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PHASE 2: GEO-ENVIRONMENTAL INVESTIGATION REPORT

COMMERCIAL DEVELOPMENT PROJECTS LTD

PROPOSED COMMERCIAL DEVELOPMENT

LAND OFF ESTUARY BOULEVARD

SPEKE

LIVERPOOL

L24 8RL

Project No: 16-433

Prepared By:

Matt Bradford

Date: 30th June 2016

Approved By:

Mark Berriman

Date: 30th June 2016

CONTENTS

APPENDICES

Appendix I	**Site Location Plan, Aerial Photograph, Existing & Proposed Site Layout Plans**
Appendix II	**Borehole & Trial Pit Location Plan, Borehole & Trial Pit Record Sheets and Historic Pond Cross Sections**
Appendix III	**Ground Gas and Groundwater Monitoring Certificate**
Appendix IV	**Laboratory Testing Results**
Appendix V	**Ground Contamination Risk Assessment Data: Methodology, Notes for Off-Site Disposal, Conceptual Site Model (CSM), CLEA Calculation Sheets & Statistical Analysis**

1.0 Introduction June 2016

As requested by Adept Consulting Engineers on behalf of their client Commercial Development Projects Ltd., and in conjunction with the Phase 1: Desk Top Study (DTS) report produced for this site (Ref. 16-433, May 2016), together with extensive ground investigation works carried out during April & July 2014 by Arc Environmental Ltd, a Phase 2: Geo-environmental Investigation Report has been compiled for a proposed commercial development situated off Estuary Boulevard, Liverpool Business Park, Speke, Liverpool.

This Phase 2: Geo-environmental Investigation Report has targeted the proposed development areas across the site utilising the extensive ground investigation works undertaken by Arc Environmental Ltd during April & July 2014. It is understood that the development is to comprise the construction of 3 industrial units with associated car parking, service yards and areas of soft landscaping.

In total, the intrusive investigation works comprised 24 no. mechanically excavated trial pits (TP's 01 - 12 & TP's A - L) and 16 no. cable percussive boreholes (BH's 01 - 11 & BH's A - E) incorporating 7 no. combined ground gas/groundwater monitoring standpipes (BH's 02, 04, 07, 10, A, B & E), the final locations of which can be seen on the Borehole and Trial Pit Location Plan, a copy of which can be seen in Appendix II. It should be noted that this plan is primarily for orientating purposes, as the scale of the investigation positions are approximate and the plan is not to a standard scale.

2.0 Site Details

Table 2.1 N = north, S = south, E = east, W = west

Site Name & Address:	Proposed Commercial Development, Land Off Estuary Boulevard, Speke, Liverpool L24 9RL.
National Grid Reference:	341760, 383060 (representative for the central part of the site).
Description of Location:	The site is located in a commercial / industrial setting within Speke, Liverpool.
Site Boundaries:	N = Commercial unit, E = A wooded area leading to undeveloped land, S = Garston Shore Road leading to undeveloped land with the River Mersey beyond, W = Estuary Boulevard.

3.0 Scope of Works

Table 3.1

Client:	Commercial Development Projects Ltd.
Consultant:	Adept Consulting Engineers Ltd.
Project type:	Commercial development comprising 3 proposed industrial units with associated car parking, service yards & soft landscaping.
Site Location plan:	See Appendix I.
Layout plan (existing):	See Appendix I.
Layout plan (proposed):	See Appendix I.
Intrusive Investigation Works:	24 no. mechanically excavated trial pits (TP's 01 - 12 & TP's A - L) 16 no. cable percussive boreholes (BH's 01 - 11 & BH's A - E) and 7 no. combined ground gas/groundwater monitoring standpipes (BH's 02, 04, 07, 10, A, B & E).
Laboratory Testing:	Geotechnical & Ground Contamination.
CLEA Classification:	*Commercial.*
Reporting:	Factual & Interpretative including Level 1 Quantitative Risk Assessment for Human Health and Controlled Waters. Works carried out in accordance with the current UK Guidance and various British Standards.

The information contained in this report is limited to the area of the site, as indicated on the Existing and Proposed Site Layout Plans shown in Appendix I, and to those areas accessible during the ground investigation. When considering the full scope of the development any features and / or issues not specifically mentioned in this report cannot be assumed to have been covered.

4.0 Investigation Rationale

The locations for the intrusive investigation work were designed to provide information on the general ground and groundwater conditions below the site, whilst targeting any specific potential areas of concern. Following the completion of the DTS, it was identified that the ground conditions below and immediately adjacent to the site were likely to comprise topsoil with interspersed areas of made ground associated with the historical use and development of the site (i.e. adjacent railway line and Liverpool Airport / RAF Speke).

From the previous ground investigation reports reviewed as part of the DTS, an increased depth of made ground was also recorded on the development area to the immediate north of the site, where a maximum c.4.60m of made ground was identified and which is considered to be associated with a backfilled pond feature. Consequently, it was considered prudent to assume that similar isolated areas of deep made ground may also be present across this site, since a similar pond type feature has historically been recorded on the southern portion.

From the Phase 1: DTS, potentially elevated levels of several analytes were also recorded in the made ground below and immediately adjacent to the site and therefore provision was made for screening of any made ground encountered on this site. Similarly, due to the presence of several on and off site sources of ground gas generation, and also taking into account the monitoring results for the development to the immediate north, provision was made for a period of gas monitoring, and at this stage these sources are considered to represent a very low risk for gas generation.

During the fieldworks completed across this development area, there was no visual and/or olfactory evidence of unknown or unforeseen heavy/gross contamination (such as fuels, oils, discoloured or odorous soils, etc.), with no evidence of any made ground associated with the former railway line. However, ash fragments were identified at the location of BH's 03, 05, 07, 08 & TP 03, whilst ash fragments were also identified at the locations of TP's K & L, which were undertaken within the historically recorded backfilled pond feature on the southern portion of the site. The rationale behind the location of each exploratory hole is summarised in Table 4.1 below.

Table 4.1

Potential issue	Exploratory hole
To assess general site wide contamination.	BH's 01 - 11 & A - E TP's 01 - 12 & A - L
To investigate the historically recorded extraction / backfilled water feature on the southern portion of the site.	TP's G to L
To assess the potential risk to this site from ground gas production and migration. From the Phase 1: DTS the presence of several on and off site sources of ground gas generation were identified for this site, and at this stage these sources are considered to represent a very low risk for gas generation.	BH's 02, 04, 07, 10, A, B & E

4.1 Contamination Related Sampling & Site Protocols:-

4.1.1 Ground Contamination Sampling:-

Samples were recovered by a representative of ARC Environmental Ltd. during the intrusive investigation works. Samples of soil and water for chemical analysis were placed into air tight amber glass jars. All samples were stored at approximately 4°C using cool boxes and ice packs prior to delivery to a UKAS/MCERTS accredited laboratory.

4.0 Investigation Rationale (Cont'd)

4.1 Contamination Related Sampling & Site Protocols (Cont'd):-

4.1.2 Avoiding Cross-Contamination between Sample Locations:-

To avoid cross-contamination of materials, drill casing was used to seal off the made ground. With regards to the trial pits, the samples were recovered manually using dedicated disposable plastic gloves, replaced between each sample recovery with the equipment being cleaned between each investigation position. The trial pits were backfilled in the reverse order to which they were excavated to ensure that the materials removed were generally replaced to a similar depth from which they were removed.

4.1.3 Onsite Health & Safety Requirements:-

All site representatives wore relevant and appropriate PPE including (where required) safety footwear, high visibility jacket/vest and hard hats, in accordance with the site Health and Safety policy.

5.0 Ground Conditions

For an accurate description of the ground conditions encountered at each investigation position, reference should be made to the trial pit and borehole record sheets in Appendix II.

5.1 Soil Profile:-

A summary of the soil profile for this site can be found in Table 5.1 below and continued on the following page.

