	High	High leachability. Monitoring indicates groundwater near base of stratum. Direct pathway between Made Ground Type 2, Sherwood Sandstone and Kirkby Brook.
		Phytotoxic metals	Flora	Direct contact, up-take via root system	Mild	Unlikely	Very Low	>50% copper results >DIV. Hotspot of zinc. Made Ground Type 2 typically overlain by Topsoil and Made Ground Type 1 which avoids degree of protection to surface flora. Site walkover indicates no evidence of grass dieback, discolouration etc, flora onsite apparently healthy.
Contaminants in solution/ landfill leachate	Identified visually at location of WS1004. Investigation indicates groundwater locally perched and present at base of landfill materials.	Heavy metals organics inc ammonia, sulphate, phenols, PAHs	Existing site users	Direct contact, ingestion.	Severe	Low likelihood	Moderate	Landfill leachate identified at surface in vicinity of WS1004. Period of exposure likely to be limited. Potential acute risk to children and dogs.
			Sherwood Sandstone Major Aquifer	Migration from landfill directly into underlying Sherwood Sandstone groundwater.	Medium	High likelihood	High	Groundwater samples show generally low concentration of contaminants relative to those in water samples from Made Ground and installations between landfill and Kirkby Brook. Elevated ammonia. Significant dilution likely to be occurring from up gradient groundwater.
			Kirkby Brook	Migration from landfill to Kirkby Brook by (a) direct flow through Natural Drift deposits present between landfill and Brook, and/or (b) flow into Sherwood Sandstone groundwater and migration in this groundwater to Brook.	Medium	High likelihood	High	Emergence of leachate in eastern bank of Kirkby Brook identified during investigation (location of WS1004). Groundwater samples from installations between landfill and Brook show elevated concentrations of ammonia, phenol, conductivity, boron, PAHs. Water samples from Kirkby Brook show no apparent deterioration from upstream to downstream, or adjacent to identified leachate emergence, however significant dilution likely to be occurring.
			Flora	Direct contact, up-take via root system	Mild	Likely	Moderate/Low risk	No site evidence of damage to flora at location of WS1004 or elsewhere on site.

Table 8.4 - Generic Quantitative Risk Assessment: **Enabling works/construction phase condition**

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
Made Ground Type 1	Majority of site	Locally elevated heavy metals, B(a)P	Enabling/ construction phase workforce	Dermal uptake, soil and dust ingestion.	Minor	High likelihood	Moderate/low risk	Significant earthworks exercise to be undertaken. Significant quantities of Made Ground Type 1 materials to be excavated, dust generation potential high.
			Offsite users	Dust ingestion/inhalation	Minor	Likely	Low	
		Asbestos	Enabling/ construction phase workforce Offsite users	Soil dust/fibre inhalation	Severe	Low likelihood	Moderate	Minor quantity of cement bound chrysotile identified by testing. Will be disturbed during earthworks.
		Methane, carbon dioxide.	Enabling/ construction phase workforce Offsite users Offsite structures	Outdoor vapour/gas inhalation Migration into and build up/possible explosion in occupied buildings	Minor Severe	Low likelihood Low likelihood	Very low Moderate	Made Ground Type 1 has relatively low gassing potential.
			Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport. Surface runoff.	Medium Medium	Likely Likely	Moderate Moderate	
Made Ground Type 2	Majority of site	Elevated heavy metals, B(a)P, hydrocarbons, SVOCs, VOCs, ammonia, sulphate.	Enabling/ construction phase workforce	Dermal uptake, soil and dust ingestion.	Severe	Likely	High	Significant earthworks exercise to be undertaken. Significant quantities of Made Ground Type 2 materials to be excavated, dust generation potential high.
			Offsite users	Dust ingestion/inhalation	Minor	Likely	Low	

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
		Asbestos	Enabling/ construction phase workforce Offsite users	Soil dust/fibre inhalation	Severe Severe	Likely Likely	High High	Abundant chrysotile and amosite identified by testing. Will be disturbed during earthworks.
		Methane, carbon dioxide.	Enabling/ construction phase workforce Offsite users Offsite structures	Outdoor vapour/gas inhalation Migration into and build up/possible explosion in occupied buildings	Minor Severe	Low likelihood Likely	Moderate/low High	Significant quantities of Made Ground Type 2 materials to be excavated and removed offsite. Majority of existing Made Ground Type 2 to remain insitu. Ground improvement methods may enhance migration offsite (risk assessment assumes no protective measures in place).
		Leachable contaminants including heavy metals, organics, ammonia, sulphate	Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport. Surface runoff	Medium Medium	Likely Likely	Moderate Moderate	Increased probability during enabling works resulting from excavations directly exposed to rainfall plus stockpile runoff. Possible creation of preferential vertical pathways during any piling.
		Heavy metals organics inc ammonia, sulphate, phenols, PAHs	Enabling/ construction phase workforce	Direct contact, ingestion.	Minor	Likely	Low	Risk assessment assumes adoption of PPE.
			Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport. Surface runoff	Severe	Likely	High	Potential during enabling works for increased mobilization of groundwater/leachate and pollution of Kirkby Brook via direct surface runoff.

Table 8.5 - Generic Quantitative Risk Assessment: **Proposed development condition**

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
Made Ground Type 1	Majority of site	Locally elevated heavy metals, B(a)P Asbestos	Site end users Offsite users		-	-	-	Site covered by structures or hardstanding (direct contact, soil and dust ingestion therefore not possible). Football pitch to be considered separately – clean build up required.
		Methane, carbon dioxide.	Site end users Offsite users Onsite structures Offsite structures	Indoor/outdoor vapour/gas inhalation Migration into and build up/possible explosion in occupied buildings	Severe	Low likelihood	Moderate	Structural build-ups and requirements of hardstanding/proposed stadium to provide degree of protection. (current risk assessment assumes no gas protection measures). Effect of proposed development on ground gas regime and flow behaviour unknown – potential for confinement by hardstanding/structures to increase gas pressures and flow rates (including flow offsite).
		Leachable contaminants including heavy metals, organics	Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport. Surface runoff.	Medium Medium	Low likelihood Low likelihood	Moderate/low Moderate/low	Proposed to reuse Made Ground Type 1 materials in cut and fill exercise. Site to be covered with structures or hardstanding which will prevent rainwater infiltration and reduce leaching of contaminants. Football pitch considered separately – drainage and impermeable membrane within build-up will prevent rainwater infiltration into underlying Made Ground. .
		pH, sulphate, phenols etc (potential to damage built environment)	Buried concrete Plastic water supply pipes	Attack on concrete Permeation of plastic pipes.	Mild Mild	Low likelihood Low likelihood	Low Low	Generally low concentrations of phenols and other organic determinands with potential to attack plastics.
Made Ground Type 2	Majority of site	Elevated heavy metals, B(a)P, hydrocarbons, SVOCs, VOCs, ammonia, sulphate. Asbestos	Site end users Offsite users	-	-	-	-	Site covered by structures or hardstanding (direct contact, soil and dust ingestion therefore not possible). Football pitch to be considered separately – clean build up required.

Source			Receptor	Pathway	Risk assessment following CIRIA C552			Comment
Origin	Affected	Contaminants of Concern			Consequence	Probability	Risk	
		Methane, carbon dioxide.	Site end users Offsite users Onsite structures Offsite structures	Indoor/outdoor vapour/gas inhalation Migration into and build up/possible explosion in occupied buildings	Severe	Likely	High	Structural build-ups and requirements of hardstanding/proposed stadium to provide degree of protection. (current risk assessment assumes no gas protection measures). Effect of proposed development on ground gas regime and flow behaviour unknown – potential for confinement by hardstanding/structures to increase gas pressures and flow rates (including flow offsite).
		Leachable contaminants including heavy metals, organics, ammonia, sulphate	Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport. Surface runoff.	Medium Medium	Low likelihood Low likelihood	Moderate/low Moderate/low	Majority of Made Ground Type 2 materials will be left insitu as part of proposed development. Site to be covered with structures or hardstanding which will prevent rainwater infiltration and reduce leaching of contaminants. Lateral groundwater flow from up gradient to east will continue. Football pitch considered separately – drainage and impermeable membrane within build-up will prevent rainwater infiltration into underlying Made Ground.
		pH, sulphate, phenols etc (potential to damage built environment)	Buried concrete Plastic water supply pipes	Attack on concrete Permeation of plastic pipes.	Mild Mild	Low likelihood Low likelihood	Low Low	Locally elevated concentrations of phenols and other organic determinands with potential to attack plastics.
Contaminants in solution/ landfill leachate	Identified visually at location of WS1004. Investigation indicates groundwater locally perched and present at base of landfill materials.	Heavy metals organics inc ammonia, sulphate, phenols, PAHs	Site end users	-	-	-	-	Hardstanding/capping will prevent contact. Risk to maintenance workers of any leachate collection/treatment system – appropriate management required.
			Sherwood Sandstone Major Aquifer Kirkby Brook	Leaching of contaminants and groundwater transport.	Medium	Likely	Moderate	Hardstanding/capping will prevent rainwater infiltration and reduce vertical leaching.
			On site structures (including buried water supply pipe infrastructure)	Aggressive attack on concrete. Direct contact. Permeation of plastic and contamination of water supplies.	Mild Mild	Likely Likely	Moderate/low Moderate/low	Elevated concentrations of phenols and other organic determinands with potential to attack concrete and plastics (risk assessment assumes no protective measures currently). Specify appropriate building materials to mitigate risk.

8.4 Conclusions of risk assessment and unacceptable risks

A number of pollutant linkages have been identified as being of unacceptable risk based on the assessment presented in Tables 8.3, 8.4 and 8.5, which are summarised as follows below.

1. Pollution of Sherwood Sandstone Major Aquifer by contaminants in solution/landfill leachate;
2. Pollution of Kirkby Brook by contaminants in solution/landfill leachate;
3. Ground gas migration into proposed occupied structures and inhalation in confined spaces, or build up causing explosion;
4. Ground gas migration to offsite receptors, with probable increased risk during enabling works/construction phase and post construction phase;
5. Risks to enabling works/construction workforce via direct contact with Made Ground Type 2 materials including asbestos fibres, and contaminated groundwaters; and
6. Risks to offsite human receptors during enabling works/construction, particular gas/vapours and asbestos.

8.5 Uncertainties and further risk assessment

The Generic Quantitative Risk Assessment has identified a number of unacceptable risks to receptors from contaminant sources. A Detailed Quantitative Risk Assessment following CLR 11 is not considered to be necessary to clarify the degree of risk based on the relative certainty of some pollutant linkages being realised. As such a Remedial Options Appraisal has been carried out following CLR11 in order to identify feasible remedial solutions for the pollutant linkages identified in Section 9.4 above.

9 Remedial Options Appraisal

9.1 Remediation Objectives

The overall remedial objective is to ensure that the ground conditions on the site, following redevelopment, do not give rise to unacceptable risks to future occupiers or the wider environment in both the short and the long term. The specific objectives and constraints specific to the remedial strategy on this site are set out below.

Contamination related objectives

- Ensure that site clearance, enabling works, and construction activities do not cause secondary contamination;
- Minimise the potential for the development to encourage the mobilisation of contaminants into groundwater or create pathways to encourage off-site migration;
- Reduce pollution/improve water quality of Kirkby Brook and groundwater;
- Prevent exposure of future site users to contaminated soils, leachate and/or ground gases; and
- Ensure off-site residents are not subject to nuisance dust, noise or odour and are not exposed to contaminated dusts vapours etc.

Engineering related objectives

- Ensure that ground conditions are suitable for the proposed development;
- Ensure foundations for the new development do not create new migration pathways;
- Protect plantings, building structures and underground services from the effects of contaminated soils, groundwater and ground gases; and
- Use a set of remedial design features which are simple, economically feasible, robust and will provide long term protection requiring minimum maintenance and causing minimum inconvenience to site occupiers.

9.2 Design Constraints

There are a number of site specific constraints to be considered when appraising remedial options which are detailed below.

1. The Made Ground materials on site are heterogeneous with a large range in grain sizes from clay to boulder size in addition to its variable component of municipal waste, which may limit the ability of sorting techniques to effectively segregate fractions of the material;

2. Made Ground and groundwater contain a number of different types of contaminants which may restrict a number of techniques which only target specific chemical compounds;
3. The proximity of Kirkby Brook increases the potential for contaminated run-off to enter the river and the risks of pollution associated with on site storage of mobile contaminants. The proximity of the river necessitates the implementation of a rigorous management regime and the employment of secondary containment bunds;
4. Groundwater/landfill leachate is present. Water within remedial excavations will require a rigorous management procedure to prevent ingress during the actual excavation and treatment/disposal of any water trapped within the excavation;
5. Residential housing and Knowsley Community College are present in close proximity. Residents/college users must not be subjected to nuisance or placed at risk from contamination. It should be noted the All Saints school will be demolished as part of the proposed development;
6. The Phase 1 ground investigation was limited in spatial extent due to access restrictions at the time. It is known from previous investigations (refer Buro Happold Site Appraisal Report) that landfill materials are present further east of the area investigated. Further investigation will be undertaken when access is available in this area; and
7. It is likely that hotspots of unknown contamination will be encountered during the enabling works. A strategy to deal with these scenarios should be incorporated into the Environment Management Plan for the works (EMP).

9.3 Remediation Criteria

Appropriate site-specific remediation criteria will be agreed with the regulatory authorities. It should be noted further groundwater, surface water and ground gas sampling/analysis will be undertaken in order to characterise site conditions to a higher level of confidence, which will allow a more informed assessment of remediation criteria to be included in the Remedial Strategy.

9.4 Remediation Factors

Table 9.1 details the factors and associated criteria that will be used to evaluate the remedial options to achieve the remedial objectives with respect to the site specific conditions and constraints.

Table 9.1 – Remediation selection factors

Factor	Criteria
Effectiveness	Performance with respect to reducing the respective pollutants to levels that are acceptable. Therefore options that are not suitable for the particular physical and chemical characteristics of the site are not considered any further.
Timescale	Remediation techniques that require a significant period of time to successfully meet the remedial objectives are not considered suitable for this site given the proposed development timetable.
Cost	Only remedial options that fulfil the remedial objectives within an acceptable cost bracket have been considered any further.
Durability	All remedial options must be long lasting and minimise the potential for residual impacts to become apparent as following the construction of the proposed development, the ability to undertake further remedial works successfully will be significantly reduced and more costly.
Commercial availability	There are many remediation technologies that have been used, particularly in the USA, however only a limited number of these are commercially available and proven in UK.
Track Record	Only remedial options with a proven track record in the UK have been selected. Options with no or poor UK track records may impact on other factors in this table such as effectiveness, timescale and cost.
Environmental Impact	Some remedial options have not been selected because of the likely environmental impacts. Examples include energy and material requirements and traffic movements.
Compatibility	The risk assessment has identified a number of pollutant linkages that may require different remediation techniques to successfully meet the remedial objectives. Therefore all remedial options must be compatible with each other as well as the proposed development scheme, specifically the programme of earthworks.
Permissions	Some remedial options will require forms of waste management licences & potentially other forms of licensing such as discharge consents etc. The form of licence may influence the selection of the remediation technique because of the likely timescales required for applications.

9.5 Options Appraisal

In considering potential remedial options, account must be taken of the contamination related objectives, the engineering related objectives and the site specific constraints. Tables 9.2 to 9.4 overleaf evaluate a number of remedial options dividing remedial techniques into source treatments (Table 9.2) pathway treatments (Table 9.3) and receptor related treatments (Table 9.4). Not all potential treatment options are assessed (for example the removal of human receptors from the site following development is clearly not realistic for a redevelopment project). However a number of different techniques with the potential to satisfy the remedial objectives are evaluated in terms of their advantages and disadvantages.

The following published sources have been used to obtain information about each remedial technology discussed in Tables 9.2-9.4.

- www.claire.co.uk – Contaminated Land: Application in Real Environments;
- Environment Agency Guidance - Remedial Treatment Datasheets;
- CIRIA Special Publication SP124, Barriers liners and cover systems for containment and control of land contamination, 1996;
- CIRIA Special Publication SP105, Remedial treatment for contaminated land, Volume V, Excavation and Disposal, 1995; and
- Personal communications with specialist contractors (Kellers Ground Engineering, PA Geotechnical).

Table 9.2 - Source treatment techniques

Source Treatment			
Source	Treatment options	Suitability	
		Pros	Cons
Landfill (predominantly Made Ground Type 2 materials, and contaminants in solution/landfill leachate)	(1) Excavation and disposal.	Removes contamination source; Can be undertaken relatively quickly. Most effective at reducing potential for residual liability. No waste management licensing needed for the site. Can be used in conjunction with other remediation technologies such as sorting to reduce volumes requiring disposal.	Very large volumes if all Made Ground to be removed. Limited number of landfills able to accept hazardous waste. Hazardous waste must be pre-treated;; Removed material would have to be replaced by clean inert fill. Substantial environmental impacts associated with this option (e.g. transport). The substantial volumes involved indicate that costs will not be economic. Will take long period of time – project programme tight. Potentially onerous waste management issues. High and prolonged nuisance factor with respect to neighbouring properties
	Variations; Excavate, sort and treat offsite (potential reuse recycling of domestic waste fraction, or composting of organic soil fraction)	Reduces costs and environmental impact.	May not be technically feasible.
	Excavate remove offsite and incinerate		Incinerator may not accept waste. Incineration still likely to be extremely high cost.
	Sorting	May significantly reduce volume of unsuitable materials requiring offsite disposal. (Aim- to separate domestic waste fraction from soil component). Significant reduction in environmental impacts, especially with respect to traffic movement.	Relies on the “clean” fraction being the bulk of the soil. Would require trial scale tests – technically difficult to separate components. Significant earthworks, stockpiling and process area required.
	Stabilisation	Prevents contact and leaching of contaminants. Also effective at improving engineering properties of poor soils and treating contaminants in a wide range of soil matrices.	Testing required; May not work for the mix of contaminants present in Made Ground, coarse fraction may jam machinery. Potentially unsuitable for ground conditions – clay-rich Made Ground with relatively low permeability. Contamination source remains. High cost may render development untenable
	Do nothing	Low cost; no disturbance of contamination source; no risk of causing increased contamination.	Significant cut and fill required to create developable site, therefore ‘do nothing’ not feasible. No mitigation of risks.
	Bioremediation	Sustainable treatment reduces/removes contaminants from source zone. May allow re-use of materials on site. Can be low cost. Reduced transport requirements in comparison with traditional landfilling techniques	Chemical composition of soils may limit effectiveness, only effective on specific organic determinands. Treatment unlikely to reduce contaminant concentrations significantly and likely to be slow. Significant excavation and process area required. Prolonged nuisance to neighbouring properties. Additional time would make development unfeasible.

Table 9.3 - Pathway related techniques

Pathway Related Treatments			
Pathway	Treatment options	Suitability	
		Pros	Cons
Direct contact by humans	Capping/Hardstanding	Provides a barrier between contamination and humans. Several different designs available for capping solutions. Easily incorporated into proposed development & remediation strategy.	May require low level of long term management; potential for breach (e.g. maintenance workers). May involve raising of ground levels.
Inhalation of ground gases by humans/ build-up of gas and explosion	Installation of passive ground gas protection system for buildings and areas of reduced ventilation	Provides a barrier to the migration of ground gases and ventilates under-floor subspace to prevent the build-up of potentially explosive ground gas. Low maintenance. Relatively low cost if installed during initial construction. Established and well recognised technology widely applied in the UK.	Passive ground gas protection systems are generally only acceptable for sites where risks associated with ground gas are low-moderate and therefore would not provide the necessary level of ventilation required for buildings constructed on this site.
	Installation of active gas protection system for buildings and areas of reduced ventilation	Provides a barrier to the migration of ground gases and a high level of sub-floor ventilation to prevent the build-up of potentially explosive ground gas. Although potentially greater cost than more basic passive system, still relatively economic. Established technology in UK with a number of specialist contractors available to install.	Active systems require a power source and long term maintenance plan to ensure the pump system runs continuously. More expensive than passive system. May require modelling to ensure entire building footprint is adequately ventilated.
Migration of contaminants into Major Aquifer (vertical pathway)	Capping/Hardstanding (including drainage and membrane under football pitch)	Will prevent vertical infiltration of rainwater into landfill and reduce leaching. Easily incorporated into proposed development strategy.	Will not prevent leaching via lateral water migration from up hydraulic gradient to east.
	Engineered liner (dig out landfill materials, place basal and lateral synthetic/natural liner, replace landfill, compact)	Will provide protection to underlying Major Aquifer, as well as Kirkby Brook, removing direct pathways currently present.	Long time period would be required. Large area would require lining, including extending outside of the Phase 1 ground investigation area to the east – not economically feasible. Prolonged nuisance to surrounding neighbours. Potentially onerous waste management issues.
Migration of contaminants into Kirkby Brook (lateral pathway)	In ground barrier (i.e. permeable reactive barrier-type system)	Will reduce shallow groundwater/leachate migration into Kirkby Brook. Potential cost-savings through combining with retaining walls which will be required between new development and Kirkby Brook (impermeable wall drained at rear, pumping/gravity drainage to leachate processing point before discharge of remediated water into Brook downstream.	Would require long-term management and testing. Moderate cost..Depth of barrier limited (possibly anchor into sandstone bedrock) - will not prevent contaminants migrating underneath barrier and into Brook (diffusion).

Table 9.4 - Receptor related techniques

Receptor Related Treatments			
Receptor (contaminant)	Treatment options	Suitability	
		Pros	Cons
Major Aquifer	Pump and disposal / treatment	Removes contaminated groundwater would be able to deal with large volumes. Simple to install and monitor, can be effective with dissolved phase contamination and appropriate above ground treatment plant to complement specific contamination.	Very large volumes would require removal; liquid wastes no longer disposable to landfill. High cost. Would require licensing and may not be effective; could mobilise more contamination. Non sustainable treatment. Free product will require separation. Sheet piling required to prevent excessive water treatment. Can lead to protracted treatment period.
	Variation –pumping to regulate groundwater levels below Made Ground source materials.	Could be combined with ground source heat pump system, economic benefits. Will reduce leaching of landfill contaminants.	Concern over causing additional aquifer contamination (leachate and temperature). Discussions with Environment Agency indicate no abstraction licenses available currently or expected to be released in future.
	Bio-remediation	Can reduce concentrations and interconvert forms; can process large volumes of water. Relatively low cost	Difficult to determine it has been successful; testing required; Heavy end TPH contamination may not be suitable for treatment.
	Monitored natural attenuation (MNA)	Low cost; non interventionist, no risk of creating new pollution. Often used in conjunction with source removal. Suitable for hydrocarbon contamination.	Long term strategy, intensive monitoring requirement. Does not address immediate contamination issues. Relies upon acceptability of current conditions.
	Do Nothing		Does not address contamination issues.
Kirkby Brook - to be re-aligned	Installation of reed-beds	Relatively low cost, requires low level of maintenance, potentially creates/enhances ecological habitat, visually acceptable treatment option, and sustainable. Has been used to treat landfill leachate in USA and trialled in the UK	Requires a large area to achieve low flow rates required to ensure treatment is successful.
	Do nothing		Does not address contamination issues

9.6 Preferred remediation scheme

The preferred remediation scheme has been determined by taking into account the factors set out in Table 9.1 and the critique of possible remedial options described in Tables 9.2 to 9.4. This preferred approach is summarised below, and discussed in more detail in the following sections.:

- Controlled waters (Kirkby Brook and Major Aquifer): Reduce infiltration by hardstanding/capping to reduce contaminant leaching and improve quality of Kirkby Brook and Major Aquifer. Installation of Permeable Reactive Barrier (PRB) system along Kirkby Brook. Possible drawdown and regulation of groundwater levels via pumping system.. Appropriate site management during enabling works including bunds, stockpile covers, wheel washes, daily cover, monitoring etc. Post construction long-term groundwater and surface water level and quality monitoring;
- Human health: – Appropriate PPE and working practices during enabling works/construction. Permanent works - capping/hardstanding to break pathway between ground contaminants and end users.
- Ground gas: During enabling works/ground improvement construct and maintain site perimeter gravel trench with membrane on outer wall to mitigate risk of gas migration offsite. For permanent works (stadium) active venting system and gas membrane (current design subject to ongoing gas monitoring). Post construction monitoring of protection system and site perimeter concentrations/flows to validate performance.