Table 5.1

Type of Strata	Depths Recorded (BGL)	Description & General Comments
MADE GROUND:	From 0.00m up to c.0.20m to c.3.50m	Made ground materials comprising disturbed sandy soil, fine to medium sand, firm sandy gravelly clay and sandy clayey gravel with occasional anthropogenic debris (i.e. brick, concrete etc) was identified at the majority of the exploratory positions, to depths of between c.0.20m and c.1.50m. Exceptions to this were noted at the locations of BH03 & BH05 where shallow bands of black ash gravel, were recorded to a depth of c.0.50m, and TP03 where dolomite gravel surfacing, with occasional ash, was noted to c.0.45m. In addition, at the locations of TP06, BH07 & BH08 an initial thickness of made ground with brick was also noted to depths of between c.0.50m and c.1.00m, whilst a deeper band of disturbed dark brown sand was noted at TP06 to c.1.10m. Relic concrete was encountered at a depth of c.0.50m in TP11 & TP12. The historically recorded extraction / backfilled water feature was targeted by TP's G to L. This recorded sandy clayey gravel to a depth of between c.0.30m to c.0.50m underlain by concrete with rebar. TP's G to J were terminated on this concrete. The concrete was broken out in TP's K and L and was noted as c.150mm thick underlain by dolomitic limestone hardcore from c.0.65m to c.1.00m. Made ground was then recorded to a depth of between c.2.60m and c.3.50m comprising black sandy gravel of brick, glass, wood, concrete, rope, pottery, rag, burnt ash, shoes and bottles with an organic peaty odour noted. This made ground is deemed to be associated with the infilled exctraction / water feature. Standing water was recorded between c.2.00m and c.2.50m within this feature. The southern and eastern edges of this feature were located in TP's K and L respectively.

5.0 Ground Conditions (Cont'd)

5.1 Soil Profile (Cont'd):-

Table 5.1 (Cont'd)

Type of Strata	Depths Recorded (BGL)	Description & General Comments
MADE GROUND (Cont'd):	From 0.00m up to c.0.20m to c.3.50m	In addition, a brick obstruction was also encountered in BHC from a depth of c.1.50m to c.3.10m and may be associated with a below ground feature / service in this area.
DRIFT GEOLOGY: Blown Sand (Shirdley Hill Sand) & Boulder Clay	From 0.20m and c.3.50m up to a maximum recorded depth of c.15.00m	Drift deposits generally comprising loose and medium dense fine to medium SAND (Shirdley Hill Sand), with an occasional clay, silt and gravel content, were initially identified below the site area to depths of between c.0.90m and c.3.60m. Underlying the initial sand deposits, drift deposits comprising soft to very stiff (low to extremely high strength) initially soft in places, sandy gravelly CLAY (Boulder Clay) were identified below the site, to a maximum recorded depth of c.15.00m. An exception to this was noted at the location of TP01, where an isolated shallow band of soft very sandy slightly organic CLAY was noted to depths of between c.1.45m and c.2.20m. In addition, occasional decomposed plant remains were noted contained within the initial SAND deposits at TP's 06 & 10 up to c.2.20m. Furthermore, made ground in in BHC at c.3.10m was immediately underlain by boulder clay. The base of the historically recorded extraction / backfilled water feature was encountered between a maximum depth of c.2.60m and c.3.50m and comprised a grey and dark brown organic silt with decomposed roots noted underlain by sand and firm clay.
SOLID GEOLOGY: Triassic Pebble Beds	~	Not encountered during the completion of these site works.

There was no visual and/or olfactory evidence of significant ground contamination (i.e. hydrocarbon or fuel-derived contaminants, asbestos, etc.) present within any of the trial pits or boreholes undertaken across the site. However, the presence of ash was noted within the made ground materials at the locations of BH's 03, 05, 07, 08 & TP03 and also TP's K and L within the historically recorded extraction / backfilled water feature. In addition, there was also evidence of demolition type materials identified within the made ground below areas of the site (i.e. brick, concrete, etc.). Therefore, as indicated within the DTS, representative samples of made ground were screened for some limited contamination (i.e. Speciated Polycyclic Aromatic Hydrocarbons (PAH's), Speciated Total Petroleum Hydrocarbons (TPH's) and asbestos screening), the results of which are discussed further in Sections 8.3 & 8.4.

5.2 Groundwater:-

Occasional minor water ingresses were noted within several of the investigation positions completed across the site. These ingresses were noted as 'slight seepages' and were generally recorded at the interface between the Shirdley Hill Sand deposits and underlying Boulder Clay, at depths of between c.0.20m up to c.2.00m.

However, at the locations of BH's 01, 02, 05, 07 and 08, the initial made ground and drift deposits were also noted to be 'damp' during the intrusive works, from depths of between c.0.20m and c.1.50m.

5.0 Ground Conditions (Cont'd)

5.2 Groundwater (Cont'd):-

Furthermore, at the location of TP's K and L, which were completed in the area of the historically recorded extraction / backfilled water feature, significant water ingresses were recorded at a depth of c.1.00m bcgl's within the made ground materials with standing water recorded at between c.2.00m and c.2.50m on completion. This is felt to be surface water trapped within this feature, rather than representing a shallow continuous groundwater surface ('water table') and should be taken into consideration during the development of this site.

When considering the above, the minor water ingresses noted during the intrusive works are also considered to be attributable to surface water trapped within the shallow made ground and drift deposits below the site, rather than representing a shallow continuous groundwater surface ('water table') below the site. However, an allowance should be made for the introduction of temporary groundwater control measures, i.e. pumping equipment, etc., in order to take care of surface and ground water ingresses, particularly during the wetter periods of the year.

In order to monitor these water levels and assess the potential for soil/gas production below the site, combined gas and groundwater monitoring wells were installed within BH's 02, 04, 07, 10, A, B & E to enable a detailed programme of gas and groundwater monitoring to be carried out, the results of which are discussed further in Section 6.4 of this report.

6.0 Insitu Testing

6.1 Insitu Standard Penetration Tests:-

Insitu standard penetration tests were carried out within the boreholes with the use of a normal split spoon sampler (SPT), in order to determine the strength and density of the made ground and natural drift deposits.

The results are shown as uncorrected 'N' values on the graphic borehole record sheets, adjacent to the appropriate sample level. Where the full penetration depth, including seating blows (450mm), could not be achieved, the bottom sampling depth is indicated as less than 0.45m from the top (start of test), with the actual depth of penetration and number of blows undertaken also being recorded.

A summary of the findings is given below:-

- Tests were completed within the made ground materials encountered in BHC with an 'N' value of 49 and 50 Blows for limited penetration indicating generally dense strata.
- Tests were completed within the initial sand drift deposits encountered across the site with 'N' values of between 5 up to 15 being recorded, indicating generally loose to medium dense strata.
- Tests were also completed within the 'fine' drift deposits (i.e. clay) encountered across the site with 'N' values of between 12 up to 28 being recorded, indicating generally firm to stiff strata.

6.2 Insitu Field Vane Tests:-

Insitu hand vane tests were carried out using a portable Controls Testing insitu hand vane tester, within the 'fine' drift deposits (clay) encountered within the trial pits in order to determine the undrained shear strength of the clays encountered. Where possible a series of tests were carried out, and an average of the results obtained can be found adjacent to the appropriate sample level, on the graphic trial pit record sheets with the results summarised on the following page.

6.0 Insitu Testing (Cont'd)

6.2 Insitu Field Vane Tests (Cont'd):-

- Tests completed within the shallow natural clays encountered within the trial pits appear to be soft to firm (low to medium strength) in nature with shear strength values of between 25kN/m^2 up to 82kN/m^2 being recorded.

6.3 Insitu Equivalent California Bearing Ratio (CBR) Tests:-

Insitu equivalent CBR tests were carried out within the trial pits using a MEXE Cone Penetrometer, in accordance with the manufacturer's instructions, in order to estimate the insitu CBR values of the upper strata across the site. A series of tests were carried out, and an average of the results obtained can be found adjacent to the appropriate sample level, on the graphic trial pit record sheets in Appendix II.