9.6.1 Discussion: Controlled waters

Development of the site will consist of a change from soft to hard landscaping which will significantly reduce rainwater infiltration volumes into the subsurface. It should be noted the proposed football pitch build up contains a surface water drainage collection system and basal impermeable membrane. It is considered the reduction in rainwater infiltration rates will reduce leaching of contaminants from the Made Ground Type 2 materials and, as such, act to mitigate potential contamination of the major aquifer, as well as Kirkby Brook which is effectively down hydraulic gradient,

A groundwater barrier/Permeable Reactive Barrier system is proposed to protect Kirkby Brook from future contamination arising from landfill leachate resulting from potential rising groundwater. Due to the current topography of the site, redevelopment will require retaining walls along the western side of the football stadium podium. It is proposed to incorporate a groundwater barrier system into the retaining wall design, with drainage to a downstream groundwater collection and treatment point. A treatment gate system would allow groundwater contaminants (principally pH, metals, ammonia and other organic determinands) to be reduced to acceptable concentrations prior to remediated groundwater being discharged into Kirkby Brook downstream of the site. It should be noted that flow of dissolved phase contaminants in groundwater underneath any barrier system will still be possible, however by founding the barrier in the Weathered Sherwood Sandstone bedrock it

is considered the majority of groundwaters arising from the landfill would be intercepted. Design of such a barrier system will be subject to further discussions with the Environment Agency and planning authority.

Full remediation of the pollution of Kirkby Brook and the major aquifer underlying the site is only considered feasible by removing the source of the contamination. Excavation and removal could successfully remove the hazard but this would be at a very high cost due to the very large volume and nature of material requiring removal. The removal of this material would also necessitate replacement by clean inert fill imported from off-site. The environmental impact of such large scale earthworks would be significant with thousands of lorry movements required, and associated nuisance to neighbours from odour, dust and increased traffic.

Alternatives

Other remedial solutions which are considered feasible, potentially in addition to a groundwater barrier system rather than as an alternative, are reed-beds and groundwater regulation via pumping. A reed-bed system could be designed to extend along the full length of the eastern bank of the realigned Kirkby Brook if space permits, or incorporated in a specific treatment area as part of a PRB system. Groundwater abstraction is also considered a potential remedial solution with the aim of regulating the main groundwater table within the major aquifer (Sherwood Sandstone) below the base of the contaminated Made Ground Type 2 materials which have been shown to contain leachable contaminants

9.6.2 Discussion: Human health

Capping/Hardstanding system

The preferred remedial option to address the potential risks to end users associated with contaminants in the Made Ground materials underlying the site is to provide a capping/hardstanding layer. This will act to break the pathway between ground contaminants and human receptors at surface.. Capping is considered a cost effective, environmentally sustainable option with respect to the remedial objectives and offers significant advantages with respect to durability and compatibility.

The cap will be formed by buildings and hardstanding (concrete, tarmac and paving) in areas of development. The capping system will require the establishment of a rigorous QA procedure during installation and the provision of appropriate information to ensure that;

- The physical integrity of the capping is maintained over the long term;
- The potential risks to construction workers engaged in work on below ground services are capable of mitigation;
- There is no realisation of the potential risks to the occupiers of the site who could carry out extra ordinary excavations during building works (e.g. installation of deep ponds or foundations) are;
- The potential risks to flora and fauna are not realised

Providing a capping will also reduce vertical leaching of contaminants to groundwater by reducing infiltration into the underlying Made Ground materials.

Service corridors/ trenches

In addition to the construction of a capping system it is also recommended that service trenches containing water supplies are backfilled with clean soils. Below ground service trenches should also be lined with a gas proof membrane and well ventilated to ensure risks to future maintenance workers associated with ground gas are adequately mitigated.

Alternatives

Possible alternatives to capping & construction of clean service trenches include excavation/removal, though this has already been discounted on the basis of being unfeasible due to cost.

9.6.3 Discussion: Ground Gas

Site monitoring carried out to date indicates a worse case Characteristic Situation (CS) following CIRIA C659 of CS3. It should be noted ground gas protection requirements for the remainder of the masterplan site to the east are not considered here, and will be assessed in subsequent investigations.

Discussions with specialist gas protection supplier PA Geotechnical indicate a Low Energy Clean Air Blanket (CAB) system is appropriate for the ground gas conditions indicated by investigations thus far and the proposed development. Details of this system are provided below;

- Zone of positive pressure created in granular sub-base underneath structure, underlying oversite gas resistant membrane.
- Air mass leaks away around perimeter, constantly topped up by Positive Pressurisation Units.
- Remote status indicators and monitoring can be installed.

Detailed design of the ground gas protection system for the proposed development will require consideration of the following factors;

- car parking,
- the football pitch and
- all occupied structures within 250m of the GDO 205 landfill, including those outside the Masterplan boundaries.
- long term monitoring and validation

Alternatives

Passive ground gas systems are not considered to provide a sufficient level of protection based on the ground conditions and proposed development, and are often subject to variable performance due to wind conditions. Although site monitoring indicates a worse case of low-end CS3, the uncertainty regarding characterisation of worse case gas flow rates and particularly how this may change during and after site redevelopment, means it is considered prudent for a higher level of protection.

Source removal in another alternative, which would essentially remove the risk from ground gases and therefore the requirement for any protection systems, however this has been already discounted on economic grounds.

10 Waste Management

10.1 The definition of waste

The Environment Agency have previously stated that contaminated soils become “waste” once excavated and therefore a Waste Management Licence (WML) was normally required to cover their treatment and/or redeposit. Recently the Environment Agency have reconsidered their position⁷ and contaminated soils that are excavated to be reused elsewhere on site are not considered “waste”, providing;

- There is no risk to human health or pollution of the environment;
- They are suitable for use (either as excavated, or following some pretreatment);
- Only the quantity necessary for the specified works is used (otherwise it becomes a disposal activity);
- Their use is not a mere possibility but a certainty; and
- It is undertaken in accordance with the planning permission that authorises the use of the material as part of the site development.

Using this assessment, the Environment Agency will then decide whether the material should be classified as ‘waste’ and therefore whether the earthworks described are potentially a licensable activity.

10.2 Approach

The proposed development will require a significant programme of earthworks within the Phase 1 ground investigation area. This is due to the current topography and the requirement to create a series of platforms for the proposed development.

The majority of the material requiring excavation will comprise Made Ground, however there is also likely to be some excavation within Natural Drift Deposits and Sherwood Sandstone. Pending regulatory approval the majority of this material will be re-used elsewhere on site as fill subject to geotechnical and environmental suitability.

Given the characteristics of the materials encountered during the ground investigation, the following approach is considered appropriate and proposed with respect to the earthworks exercise on site;

- Made Ground Type 1: Considered chemically suitable for reuse on site, subject to physical suitability, however requirement for watching brief and removal of any asbestos containing materials (ACM).

⁷ Definition of Waste, Developing Greenfield and brownfield sites, Environment Agency, April 2006.

- Made Ground Type 2: Not considered chemically or physically suitable for reuse on site as bulk material. Sorting proposed where practicable in order to separate the municipal waste and soil matrix fractions, with reuse on site of the soil component if chemically and physically suitable. Unsuitable materials to be removed offsite as waste.

All materials should be subjected to selective excavation, separation and handling as far as practicable to achieve the most cost-effective and optimum disposal regime. It should be noted that it is the excavation contractor's responsibility, in association with the operator/owner of the receiving site, to classify the materials for disposal/reuse.

10.3 Outline Characterisation for Waste Disposal Purposes

It is considered the majority of material will be re-used on site where suitable, however a quantity of material will not be suitable for re-use and will require off-site disposal. As such an outline assessment of likely waste characterization has been undertaken in accordance with current guidance outlined below.

- Values indicating Hazardous Waste according the 'Environment Agency (2004) Framework for the Classification of Contaminated Soils as Hazardous Waste, Version 1, July 2004'⁸,
- 'Technical Guidance WM2 – Hazardous Waste, Interpretation of the definition and classification of hazardous waste'⁹
- Waste Acceptance Criteria (WAC) limit values for inert and hazardous waste¹⁰.

Results of the Tier 1 assessment (Hazardous Waste) based on the analytical soil data is included as Appendix I. Results of the Tier 2 assessment (Waste Acceptance Criteria) based on the analytical soil and leachate data is included as Appendix J.

Table 10.1 – Waste Classification

⁷ Framework for the classification of Contaminated Soils as Hazardous Waste, Environment Agency, 2004.

⁸ Technical Guidance WM2 – Hazardous Waste, Interpretation of the definition and classification of hazardous waste, Environment Agency (second edition, version 2.1, October 2006)

⁹ Guidance on Sampling and testing of waste to meet landfill waste acceptance criteria, Environment Agency, Version 1. April 2005

Material	Summary of Tier 1 Hazardous Waste Assessment	Summary of Tier 2 Waste Acceptance Criteria Assessment
Made Ground Type 1	3 out of 42 no. samples contained asbestos – Hazardous waste (no further testing was carried out on these samples) 39 out of remaining 39 no. samples show no Hazardous properties.	Overall none out of 27 no. samples contain a soil parameter in excess of an Inert WAC. Overall 11 out of 28 no. samples contain one or more leachable determinand which exceeds an Inert WAC, with details as follows; cadmium: 5 out of 28 no. samples > Inert WAC lead: 1 out of 28 no. samples antimony: 3 out of 28 no. samples fluoride: 1 out of 28 no. samples sulphate: 2 out of 28 no. samples TDS: 3 out of 28 no. samples
Made Ground Type 2	10 out of 33 no. samples contained asbestos- Hazardous waste (no further testing was carried out on these samples) 3 out of remaining 23 no. samples indicated to be Hazardous waste on basis of H14 (Ecotoxic). 1 out of remaining 23 no. samples indicated to be Hazardous waste on basis of H7 (carcinogenic).	Of the 4 no. samples showing Hazardous properties; 3 no. comply with the SNRHW WAC, and 1 no. exceeds the Hazardous WAC on account of TOC, LOI (soil) and DOC (leachable). Of 12 no. samples showing no Hazardous properties, all 12 no. contain one or more determinand that exceeds an Inert WAC
Natural Drift Deposits	4 out of 4 no. samples show no Hazardous properties	Overall none out of 3 no. samples contain a soil parameter in excess of an Inert WAC. Overall 3 out of 3 no. samples contain one or more leachable determinand which exceeds an Inert WAC, with details as follows; cadmium: 2 out of 3 no. samples > Inert WAC lead: 1 out of 3 no. samples antimony: 1 out of 3 no. samples TDS: 1 out of 3 no. samples

Based on the approach outlined in Section 10.2, the Made Ground Type 1 materials are proposed to be reused on site as fill as part of the earthworks exercise. Notwithstanding the foregoing, an outline characterisation of the Made Ground Type 1 materials for waste disposal purposes has been undertaken, with a summary based on the testing as follows; 40% Non Hazardous Waste, 60% Inert Waste. Any asbestos containing materials arising from this stratum will require disposal to a Hazardous waste landfill facility.

For the Made Ground Type 2, it should be noted the chemical testing summarized above has been carried out on the soil (matrix) component of this material, and does not therefore take into account the component of municipal waste. Furthermore 10 out of 33 no. samples were found to contain asbestos and as such no further laboratory testing (for waste classification purposes) was possible on these samples due to the laboratories health and safety procedures. Based on the results of the testing carried out on the soil component of samples (i.e. excluding asbestos and municipal waste), a breakdown as follows is representative of the testing results;

20% Hazardous Waste, 80% Non-Hazardous Waste. The testing results summarised above do indicate that if separation/sorting on site of the soil matrix and bulk waste/asbestos fractions is practicable, the majority of the soil fraction could be reused on site (providing it meets the criteria outlined above) or disposed of as Non-Hazardous Waste thus reducing landfilling costs. It should be noted that the % split between the soil and bulk waste fractions in the Made Ground Type 2 materials is highly variable.

It should be noted that it is the excavation contractor's responsibility, in association with the operator/owner of the receiving site, to classify the materials for disposal/reuse.

10.3.1 Asbestos containing materials (ACM)

Asbestos has been identified during site works and confirmed by laboratory inspection. The majority of ACM identified were within Made Ground Type 2 materials however a smaller proportion of Made Ground Type 1 soil samples also contained ACM (refer Section 5.3.2). With reference to Environment Agency WM2 guidance, all forms of asbestos, regardless of chemical form or product are regarded as hazardous waste where the asbestos content is greater than 0.1% w/w. Waste asbestos cement containing typically 10-15% (predominantly chrysotile) is therefore hazardous, with the ability to release free fibres not relevant in the assessment.

Should a stockpile be classified as Non Hazardous Waste due to asbestos concentrations being less than 0.1% a watching brief is recommended during the removal offsite of the stockpile and any larger fragments of asbestos cement are removed and disposed of separately, to ensure that the threshold of 0.1% asbestos by volume for the whole material is not breached.

If it is proposed to re-use a stockpile on site, it is recommended the asbestos cement is removed from the stockpile to mitigate risks to construction workers during the construction process. Despite the removal of visible asbestos cement material from the stockpile it is likely that small concentrations of asbestos cement will remain. The material from the stockpile would therefore be unsuitable for use in soft landscaping areas unless it was beneath a suitable capping layer.

10.3.2 Other materials

A topsoil strip is proposed as part of the enabling works for the proposed development. The topsoil layer as recorded on the exploratory hole logs is typically ~10cm thick over the main landfill 'mounds', though is thicker away from these mounds and adjacent to Kirkby Brook. The proposed development consists of a commercial-type development with hardstanding and structures, as such there will not be a requirement for topsoil (the proposed football pitch will be constructed from imported materials). If site-won topsoil is physically and chemically suitable this material could be transported offsite and sold for re-use at other development sites. It should be noted however the topsoil over the landfill mounds is generally of poor quality and in some instances contains brick, concrete and domestic waste making it unsuitable for reuse.

10.3.3 Materials unsuitable for landfill

It should be noted car tyres were encountered within the Made Ground Type 2 materials which are now banned from landfills and will require selective separation and recycling at an appropriate licensed facility.

11 Geotechnical Considerations

11.1 Proposed Development

An architects drawing of the Kirkby Redevelopment masterplan is included as Appendix A. The proposals within the area covered by the Phase 1 ground investigation comprise a major new football stadium with associated access roads and car parking.

11.2 Earthworks

A major cut and fill exercise is required to facilitate the proposed development, to create level platforms predominantly within the Phase 1 ground investigation area which currently comprises a series of 'mounds' up to a maximum of approximately 29 m AOD in elevation. The remaining area of the redevelopment site is generally level and proposed levels are understood to be broadly similar to existing ground levels.

Excavations within the Made Ground materials should be feasible using conventional plant, although allowance should be made for the use of pneumatic breakers to aid in the removal of any buried obstructions and also for any excavations necessary within the Sherwood Sandstone bedrock. All excavations should be supported in accordance with the guidelines presented in CIRIA Report 97¹¹.

Earthworks suitability testing indicate the material capping the landfill and natural soils can be re used as general fill. In areas where the material above the landfill is to be removed, earthworks shall be carried out in a controlled manner to maintain a capping layer and avoid the ingress of water into the landfill materials that could generate leachate. Refer to Section 10 for further details on the proposed approach to earthworks and waste management.

11.3 Ground Improvement

Based on the latest date on newspapers present in the Made Ground Type 2 materials (1964, refer Section 3.2) a period of up to 44 years has passed between landfilling and present day. The overlying Made Ground Type 1 materials based on desk study information were deposited in the late 1960's, and as such may be considered to have acted to surcharge the underlying landfill materials.

In order to provide a consistent suitable engineered material to support the football pitch, car parks and access roads, dynamic compaction of the landfill materials is proposed. The technique involves dropping a heavy weight in a controlled manner to compact the landfill material and collapse existing near-surface voids.

¹¹ CIRIA Report 97. *Trenching Practice*. CIRIA R97, 1983.

An 8 ton weight dropped from heights of up to 12m should be capable of achieving the ground improvement required to depths of 5 to 6m.

To restrict the transmission of vibration through the underlying soils and rock the dynamic compaction shall be controlled by varying the drop height to suit rockhead level and landfill thickness. Shallow cut-off trenches shall also be provided to control the effect of vibrations on existing structures and services. The cut off trenches shall also be used for gas venting to control any migration of ground gas during the process. Site trials of the proposed treatment method are recommended in order to confirm feasibility.

Long term creep of the landfill materials due to decay of the degradable fill constituents will occur after ground treatment. Loss on ignition testing results can be used as an indicator of potential future long-term settlement of the landfill materials through degradation of organic material. The average loss on ignition result for the Made Ground Type 2 samples is 8.2%, which is considered to provide a reasonable estimate of potential volume loss due to long-term degradation. Long term settlement shall be controlled by the use of geotextiles and granular blanket placed over treated areas

11.4 Foundations

To support the stadium and other structures in areas of deep fill, pile foundations will be required.

Factors to be considered for the design of pile foundations include; negative skin friction from long term settlement of fill, creation of migration pathways for water and ground gas, obstructions in the Made Ground, generation of pile arisings, chemical attack of building materials, site constraints and access.

The choice of pile type will depend on the ground conditions, required load settlement performance and environmental constraints. To prevent the generation of spoil it is likely that a combination of driven cast in situ and pre cast driven piles will be adopted in landfill areas.

Adopting the source pathway receptor linkage model, driven cast in-situ bearing piles are considered to offer the least risk of environmental impact at the site. As the casing is withdrawn during pile construction, the concrete bleeds into the surrounding soil forming a good seal at the pile soil interface mitigating risk from leachate and ground gas migration. Precast driven piles may have the potential to create vertical pathways for contaminants, however if this piling method is required to provide the required foundation performance, mitigation measures can be incorporated into design.

A Foundation Works Risk Assessment Report will be required in accordance with Environment Agency 'Piling and penetrative ground improvement methods on land affected by contamination: Guidance on pollution prevention.' National groundwater and contaminated land centre project NC/99/73, dated 2001.

12 Conclusions and recommendations

12.1 Conclusions

The following conclusions can be made from this report.

- The intrusive Phase 1 ground investigation completed within the GDO 205 landfill area has identified a sequence of fill materials comprising typically non-engineered reworked natural clays (Made Ground Type 1) overlying soils contaminated with early 1960s municipal waste (Made Ground Type 2).
- Due to historical extraction of drift deposits, the Sherwood Sandstone bedrock directly underlies the fill materials over a large proportion of the area investigated, though localised areas of glacial deposits are present, as well as alluvium adjacent to Kirkby Brook.
- The Sherwood Sandstone, designated by the Environment Agency as a major aquifer, is largely unconfined, with a groundwater flow direction towards the west, and is in hydraulic continuity with Kirkby Brook which is hydraulically down gradient of the landfill.
- A breakout of leachate has been identified in the eastern bank of Kirkby Brook, in addition laboratory testing of groundwater samples has indicated contamination of the major aquifer.
- The risk assessment has identified a number of unacceptable risks to both human health and controlled waters. A remedial options appraisal has therefore been undertaken.
- To improve surface water and groundwater quality, hardstanding/capping will minimise rainwater infiltration and subsequent contaminant leaching. A groundwater barrier/PRB system is proposed to improve water quality in Kirkby Brook. Alternatives/additional solutions include reed-bed treatment areas and/or groundwater level regulation via pumping. It is noted that 'full' remediation of the Sherwood Sandstone major aquifer is not considered possible without removal of the leachate producing fill materials, an option which is not feasible economically.
- To mitigate risks to human health, rigorous health and safety procedures will need to be adopted during the enabling works/construction phase, in particular with regard to contact with asbestos-containing materials, dust and gas/vapours.
- An active gas protection system is proposed for the football stadium.
- A significant programme of earthworks will be required within the Phase 1 ground investigation area to create development platforms and access roads.
- The proposed approach to waste management currently, subject to regulator approval, is to reuse the majority of excavated materials on site as fill. The Made Ground Type 1 materials are considered suitable

for reuse. The Made Ground Type 2 materials are not considered suitable for reuse due to asbestos and municipal waste content, though separation and sorting is proposed in order to maximise material reuse. Proposed site levels should minimise excavations into unsuitable materials requiring offsite disposal.

- Permanent works design needs to account for long term settlement of the landfill materials (principally via degradation of the organic component of the Made Ground Type 2 materials).
- Dynamic compaction is proposed in areas of landfill in order to improve geotechnical properties, particularly to collapse any voids.
- A piled foundation solution is required for the new stadium structure, transferring loads through the fill materials into the underlying Sherwood Sandstone bedrock. A Foundation Works Risk Assessment will be required by the Environment Agency due to the presence of contaminated landfill materials overlying the major aquifer.

12.2 Further Actions Required

The following actions are considered necessary based on the findings of this report.

1. Issue report to Environment Agency and Knowsley Metropolitan Borough Council Environmental Health for review and comments.
2. Further site monitoring to obtain more representative dataset on ground gas regimes, in particular flow rates, in order to design mitigation measures.
3. Undertake further ground investigation of Kirkby Redevelopment masterplan area for geotechnical and geo-environmental purposes.
4. Undertake further discussion with specialist remediation contractors and progress remedial strategy.

Figures



Reproduced from Ordnance Survey by permission of ordnance survey® on behalf of the controller of Her Majesty's stationary office, Crown Copyright 2006 all rights reserved. Licence number: AL 100005517.



Project Name: Kirkby Redevelopment, 021706

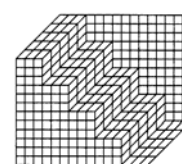
Report Title: Geoenvironmental and Geotechnical Interpretative Report: Phase 1 Ground Investigation (GDO 205 landfill)

Figure Title: Site Location Plan

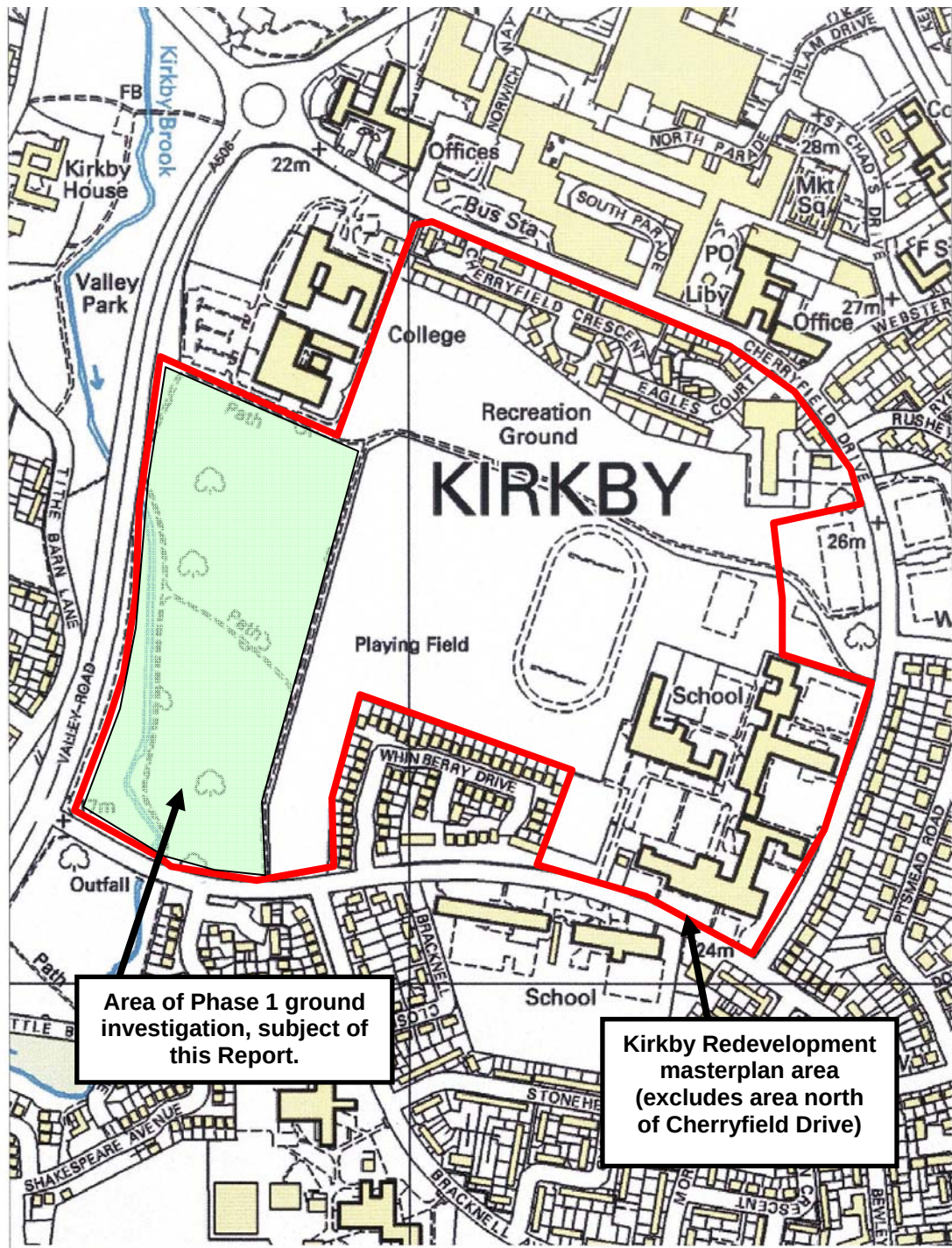
Scale: NTS

Date: November 2007

Fig No: 1



Buro Happold
Ground Engineering



Area of Phase 1 ground investigation, subject of this Report.

Kirkby Redevelopment masterplan area (excludes area north of Cherryfield Drive)



© Crown Copyright 2006. All rights reserved. Licence number 100020449. Plotted Scale - 1:5611

This map was created with Promap

Red line indicates site boundaries

Project Name: Kirkby Redevelopment

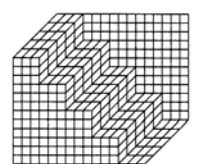
Report Title: Geoenvironmental and Geotechnical Interpretative Report: Phase 1 Ground Investigation (GDO 205 landfill)

Figure Title: Existing Site Layout and area of investigation

Scale: NTS

Date: November 2007

Fig No: 2



Buro Happold
Ground Engineering



Project Name: Kirkby Redevelopment, 021706

Report Title: Geoenvironmental and Geotechnical Interpretative Report: Phase 1 Ground Investigation (GDO 205 landfill)

Figure Title: Recent aerial photograph and walkover observations

Scale: NTS

Date: November 2007

Fig No: 3

Notes

- BOUNDARY OF GDO 205 LANDFILL AS RECORDED IN ENVIROCHECK REPORT
- 23.50 CONTOUR – EXISTING GROUND SURFACE (mOD)
- - - FOOTPRINT OF PROPOSED STRUCTURE
- TP1001 TRIAL PIT – SOIL MECHANICS 2007 (PHASE 1)
- BH1001 BOREHOLE – SOIL MECHANICS 2007 (PHASE 1)
- WS1001 WINDOW SAMPLE – SOIL MECHANICS 2007
- KB1 KIRKBY BROOK SURFACE WATER MONITORING POINT

1 GEOPHYSICAL SURVEY LINES – PELORUS 2007

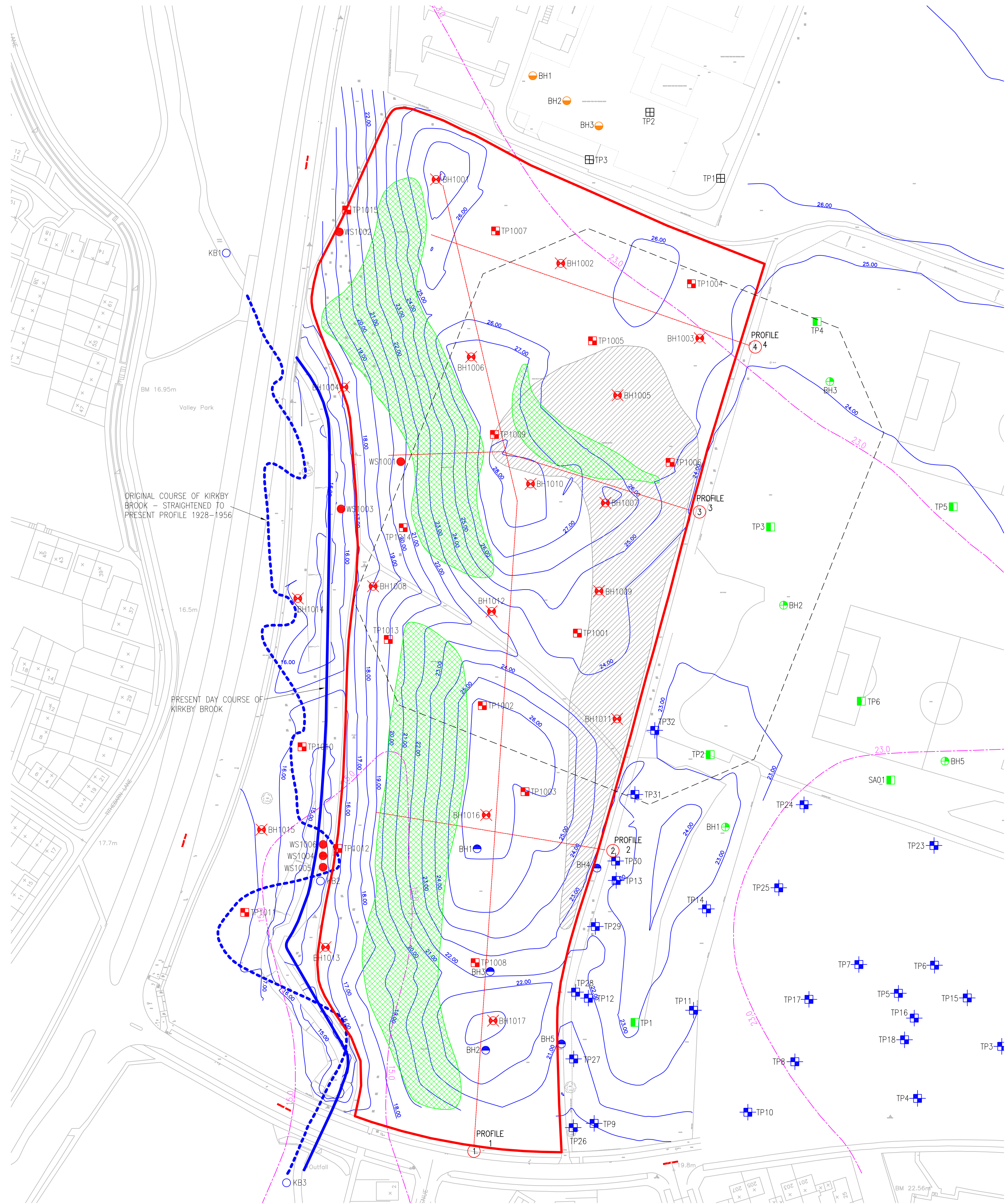
PREVIOUS INVESTIGATIONS

- BOREHOLE – ABATEC 2006
- TRIAL PIT – ABATEC 2006
- BOREHOLE – KNOWSLEY COMMUNITY COLLEGE 1997
- TRIAL PIT – KNOWSLEY COMMUNITY COLLEGE 1995
- BOREHOLE – COOPER ASSOCIATES 1998–2002
- TRIAL PIT – COOPER ASSOCIATES 1998–2002

23.0 CONTOUR FROM 1956 MAP (mAOD)

EXISTING TREES

FORMER CUTTING SHOWN ON 1961 MAP



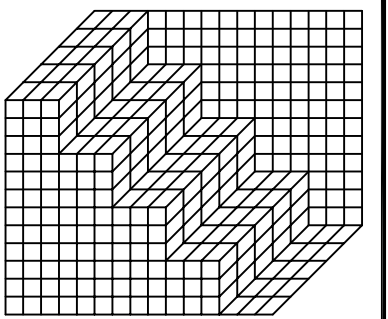
Rev	Description	Date	Dm	Ch'd
-----	-------------	------	----	------

INFORMATION

Status of drawing

Camden Mill
Lower Bristol Road
Bath BA2 3DQ
UK

Tel: +44 (0)1225 320600
Fax: +44 (0)870 787 4148
Email: 021706@burohappold.com
Web: www.burohappold.com



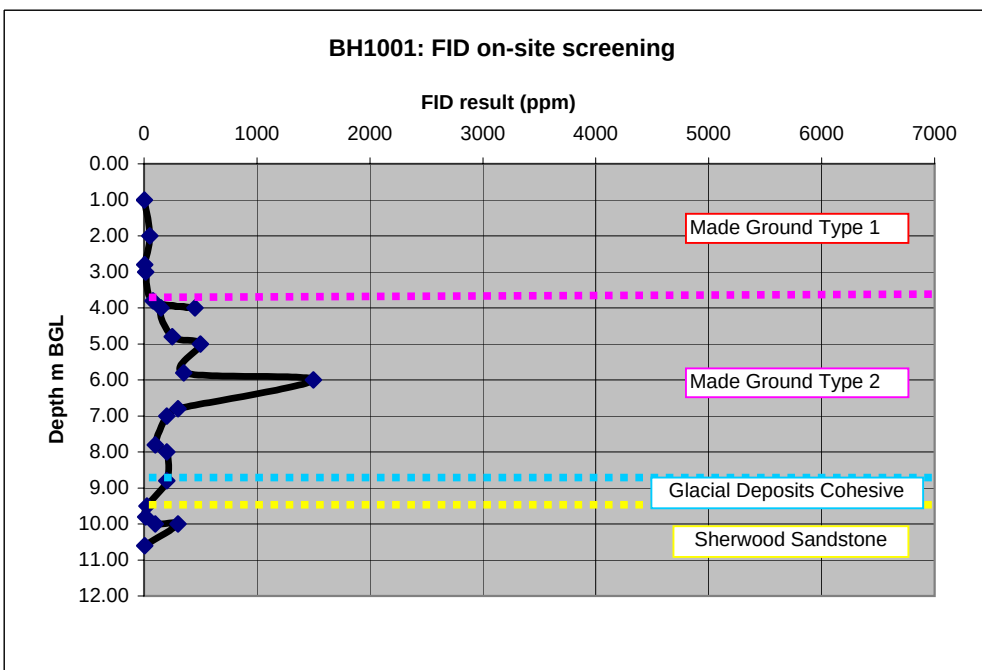
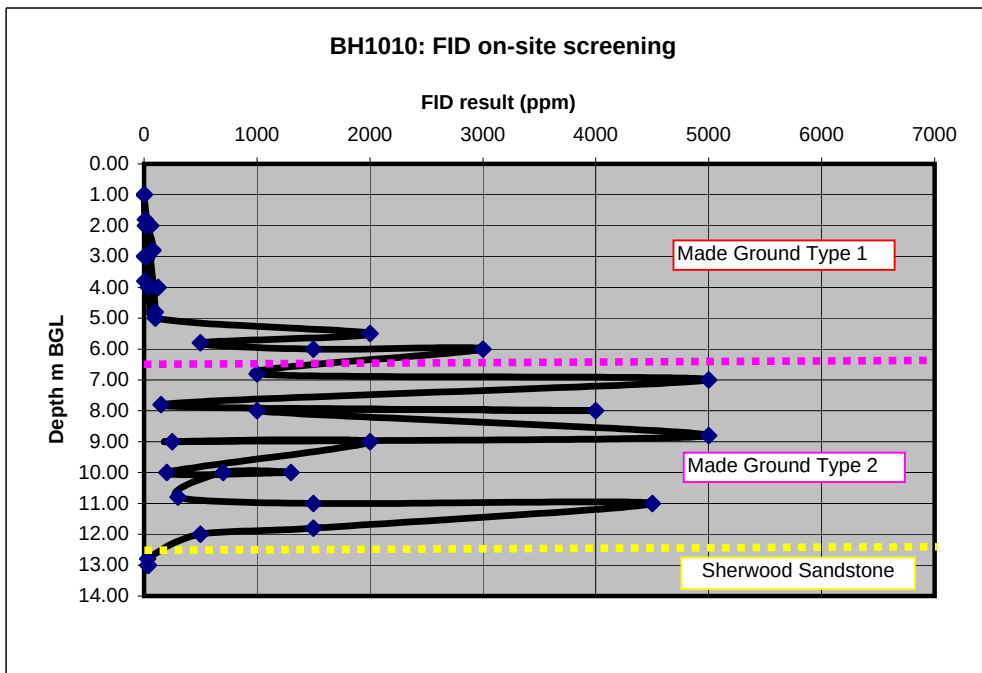
Buro Happold
Consulting Engineers

Architect **BROADWAY MALYAN**

Project **KIRKBY REDEVELOPMENT**
Drg Title **PHASE 1 GROUND INVESTIGATION
GDO 205 LANDFILL AREA - EXPLORATORY
HOLE PLAN**

Scales/BA1 1:1000
Drawn by NG
Checked by PH
Date 17.09.07

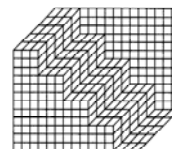
Job No. **021706**
Drawing No. **FIGURE 4**
Rev **00**



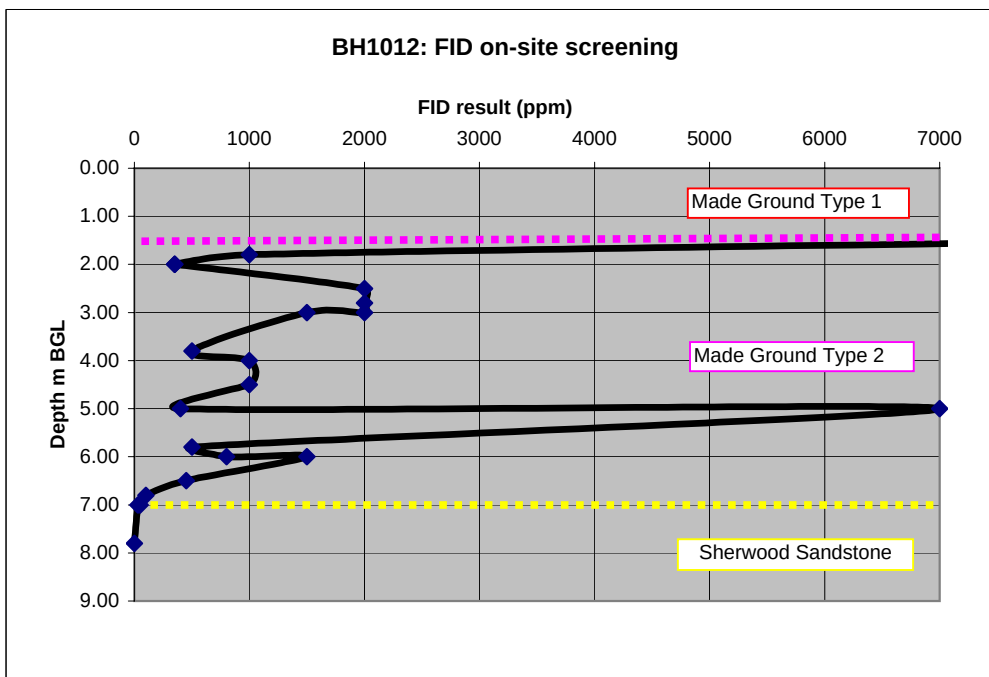
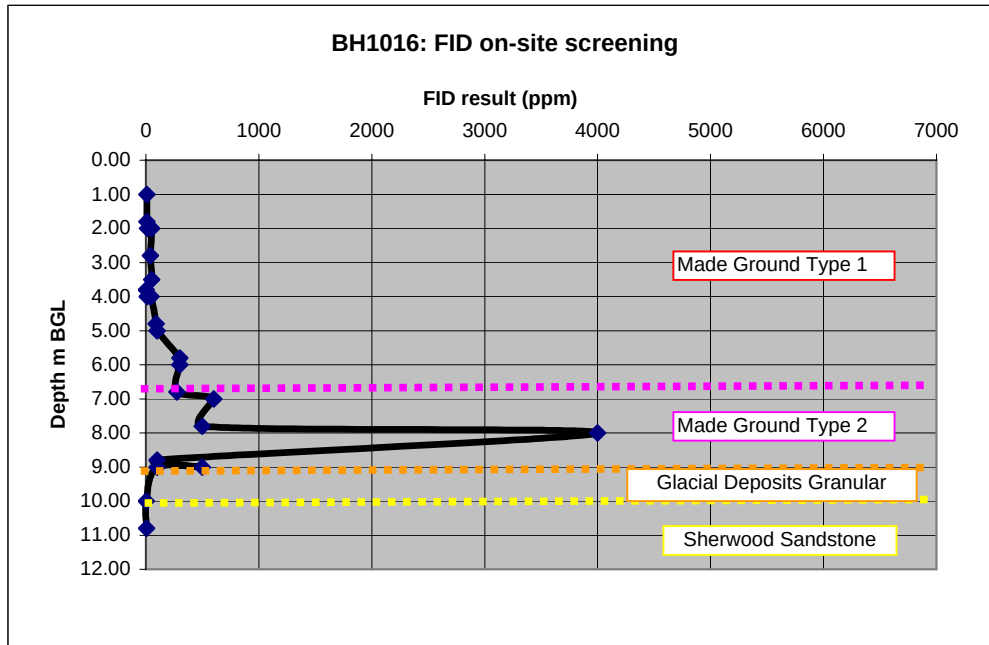
Report Title: Geoenvironmental and Geotechnical Interpretative Report- Phase 1 Ground Investigation (GDO 205 landfill area)

Figure: 5 (a),(b)

Date: November 2007



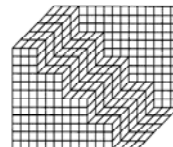
Buro Happold
Ground Engineering



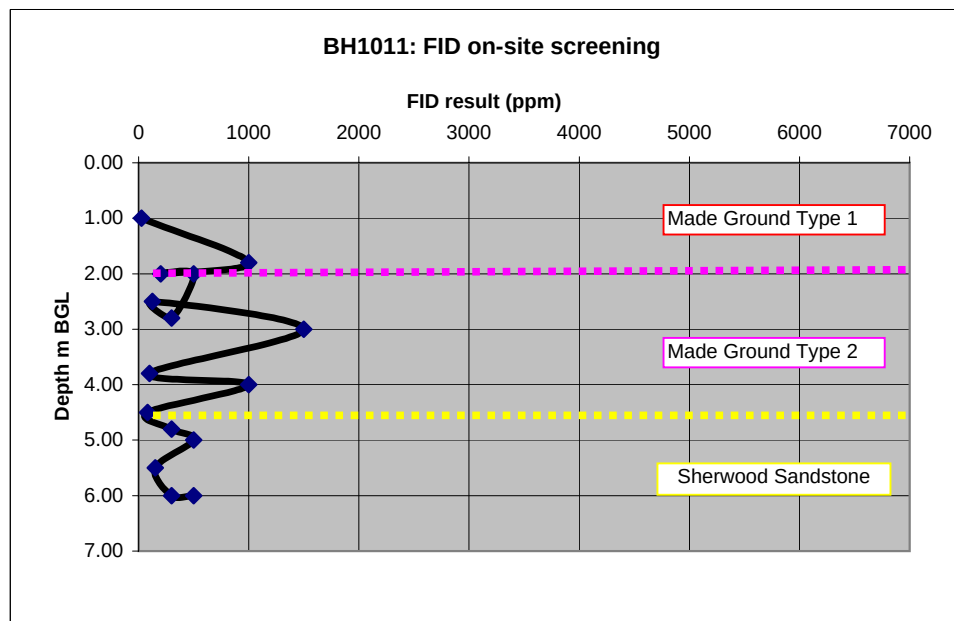
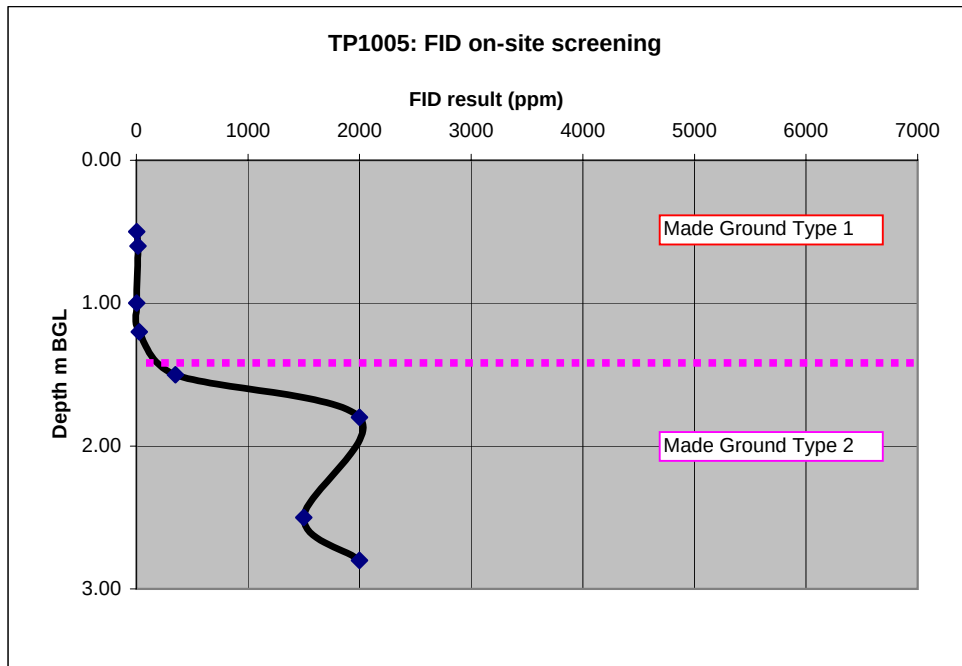
Report Title: Geoenvironmental and Geotechnical Interpretative Report- Phase 1 Ground Investigation (GDO 205 landfill area)

Figure: 5 (c),(d)