CBR tests completed within the underlying drift deposits, with CBR values of between 3.0% up to 6.5% generally recorded at various locations across the site. Therefore, when considering the future design and construction of any new access roads, car parking areas, ground bearing floor slabs, etc., it is recommended that a conservative characteristic design CBR value of 3.0% be utilised where the initial natural deposits are to be used as an undisturbed sub-grade.

However, it should be noted that the achievable CBR value for the natural strata may improve under compaction/proof rolling, prior to emplacement of the stone sub-base, which will also help to identify any soft spots that may require re-compaction or digging out and replaced with additional compacted sub-base.

6.4 Insitu Ground Gas & Groundwater Monitoring:-

6.4.1 Hazardous Ground Gas Risk Assessment:-

Soil gas/vapour & water monitoring standpipes were installed within BH's 02, 04, 07, 10 A, B & E, primarily to check for the possible presence of hazardous ground gases associated with the made ground materials below the site as well as any gas potentially migrating below the site from nearby potential sources. These monitoring wells were also utilised to monitor insitu groundwater levels. A standard 50mm diameter HDPE standpipe, with gravel and/or geo-wrap surround, bentonite seal, gas valve cap and security cover, was installed at each borehole locations to a depth of c.5.00m bcgl.

The soil gas and water levels were allowed to reach equilibrium, prior to the first monitoring visit. Monitoring was undertaken using LMSxi, GFM 430 and 435 series soil gas analysers, with integral flow meters, and a Geotechnical Instruments electronic dip-meter.

In accordance with CIRIA Report C665, November 2007, the current NHBC Document; Guidance on evaluation of development proposals on site where methane and carbon dioxide are present, Report Edition No. 04, March 2007 and BS8485:2015 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings, as well as the results of the Phase 1: DTS carried out and these intrusive investigation works, it is felt that an adequate risk assessment can be undertaken based on the following limiting factors:

- The development has been considered as **low sensitivity** (Tables 5.5a & 5.5b – Typical/Idealised frequency and period of monitoring, after Wilson et al, 2005).
- The risk associated with the generation potential of a source is considered as **very low**, (assessment based on the environmental setting, etc.).

6.0 Insitu Testing (Cont'd)

6.4 Insitu Ground Gas & Groundwater Monitoring (Cont'd):-

6.4.1 Hazardous Ground Gas Risk Assessment (Cont'd):-

- Monitoring over a **minimum** of **one month** with a minimum **four recorded** readings (Table 5.5 – Typical /idealised frequency and period of monitoring after Wilson et al, 2005).
- **Negligible** flow rates have been recorded (Table 8.5 – Modified Wilson & Card classification).

A summary of the results for the visits undertaken, compared with the 'inert' background gas levels are presented in Table 6.1 below with a copy of the monitoring certificate attached in Appendix III.

As there was no historical sources identified during the completion of the DTS and no hydrocarbon type contamination was identified across the site during the completion of the fieldworks, at this stage it has not been deemed necessary to undertake a Photoionization Detector meter (PID) for the presence of hydrocarbons and volatile organic compounds (VOC's).

Table 6.1 Elevated levels shown **Bold**.

Position	Date	Atmospheric Pressure (mbar)	Water (m bgl)	CH_4 (%v/v)	LEL (%v/v)	CO_2 (%v/v)	O_2 (%v/v)	Flow Rate (l/hr)
Background		~	~	**0**	**0**	**0**	**21.0**	**<0.1**
BH02	09/04/2014	1010 - 1015 (falling)	0.92	0.0	0.0	0.0	19.4	<0.1
BH04			0.23	0.0	0.0	0.0	20.0	<0.1
BH07			0.64	0.0	0.0	0.7	19.2	<0.1
BH02	01/05/2014	1005-1006 (falling)	1.40	0.0	0.0	1.1	18.8	<0.1
BH04			1.50	0.0	0.0	0.9	19.7	<0.1
BH07			1.72	0.0	0.0	0.5	19.9	<0.1
BH02	19/05/2014	997 (steady)	1.25	0.0	0.0	2.1	19.7	<0.1
BH04			1.30	0.0	0.0	4.3	16.3	<0.1
BH07			1.20	0.0	0.0	2.5	18.1	<0.1
BH02	26/06/14	1008 (steady)	1.13	0.0	0.0	1.7	13.6	<0.1
BH04			1.33	0.0	0.0	0.1	18.8	<0.1
BH07			0.86	0.0	0.0	0.9	16.7	<0.1
BH10	22/07/14	1020 (steady)	1.24	0.0	0.0	3.9	16.7	<0.1
BH10	25/07/14	1019 (steady)	1.24	0.0	0.0	0.0	20.7	<0.1
BH10	19/08/14	1008 (steady)	1.03	0.0	0.0	4.2	16.1	<0.1
BH10	28/08/14	1002 (falling)	1.01	0.0	0.0	3.1	17.8	<0.1
BHA	22/07/14	1016 - 1019 (rising)	0.69	0.0	0.0	2.9	18.3	<0.1
BHB			1.24	0.0	0.0	2.5	18.7	<0.1
BHE			1.18	0.0	0.0	3.9	17.4	<0.1
BHA	25/07/14	1019-1020 (falling)	0.83	0.0	0.0	0.2	20.7	<0.1
BHB			1.22	0.0	0.0	4.6	15.0	<0.1
BHE			1.10	0.0	0.0	0.0	20.9	<0.1
BHA	19/08/14	1008 (steady)	0.70	0.0	0.0	4.0	18.8	<0.1
BHB			1.26	0.0	0.0	4.2	15.2	<0.1
BHE			1.05	0.0	0.0	4.0	17.2	<0.1
BHA	28/08/14	991-992 (falling)	0.52	0.0	0.0	3.7	17.7	<0.1
BHB			1.03	0.0	0.0	3.5	14.1	<0.1
BHE			0.95	0.0	0.0	2.4	17.1	<0.1

6.0 Insitu Testing (Cont'd)

6.4 Insitu Ground Gas & Groundwater Monitoring (Cont'd):-

6.4.1 Hazardous Ground Gas Risk Assessment (Cont'd):-

As can be seen from the results undertaken, no concentrations of Methane (CH_4) were recorded within any of the boreholes. However, detectable levels of Carbon Dioxide (CO_2) were recorded within the majority of the boreholes, up to a maximum level of 4.6% *v/v*, with associated depleted oxygen (O_2) concentrations (minimum 13.6% *v/v)*. In addition, negligible flow rates of <0.1l/hr have been recorded during the monitoring visits.

Based on the results and in accordance with CIRIA Report C665, the risk to the site from ground gases has been assessed by converting the results in Table 6.1 above to a gas screening value (GSV), calculated by multiplying the typical maximum gas concentrations with the recorded maximum flow rates (after Wilson & Card). At this stage, as no concentrations of Methane have been recorded, only a GSV for Carbon Dioxide has been calculated, using the maximum recorded value of 4.6% v/v with a maximum flow rate of 0.1l/hr. The GSV can be calculated as follows:

Carbon Dioxide GSV = 0.046 (4.3%) x 0.1 = 0.0046 l/hr

From this result it can be seen that the GSV value does not exceed the GSV minimum assessment value of 0.07 l/hr (Characteristic Situation 1 – CS1). Therefore, the proposed building will not require any gas protection measures.

6.4.2 Groundwater:-

When considering the results of the groundwater monitoring completed, it can be seen that standing water levels of between c.0.23m and c.1.72m bcgl have been recorded within the monitoring installations with these water levels potentially indicating the presence of perched shallow water, most likely associated with surface water infiltration, within both the made ground and underlying granular drift deposits.

It is therefore considered prudent to allow for the introduction of temporary groundwater control techniques (i.e. pumping equipment), in order to take care of any localised ingresses of surface water which may occur, during the construction period, especially if construction takes place during the wetter periods of the year.

7.0 Laboratory Testing

All laboratory geotechnical testing was carried out in accordance with BS1377:1990:Parts 1-9 by Professional Soils Laboratory (PSL) of Doncaster, South Yorkshire and Chemtech Environmental Limited, of Consett, County Durham (UKAS accredited) unless otherwise stated.