Date: November 2007



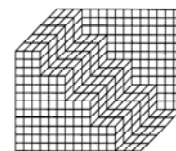
Buro Happold
Ground Engineering



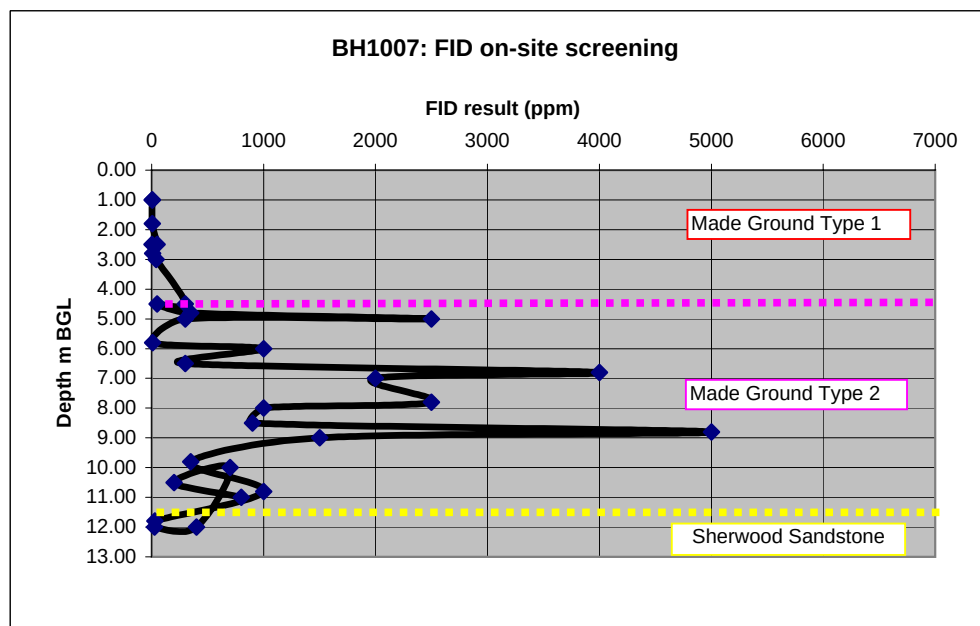
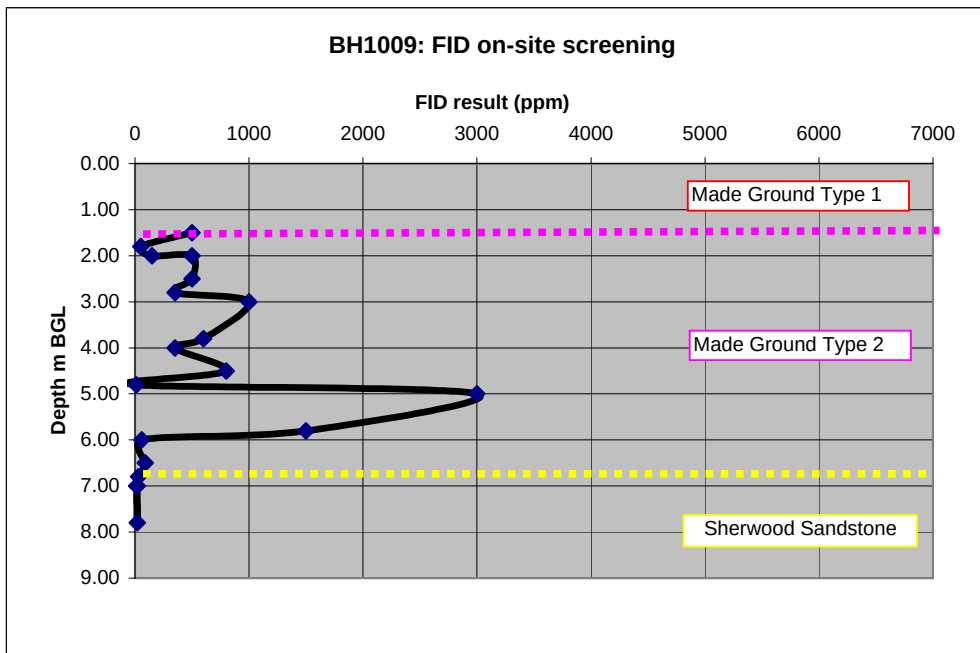
Report Title: Geoenvironmental and Geotechnical Interpretative Report- Phase 1 Ground Investigation (GDO 205 landfill area)

Figure: 5 (e),(f)

Date: November 2007



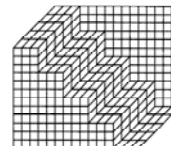
Buro Happold
Ground Engineering



Report Title: Geoenvironmental and Geotechnical Interpretative Report- Phase 1 Ground Investigation (GDO 205 landfill area)

Figure: 5 (g),(h)

Date: November 2007



Buro Happold
Ground Engineering

Report Title: Geoenvironmental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)

Date: November 2007

Figure: 6 (a) Cross section BH1001 to BH1017 (approx. north-south, refer Figure 4)



Ground Stratum key

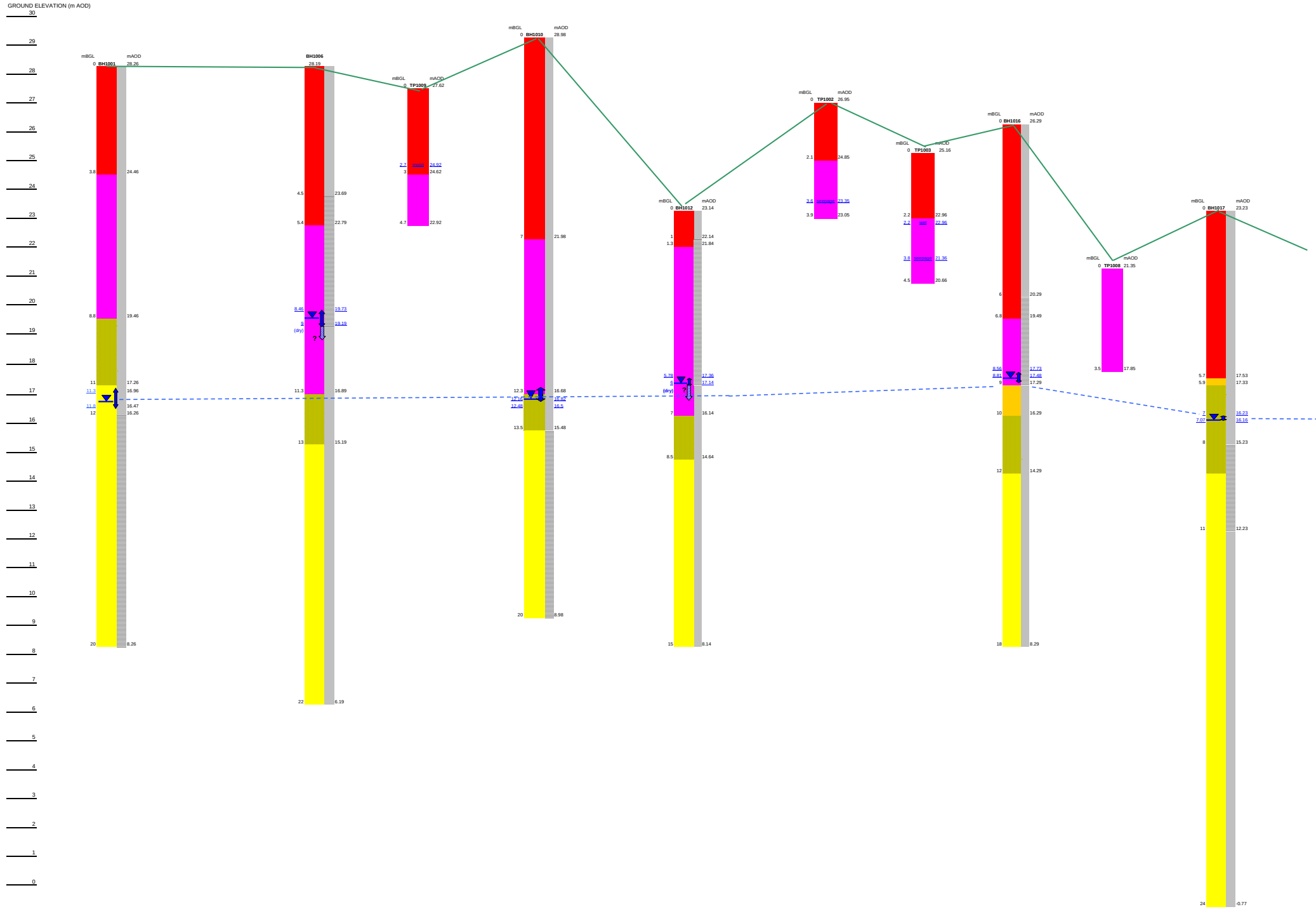
- Topsoil: Grass overlying topsoil. (not shown on exploratory logs)
- Made Ground Type 1: Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete, rare wood, metal, rare asbestos-containing cement.
- Made Ground Type 2: Typically damp, dark brown/black sandy gravelly matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.
- Glacial Deposits Granular (Glacial Sand and Gravel or Shirdley Hill Sand): Typically yellow/brown slightly silty slightly gravelly coarse sand.
- Glacial Deposits Cohesive (Glacial Boulder Clay): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies
- Alluvium: Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel
- Weathered Sherwood Sandstone: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion boring)
- Sherwood Sandstone: Typically moderately strong red fine-grained sandstone (recovered by rotary coring)
- Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)
- Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

Other details

- Monitoring installation response zone
- Bentonite seal
- Interpolated existing ground level
- Groundwater levels and variation during site monitoring to date
- Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)
Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes.



Report Title: Geoenvironmental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)

Date: November 2007

Figure: 6 (b) Cross section TP1015 to TP1004 (approx. west-east, refer Figure 4)



Ground Stratum key

Topsail Grass overlying topsoil. (not shown on exploratory logs)

Made Ground 'Type 1': Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete. Rare wood, metal. Rare asbestos-containing cement.

Made Ground 'Type 2': Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.

Glacial Deposits Granular (*Glacial Sand and Gravel* or *Shirley Hill Sand*): Typically yellow/brown slightly silty slightly gravelly coarse sand.

Glacial Deposits Cohesive (*Glacial Boulder Clay*): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies

Alluvium: Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel

Weathered Sherwood Sandstone: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion boring)

Sherwood Sandstone: Typically moderately strong red fine-grained sandstone (recovered by rotary coring)

Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)

Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)

Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)

Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

Other details

Monitoring installation response zone

Bentonite seal

Interpolated existing ground level

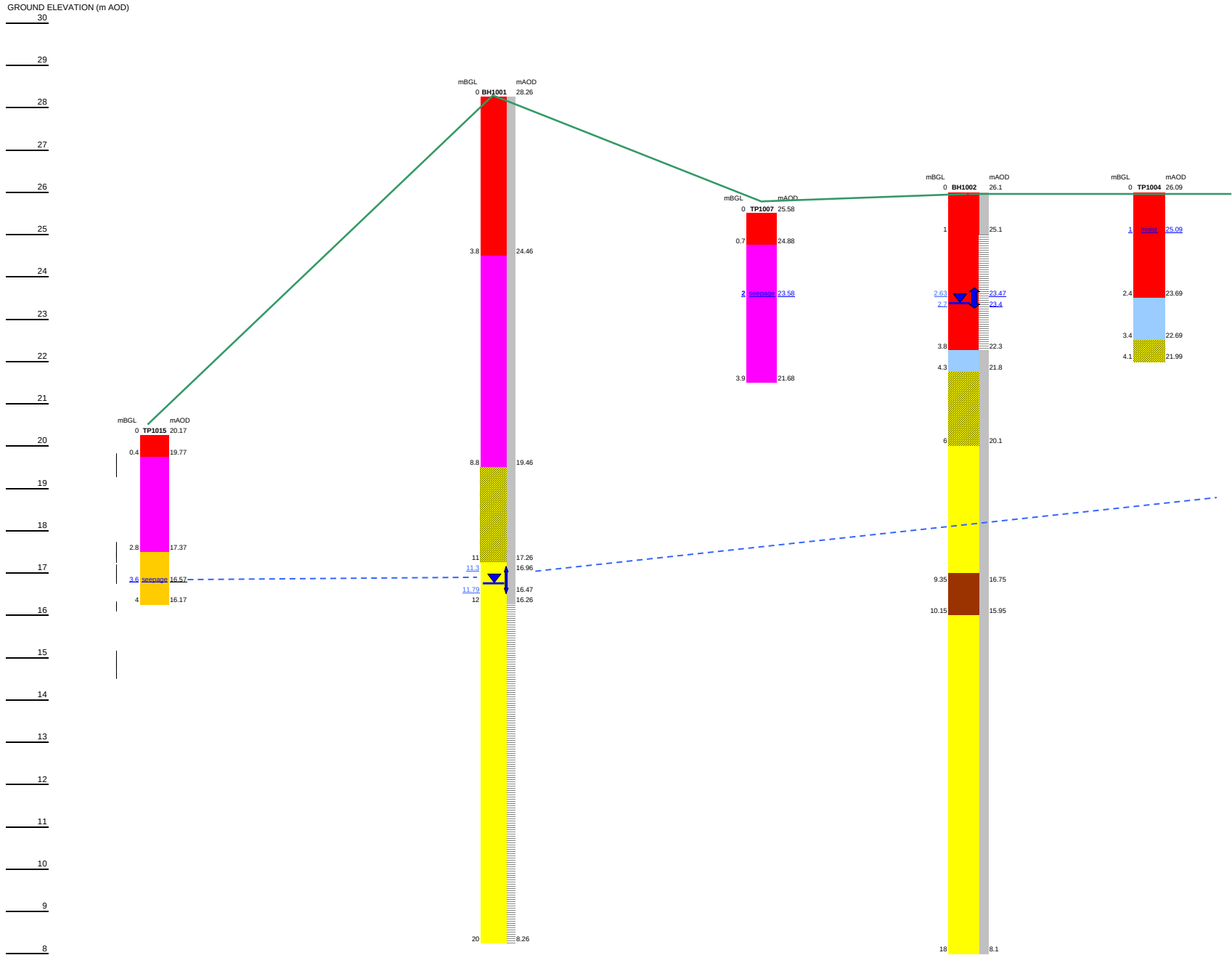
Groundwater levels and variation during site monitoring to date

Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)

Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes.



Report Title: Geoenvironmental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)

Date: November 2007

Figure 6 (c) Cross section BH1004 to BH1003 (approx. west-east, refer Figure 4)



Ground Stratum key

Topsoil Grass overlying topsoil. (not shown on exploratory logs)

Made Ground 'Type 1': Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete. Rare wood, metal. Rare asbestos-containing cement.

Made Ground 'Type 2': Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.

Glacial Deposits Granula (Glacial Sand and Gravel or Shirdley Hill Sand): Typically yellow/brown slightly silty slightly gravelly coarse sand.

Glacial Deposits Cohesive (Glacial Boulder Clay): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies

Alluvium: Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel

Weathered Sherwood Sandstone: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion boring)

Sherwood Sandstone: Typically moderately strong red fine-grained sandstone (recovered by rotary coring)

Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)

Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)

Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)

Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

Other details

Monitoring installation response zone

Bentonite seal

Interpolated existing ground level

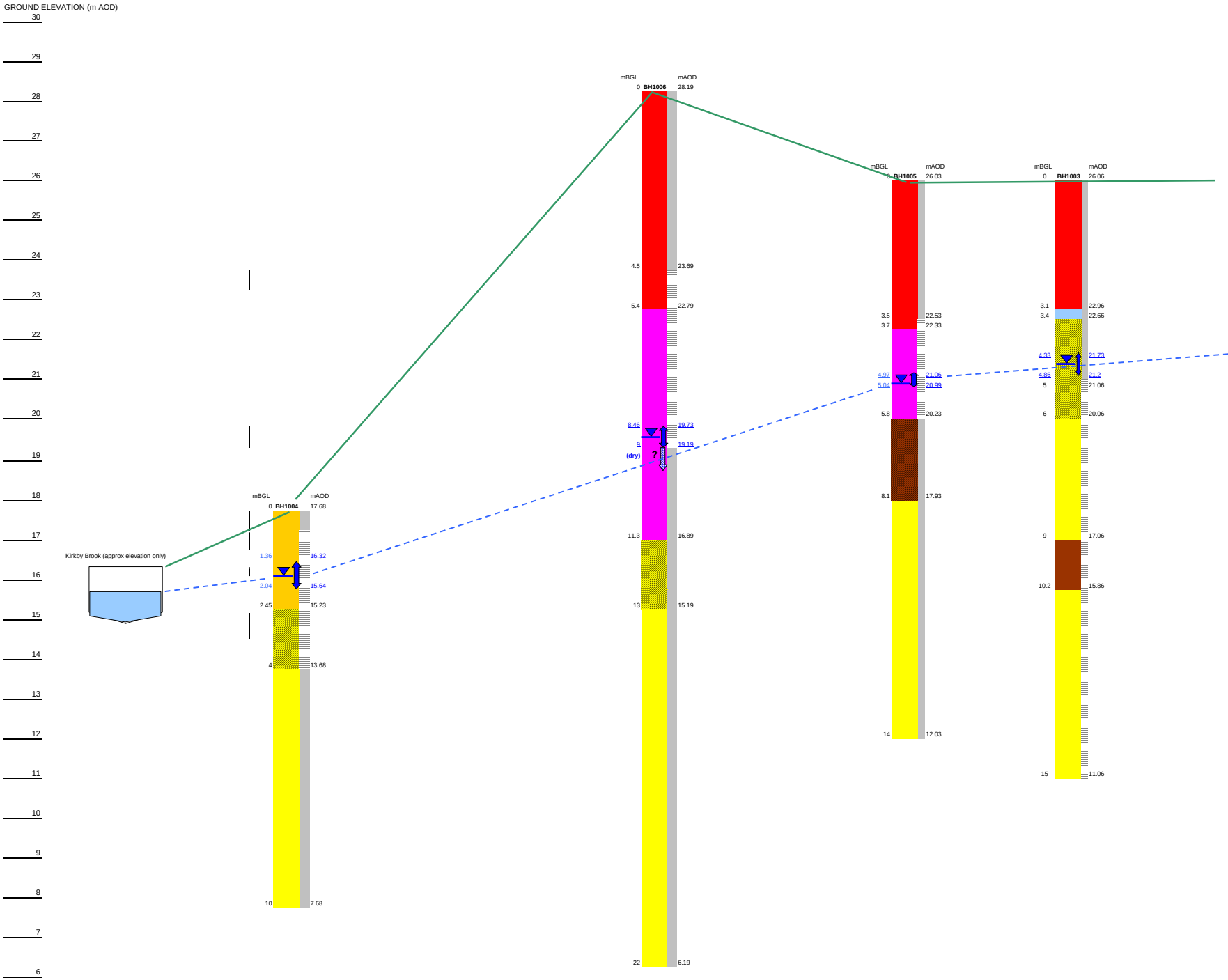
Groundwater levels and variation during site monitoring to date

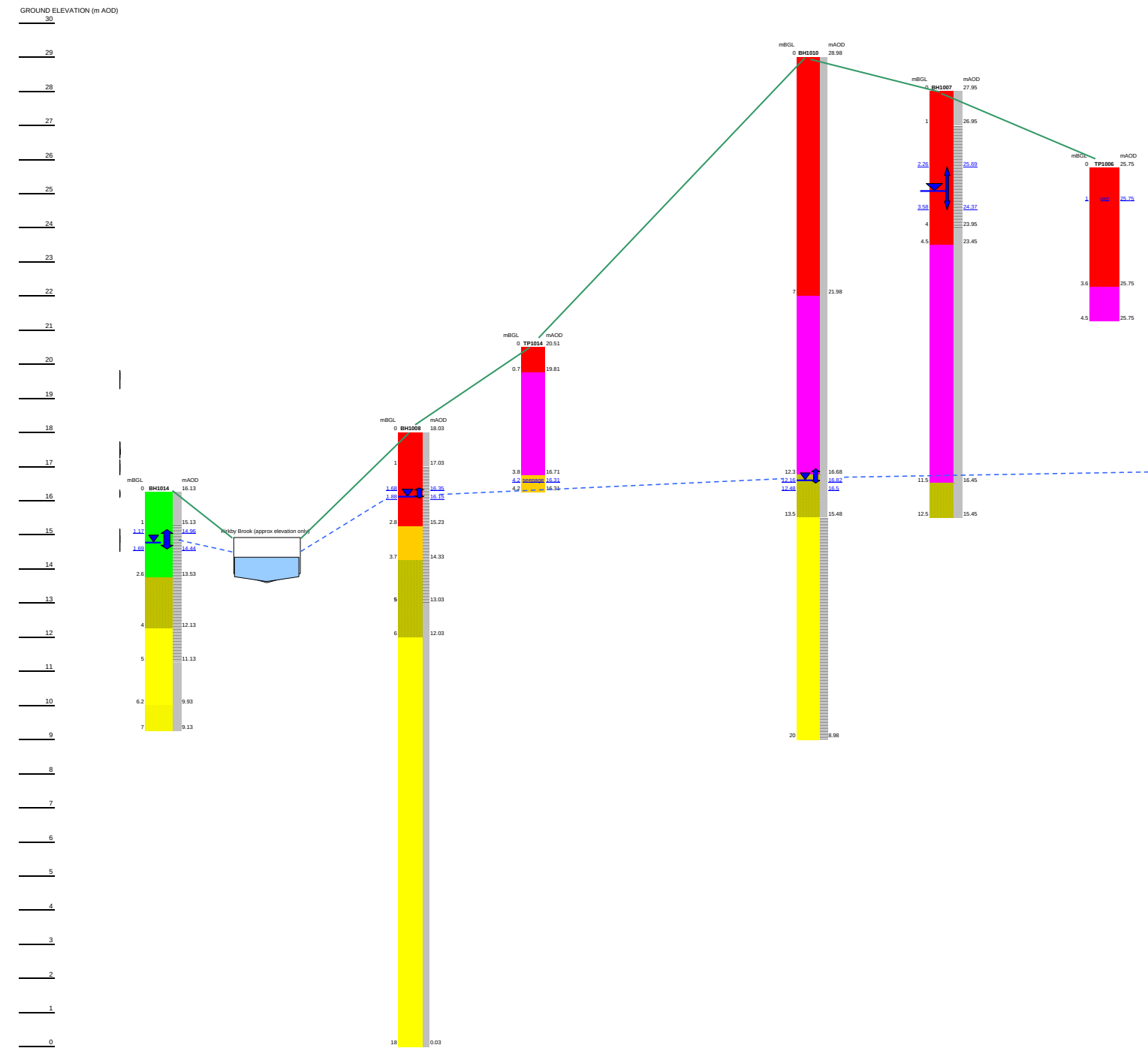
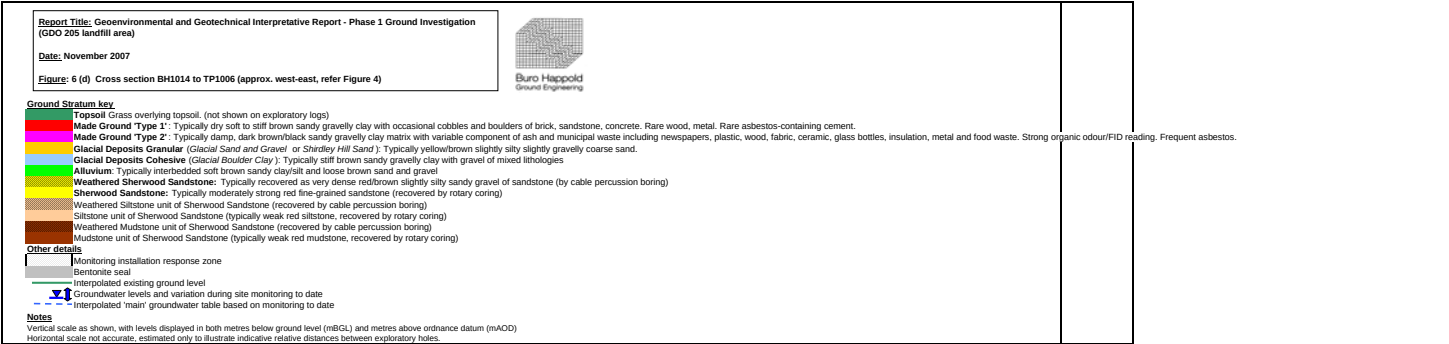
Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)

Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes.

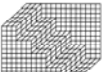




Report Title: Geoenviromental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)

Date: November 2007

Figure: 6 (e) Cross section BH1014 to BH1009 (approx. west-east, refer Figure 4)



Buro Happold
Ground Engineering

Ground Stratum key

- Topsoil** Grass overlying topsoil. (not shown on exploratory logs)
- Made Ground 'Type 1'**: Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete. Rare wood, metal. Rare asbestos-containing cement.
- Made Ground 'Type 2'**: Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.
- Glacial Deposits Granular** (*Glacial Sand and Gravel* or *Shirdley Hill Sand*): Typically yellow/brown slightly silty slightly gravelly coarse sand.
- Glacial Deposits Cohesive** (*Glacial Boulder Clay*): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies
- Alluvium**: Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel
- Weathered Sherwood Sandstone**: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion boring)
- Sherwood Sandstone**: Typically moderately strong red fine-grained sandstone (recovered by rotary coring)
- Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)
- Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

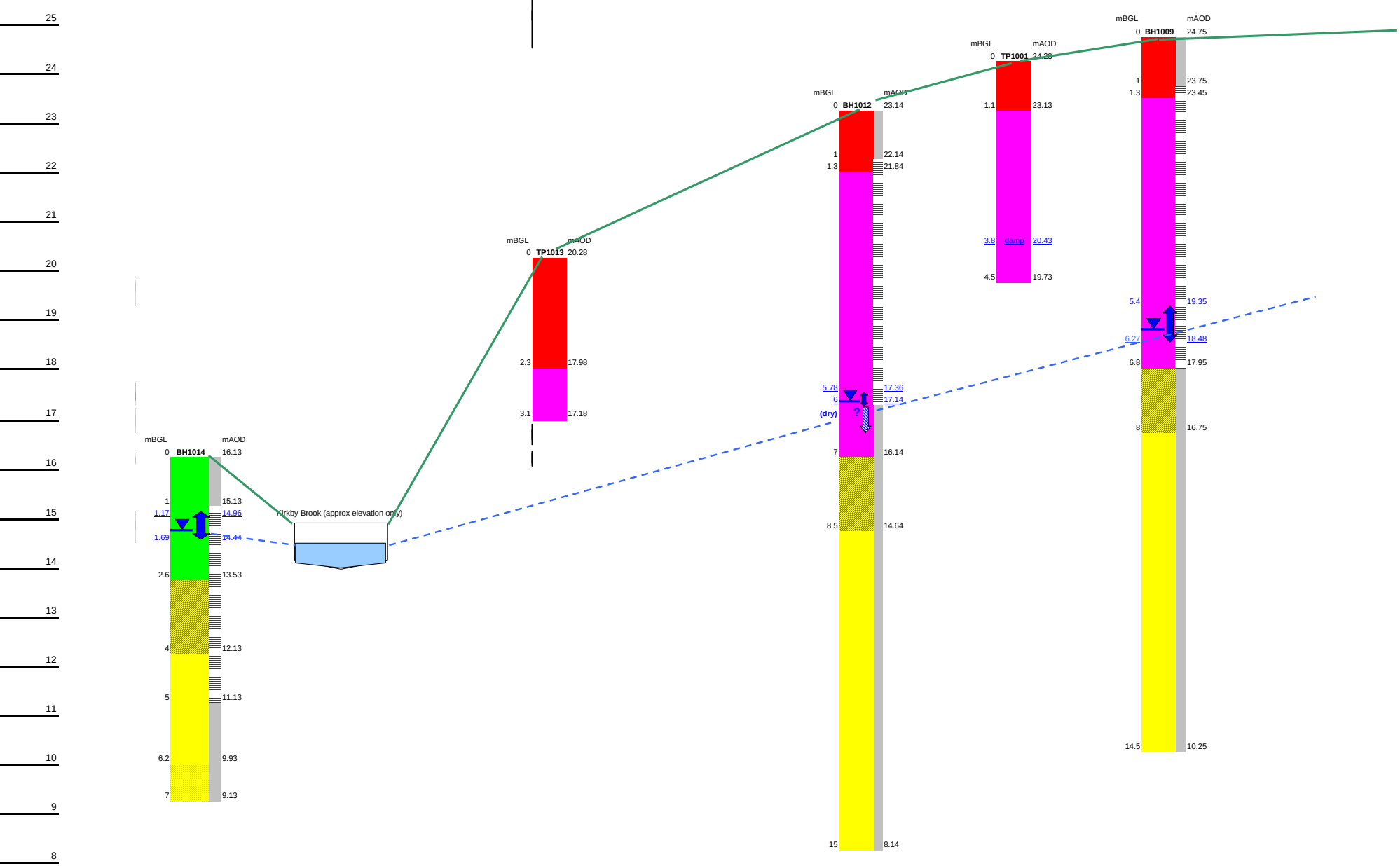
Other details

- Monitoring installation response zone
- Bentonite seal
- Interpolated existing ground level
- Groundwater levels and variation during site monitoring to date
- Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)
Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes.

GROUND ELEVATION (m AOD)



Report Title: Geoenvironmental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)
Date: November 2007
Figure: 6 (f) Cross section BH1015 to BH1011 (approx. west-east, refer Figure 4)



Ground Stratum key

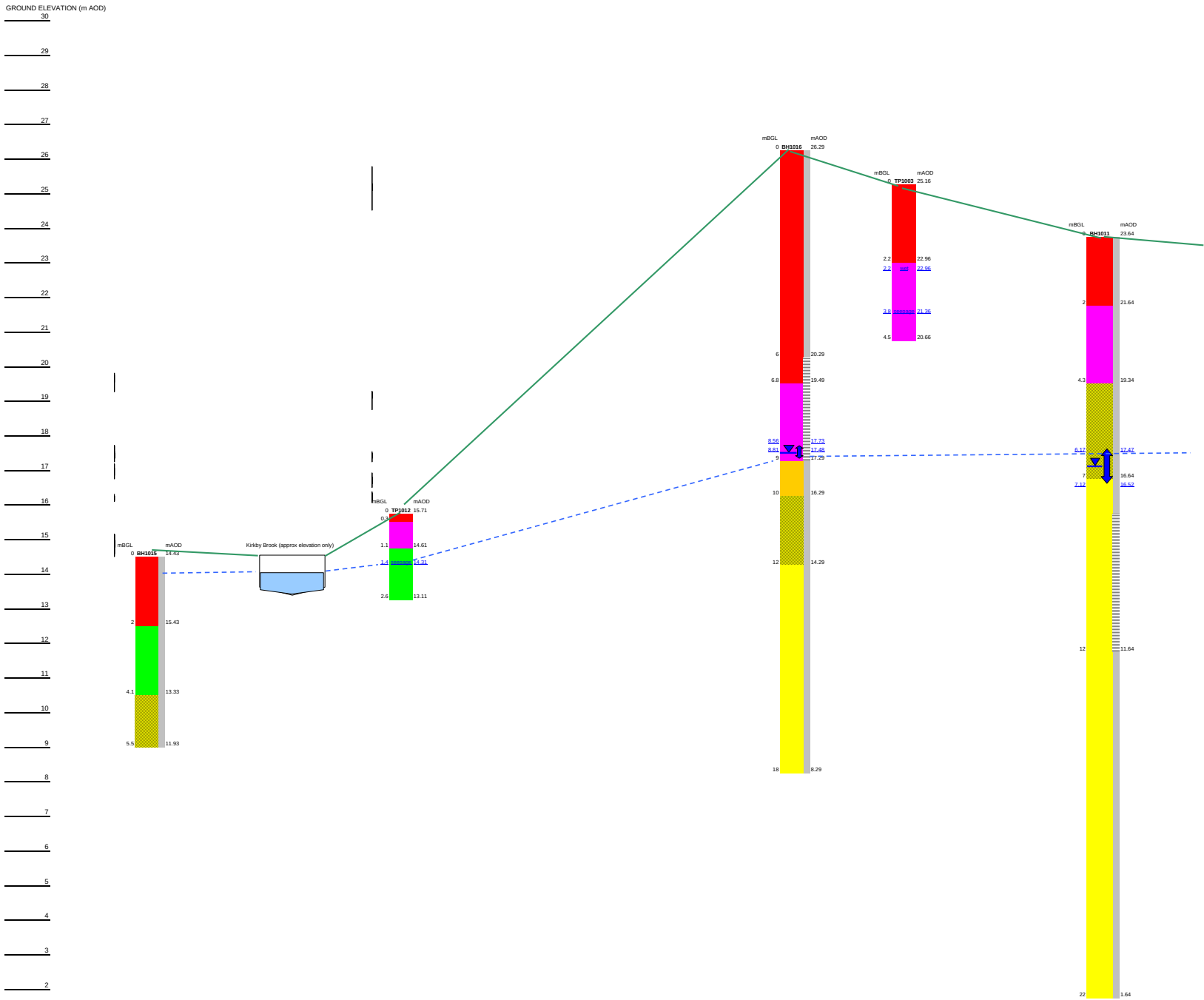
- Topsoil: Grass overlying topsoil. (not shown on exploratory logs)
- Made Ground 'Type 1': Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete. Rare wood, metal. Rare asbestos-containing cement.
- Made Ground 'Type 2': Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.
- Glacial Deposits Granular (Glacial Sand and Gravel or Shireley Hill Sand): Typically yellowbrown slightly silty slightly gravelly coarse sand.
- Glacial Deposits Cohesive (Glacial Boulder Clay): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies
- Alluvium: Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel
- Weathered Sherwood Sandstone: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion boring)
- Sherwood Sandstone: Typically moderately strong red fine-grained sandstone (recovered by rotary coring)
- Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)
- Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

Other details

- Monitoring installation response zone
- Bentonite seal
- Interpolated existing ground level
- Groundwater levels and variation during site monitoring to date
- Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)
Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes



Report Title: Geoenvironmental and Geotechnical Interpretative Report - Phase 1 Ground Investigation (GDO 205 landfill area)
Date: November 2007
Figure: 6 (g) Cross section TP1011 to BH1017 (approx. west-east, refer Figure 4)



Ground Stratum key

- Topsoil** Grass overlying topsoil. (not shown on exploratory log)
- Made Ground 'Type 1'**: Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, sandstone, concrete. Rare wood, metal. Rare asbestos-containing cer
- Made Ground 'Type 2'**: Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Strong organic odour/FID reading. Frequent asbestos.
- Glacial Deposits Granular** (Glacial Sand and Gravel or Shirdley Hill Sand): Typically yellow/brown slightly silty slightly gravelly coarse sand.
- Glacial Deposits Cohesive** (Glacial Boulder Clay): Typically stiff brown sandy gravelly clay with gravel of mixed lithologies
- Alluvium**: Typically interbedded soft brown sandy clay/silt and loose brown sand and gra
- Weathered Sherwood Sandstone**: Typically recovered as very dense red/brown slightly silty sandy gravel of sandstone (by cable percussion bor
- Sherwood Sandstone**: Typically moderately strong red fine-grained sandstone (recovered by rotary cori
- Weathered Siltstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Siltstone unit of Sherwood Sandstone (typically weak red siltstone, recovered by rotary coring)
- Weathered Mudstone unit of Sherwood Sandstone (recovered by cable percussion boring)
- Mudstone unit of Sherwood Sandstone (typically weak red mudstone, recovered by rotary coring)

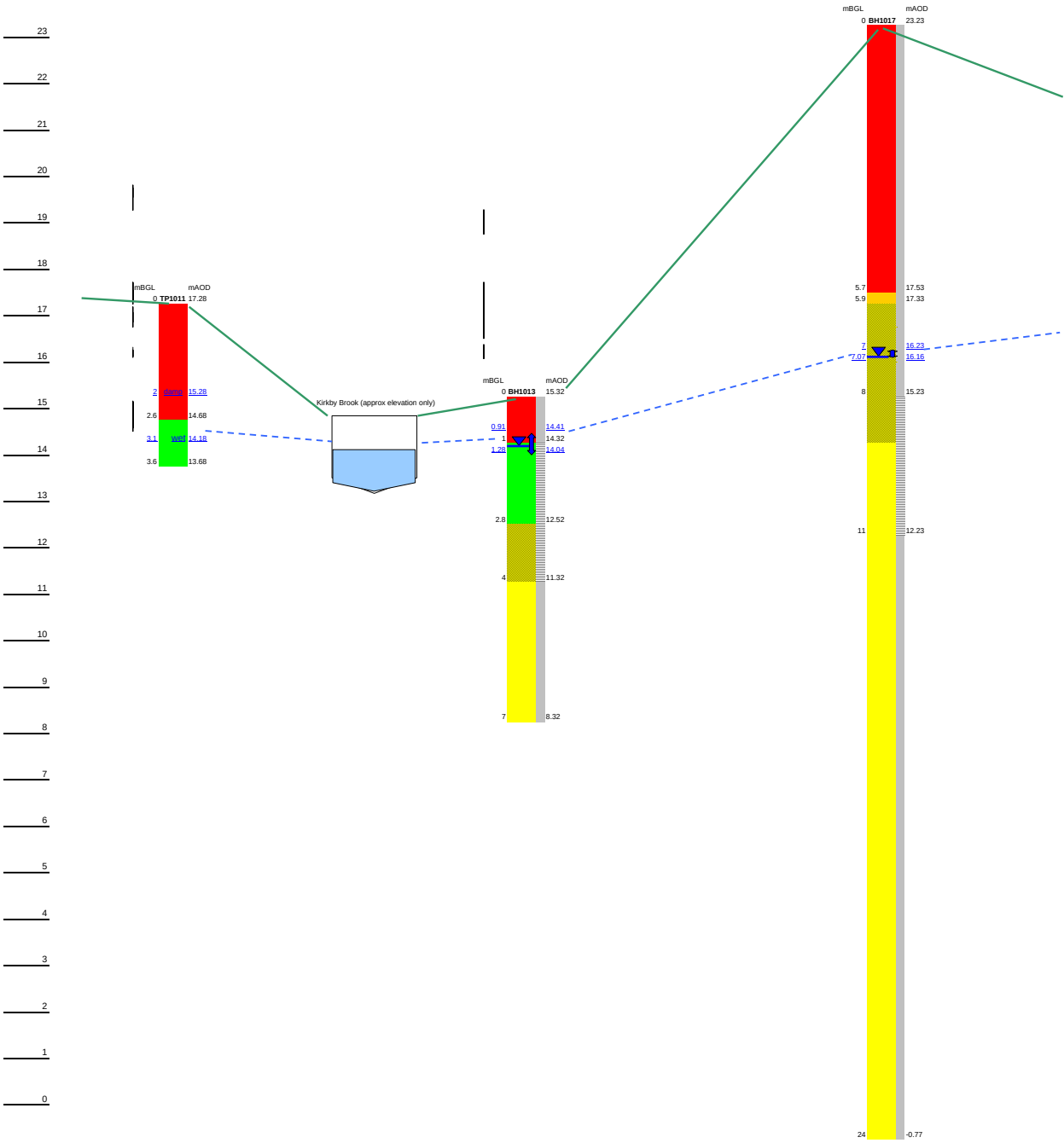
Other details

- Monitoring installation response zone
- Bentonite seal
- Interpolated existing ground level
- Groundwater levels and variation during site monitoring to date
- Interpolated 'main' groundwater table based on monitoring to date

Notes

Vertical scale as shown, with levels displayed in both metres below ground level (mBGL) and metres above ordnance datum (mAOD)
Horizontal scale not accurate, estimated only to illustrate indicative relative distances between exploratory holes.

GROUND ELEVATION (m AOD)



Notes

Vertically exaggerated to illustrate ground profile

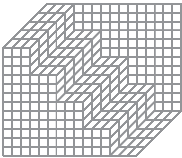
Contaminant sources, pathways & receptors relate to existing site condition

Rev Description/Date Drn/Chk

INFORMATION

Status of drawing

Camden Mill
Lower Bristol Road
Bath BA2 3DQ
Tel: +44 (0)1225 320600
Fax: +44 (0)870 787 4148
Email: 021706@burohappold.com
Web: www.burohappold.com



Buro Happold
Consulting Engineers

Architect Broadway Maylan

Project Kirkby Regeneration

Conceptual Ground Model
For Existing Site Condition

GD0 205 Landfill Area

Scales@A3 NOT TO SCALE

Drawn by NG

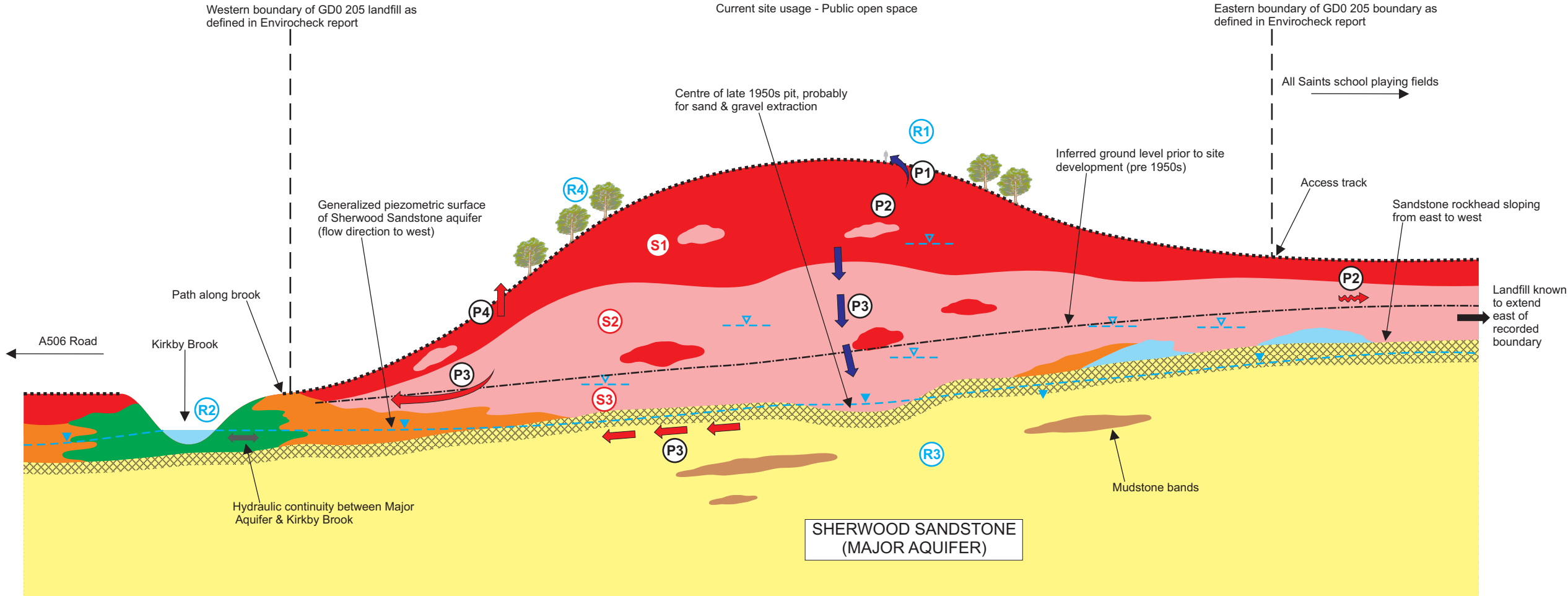
Checked by PH

Date 18/09/07

Job No. 021706

Drg No. FIGURE 8

Rev 00



Key to Ground Conditions

- Topsoil - Typically 0.10m thickness of grass overlying topsoil present across site

Made Ground (Type 1) - Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, concrete wood and metal. Rare asbestos

Made Ground (Type 2) - Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Generally strong organic odour. Abundant asbestos

Glacial Deposits Granular (Glacial Sand and Gravel or Shirdley Hill Sand) Typically yellow/brown slightly silty slightly gravelly coarse sand

Glacial Deposits Cohesive (Glacial Boulder Clay) - Typically stiff brown sandy gravelly clay

Alluvium - Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel

Weathered Sherwood Sandstone - Typically very dense red/brown slightly silty sandy gravel of sandstone (recovered by cable percussion boring)

Sherwood Sandstone - Typically moderately strong red fine grained sandstone (recovered by rotary coring)

Mudstone unit of Sherwood Sandstone

Localised groundwater

Main groundwater table

Potential Sources

- S1

S2

S3
- Made Ground - Type 1

Made Ground - Type 2

Contaminants in solution/landfill leachate

Potential Contaminant Pathways

- P1

P2

P3

P4
- Soil & soil dust ingestion & skin contact (soft landscaped areas)

Gas and vapour migration/inhalation

Leaching/transport of contaminants

Plant uptake & phytotoxic effects

Possible Receptors

- R1

R2

R3

R4

R5

R6
- Current site users

Kirkby Brook - controlled surface water/ecology

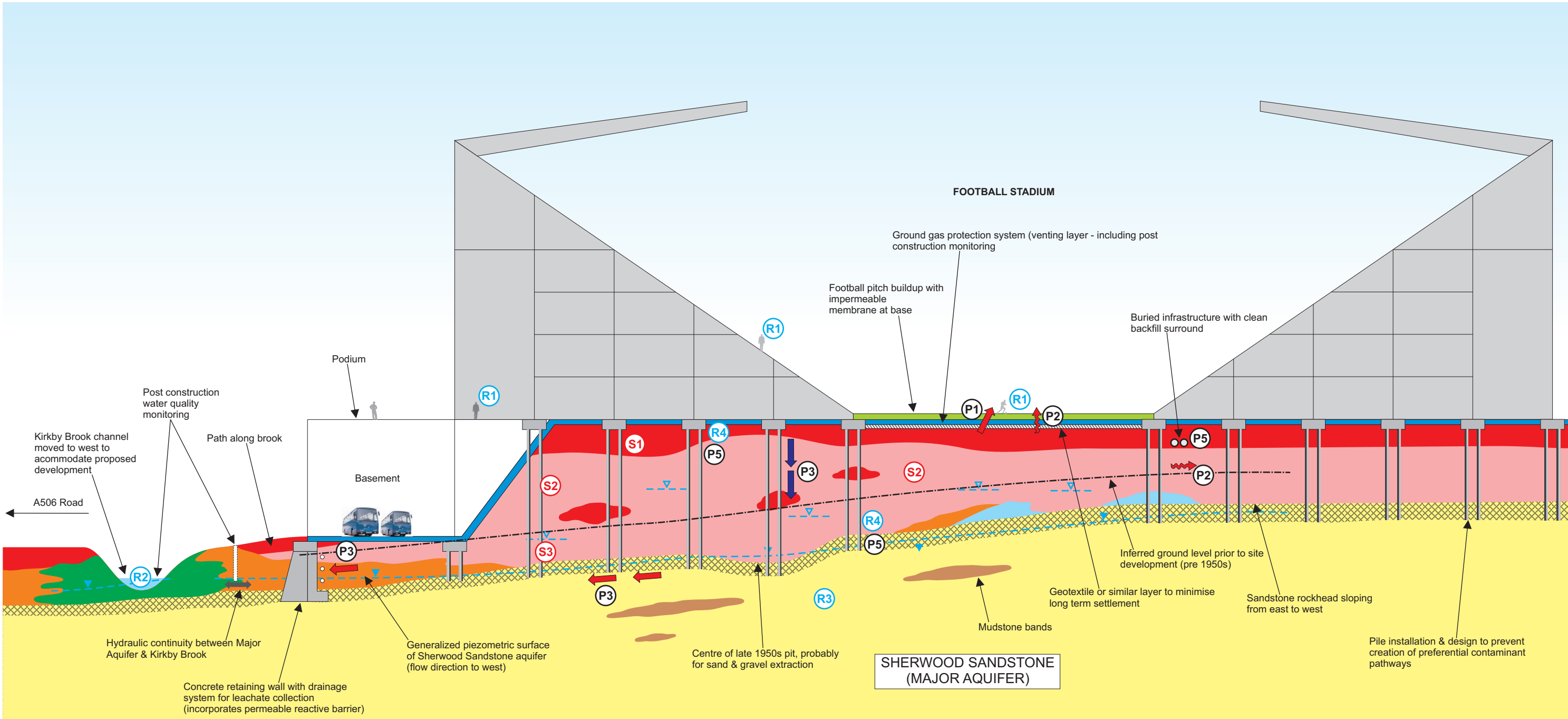
Groundwater in Sherwood Sandstone Major Aquifer

Flora

Offsite Structures

Offsite users - (residents and Knowsley Community College)

Notes



- Key to Ground Conditions**
- Topsoil - Typically 0.10m thickness of grass overlying topsoil present across site
 - Made Ground (Type 1)** - Typically dry soft to stiff brown sandy gravelly clay with occasional cobbles and boulders of brick, concrete wood and metal. Rare asbestos
 - Made Ground (Type 2)** - Typically damp, dark brown/black sandy gravelly clay matrix with variable component of ash and municipal waste including newspapers, plastic, wood, fabric, ceramic, glass bottles, insulation, metal and food waste. Generally strong organic odour. Abundant asbestos
 - Glacial Deposits Granular** (Glacial Sand and Gravel or Shirdley Hill Sand) Typically yellow/brown slightly silty slightly gravelly coarse sand
 - Glacial Deposits Cohesive** (Glacial Boulder Clay) - Typically stiff brown sandy gravelly clay
 - Alluvium** - Typically interbedded soft brown sandy clay/silt and loose brown sand and gravel
 - Weathered Sherwood Sandstone** - Typically very dense red/brown slightly silty sandy gravel of sandstone (recovered by cable percussion boring)
 - Sherwood Sandstone** - Typically moderately strong red fine grained sandstone (recovered by rotary coring)
 - Mudstone unit of Sherwood Sandstone**
 - ▽--- Localised groundwater
 - ▽--- Main groundwater table