7.1 Determination of Chemical Attack on Buried Concrete:-

Representative samples of soil recovered during the investigation were tested in order to determine their acidic (pH) and soluble sulphate (SO_4) levels. The results are shown in Table 7.1 on the following page and are also contained within the Chemtech Environmental Limited Analytical Reports (ref no's: 51293(1), 51114(1), 52171, 52172 & 52205), copies of which can be seen in Appendix IV.

From these results it can be seen that the pH values for the samples tested range from 5.6 to 10.0, and the amount of Soluble Sulphate present falls between 10mg/l and 583mg/l. Therefore, in accordance with BRE Special Digest 1: 2005, the site outwith the area of TPK can be given a classification of Class DS-1.

7.0 Laboratory Testing (Cont'd)

7.1 Determination of Chemical Attack on Buried Concrete (Cont'd):-

Table 7.1

Position	Depth (m)	pH	SO_4(mg/l)	Design SO_4 Class	ACEC Class
TP01	0.20-0.40	6.0	27	DS-1	AC-2z
TP02	0.10-0.40	6.5	13	DS-1	AC-2z
TP03	0.10-0.40	6.8	29	DS-1	AC-1
TP04	0.20-0.60	7.1	150	DS-1	AC-1
TP06	0.10-0.40	8.1	131	DS-1	AC-1
TP07	0.20-0.40	6.0	26	DS-1	AC-2z
TP08	0.20-0.60	8.0	27	DS-1	AC-1
TP09	0.20-0.50	7.5	17	DS-1	AC-1
TP10	0.30	6.2	19	DS-1	AC-2z
TP10	1.00	6.6	67	DS-1	AC-1
TP12	0.40	7.8	10	DS-1	AC-1
BH07	0.20	5.6	183	DS-1	AC-2z
BH08	0.50	7.9	72	DS-1	AC-1
TPA	0.25	7.9	30	DS-1	AC-1
TPA	1.00	7.0	43	DS-1	AC-1
TPB	0.20	8.3	23	DS-1	AC-1
TPC	0.30	7.2	14	DS-1	AC-1
TPC	1.00	7.8	24	DS-1	AC-1
TPD	0.40	8.4	25	DS-1	AC-1
TPD	1.00	7.6	16	DS-1	AC-1
TPE	0.30	6.9	80	DS-1	AC-1
TPE	1.00	7.2	18	DS-1	AC-1
TPF	0.50	8.3	48	DS-1	AC-1
TPG	0.40	8.4	44	DS-1	AC-1
TPH	0.40	8.4	72	DS-1	AC-1
TPK	1.50	10.0	316	DS-1	AC-1
TPK	2.50	7.6	583	DS-2	AC-2

ACEC = Aggressive Chemical Environment for Concrete site classification

When considering the nature of the materials tested and assuming mobile groundwater the assessment of the Aggressive Chemical Environment for Concrete (ACEC) for the site outwith the area of TPK, is AC-2z.

7.2 Determination of Liquid & Plastic Limits:-

Representative samples of the natural clay deposits recovered during the intrusive works were tested in order to determine their liquid and plastic limits, so these materials could be classified. The results can be seen in Table 7.2 on the following page, and are also contained in the PSL analytical report ref no. PSL14/1976, PSL14/2300, PSL14/3631 & PSL14/3632, a copy of which can be found in Appendix IV.

From these results it can be seen that the natural clay deposits tested are generally inorganic in nature, and when plotted on the plasticity chart, fall within the low and intermediate ranges, and from the resulting plasticity indices, have a negligible to low volume change potential, when taking into account the amount passing the 425µm sieve. The sample tested at c.1.00m in TPB was deemed to be non plastic, i.e. too granular in nature.

7.0 Laboratory Testing (Cont'd)

7.2 Determination of Liquid & Plastic Limits (Cont'd):-

Table 7.2

Position	Depth (m)	Strata Type	M/C	LL	PL	PI	Class	% Passing 425µm Sieve
BH02	2.00	Clay	15	27	13	14	CL	96
BH03	2.50-3.00	Clay	17	27	14	13	CL	97
BH04	2.00	Clay	15	24	12	12	CL	93
BH05	2.50-3.00	Clay	16	25	13	12	CL	96
BH06	2.00	Clay	16	25	13	12	CL	95
BH06	3.50-4.00	Clay	11	28	13	15	CL	94
BH07	2.00	Clay	16	27	13	14	CL	94
BH08	2.50-2.95	Clay	18	27	14	13	CL	96
BH09	6.00-6.50	Clay	18	28	17	11	CL	95
BH09	12.00-12.50	Clay	15	29	17	12	CL	92
BH11	3.50-4.00	Clay	16	27	16	11	CL	93
TP01	2.40-2.80	Clay	16	27	13	14	CL	87
TP02	1.70-2.00	Clay	17	25	12	13	CL	85
TP03	18.0-2.20	Clay	17	23	12	11	CL	89
TP04	2.20-2.40	Clay	16	26	13	13	CL	84
TP05	2.40-2.80	Clay	17	25	12	13	CL	84
TP06	2.40-2.60	Clay	18	24	13	11	CL	82
TP08	2.40-2.60	Clay	14	30	15	15	CI	97
TPA	2.00	Clay	16	32	16	16	CL	94
TPB	1.00	Sand	18		NP			
TPC	2.00	Clay	18	39	19	20	CI	91
TPD	2.00	Clay	22	38	19	19	CI	93
TPE	3.00	Clay	16	32	15	17	CL	94
TPF	2.00	Clay	18	38	18	20	CI	92
BHA	4.00	Clay	16	37	18	19	CI	95
BHB	5.00	Clay	16	37	18	19	CI	94
BHC	3.50-4.00	Clay	17	38	19	19	CI	93
BHD	3.20	Clay	15	38	19	19	CI	92
BHE	3.00	Clay	16	39	18	21	CI	92

M/C = Moisture Content (%), LL = Liquid Limit (%), PL = Plastic Limit (%), PI = Plasticity Index (%), NP = Non-Plastic.

Subsequently, it can be seen that these materials are unlikely to undergo significant changes in volume, if large changes in their natural moisture content were to occur due to seasonal variations or the like, and if new foundations were to be based within these materials, they would need to be taken down to a minimum depth of 0.75m below finished ground levels.

When considering the above, an increase in this minimum depth will be required where increased depths of made ground/fill are identified below the site. In addition, should the proposed building extend close to existing vegetation, an increase in the minimum foundation depth may also be required, even if trees are to be removed, in order to ensure no additional future shrinkage and swelling of these materials occurs. Reference should be made to BS5837:2012, "Trees in relation to design, demolition and construction".

7.3 Determination of Particle Size Distribution (PSD):-

Representative samples of the natural deposits were tested in order to determine their particle size distribution, so these materials might be classified. The results of the tests are represented both graphically and numerically on the PSD results sheets in Appendix IV and are also summarised in Table 7.3 on the following page.

7.0 Laboratory Testing (Cont'd)

7.3 Determination of Particle Size Distribution (PSD) (Cont'd):-

Table 7.3

Position	Depth (m)	Clay/Silt Fraction (%)	Sand Fraction (%)	Gravel Fraction (%)	Cobble Fraction (%)	Grading Characteristics	Brief Soil Description
BH01	1.50-2.00	30	65	5	0	Poorly Graded	Slightly gravelly very silty SAND
BH05	1.50-2.00	32	62	6	0	Poorly Graded	Slightly gravelly very silty SAND
BH09	2.50-3.00	15	75	10	0	Poorly Graded	Gravelly clayey silty SAND
TP03	0.80-1.20	6	93	1	0	Poorly Graded	Slightly gravelly silty SAND
TP04	1.20-1.60	6	94	0	0	Poorly Graded	Silty SAND
TP05	0.70-1.00	16	79	5	0	Poorly Graded	Slightly gravelly silty SAND
TP06	1.60-1.80	18	81	1	0	Poorly Graded	Slightly gravelly silty SAND
TP10	2.00	9	91	0	0	Poorly Graded	Silty SAND
BHA	1.50-2.00	9	82	9	0	Poorly graded	Slightly clayey gravelly SAND
BHB	1.50-3.00	34	59	7	0	Poorly graded	Slightly gravelly very clayey very silty SAND
BHD	1.50-3.00	28	55	17	0	Poorly graded	Gravelly clayey silty SAND
BHE	1.00	25	55	20	0	Poorly graded	Very gravelly clayey silty SAND
TPB	3.00	56	38	6	0	Poorly graded	Slightly gravelly very sandy CLAY
TPF	1.00	7	93	0	0	Poorly graded	Clayey SAND

7.4 Determination of Organic Matter Content:-

Representative samples of the clay and sand deposits recovered from TP01 and TP06, together with samples of the organic silt deposits recovered from the base of the infilled pond encountered within TPK and TPL, that were suspected to be potentially organic (compressible), were tested in order to determine their organic content, so that the potential for compressibility could be assessed. The results are shown in the Chemtech Environmental Testing Reports (ref nos: 51293(1) & 52205), copies of which are attached within Appendix IV.

The results of the testing completed on the sample from TP06 at 1.20m-1.40m revealed a generally negligible organic content of 0.53%. However, the clay sample screened from TP01 at 1.60m-1.80m and TPL at 2.80m revealed an organic content of 3.75% and 5.38% respectively indicating a low organic content. TPK at 3.60m revealed an organic content of 14.59% indicating a medium organic content. Taking this into account, there is a possibility that the initial clay materials at the location of TP01 and the organic silt materials at the base of the infilled pond could potentially be susceptible to consolidation through loss of water, or compressibility normally associated with organic materials.

7.5 Undrained Shear Strength (Triaxial):-

In total, 22 no. undisturbed samples of the natural clay deposits recovered during the investigation from across the site were dispatched to the laboratory for examination and subsequent testing. The results obtained are shown in Table 7.4 on the following page, along with the value of moisture contents (as received) and bulk densities, the angle of shearing resistance has been taken as zero, assuming fully saturated conditions.

In summary, the undrained shear strength of the clays tested range from 21kN/m^2 to 826kN/m^2 and are classed as low to extremely high strength materials. These laboratory results/descriptions generally correspond with the field descriptions of these materials.

7.0 Laboratory Testing (Cont'd)

7.5 Undrained Shear Strength (Triaxial) (Cont'd):-

Table 7.4

Position	Depth(m)	M/C (%)	Bulk Density (Mg/m³)	Shear Strength Cu (kN/ m²)
BH02	2.50-2.95	13	2.27	124
BH02	4.50-4.95	13	2.25	114
BH03	1.50-1.95	18	2.19	27
BH04	2.50-2.95	11	2.20	286
BH04	4.50-4.95	14	2.31	140
BH05	3.50-3.95	15	2.21	79
BH05	5.50-5.95	13	2.23	108
BH06	2.50-2.95	14	2.25	77
BH07	4.50-4.95	15	2.23	106
BH08	4.50-4.95	14	2.26	135
BH09	7.50-7.95	15	2.24	54
BH09	13.50-13.95	14	2.19	45
BH10	4.50-4.95	15	2.22	62
BHA	4.50-4.95	14	2.17	40
BHA	7.50-7.95	15	2.22	83
BHB	3.50-3.45	14	2.20	93
BHB	6.00-6.45	14	1.93	21
BHC	4.50-4.95	13	2.27	95
BHD	3.50-3.95	14	2.10	68
BHD	7.50-7.95	19	2.15	57
BHE	3.50-3.95	8.3	2.22	483
BHE	6.00-6.45	8.5	2.22	826

M/C = Moisture Content, LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index

7.6 One Dimensional Consolidation Tests:-

Seven representative samples of the natural clay deposits encountered in the boreholes were tested, in order to determine their one dimensional consolidation properties, using conventional front loading oedometers, with a five loading increment regime applied, to aid in settlement estimations and for classification. The tests were carried out in order to determine the initial and subsequent void ratio (e_o), coefficient of volume compressibility (m_v), and coefficient of consolidation (c_v), so that an assessment to the overall compressibility of these materials could be carried out.

The results of the tests indicate that the m_v value, the void ratio change from effective original overburden pressure + 100kN/m^2 additional imposed loading (where possible), range from 0.03m^2/MN – 0.165m^2/MN. These results suggest very low to medium compressibility for the natural clay deposits encountered.

7.7 Contamination Screening & Screening Strategy:-

Representative samples of the made ground materials recovered from across the site were passed onto Chemtech Environmental Limited in Consett, Co. Durham, so that generic and targeted contamination screening could be carried out. The results of all the testing can be found in the Chemtech Environmental Limited Analytical Reports (ref no's: 51293(1), 51114(1), 52171, 52172 & 52205), copies of which can be seen in Appendix IV.

7.0 Laboratory Testing (Cont'd)

7.7 Contamination Screening & Screening Strategy (Cont'd):-

Based on the historical use of the site and the findings of the intrusive fieldworks, selected samples of soil and groundwater have undergone a range of appropriate chemical screening and the total analysis carried out is summarised below.

In total 22 no. representative soil samples were screened using a standard generic contamination suite (based on the current CLEA SGV listed analytes with historical additions), which is used to assess typical made ground (disturbed natural strata mixed with anthropogenic debris) of an unknown source. Taking into account the presence of ash within the made ground materials below areas of the site and within the made ground materials at TP's K & L, representative samples of made ground have also been targeted for speciated PAH's (Polycyclic Aromatic Hydrocarbons) & TPH's (Total Petroleum Hydrocarbons).

There was no visual and/or olfactory evidence of significant fuel/hydrocarbon contamination present within any of the trial pits or boreholes undertaken across the site. However, when considering the historically perched groundwater, trapped within a former in filled pond feature, it was considered prudent to screen a sample of water from this site (recovered from TPL - located within the historically recorded extraction / backfilled water feature identified on site). Representative soil samples were also targeted for generic and targeted leachate screening due to insufficient recharge rates within the water monitoring standpipes, in accordance with BS ISO 5667-11:2009.

In addition, due to the presence of demolition rubble within the made ground below areas of the site, although no ACM's were identified in any of the investigation positions, samples of the made ground were also selected and screened for the presence of asbestos fibres.

The potential risk to Controlled Waters is also considered to be low primarily due to the lack of significant sources of gross/heavy contamination being present as well as the length of time that the made ground has been present on this site. Consequently, any groundwater within both the Shirdley Hill Sands (Secondary A Aquifer) and Sherwood Sandstone (Principal Aquifer) Formations, is not considered to be at significant risk, particularly when taking into account the significant thickness of relatively impermeable drift deposits (i.e. Boulder Clay) which overlie the bedrock. In addition, there are no potable groundwater or surface water abstractions within 1km of the site and the site does not lie within a Source Protection Zone.

The full catalogue of testing results can be found in the Chemtech Analytical Report (ref no's. 51114(1), 51293(1), 52171, 52172 & 52205), copies of which are attached in Appendix IV, and the total analysis carried out is summarised below and on the following page. The generic and targeted contamination results have been used to carryout Level 1 Quantitative Human Health Risk Assessment for the ground contamination present and are discussed in Section 8.0.

- 22 no. soil samples screened using a Generic Soils Suite - based on the current CLEA SGV listed analytes with historical additions and which is used to assess typical made ground of an unknown source (suite comprises; *Arsenic, Cadmium, Chromium III, Chromium VI, Copper, Lead, Mercury, Nickel, Selenium, Zinc & Cyanide*).
- 19 no. soil samples screened for speciated *Polycyclic Aromatic Hydrocarbons (PAH's)* – based on the current USEPA 16.
- 11 no. soil samples screened for speciated *Total Petroleum Hydrocarbons (TPH's)* – Aliphatic & Aromatic Spilt, with BTEX.
- 20 no. soil samples targeted for the presence of Asbestos (ACM's & fibres).