- Potential Sources**
- S1** Made Ground - Type 1
 - S2** Made Ground - Type 2
 - S3** Contaminants in solution/landfill leachate

- Potential Contaminant Pathways**
- P1** Soil & soil dust ingestion & skin contact (soft landscaped areas)
 - P2** Gas and vapour migration/inhalation
 - P3** Leaching/transport of contaminants
 - P4** Plant uptake & phytotoxic effects
 - P5** Direct contact

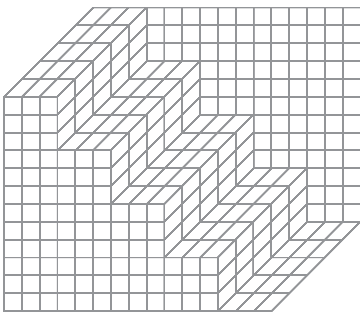
- Possible Receptors**
- R1** Site end users
 - R2** Kirkby Brook - controlled surface water/ecology
 - R3** Groundwater in Sherwood Sandstone Major Aquifer
 - R4** Proposed structure including water supply pipes
 - R5** Offsite Structures
 - R6** Offsite users - (residents and Knowsley Community College)

INFORMATION

Status of drawing

Camden Mill
Lower Bristol

Tel: +44 (0)1225 320600
Fax: +44 (0)870 787 4148
Email: 021706@burohappold.com
Web: www.burohappold.com



Buro Happold
Consulting Engineers

Architect Broadway Maylan

Project Kirby Regeneration

Conceptual Ground Model For Proposed Site Condition With
Possible Engineering Solutions
GD0 205 Landfill Area

Scales@A2 NOT TO SCALE

Drawn by NG
Checked by PH

Date 20/09/07

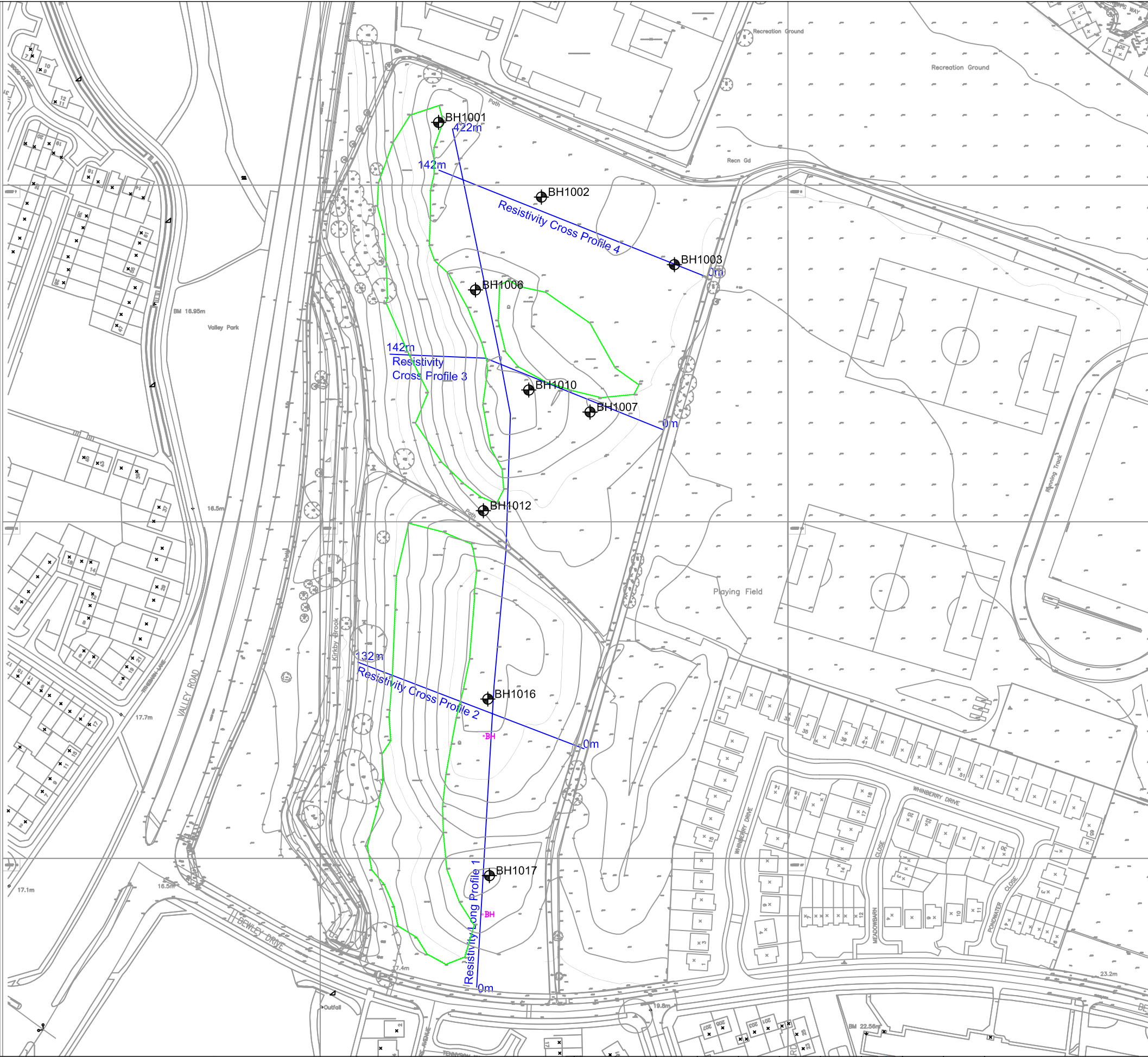
Job No. 021706

Drawing No. FIGURE 9

Rev 00

Appendix A – Current Masterplan

Appendix B – Pelorus Geophysical Survey Resistivity Sections



Legend:

- Resistivity Profile (with start & end chainages)
- Tree Line
- BH1016 Borehole
- Previous Ground Investigation Location

Notes:

- 1) Co-ordinate System: OS National Grid (OSGB36)
- 2) Positioning provided by a Trimble ProXRS GPS using the General Lighthouse Authorities' differential GPS service.
- 3) All levels are related to Ordnance Datum Newlyn (OD(N)).
- 5) Approximate borehole locations taken from Drawing G004 - Exploratory Hole Location Plan G00 205 Land Fill Area as supplied by Buro Happold Limited.
- 6) Background mapping provided in digital format by Buro Happold Limited. Reproduced with the permission of Ordnance Survey on the behalf of The Controller of Her Majesty's Stationery Office, © Crown Copyright, All Rights Reserved. Licence No. 100020449.

Scale: 1:2000

1	RD	June 07	PWR	MJW	BH locations updated
0	RD	May 07	RV	MJW	
Rev.	Drawn	Date	Checked	Approved	Details
Survey Date: 17/04/2007 - 19/04/2007			Surveyor: RD		Drawn By: RD

Client:

TESCO STORES LTD

Engineer:

BURO HAPPOLD LTD

Contractor:

Pelorus Surveys
Geotechnical House
18 Deeside Industrial Estate
Deeside, Flintshire
CH5 2LR

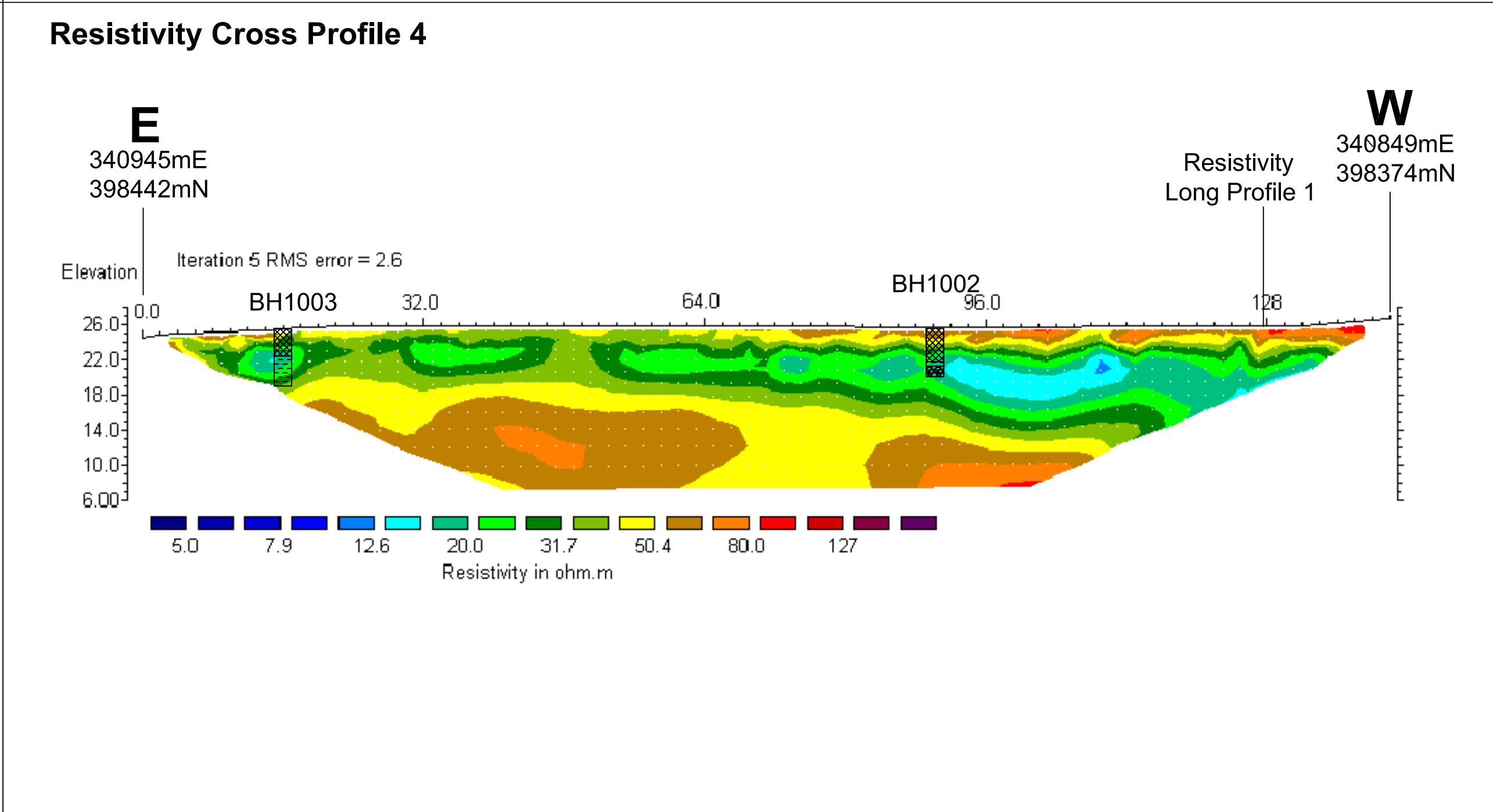
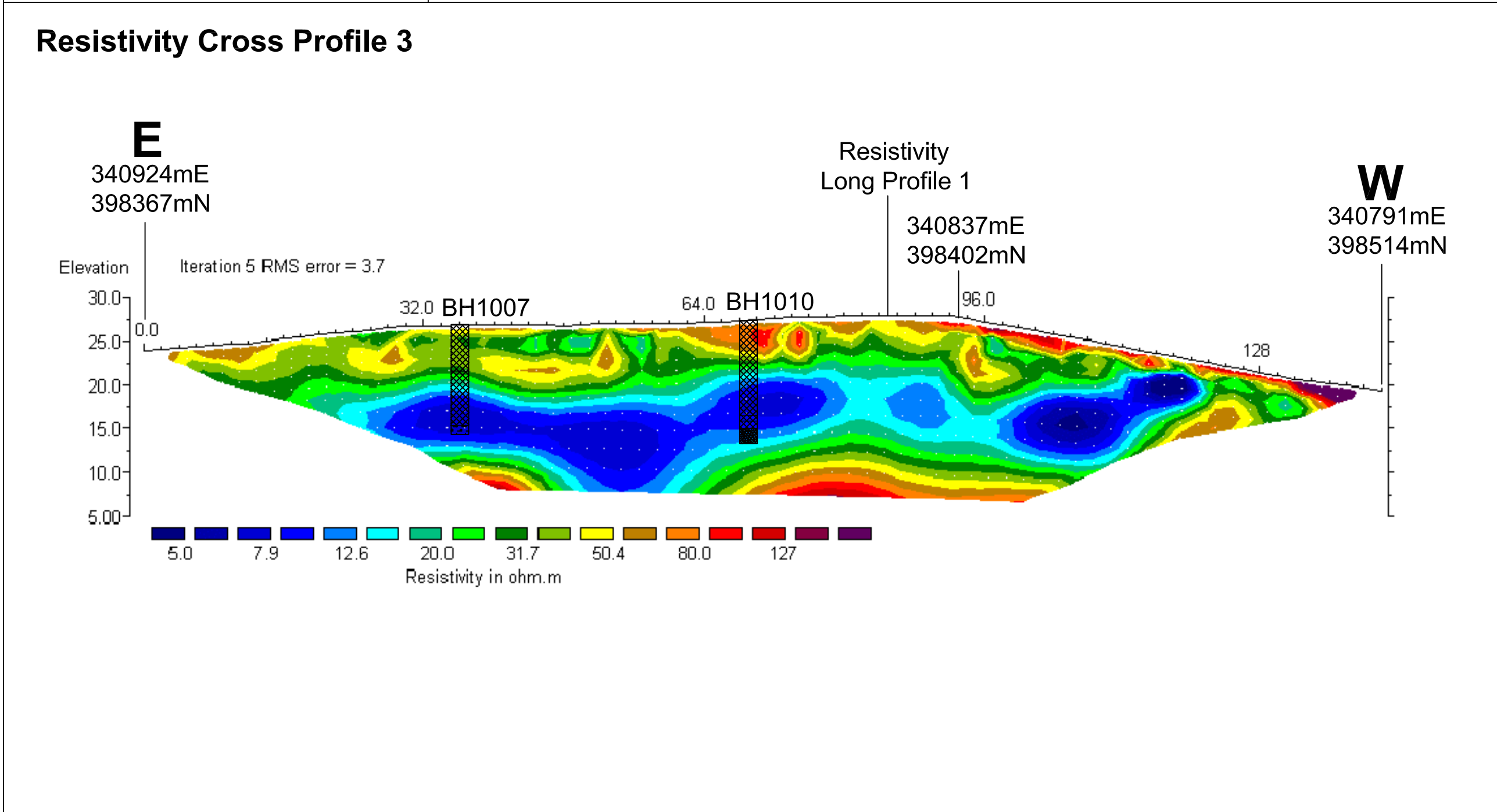
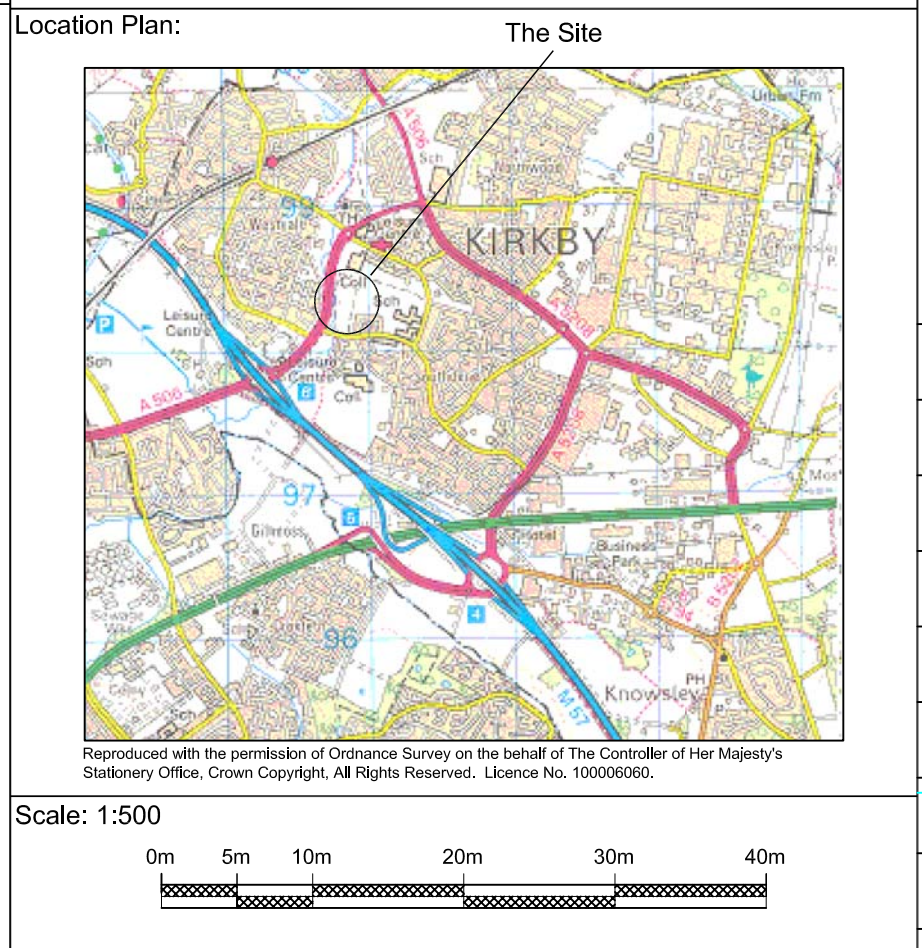
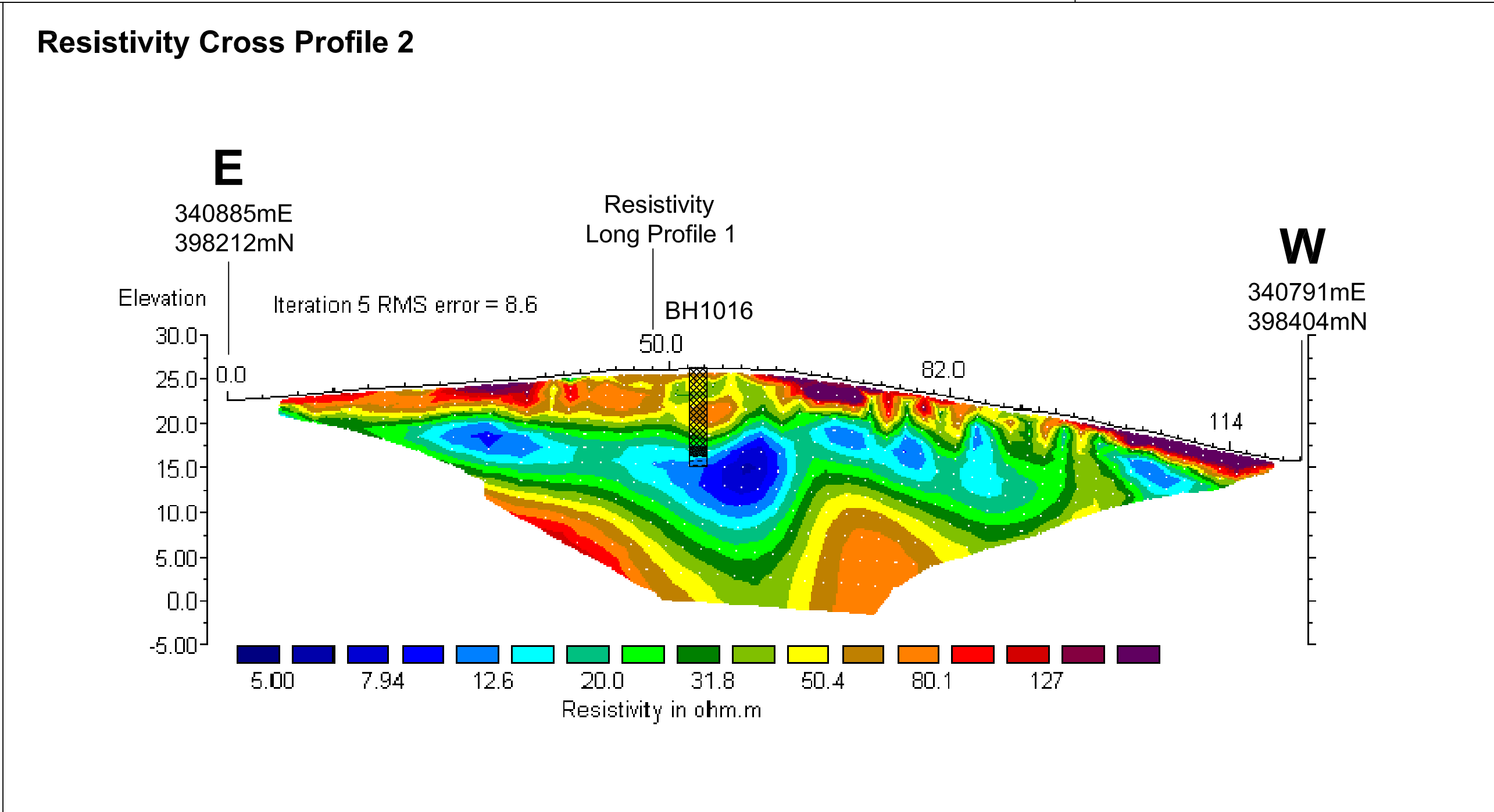
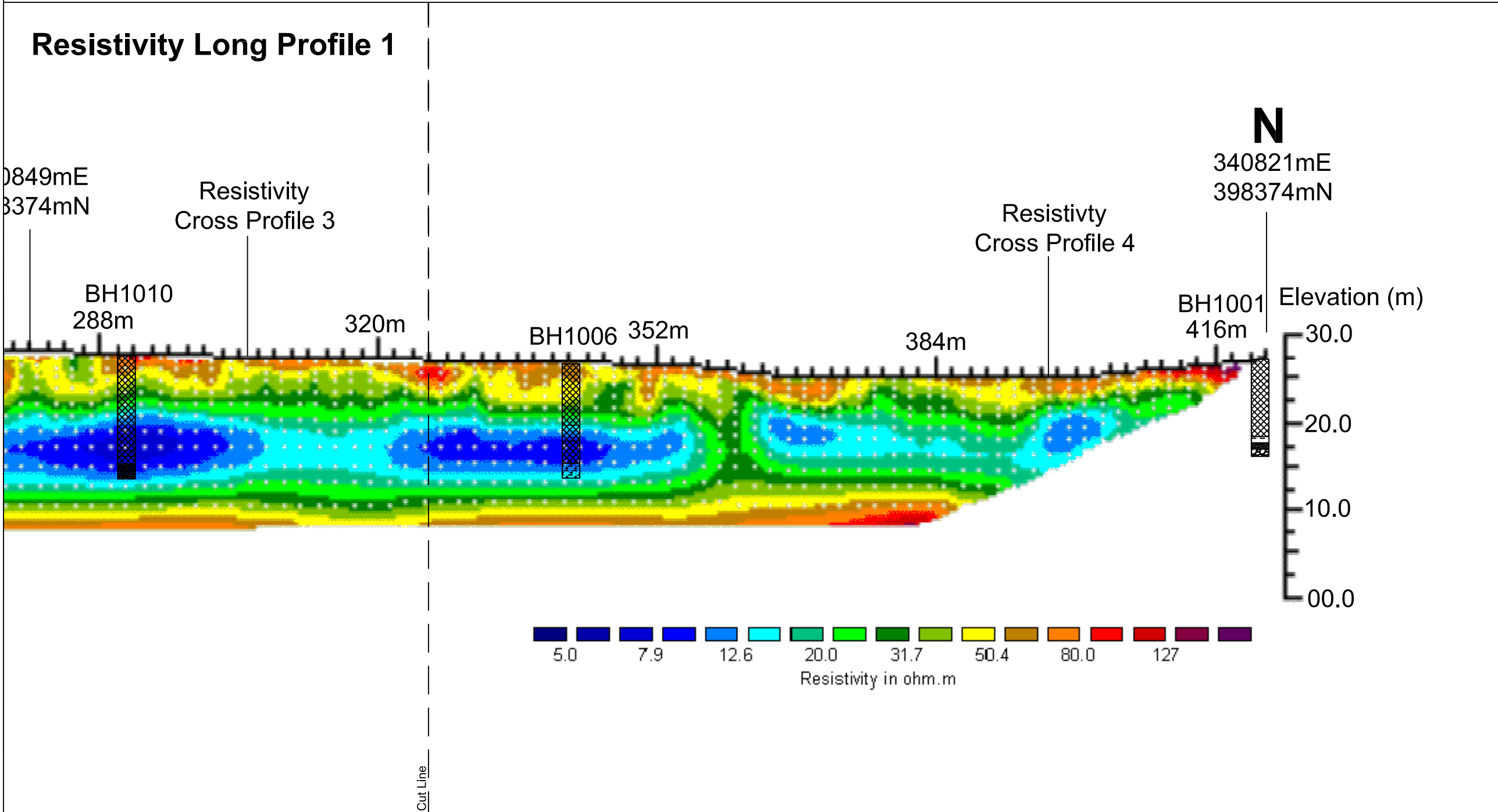
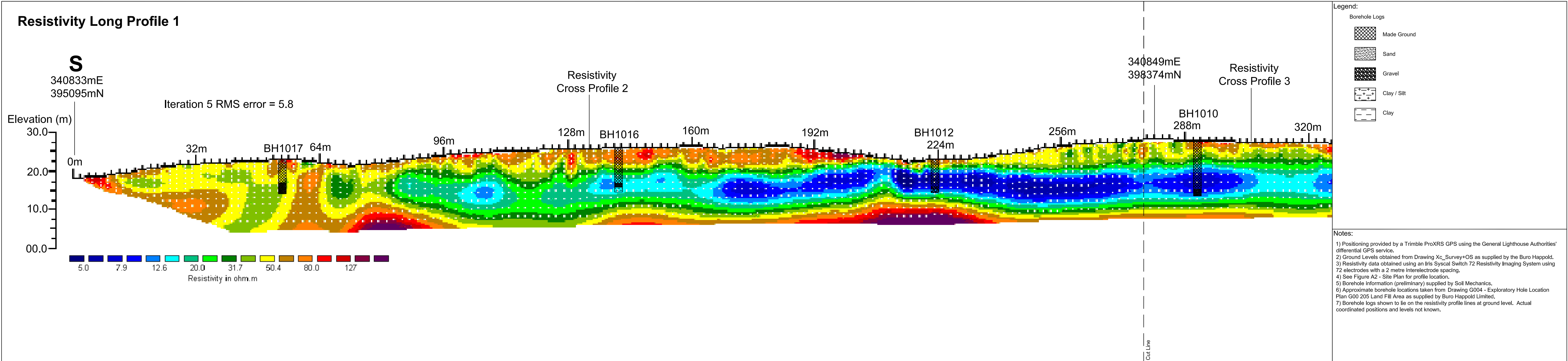
pelorus-surveys@esgl.co.uk
Tel: 01244 288200
Fax: 01244 288100