7.0 Laboratory Testing (Cont'd)

7.7 Contamination Screening & Screening Strategy (Cont'd):-

- 5 no. soil leachate samples and 1 no. water sample tested for a generic suite (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc, Sulphate, Boron, Free Cyanide and Sulphide)
- 5 no. soil leachate samples and 1 no. water sample tested for Poly-cyclic Aromatic Hydrocarbon's (USEPA 16)
- 4 no. soil leachate samples and 1 no. water sample targeted for Total Petroleum Hydrocarbon's (Aliphatic/Aromatic Split)

These results have been used to carryout Level 1: Quantitative Human Health and Controlled Waters Risk Assessment for the ground contamination present, and are discussed in Section 8.0 below and on the following pages. These results can also be used for a preliminary assessment for off-site disposal classification.

8.0 Level 1 Ground Contamination Risk Assessment

8.1 Methodology:-

Following completion of the contamination screening undertaken on various samples from this site, Level 1 quantitative ground contamination risk assessments have been undertaken, generally in accordance with CLR11: Model Procedures for the Management of Land Contamination. A detailed description of the Assessment Framework and Methodology used for these risk assessments can be found in Appendix V.

This quantitative ground contamination risk assessment uses the current UK practice for assessing the risks from land contamination, which is based on the established *source-pathway-receptor* pollutant linkage methodology and 'suitable for use' approach (Part IIA, EPA 1990 - inserted through Section 57 EA 1995).

Based on the Conceptual Site Model (CSM) for this site (described further in the following Section 8.2), a site specific screening strategy for the site has been developed (see Section 7.7) and the risks from potential contaminants have been assessed for human health and controlled waters. The results of the risk assessment can be found in Sections 8.3 & 8.4. Comments regarding off-site disposal can also be found in Appendix V.

8.2 Conceptual Site Model (CSM):-

From the findings of the results of the intrusive investigation works, a revised Conceptual Site Model (CSM) has been developed for this site, and is represented in Table 8.1 on the following page, which summarises the various contaminant sources, plausible migration pathways and potentially sensitive receptors identified for this site, assuming no remediation, additional protection measures and/or removal of the sources contamination takes place.

8.2.1 Sources:-

There are areas of made ground associated with the historical development of the site which has been utilised as Liverpool Airport / RAF Speke as well as an adjacent railway line and extraction feature/backfilled water feature being recorded on site. Even when taking in to consideration the historical development of the site, no heavy / gross contamination was identified across the site during the completion of the fieldworks.

However, small amounts of ash were identified within the made ground materials across the site and at the location of TP's K & L (i.e. the location of the historical extraction / backfilled water feature). Although these made ground materials were not considered to represent a significant risk to the end users it was deemed prudent to select samples for a range of screening as discussed in Section 7.6.

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.2 Conceptual Site Model (CSM) (Cont'd):-

8.2.1 Sources (Cont'd):-

Table 8.1

	Sources (S)
S1	Made ground associated with the historical development of the site including the presence of ash outwith and within historically recorded extraction / backfilled water feature (i.e. PAH's).
S2	Possible hazardous ground gas production / migration from both on site and off site sources (i.e. made ground & & infilled extraction / water features).
S3	Due to the historical development of the site there may be the presence of hydrocarbon 'hot spots' associated with oils, fuels, etc. (i.e. TPH's). In addition, due to the presence of demolition type material within the made ground below areas of the site, the presence of ACM's was also verified.

	Pathways (P)
P1	Ingestion
P2	Inhalation of indoor / outdoor air
P3	Dermal contact
P4	Migration through permeable ground, existing services, etc.
P5	Direct contact with building materials
P6	Surface run off and leachate Migration

	Receptors (R)
R1	Human health (End users and construction workforce)
R2	Groundwater (Secondary A Aquifer & Principal Aquifer)
R3	Building materials*
R4	Adjacent sites
R5	Flora and fauna*
R6	Nearby culverts and watercourses.

* - not considered part of Level 1 Human Health risk assessment. Screening results can be used to assess level of protection, where necessary.

8.2.2 Pathways:-

When considering the proposed end use (taken as *Commercial*), and without considering treatment, removal or protection measures, there are some potential plausible pathways available for direct contact, dermal contact, ingestion, inhalation, wind (dust / particulate), volatilization, and vertical and lateral transportation below the site.

Within the CLEA Risk Assessment Model for Human Health, there are 3 exposure mediums considered for on site receptors, comprising ingestion of soil containing contaminants, inhalation of contaminated dust/vapours and dermal contact, with up to 10 no. exposure pathways considered, as shown below.

1. Ingestion of soil and indoor dust 2. Consumption of home-grown produce and attached soil 3. Dermal contact (indoor) 4. Dermal contact (outdoor) 5. Inhalation of dust (indoor) 6. Inhalation of dust (outdoor) 7. Inhalation of vapour (indoor) 8. Inhalation of vapour (outdoor) 9. Oral background intake 10. Inhalation background intake.

Where the future site has hard cover and below new structures, a number of these pathways may not be available. In addition, when considering the potential pathways for leachate migration, where either hard cover and/or future surface water drainage systems are present, the potential effects of surface infiltration or contaminated surface water runoff will be greatly reduced.

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.2 Conceptual Site Model (CSM) (Cont'd):-

8.2.2 Pathways (Cont'd):-

Similarly, when considering the construction work force, exposure pathways through direct contact, ingestion and dust inhalation will be available during part of the construction process, and therefore adequate PPE should be provided to protect the work force during this period.

8.2.3 Receptors:-

Within the CLEA Risk Assessment Model for Human Health, the potential receptors are assessed initially on site end use, followed by a delineation of age category (i.e. child or adult), with default settings for *Residential, Allotment* and *Public Open Space (Park)* end uses based on a child aged 0 to 6 years, *Public Open Space (Residential)* based on a child aged 3 to 9 and *Commercial* end uses based upon an adult working exposure period of up to 49 years (i.e. 16 to 65).

Key generic assumptions for *Residential* and *Public Open Space (Residential)* are based upon a typical residential property, consisting of a two-storey small terraced house, with private garden, and a *Commercial* end use based upon a typical commercial or light industrial property, consisting of a three-storey office building (pre-1970). No buildings are anticipated for *Allotment* or *Public Open Space (Park)* end uses.

Within the CLEA Risk Assessment Model for Human Health there are 6 no. generic end use categories presently in use, as follows;

1) Residential - with home grown produce, 2) Residential - without home grown produce, 3) Allotments, 4) Commercial
5) Public Open Space – Residential, 6) Public Open Space - Park

When considering the proposed end use of this site, the Level 1 Risk Assessment has taken a conservative best fit end use category as:

4) Commercial

For controlled waters the primary receptor is groundwater within the underlying Shirdley Hill Sands (Secondary A Aquifer), the Sherwood Sandstone Formation (Principal Aquifer) as well as the culverted drains / sewers and adjacent surface water features.

8.3 Level 1 Human Health Risk Assessment (Soils):-

8.3.1 Human Health – Generic Made Ground & Hydrocarbon Screening (PAH's & TPH's):-

The soil screening results have been subjected to statistical analysis utilising the contaminated land statistical analysis sheets developed by CL:AIRE and a copy of the calculation sheets and the statistical methodology can be found in Appendix V. In addition, taking into account the presence of ash recorded within the made ground, appropriate samples of the made ground have also been subjected to PAH & TPH screening.

A summary of the results for this Level 1 Risk Assessment (Human Health) can be seen in Table 8.2 on the following page:

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.3 Level 1 Human Health Risk Assessment (Soils) (Cont'd):-

8.3.1 Human Health – Generic Made Ground & Hydrocarbon Screening (PAH's & TPH's) (Cont'd):-

Table 8.2

Whole of Site Analyte	Critical Conc. (C_C) mg/kg	No. of Samples Screened	Max. Conc. (C_M) recorded	Statistical Upper Confidence Limit ($UCL_{0.95}$) mg/kg	Has $UCL_{0.95}$ exceeded C_C	No. of Samples > C_C	Is C_M a statistical outlier
Arsenic	640[1]	22	54.4	19.9	NO	0	YES
Cadmium	190[1]	22	2.5	0.9	NO	0	YES
Chromium III	8600[1]	22	98	78.1	NO	0	NO
Chromium VI	33[1]	22	<1	0.5	NO	0	NO
Copper	68000[1]	22	201	75.7	NO	0	YES
Lead	2330[2]	22	854	249.9	NO	0	YES
Mercury	1100[1]	22	<0.5	0.3	NO	0	NO
Nickel	980[1]	22	0.7	23.0	NO	0	YES
Selenium	12000[1]	22	0.9	0.8	NO	0	NO
Zinc	730000[1]	22	597	205.5	NO	0	YES
Cyanide	34[3]	22	<2	1.0	NO	0	NO
PAH's							
Acenaphthene	100000[1]	19	2.67	0.99	NO	0	NO
Acenaphthylene	100000[1]	19	0.16	0.06	NO	0	YES
Anthracene	540000[1]	19	20.59	6.10	NO	0	NO
Benzo(a)anthracene	180[1]	19	50.27	14.69	NO	0	NO
Benzo(a)pyrene	36[1]	19	29.33	8.81	NO	0	NO
Benzo(b)fluoranthene	45[1]	19	**45.26**	13.40	NO	**1 (BH07)**	NO
Benzo(ghi)perylene	4000[1]	19	14.60	4.45	NO	0	NO
Benzo(k)fluoranthene	1200[1]	19	17.02	5.08	NO	0	NO
Chrysene	350[1]	19	69.79	20.19	NO	0	NO
Dibenz(ah)anthracene	3.6[1]	19	**4.78**	1.42	NO	**1 (BH07)**	NO
Fluoranthene	23000[1]	19	111.21	32.73	NO	0	NO
Fluorene	71000[1]	19	3.08	1.10	NO	0	NO
Indeno(123cd)pyrene	510[1]	19	16.31	4.92	NO	0	NO
Naphthalene	1100[1]	19	0.24	0.10	NO	0	NO
Phenanthrene	23000[1]	19	49.26	14.94	NO	0	NO
Pyrene	54000[1]	19	81.10	23.98	NO	0	NO
BTEX & Speciated TPH's							
Benzene	90[1]	6	<0.01	0.005	NO	0	NO
Toluene	180000[1]	6	<0.01	0.005	NO	0	NO
Ethylbenzene	27000[1]	6	<0.01	0.005	NO	0	NO
m & p-Xylene	30000[1]	6	<0.01	0.005	NO	0	NO
o-Xylene	33000[1]	6	<0.01	0.005	NO	0	NO
TPH Aliphatic (EC5-EC6)	12000[1]	11	<0.1	0.05	NO	0	NO
TPH Aliphatic (EC6-EC8)	40000[1]	11	0.3	0.22	NO	0	NO
TPH Aliphatic (EC8-EC10)	11000[1]	11	0.8	0.45	NO	0	YES
TPH Aliphatic (EC10-EC12)	47000[1]	11	7	4.22	NO	0	NO
TPH Aliphatic (EC12-C16)	90000[1]	11	14	8.03	NO	0	NO
TPH Aliphatic (EC16-EC35)	1800000[1]	11	462	334.05	NO	0	NO
TPH Aliphatic (EC35-EC44)	1800000[1]	11	305	189.25	NO	0	YES
TPH Aromatic (EC5-EC7)	86000[1]	11	<0.01	0.01	NO	0	NO
TPH Aromatic (EC7-EC8)	180000[1]	11	<0.01	0.01	NO	0	NO
TPH Aromatic (EC8-EC10)	17000[1]	11	<0.01	0.01	NO	0	NO
TPH Aromatic (EC10-EC12)	34000[1]	11	<1	0.50	NO	0	NO
TPH Aromatic (EC12-EC16)	38000[1]	11	1	0.74	NO	0	YES
TPH Aromatic (EC16-EC21)	28000[1]	11	20	11.32	NO	0	NO
TPH Aromatic (EC21-EC35)	28000[1]	11	17	10.66	NO	0	NO
TPH Aromatic (EC35-EC44)	28000[1]	11	2	1.23	NO	0	YES

[1] = LQM CIEH Suitable 4 Use Levels (S4UL Nov 2014 (Revised August 2015)) – *Commercial 6% SOM*, [2] = C4SL Values (*Commercial*), [3] = ATRISK^{SOIL} SSV, **Bold** = result exceeds critical concentration, Note = All units are mg/kg.

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.3 Level 1 Human Health Risk Assessment (Soils) (Cont'd):-

8.3.1 Human Health – Generic Made Ground & Hydrocarbon Screening (PAH's & TPH's) (Cont'd):-

The results have identified the following:

- None of the Upper Confidence Limit values ($UCL_{0.95}$) for any of the generic analytes exceed the chosen critical concentration (C_C) values for this site.
- The maximum concentration (C_M) values for Benzo(b)fluoranthene and Dibenz(ah)anthracene exceeds the chosen C_C values for this site at the location of BH07. However, as the $UCL_{0.95}$ values for these analytes fall below the chosen C_C values, and the C_M values at the location of BH07 do not represent statistical outliers, no significant risk is anticipated to human health with regards to potential Benzo(b)fluoranthene and Dibenz(ah)anthracene present.
- None of the remaining C_M values exceed the chosen C_C values for this site.
- The C_M values for Arsenic, Cadmium, Copper, Lead, Nickel, Zinc, Acenaphthylene, TPH Aliphatic (EC8-EC10), TPH Aliphatic (EC35-EC44), TPH Aromatic (EC12-EC16) and TPH Aromatic (EC35-EC44) are recorded as statistical outliers. However, since neither the C_M nor the $UCL_{0.95}$ values exceed the C_C values for this site, it is felt that these analytes do not represent a potential risk.
- From these results it can be seen that there is no requirement for removal, protection measures and/or further risk assessment (DQRA), of these materials (generic made ground), in order to protect sensitive receptors in the future i.e. human health.

8.3.2 Human Health Risk Assessment - Asbestos Screening:-

Although no evidence of ACM's was recorded on site during the fieldworks, taking into account the presence of demolition type materials (i.e. brick, etc,) within the made ground below the site it was considered prudent to screen samples for the presence of asbestos. A summary of the results obtained from the targeted asbestos screening carried out can be seen in Table 8.3 below.

Table 8.3

Position	Depth (m)	Chrysotile	Amosite (brown)	Crocidolite (blue)	Anthophyllite	Actinolite	Tremolite
TP01	0.20-0.40	NAD	NAD	NAD	NAD	NAD	NAD
TP02	0.10-0.40	NAD	NAD	NAD	NAD	NAD	NAD
TP03	0.10-0.40	NAD	NAD	NAD	NAD	NAD	NAD
TP04	0.20-0.60	NAD	NAD	NAD	NAD	NAD	NAD
TP06	0.10-0.40	NAD	NAD	NAD	NAD	NAD	NAD
TP08	0.20-0.50	NAD	NAD	NAD	NAD	NAD	NAD
TP10	0.30	NAD	NAD	NAD	NAD	NAD	NAD
TP12	0.40	NAD	NAD	NAD	NAD	NAD	NAD
BH07	0.20	NAD	NAD	NAD	NAD	NAD	NAD
BH08	0.50	NAD	NAD	NAD	NAD	NAD	NAD
TPA	0.25	NAD	NAD	NAD	NAD	NAD	NAD
TPB	0.20	NAD	NAD	NAD	NAD	NAD	NAD
TPC	0.30	NAD	NAD	NAD	NAD	NAD	NAD
TPD	0.40	NAD	NAD	NAD	NAD	NAD	NAD
TPE	0.30	NAD	NAD	NAD	NAD	NAD	NAD
TPF	0.50	NAD	NAD	NAD	NAD	NAD	NAD
TPG	0.40	NAD	NAD	NAD	NAD	NAD	NAD
TPH	0.40	NAD	NAD	NAD	NAD	NAD	NAD
TPK	1.50	NAD	NAD	NAD	NAD	NAD	NAD
TPK	2.50	NAD	NAD	NAD	NAD	NAD	NAD

YES – Fibres and/or fragments detected, NAD – No asbestos detected.