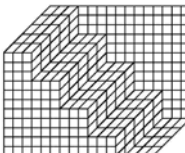
Contract:

Kirkby Redevelopment
Geophysical Survey

Site Plan
L7033/01

Original Sheet Size: A3	Scales: Horiz.: 1:2000 Vert.: N.A.	Rev.: 1
-----------------------------------	---------------------------------------	-------------------



1	RD	June 07	PWR	MJW	BH logs updated		
0	RD	May 07	RV	MJW			
Rev.	Drawn	Date	Checked	Approved	Details		
Survey Date: 17/04/2007 - 19/04/2007		Surveyor: RD		Drawn By: RD			
Client:  Tesco Stores Limited PO Box 400, Circus Building Shire Park Welwyn Garden City Hertfordshire AL7 1AB			Engineer:  Buro Happold 2 Brewery Place Brewery Wharf Leeds LS10 1NE UK				
Contractor:			 Soil Mechanics Pelorus Surveys Geotechnical House 18 Deeside Industrial Estate Deeside, Flintshire CH5 2LR pelorus-surveys@esgl.co.uk Tel: 01244 288200 Fax: 01244 288100				
Contract:							
KIRKBY REDEVELOPMENT GEOPHYSICAL SURVEY							
RESISTIVITY IMAGING PROFILES L7033/02							
Original Sheet Size:		Scale:				Rev.:	
A1		Horiz.: 1:500 Vert.: N.A.				1	

Appendix C – Soil Analytical Data

Appendix D – Soil Leachate Analytical Data

Report Title: Geoenvironmental and Geotechnical Interpretative Report- Phase 1 Ground Investigation (GDO 205 landfill area)
Appendix D: Leachate results Date: November 2007



ASD METHOD	CATE	METHOD	CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE		CATE	
------------	------	--------	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--	------	--

AES METHOD			0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026		
DETERMINAND			2,2-Dichloropropane	1,4-Dichlorobenzene	1,1,2-Trichloroethane	1,3,5-Trimethylbenzene	N-Propylbenzene	Dichlorodifluoromethane	Dibromomethane	1,2,3-Trichlorobenzene	Ortho-Xylene	Bromochloromethane	Trans-1,2-Dichloroethene	4-Chlorotoluene	1,2-Dichloroethane	1,1,2,2-Tetrachloroethane	Bromobrom	Sec-Butylbenzene	Dichloromethane	N-Butylbenzene	Hexachlorobutadiene	Chlorobrom	1,2-Dichloropropane	1,3,5-Trichlorobenzene	Vinyl Chloride	1,2,4-Trimethylbenzene	Styrene	Benzene	
AES Sample ID	Explor Hole / Sample ID / Depth (m BGL) / Liquid solid (L/S)	Material Type	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	
3221491	TP1003 ES2 0.5 10:1	MGT1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3221490	TP1001 ES15 4 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3221492	TP1005 ES14 4.4 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3221493	TP1007 ES6 2.2 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225166	BH 1005 ES14 4M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225167	BH 1005 ES14 4M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225188	BH 1010 ES46 12M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225193	BH 1010 ES46 12M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225194	BH 1012 ES19 9M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225195	BH 1012 ES19 9M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225202	BH 1016 ES27 8M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
3225203	BH 1016 ES27 8M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<100	<1.0	<1.0	<1.0	<1.0	<1.5	<1.0	<1.0	<1.0		
Leachate Screening Value adopted as LOD			MAX	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.9	
			UNITS	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l

Key to Response Zone Stratum

MGT1	Made Ground Type 1
MGT2	Made Ground Type 2
ND	Natural Drift Deposits

SVOCs																												
AES METHOD		0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0026	0034	0034	0034	0034	0034	0034	
DETERMINAND		2-Chlorotoluene	Trichloroethene	Dichlorobromomethane	Carbon Tetrachloride	Cis 1,3-Dichloropropene	1,1-Dichloropropene	Meta + Para Xylene	Cis 1,2-Dichloroethene	1,1-Dichloroethane	1,1-Dichloroethene	1,3-Dichloropropane	Trichlorofluoromethane	Ethylbenzene	Chlorobenzene	1,2-Dibromo-3-Chloropropane	Tetrachloroethene	Isopropylbenzene	1,2,3-Trichloropropane	Chloromethane	1,2-Dibromoethane	1,2-Diphenylhydrazine	4-Nitroaniline	Diethylphthalate	1-Chloronaphthalene	2-Methylnaphthalene	N-Nitrosopiperidine	
AES Sample ID	Explor Hole / Sample ID / Depth (m BGL) / Liquid-solid (S/L)	Material Type	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
3221491	TP1003 ES2 0.5 10:1	MGT1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0							
3221490	TP1003 ES16 4 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0							
3221492	TP1005 ES14 4.4 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0							
3221493	TP1007 ES6 2.2 10:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0							
3225166	BH 1005 ES14 4M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00040	<0.0010	<0.00040	<0.00040	<0.00040	<0.00040	
3225167	BH 1005 ES14 4M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00020	<0.00060	<0.00020	<0.00020	<0.00020	<0.00020	
3225188	BH 1010 ES46 12M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.6	220	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00040	<0.0010	<0.00040	<0.00040	<0.00040	<0.00040	
3225193	BH 1010 ES46 12M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	6.6	220	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00020	<0.00060	<0.00020	<0.00020	<0.00020	<0.00020	
3225194	BH 1012 ES19 9M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00080	<0.0020	<0.00080	<0.00080	<0.00080	<0.00080	
3225195	BH 1012 ES19 9M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00030	<0.00070	<0.00030	<0.00030	<0.00030	<0.00030	
3225202	BH 1016 ES27 8M 2:1	MGT2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00040	<0.0010	0.0006	<0.00040	<0.00040	<0.00040	
3225203	BH 1016 ES27 8M 8:1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.00020	<0.00060	0.0006	<0.00020	<0.00020	<0.00020	
Leachate Screening Value adopted as LoD			MAX	0	0	0	0	0	0	0	0	0	0	6.6	220	0	0	0	0	0	0	0	0	0	0	0	0	
			UNITS	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

Key to Response Zone Stratum	
MGT1	Made Ground Type 1
MGT2	Made Ground Type 2
ND	Natural Drift Deposits

AES METHOD			O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	
DETERMINAND			2,6-Dichlorophenol	2-Chloronaphthalene	Dibenz(a,j)acridine	7,12-Dimethylbenz(a)anthracene	1,2-Dichlorobenzene	2,4,5-Trichlorophenol	N-Nitrosodiphenylamine	2,4-Dinitrotoluene	2-Nitroaniline	Heptachlorocyclopentadiene	Butylbenzylphthalate	1,2,4-Trichlorobenzene	1,4-Dichlorobenzene	1-Naphthylamine	Dimethylphthalate	Pentachlorobenzene	Benzoic Acid	2,4-Dimethylphenol	2-Nitrophenol	Bis(2-chloroethyl)ether	Pentachlorophenol	Dibenz(a,h)anthracene	4,6-Dinitro-2-methylphenol	2,3,4,6-Tetrachlorophenol	2,6-Dinitrotoluene	1,2,4,5-Tetrachlorobenzenes	
AES Sample ID	Exploit Hole / Sample ID / Depth (m BGL) / Liquid solid (SS)	Material Type	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
3221491	TP1003 ES2 0.5 10-1	MGT1																											
3221490	TP1001 ES15 4 10-1	MGT2																											
3221492	TP1005 ES14 4.4 10-1	MGT2																											
3221493	TP1007 ES6 2.2 10-1	MGT2																											
3225166	BH 1005 ES14 4M 2-1	MGT2	<0.00040	<0.00040	<0.00040	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0040	<0.00080	<0.00040	<0.00040	<0.00060	<0.00020	<0.00060	<0.00040	<0.00040	<0.00040	
3225167	BH 1005 ES14 4M 8-1		<0.00020	<0.00020	<0.00020	<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.0022	<0.00040	<0.00020	<0.00020	<0.00030	<0.00010	<0.00030	<0.00020	<0.00020	<0.00020	
3225188	BH 1010 ES46 12M 2-1	MGT2	<0.00040	<0.00040	<0.00040	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0040	<0.00080	<0.00040	<0.00040	<0.00060	<0.00020	<0.00060	<0.00040	<0.00040	<0.00040	
3225193	BH 1010 ES46 12M 8-1		<0.00020	<0.00020	<0.00020	<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.0022	0.0013	<0.00020	<0.00020	<0.00030	<0.00010	<0.00030	<0.00020	<0.00020	<0.00020	
3225194	BH 1012 ES19 5M 2-1	MGT2	<0.00080	<0.00080	<0.00080	<0.0080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.0012	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.0080	0.0017	<0.00080	<0.00080	<0.0012	<0.00040	<0.0012	<0.00080	<0.00080	<0.00080	
3225195	BH 1012 ES19 5M 8-1		<0.00030	<0.00030	<0.00030	<0.0028	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00040	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.0028	<0.00060	<0.00030	<0.00030	<0.00040	<0.00010	<0.00040	<0.00030	<0.00030	<0.00030	
3225202	BH 1016 ES27 8M 2-1	MGT2	<0.00040	<0.00040	<0.00040	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.0040	<0.00080	<0.00040	<0.00040	<0.00060	<0.00020	<0.00060	<0.00040	<0.00040	<0.00040	
3225203	BH 1016 ES27 8M 8-1		<0.00020	<0.00020	<0.00020	<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.0022	<0.00040	<0.00020	<0.00020	<0.00030	<0.00010	<0.00030	<0.00020	<0.00020	<0.00020	
Leachate Screening Value adopted as LoD			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.013	0	0	0	0	0	0	0	0	
MAX UNITS			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	

Key to Response Zone Stratum

MGT1	Made Ground Type 1
MGT2	Made Ground Type 2
ND	Natural Drift Deposits

AES METHOD			O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034
Exploit Hole / Sample ID / Depth (m BGL) / Liquid solid (L/S)			bis(2-ethylhexyl)phthalate	P-Dimethylaminoazobenzene	Dibenzofuran	4-Chloro-3-Methylphenol	2,4-Dichlorophenol	bis(2-Chloroisopropyl)ether	1,3-Dichlorobenzene	1,3-Dichlorobenzene	Benzogljanztracene	3-Methylchloranthrene	Diphenylamine	2,4,6-Trichlorophenol	N-Nitroso-di-n-butylamine	Hexachlorobutadiene	2-Methylphenol	2-Chlorophenol	2-Picoline	Benzogljanztracene	4-Aminodiphenyl	Phenacetin	4-Chlorophenyl-phenylether	3-Nitroaniline	3,3'-Dichlorobenzidine	Pronamide	Acetophenone	Phenol
AES Sample ID		Material Type	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
3221491	TP1003 ES2 0.5 10.1	MGT1																										
3221490	TP1001 ES15 4 10.1	MGT2																										
3221492	TP1005 ES14 4.4 10.1	MGT2																										
3221493	TP1007 ES6 2.2 10.1	MGT2																										
3225166	BH 1005 ES14 4M 2.1	MGT2	0.0062	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<1.0	<0.00040	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
3225167	BH 1005 ES14 4M 8.1		0.0030	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<1.0	<0.00020	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
3225188	BH 1010 ES46 12M 2.1		0.0069	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<1.0	<0.00040	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
3225193	BH 1010 ES46 12M 8.1	MGT2	0.0016	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<1.0	<0.00020	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.0006	<0.00020
3225194	BH 1012 ES19 5M 2.1		0.0077	<0.00080	<0.00080	<0.0012	<0.00080	<0.00080	<1.0	<0.00080	<0.00040	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.0012	<0.00040	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	
3225195	BH 1012 ES19 5M 8.1		0.0024	<0.00030	<0.00030	<0.00040	<0.00030	<0.00030	<1.0	<0.00030	<0.00010	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00040	<0.00010	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
3225202	BH 1016 ES27 8M 2.1	MGT2	0.0089	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<1.0	<0.00040	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00020	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
3225203	BH 1016 ES27 8M 8.1		0.0011	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<1.0	<0.00020	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00010	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Leachate Screening Value adopted as LoD			MAX. 0.0089	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0015	0	0	0	0	0	0	0	0	0.0004	0
			UNITS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

Key to Response Zone Stratum

MGT1	Made Ground Type 1
MGT2	Made Ground Type 2
ND	Natural Drift Deposits

AES METHOD		O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O034	O036	O034	O034	O034
DETERMINAND		2,4-Dinitrophenol	Benzyl Alcohol	Hexachlorobenzene	2-Naphthylamine	Hexachloroethane	Pentachloronitrobenzene	4-Nitrophenol	Isophorone	Aniline	Nitrobenzene	Di-n-octylphthalate	4-Chloroaniline	4-Bromophenyl-phenylether	Bi(2-chloroethoxy)methane	4-Isopropyltoluene	Di-n-Butylphthalate	N-Nitroso-n-propylamine	4-Methylphenol
AES Sample ID	Exploit Hole / Sample ID / Depth (m BGL) / Liquid-solid (mg/L)	Material Type	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
3221481	TP1003 ES2 0.5 10-1	MGT1																	
3221490	TP1001 ES15 4 10-1	MGT2																	
3221492	TP1005 ES14 4.4 10-1	MGT2																	
3221493	TP1007 ES6 2.2 10-1	MGT2																	
3225166	BH 1005 ES14 4M 2-1	MGT2	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<1.0	0.00020	<0.00040	<0.00040
3225167	BH 1005 ES14 4M 8-1		<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<1.0	<0.00020	<0.00020	<0.00020
3225188	BH 1010 ES46 12M 2-1	MGT2	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<1.0	<0.00040	<0.00040	<0.00040
3225193	BH 1010 ES46 12M 8-1		<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<1.0	0.00020	<0.00020	<0.00020
3225194	BH 1012 ES19 5M 2-1	MGT2	<0.0080	<0.00080	<0.00080	<0.00080	<0.00080	<0.0012	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.0016	<1.0	<0.00080	<0.00080	<0.00080
3225195	BH 1012 ES19 5M 8-1		<0.0028	<0.00030	<0.00030	<0.00030	<0.00030	<0.00040	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<1.0	<0.00030	<0.00030	<0.00030
3225202	BH 1016 ES27 8M 2-1	MGT2	<0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00060	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<1.0	<0.00040	<0.00040	<0.00040
3225203	BH 1016 ES27 8M 8-1		<0.0022	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<1.0	0.00020	<0.00020	<0.00020
Leachate Screening Value adopted as LoD			MAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00020	0	0
UNITS			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l

Key to Response Zone Stratum

MGT1	Made Ground Type 1
MGT2	Made Ground Type 2
ND	Natural Drift Deposits

Appendix E – Water Analytical Data

[illegible]

Appendix F – Ground gas Data

GROUND GAS ASSESSMENT	Job name: Kirby	Job number: Q21706	Date: Monitoring up to Sept 2007
-----------------------	-----------------	--------------------	----------------------------------

NOTES:

Assessment based on guidance published in: CIRIA C659 (2006) 'Assessing risks posed by hazardous ground gases to buildings.'

Information from Table 8.5.5 of CIRIA C659

Characteristic Situation 1 conditions
Gas screening value (CH4 or CO2) < 0.07 l/h
Typically methane < 1 % by volume
Typically carbon dioxide < 5% by volume

Characteristic Situation 2 conditions
Gas screening value (CH4 or CO2) < 0.7 l/h
Borehole air flow rate < 70 l/h

Characteristic Situation 3 conditions
Gas screening value (CH4 or CO2) < 3.5 l/h

Approach:

Maximum concentration and flow values are used in the assessment below (minimum values for oxygen).

Where no detectable flow is recorded the instrument limit of detection is used

Where concentrations are recorded below LoD, the instrument LoD is used in the assessment below

Key for shading

CO2 > 5% in air
CH4 > 1 % in air
GSV > or = 0.07 l/h
GSV > or = 0.7 l/h

Key to Response Zone Stratum (refer report text)

MG1 Made Ground Type 1
MG2 Made Ground Type 2
ND Natural Drift Deposits
SDST Sherwood Sandstone

SITE MONITORING DATA

Investigation & Year of installation	Exploratory Hole	Response zone stratum	Date Monitored	Gas measurements					CO ₂ analysis		CH ₄ analysis		Characteristic Situation	Comments	
				Flow Rate (l/hr)	Atmos Pres (mb)	Min O ₂ (%) air	Max CO ₂ (%) air	Max CH ₄ (%) air	CO ₂ as fraction	Gas screening value CO ₂ (l/hr)	CH ₄ as fraction	Gas screening value CH ₄ (l/hr)			
Cooper Associates 2001	BH1	MG1	06/06/2007	NO GAS TAP	1017	6.7	1.6	0.7	0.016	0.002	0.007	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			11/06/2007	NO GAS TAP	1011	11	1.2	0.5	0.012	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			14/06/2007	NO GAS TAP	1000	9.6	1.3	0.7	0.013	0.001	0.007	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
Cooper Associates 2001	BH2	MG1	04/07/2007	NO GAS TAP	997	8.1	2.8	2.9	0.028	0.003	0.029	0.003	2	(based on concentrations only, flow assumed 0.1 l/h)	
			06/06/2007	-0.1	1019	11.9	5.9	0.5	0.059	0.006	0.005	0.001	2		
			11/06/2007	0.2	1011	8.8	8.1	0.5	0.081	0.016	0.005	0.001	2		
Soil Mechanics 2007 Phase 1	BH1002	MG1	04/07/2007	0.2	998	0.8	7.9	0.5	0.079	0.016	0.005	0.001	2		
			06/06/2007	0.2	1017	8.1	9	32.5	0.090	0.018	0.325	0.065	2		
			11/06/2007	0.1	1009	1	16.5	63	0.165	0.017	0.630	0.063	2		
Soil Mechanics 2007 Phase 1	BH1007	MG1	14/06/2007	0	999	0.5	26.6	73.8	0.266	0.027	0.738	0.074	2		
			04/07/2007	-0.4	997	0.5	22.4	70.6	0.224	0.022	0.706	0.071	2		
			06/06/2007	0	1017	16.7	3.3	0.5	0.033	0.003	0.005	0.001	1		
Soil Mechanics 2007 Phase 1	BH1008	MG1 / ND / SDST	11/06/2007	-0.1	1010	13.5	7.1	0.5	0.071	0.007	0.005	0.001	2		
			14/06/2007	0.2	1000	13.2	8.3	0.5	0.083	0.017	0.005	0.001	2		
			04/07/2007	-0.2	997	1.8	11.7	0.5	0.117	0.012	0.005	0.001	2		
Soil Mechanics 2007 Phase 1	BH1009	MG2	07/06/2007	NO DATA	1018	9	8.7	0.5	0.067	0.007	0.005	0.001	2	(based on concentrations only, flow assumed 0.1 l/h)	
			11/06/2007	0.1	1010	4.4	10.8	1.1	0.108	0.011	0.011	0.001	2		
			14/06/2007	0	1000	4.3	10.7	1.2	0.107	0.011	0.012	0.001	2		
Soil Mechanics 2007 Phase 1	BH1005	MG2	04/07/2007	-0.2	998	3.5	11.7	0.5	0.117	0.012	0.005	0.001	2		
			MADE GROUND TYPE 1 AVERAGE				7.02	9.14	13.24						
			06/06/2007	0.08	1017	5	15.3	37.6	0.153	0.012	0.376	0.030	2		
Soil Mechanics 2007 Phase 1	BH1006	MG2	11/06/2007	0.3	1011	0.7	23	56.2	0.230	0.069	0.562	0.169	2		
			14/06/2007	0.5	1000	0.5	27.5	65.3	0.275	0.138	0.653	0.327	2		
			04/07/2007	0.2	997	4.2	29.4	65.1	0.294	0.059	0.651	0.130	2		
Soil Mechanics 2007 Phase 1	BH1008	MG2	06/06/2007	0.02	1017	1.6	15.2	76.9	0.152	0.003	0.769	0.015	2		
			11/06/2007	0.3	1010	1.1	15.9	80.3	0.159	0.048	0.803	0.241	2		
			14/06/2007	0.1	1000	0.5	18.3	87.8	0.183	0.018	0.878	0.088	2		
Soil Mechanics 2007 Phase 1	BH1009	MG2	04/07/2007	0.1	997	1.7	17.7	82.4	0.177	0.018	0.824	0.082	2		
			06/06/2007	0.5	1017	0.8	20.9	98.7	0.209	0.105	0.987	0.299	2		
			11/06/2007	0.2	1011	0.6	22.1	66.9	0.221	0.044	0.669	0.134	2		
Soil Mechanics 2007 Phase 1	BH1012	MG2	14/06/2007	0.3	1000	0.5	28.1	79	0.281	0.084	0.790	0.237	2		
			04/07/2007	0.1	997	0.5	23.9	77.2	0.239	0.024	0.772	0.077	2		
			06/06/2007	0.1	1017	7.2	12.7	42.7	0.127	0.013	0.427	0.043	2		
Soil Mechanics 2007 Phase 1	BH1016	MG2	11/06/2007	0.1	1011	0.6	20.7	66.4	0.207	0.021	0.664	0.066	2		
			14/06/2007	0.1	1000	2.1	21.5	60.2	0.215	0.022	0.602	0.060	2	(based on concentrations only, flow assumed 0.1 l/h)	
			06/06/2007	0.8	1017	7	11	38.6	0.110	0.068	0.386	0.309	2		
Soil Mechanics 2007 Phase 1	BH1016	MG2	11/06/2007	0.3	1011	3.4	14.2	64.3	0.142	0.043	0.643	0.193	2		
			14/06/2007	0.1	1000	3.6	17.1	72.3	0.171	0.017	0.723	0.072	2		
			04/07/2007	-0.1	997	3.7	13.5	59.9	0.135	0.014	0.599	0.060	2		
Soil Mechanics 2007 Phase 1	WS1004	ND	MADE GROUND TYPE 2 AVERAGE				2.38	19.37	65.20						
			07/06/2007												
			12/06/2007												
Soil Mechanics 2007 Phase 1	WS1005	ND	14/06/2007												
			04/07/2007												
			07/06/2007	NO DATA	1019	20.7	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
Soil Mechanics 2007 Phase 1	WS1006	ND	12/06/2007	0.1	1010	20.5	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			14/06/2007	0.1	1000	20.1	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			04/07/2007	VANDALISED	998	20.4	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
Soil Mechanics 2007 Phase 1	BH1004	ND / SDST	07/06/2007	NO DATA	1019	20.8	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			12/06/2007	0.1	1010	20.1	0.5	0.5	0.005	0.001	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			14/06/2007	0.3	1000	20.3	0.5	0.5	0.005	0.002	0.005	0.002	1	(based on concentrations only, flow assumed 0.1 l/h)	
Soil Mechanics 2007 Phase 1	BH1013	ND / SDST	04/07/2007	VANDALISED	998	16.6	3.4	0.5	0.034	0.003	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			07/06/2007	NO DATA	1018	15.2	3.5	0.5	0.035	0.004	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			12/06/2007	0	1008	19.9	1.6	0.5	0.016	0.002	0.005	0.001	1		
Soil Mechanics 2007 Phase 1	BH1014	ND / SDST	14/06/2007	0	1000	18.9	2	0.5	0.020	0.002	0.005	0.001	1		
			04/07/2007	-0.3	998	13.1	5.1	0.5	0.051	0.005	0.005	0.001	2	(based on concentrations only, flow assumed 0.1 l/h)	
			07/06/2007	0	1017	20.6	0.5	0.5	0.005	0.001	0.005	0.001	1		
Soil Mechanics 2007 Phase 1	BH1014	ND / SDST	12/06/2007	0.2	1008	20.6	0.9	0.5	0.009	0.002	0.005	0.001	1		
			14/06/2007	0.1	1000	20.4	1.6	0.5	0.016	0.002	0.005	0.001	1		
			04/07/2007	VANDALISED	998	16.6	3.4	0.5	0.034	0.003	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
Soil Mechanics 2007 Phase 1	BH1014	ND / SDST	07/06/2007	NO DATA	1019	18.4	2.5	0.5	0.025	0.003	0.005	0.001	1	(based on concentrations only, flow assumed 0.1 l/h)	
			12/06/2007	0	1008	13.6	5.1	0.5	0.051	0.005	0.005	0.001	2		
			14/06/2007	-0.1	1000	14.7	5.5	0.5	0.055	0.006	0.005	0.001	2		
				04/07/2007	-0.3	998	19.1	1.9	0.5	0.019	0.002	0.005	0.001	1	
				NATURAL DRIFT DEPOSITS AVERAGE				18.33	2.03	0.50					
WORSE CASE CALCULATION				Max reading	0.8	1019	20.8	29.4	87.8	0.294	0.235	0.878	0.702	3	

LABORATORY DATA

Investigation & Year of installation	Exploratory Hole	Response zone stratum	Date Monitored & Sampled	FIELD RESULTS					LAB RESULTS			DIFFERENCE (FIELD% - LAB%)					
				Flow Rate (l/hr)	Atmos Pres (mb)	Min O2 (%)	Max CO2 (%)	Max CH4 (%)	O2 (%) air	CO2 (%) air	CH4 (%) air	O2 (%) air	CO2 (%) air	CH4 (%) air			
Soil Mechanics 2007 Phase 1	BH1002	MG1	14/06/2007	0	999	0.5	26.6	73.8	0.44	18.95	69.31	0.06	7.65	4.49			
Soil Mechanics 2007 Phase 1	BH1005	MG2	14/06/2007	0.5	1000	0.5	27.5	65.3	0.39	22.55	56.74	0.11	4.95	8.56			
Soil Mechanics 2007 Phase 1	BH1006	MG2	14/06/2007	0.1	1000	0.5	18.3	87.8	0.09	17.45	75.88	0.41	0.85	11.92			
Soil Mechanics 2007 Phase 1	BH1007	MG1	14/06/2007	0.2	1000	13.2	8.3	0.5	15.41	7.26	0.01	-2.21	1.04	0.49			
Soil Mechanics 2007 Phase 1	BH1009	MG2	14/06/2007	0.3	1000	0.5	28.1	79	0.15	22.57	66.79	0.35	5.53	12.21			
Soil Mechanics 2007 Phase 1	BH1012	MG2	14/06/2007	0.1	1000	2.1	21.5	80.2	0.59	22.09	86.49	1.51	-0.59	6.39			
Soil Mechanics 2007 Phase 1	BH1016	MG2	14/06/2007	0.1	1000	3.6	17.1	72.3	7.7	12	51.4	4.1	-20.9	20.9			
										AVERAGE DIFFERENCE			-0.55			5.30	7.47

Appendix G – CIRIA C659 Guidance

Extract: CIRIA C659: 2006 'Assessing Risks posed by hazardous ground gases to buildings'

Table 8.6 Typical scope of protective measures (risk management)

Characteristic situation	Residential building (Not low-rise traditional housing) ¹		Office/commercial/industrial development	
(From Table 8.5)	Number of levels of protection	Typical scope of protective measures	Number of levels of protection	Typical scope of protective measures
1	None	No special precautions	None	No special precautions
2	2	a) Reinforced concrete cast <i>in situ</i> floor slab (suspended, non-suspended or raft) with at least 1200 g DPM ⁹ and underfloor venting b) Beam and block or pre-cast concrete and 2000 g DPM/reinforced gas membrane and underfloor venting All joints and penetrations sealed.	1 to 2	a) Reinforced concrete cast <i>in situ</i> floor slab (suspended, non-suspended or raft) with at least 1200 g DPM ⁹ b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane c) Possibly underfloor venting or pressurisation in combination with a) and b) depending on use All joints and penetrations sealed.
3	2	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space.	1 to 2	All types of floor slab as above. All joints and penetrations sealed. Minimum 2000 g/reinforced gas proof membrane and passively ventilated underfloor sub-space or positively pressurised underfloor sub-space
4	3	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated underfloor subspace or positively pressurised underfloor sub-space, oversite capping or blinding and in ground venting layer.	2 to 3	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space with monitoring facility.
5	4	Reinforced concrete cast <i>in situ</i> floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and ventilated or positively pressurised underfloor sub-space, oversite capping and in ground venting layer and in ground venting wells or barriers.	3 to 4	Reinforced concrete cast <i>in-situ</i> floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space with monitoring facility. In ground venting wells or barriers.
6	5	Not suitable unless gas regime is reduced first and quantitative risk assessment carried out to assess design of protection measures in conjunction with foundation design.	4 to 5	Reinforced concrete cast <i>in-situ</i> floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and actively ventilated or positively pressurised underfloor sub-space with monitoring facility, with monitoring. In ground venting wells and reduction of gas regime.

- For low rise traditional housing see Table 8.7.
- Typical scope of protective measures may be rationalised for specific developments on the basis of quantitative risk assessments.
- Note the type of protection is given for illustration purposes only. Information on the detailing and construction of passive protection measures is given in BR414 (Johnson, 2001). Individual site-specific designs should provide the same number of separate protective methods for any given characteristic situation. See Card (1995).
- In all cases there should be minimum penetration of ground slabs by services and minimum number of confined spaces such as cupboards above the ground slab. Any confined spaces should be ventilated.
- Foundation design must minimise differential settlement particularly between structural elements and ground-bearing slabs.
- Commercial buildings with basement car parks, provided with ventilation in accordance with the Building Regulations, may not require gas protection for characteristic situations 3 and 4.
- Floor slabs should provide an acceptable formation on which to lay the gas membrane. If a block beam floor is used it should be well detailed so it has no voids in it that membranes have to span, and all holes for service penetrations should be filled. The minimum density of the blocks should be 600 kg/m³ and the top surface should have a 4:1 sand cement grout brushed into all joints before placing any membrane (this is also good practice to stabilise the floor and should be carried out regardless of the need for gas membranes).
- The gas-resistant membrane can also act as the damp-proof membrane.
- Based on Building Regulations Approved Document C (Office of the Deputy Prime Minister, 2004a) which states that "a membrane below the concrete could be formed with a sheet of polyethylene, which should be at least 300 mu thick (1200 gauge)". Please note the alteration from 300mm (as stated in the Approved Document C) to 300 mu. 300 mm is a typographical error that has been recognised and corrected for this report.

Appendix H – CIRIA C552 Guidance

Definition of Severity (Consequence) and Likelihood (Probability)

Source: CIRIA 552(2001)

Classification of consequence

Classification	Definition	Examples
Severe	Short-terms (acute) risk to human health likely to result in "significant harm" as defined by the Environment Protection Act 1990, Part IIA. Short-term risk of pollution (note: Water Resources Act contains no scope for considering significance of pollution) of sensitive water resource. Catastrophic damage to buildings/property. A short-terms risk to a particular ecosystem or organism forming part of such ecosystem (note: the definitions of ecological systems within the Draft Circular on Contaminated Land, DETR, 2000).	High concentrations of cyanide on the surface of an informal recreation area. Major spillage of contaminants from site into controlled water. Explosion, causing building collapse (can also equate to a short-term human health risk if buildings are occupied).
Medium	Chronic damage to Human Health ("significant harm" as defined in DETR, 2000). Pollution of sensitive water resources (note: Water Resources Act contains no scope for considering significance of pollution). A significant change in a particular ecosystem, or organism forming part of such ecosystem (note: the definitions of ecological systems within Draft Circular on Contaminated Land, DETR, 2000).	Concentrations of a contaminant from site exceed the generic or site-specific assessment criteria. Leaching of contaminants from a site to a major or minor aquifer. Death of a species within a designated nature reserve.
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services ("significant harm" as defined in the <i>Draft Circular on Contaminated Land</i> , DETR, 2000). Damage to sensitive buildings/structures/ services or the environment.	Pollution of non-classified groundwater. Damage to building rendering it unsafe to occupy (eg foundation damage resulting in instability).
Minor	Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as personal protective clothing etc). Easily repairable effects of damage to buildings, structures and services.	The presence of contaminants at such concentrations that protective equipment is required during site works. The loss of plants in a landscaping scheme. Discoloration of concrete.

Classification of probability

Classification	Definition
High likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probably that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place, and is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Definition of Risk

Source: CIRIA 552(2001)

Comparison of consequence against probability

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High likelihood	Very high risk	High risk	Moderate risk	Moderate/low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

Description of the classified risks and likely action required

Very high risk	There is a high probability that severe harm could arise to a designated receptor from an identified hazard, OR, there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High risk	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate risk	It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the longer term.
Low risk	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Very low risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

Appendix I – Hazardous Waste Assessment

Worst case substances		Toluene Ethylbenzene Xylene Naphthalene Lead sulphate Cadmium Oxide Copper(I)oxide Nickel carbonate Calcium Chromate Dimercury Dichloride Calcium Sulphide		Benzene Phenol Naphthalene Cadmium Oxide		Arsenic Trioxide Calcium Cyanide		Nickel- carbonate		PRO (C6-C10)		DRO (C10-C25 or >C10 in absence of specific information)		Threshold value for carcinogenic PAH in whole oil		Sum of carcinogenic PAHs (percentage of whole oil)		Arsenic Trioxide		Calcium Chromate		Max PAH (excl. Naphthalene)		Benzene		Cadmium Oxide		pH		Phenol Zinc Chloride Arsenic Trioxide		Max PAH (excl. Naphthalene)		Lead sulphate		Max PAH (excl. Naphthalene)		Lead sulphate		Max PAH (excl. Naphthalene)		Calcium Cyanide		TPH (full range - C5- C40 etc.)		Zinc Chloride Arsenic Trioxide Calcium Chromate Lead sulphate Dimercury Dichloride Nickel carbonate Calcium Sulphide Sum of PAH		Arsenic Trioxide Calcium Chromate Lead sulphate Dimercury Dichloride Nickel carbonate Calcium Sulphide Sum of PAH		Arsenic Trioxide Calcium Chromate Lead sulphate Dimercury Dichloride Nickel carbonate Calcium Sulphide Sum of PAH	
Hazard		H4 - 'Irritant'		H5 - 'Harmful'		H6(H5) - 'Toxic'		H7 - 'Carcinogenic'		H8(H4) - 'Corrosive'		H10 - 'Toxic for reproduction'		H11 - 'Mutagenic'		H12 - 'Ecotoxic'																																			
Risk Phrase		R38		R20-R22		R23-25, R48		R26-28		R40		R45		R49		R34		R60		R61		R63		R46		R32		R52/53		R50-53/0.25 + R51- S3/2.5 + R52-53/25		R50-53 + R50		R50-53 + R51-53 + R52- 53 + R53																	
Threshold value in %		20		25		3		0.1		1		0.1		0.1		0.1		0.5		0.5		5		0.1		0.2		2.5		1		25		25																	
Sample identity	Sample depth (m)	Hazardous Waste	0.033	0.1	0.00	0.002	0.02	0.0	0.0	0.000190	0.000	0.0002	9.1	5	0.11	0.0019	0.048	0.0019	0.048	0.0019	5	0.0	0.1	0.0019	0.2	0.0003	2.5	1	0.7	25	0.1	0.1																			
FP1001 ES1.0	MG11		0.00068	0.05	0.00008	0.001	0.020	0.003	0.0002	0.002	0.009	0.000073	0.000001	0.00004	8.0	0.021	0.0001	0.013	0.0001	0.013	0.0001	0.0001	0.0001	0.0001	0.0001	0.00	0.26	0.04	0.04	0.04	0.04	0.04																			
FP1008 ES1.0	MG11		0.00207	0.06	0.00006	0.002	0.007	0.003	0.0036	0.003	0.009	0.001900	0.000001	0.00003	8.4	0.033	0.0019	0.035	0.0019	0.035	0.0019	0.0001	0.0001	0.0001	0.00	0.37	0.06	0.06	0.06	0.06	0.06																				
FP1001 ES2.0	MG11		0.00148	0.02	0.00004	0.001	0.007	0.002	0.0001	0.002	0.011	0.000013	0.000001	0.00003	8.2	0.010	0.0000	0.003	0.0000	0.003	0.0000	0.0001	0.0001	0.0001	0.00	0.12	0.02	0.02	0.02	0.02	0.02																				
FP1002 ES2.0	MG11		0.00094	0.05	0.00013	0.002	0.006	0.004	0.0011	0.003	0.010	0.000510	0.000001	0.00006	8.3	0.035	0.0005	0.023	0.0005	0.023	0.0005	0.0001	0.0001	0.0001	0.00	0.30	0.04	0.04	0.04	0.04	0.04																				
FP1002 ES5.1	MG11		0.00255	0.04	0.00010	0.002	0.004	0.021	0.0011	0.003	0.008	0.000440	0.000001	0.00004	8.1	0.021	0.0004	0.027	0.0004	0.027	0.0004	0.0001	0.0001	0.0001	0.02	0.25	0.05	0.05	0.05	0.05	0.05																				
FP1003 ES2.0	MG11		0.00044	0.02	0.00005	0.001	0.005	0.002	0.0001	0.001	0.008	0.000073	0.000001	0.00003	8.4	0.008	0.0001	0.002	0.0001	0.002	0.0001	0.0001	0.0001	0.0001	0.00	0.08	0.02	0.02	0.02	0.02	0.02																				
FP1004 ES5.1	MG11		0.00137	0.03	0.00005	0.001	0.005	0.002	0.0001	0.002	0.012	0.000011	0.000001	0.00003	7.2	0.011	0.0000	0.005	0.0000	0.005	0.0000	0.0001	0.0001	0.0001	0.00	0.13	0.02	0.02	0.02	0.02	0.02																				
FP1004 ES8.2	MG11		0.00082	0.04	0.00008	0.002	0.003	0.001	0.0001	0.003	0.013	0.000026	0.000001	0.00003	6.6	0.015	0.0000	0.017	0.0000	0.017	0.0000	0.0001	0.0001	0.0001	0.00	0.19	0.03	0.03	0.03	0.03	0.03																				
FP1005 ES2.0	MG11		0.00037	0.02	0.00004	0.001	0.005	0.002	0.0001	0.002	0.011	0.000011	0.000001	0.00003	8.2	0.007	0.0000	0.001	0.0000	0.001	0.0000	0.0001	0.0001	0.0001	0.00	0.10	0.02	0.02	0.02	0.02	0.02																				
FP1006 ES2.0	MG11		0.00110	0.03	0.00005	0.001	0.006	0.002	0.0001	0.002	0.010	0.000056	0.000001	0.00003	8.5	0.018	0.0001	0.013	0.0001	0.013	0.0001	0.0001	0.0001	0.0001	0.00	0.19	0.03	0.03	0.03	0.03	0.03																				
FP1007 ES2.0	MG11		0.00037	0.02	0.00004	0.001	0.006	0.002	0.0001	0.001	0.009	0.000015	0.000001	0.00003	8.7	0.008	0.0000	0.001	0.0000	0.001	0.0000	0.0001	0.0001	0.0001	0.00	0.10	0.02	0.02	0.02	0.02	0.02																				
FP1009 ES2.0	MG11		0.00166	0.03	0.00008	0.001	0.004	0.002	0.0007	0.002	0.009	0.000230	0.000001	0.00003	8.1	0.028	0.0002	0.009	0.0002	0.009	0.0002	0.0001	0.0001	0.0001	0.00	0.21	0.03	0.03	0.03	0.03	0.03																				
FP1009 ES9.2	MG11		0.00039	0.01	0.00005	0.001	0.004	0.002	0.0001	0.002	0.008	0.000059	0.000001	0.00003	8.5	0.006	0.0001	0.001	0.0001	0.001	0.0001	0.0001	0.0001	0.0001	0.00	0.08	0.02	0.02	0.02	0.02	0.02																				
TP1009 ES13.1	MG11		0.01082	0.03	0.00006	0.001	0.005	0.003	0.0012	0.003	0.007	0.000490	0.000001	0.00003	8.2	0.024	0.0005	0.017	0.0005	0.017	0.0005	0.0001	0.0001	0.0001	0.00	0.22	0.04	0.04	0.04	0.04	0.04																				
FP1011 ES2.0	MG11		0.00380	0.03	0.00006	0.002	0.005	0.002	0.0005	0.003	0.007	0.000210	0.000001	0.00003	8.6	0.018	0.0002	0.010	0.0002	0.010	0.0002	0.0001	0.0001	0.0001	0.00	0.16	0.03	0.03	0.03	0.03	0.03																				
FP1011 ES5.1	MG11		0.00308	0.03	0.00005	0.002	0.005	0.004	0.0011	0.004	0.009	0.000400	0.000001	0.00003	8.4	0.023	0.0004	0.014	0.0004	0.014	0.0004	0.0001	0.0001	0.0001	0.00	0.22	0.04	0.04	0.04	0.04	0.04																				
H 1002 ES2.0	MG11		0.00037	0.02	0.00005	0.001	0.006	0.001	0.0001	0.002	0.010	0.000011	0.000001	0.00003	8.3	0.008	0.0000	0.003	0.0000	0.003	0.0000	0.0001	0.0001	0.0001	0.00	0.11	0.02	0.02	0.02	0.02	0.02																				
BH 1002 ES7.2	MG11		0.00114	0.06	0.00037	0.002	0.005	0.002	0.0002	0.003	0.008	0.000072	0.000001	0.00016	7.9	0.058	0.0001	0.026	0.0001	0.026	0.0001	0.0001	0.0001	0.0001	0.00	0.39	0.04	0.04	0.04	0.04	0.04																				
BH 1003 ES3.1	MG11		0.00037	0.02	0.00007	0.001	0.004	0.002	0.0001	0.002	0.009	0.000011	0.000001	0.00006	7.7	0.008	0.0000	0.004	0.0000	0.004	0.0000	0.0001	0.0001	0.0001	0.00	0.10	0.02	0.02	0.02	0.02	0.02																				
BH 1005 ES7.2	MG11		0.00037	0.02	0.00004	0.001	0.004	0.002	0.0001	0.002	0.009	0.000011	0.000001	0.00003	7.5	0.007	0.0000	0.002	0.0000	0.002	0.0000	0.0001	0.0001	0.0001	0.00	0.09	0.02	0.02	0.02	0.02	0.02																				
3H 1005 ES11	MG11		0.00061	0.02	0.00004	0.002	0.006	0.002	0.0001	0.004	0.010	0.000011	0.000001	0.00003	8.1	0.011	0.0000	0.002	0.0000	0.002	0.0000	0.0001	0.0001	0.0001	0.00	0.11	0.02	0.02	0.02	0.02	0.02																				
3H 1006 ES15	MG11		0.00129	0.03	0.00004	0.001	0.010	0.004	0.0001	0.002	0.009	0.000016	0.000001	0.00003	8.2	0.015	0.0000	0.005	0.0000	0.005	0.0000	0.0001	0.0001	0.0001	0.00	0.16	0.03	0.03	0.03	0.03	0.03																				
BH 1007 ES3.1	MG11		0.00150	0.05	0.00007	0.001	0.009	0.002	0.0013	0.003	0.008	0.000500	0.000001	0.00005	8.1	0.022	0.0005	0.030	0.0005	0.030	0.0005	0.0001	0.0001	0.0001	0.00	0.29	0.05	0.05	0.05	0.05	0.05																				
3H 1007 ES12	MG11		0.00057	0.02	0.00004	0.001	0.005	0.002	0.0001	0.002	0.009	0.000011	0.000001	0.00003	8.1	0.009	0.0000	0.004	0.0000	0.004	0.0000	0.0001	0.0001	0.0001	0.00	0.10	0.02	0.02	0.02	0.02	0.02																				
BH 1008 ES11	MG11		0.00311	0.08	0.00017	0.002	0.006	0.004	0.0001	0.004	0.010	0.000011	0.000001	0.00016	7.9	0.115	0.0000	0.048	0.0000	0.048	0.0000	0.0001	0.0001	0.0001	0.00	0.71	0.07	0.07	0.07	0.07	0.07																				
BH 1008 ES7.2	MG11		0.00093	0.03	0.00004	0.001	0.006	0.002	0.0001	0.002	0.011	0.000015	0.000001	0.00003	8.2	0.014	0.0000	0.004	0.0000	0.004	0.0000																														

Appendix J – Waste Acceptance Criteria Assessment

* Source: Table 2.1 'Guidance on Sampling and Testing of Wastes to meet Landfill Waste Acceptance Procedures' Version 1, April 2005, published by the Environment Agency

Paul Hazlehurst

Buro Happold Limited
2 Brewery Place
Brewery Wharf
Leeds
LS10 1NE
UK

Telephone: +44 (0)113 204 2200

Facsimile: +44 (0)870 787 4144

Email: paul.hazlehurst@burohappold.com