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.3 Level 1 Human Health Risk Assessment (Soils) (Cont'd):-

8.3.2 Human Health Risk Assessment - Asbestos Screening (Cont'd):-

The results have identified the following:

- From these results it can be seen that no ACM's or asbestos fibres have been identified within the samples collected across the site.
- Therefore, it can be seen that across the area of the proposed site development there is no requirement for any protective measures to be installed to protect the future site users.

8.4 Level 1 Controlled Waters Risk Assessment (Leachate): -

Based on the results of the soil screening, appropriate leachate screening (generic, PAH & TPH suites) has been carried out on the representative soil samples. A single water sample from TPL within the historically infilled pond / extraction feature has also been screened for generic, PAH and TPH suites with the results used to complete a Level 1 Risk Assessment for the potential impact on controlled waters. A summary of the results for this assessment can be seen in Table 8.4 below and on the following page.

Table 8.4

LEVEL 1 Analyte	Critical Conc. (C_c) mg/kg	Site Data: Max. Conc. (µg/l)	Site Data: Has max. C_T Value Been Exceeded	Site Data: Number of samples >C_T
Generic Contaminants				
Arsenic	50(1)	**57.43**	**YES**	**1 (TPL)**
Boron	2000(1)	567	NO	0
Cadmium	0.45-1.5(1)	0.15	NO	0
Chromium	5-250(1)	27	NO	0
Copper	1-28(1)	13	NO	0
Lead	4-250(1)	9.5	NO	0
Mercury	1(4)	<0.008	NO	0
Nickel	20(1)	14.5	NO	0
Selenium	10(2)	3.41	NO	0
Zinc	8-125(1)	4	NO	0
Cyanide	50(2)	<20	NO	0
Speciated PAH's				
Naphthalene	1.2(1)	0.8	NO	0
Acenaphthylene	0.1(1)	**0.3**	**YES**	**1 (TPL)**
Acenaphthene	0.1(1)	**1.1**	**YES**	**1 (TPL)**
Fluorene	0.1(1)	**0.9**	**YES**	**1 (TPL)**
Phenanthrene	0.1(1)	**3.8**	**YES**	**1 (TPL)**
Anthracene	0.4(1)	**2.2**	**YES**	**1 (TPL)**
Fluoranthene	1.0(1)	**14.3**	**YES**	**1 (TPL)**
Pyrene	0.1(1)	**12.0**	**YES**	**1 (TPL)**
Benzo(a)anthracene	0.1(1)	**7.2**	**YES**	**1 (TPL)**
Chrysene	0.1(1)	**8.7**	**YES**	**1 (TPL)**
Benzo(b)fluoranthene	0.1(1)	**9.5**	**YES**	**1 (TPL)**
Benzo(k)fluoranthene	0.1(1)	**4.1**	**YES**	**1 (TPL)**
Benzo(a)pyrene	0.1(1)	**7.6**	**YES**	**1 (TPL)**
Indeno(123cd)pyrene	0.1(1)	**6.0**	**YES**	**1 (TPL)**
Dibenz(ah)anthracene	0.1(1)	**1.1**	**YES**	**1 (TPL)**
Benzo(ghi)perylene	0.1(1)	**4.7**	**YES**	**1 (TPL)**

(1) = UK EQS for Freshwater, (2) = UK Drinking Water Standard, (3) = Detection limit.

8.0 Level 1 Ground Contamination Risk Assessment (Cont'd)

8.4 Level 1 Controlled Waters Risk Assessment (Leachate) (Cont'd): -

Table 8.4 (Cont'd)

LEVEL 1 Analyte	Critical Conc. (C_C) mg/kg	Site Data: Max. Conc. (µg/l)	Site Data: Has max. C_T Value Been Exceeded	Site Data: Number of samples >C_T
BTEX				
Benzene	50(1)	<1	NO	0
Toluene	50(1)	<1	NO	0
Ethylbenzene	500(1)	<1	NO	0
m & p-Xylene	30(1)	<1	NO	0
Speciated TPH's				
TPH Aliphatic (C5-C6)	10(2)	<1	NO	0
TPH Aliphatic (C6-C8)	10(2)	<1	NO	0
TPH Aliphatic (C8-C10)	10(2)	<1	NO	0
TPH Aliphatic (C10-C12)	10(2)	<10	NO	0
TPH Aliphatic (C12-C16)	10(2)	**114**	**YES**	**1 (TPL)**
TPH Aliphatic (C16-C35)	10(2)	**2697**	**YES**	**1 (TPL)**
TPH Aliphatic (C35-C44)	10(2)	**543**	**YES**	**1 (TPL)**
TPH Aromatic (C5-C7)	10(2)	3	NO	0
TPH Aromatic (C7-C8)	10(2)	**12**	**YES**	**1 (TPL)**
TPH Aromatic (C8-C10)	10(2)	**67**	**YES**	**1 (TPL)**
TPH Aromatic (C10-C12)	10(2)	<1	NO	0
TPH Aromatic (C12-C16)	10(2)	2	NO	0
TPH Aromatic (C16-C21)	10(2)	**33**	**YES**	**1 (TPL)**
TPH Aromatic (C21-C35)	10(2)	**44**	**YES**	**1 (TPL)**
TPH Aromatic (C35-C44)	10(2)	5	NO	0

(1) = UK EQS for Freshwater, (2) = UK Drinking Water Standard, (3) = Detection limit.

- The C_M value for Arsenic exceeds the chosen C_C value for this site within the water sample taken from TPL.
- The C_M values for the majority of PAH analytes exceed the chosen C_C values for this site within the water sample taken from TPL.
- The C_M values for some of the TPH analytes exceed the chosen C_C values for this site within the water sample taken from TPL.
- The remaining C_M values for the generic analytes, Speciated PAH's, BTEX and Speciated TPH's within the water sample, do not exceed the chosen C_C values for this site.
- The C_M values for the generic analytes, Speciated PAH's, BTEX and Speciated TPH's from the leachate results do not exceed the chosen C_C values for this site.

When considering these results, the made ground materials below the site outwith the historically infilled pond / extraction feature do not represent a significant risk to controlled waters. However, it can be seen that the water recorded within the historically infilled pond / extraction feature represents a potential risk to the Controlled Waters, and as such further treatment, removal, protection measures and/or DQRA is considered necessary.

9.0 Conclusions & Recommendations

9.1 Ground Conditions:-

From the findings of the intrusive investigation works, made ground materials comprising disturbed sandy soil, fine to medium sand, firm sandy gravelly clay and sandy clayey gravel, with occasional brick and concrete, were identified at the majority of the exploratory positions, to depths of between c.0.20m and c.1.50m below current ground levels (bcgl).

Exceptions to this were noted at the locations of BH03 & BH05 where shallow bands of black ash gravel, were recorded to a depth of c.0.50m, and TP03 where dolomite gravel surfacing, with occasional ash, was noted to c.0.45m bcgl. In addition, at the locations of TP06, BH07 & BH08 an initial thickness of made ground with brick was also noted to depths of between c.0.50m and c.1.00m, whilst a deeper band of disturbed dark brown sand was noted at TP06 to c.1.10m bcgl. Relic concrete was also encountered at a depth of c.0.50m in TP11 & TP12.

Furthermore exceptions were noted at the locations of TP's G to L in the area of the historically recorded extraction / backfilled water feature where sandy clayey gravel was encountered to a depth of between c.0.30m and c.0.50m underlain by concrete with rebar. TP's G to J were terminated on this concrete with the concrete in TP's K & L broken out to advance the trial pit. This concrete was noted as c.150mm thick and underlain by dolomitic limestone hardcore to a depth of c.1.00m. Made ground was then encountered to a maximum depth of c.2.60m and c.3.50m and comprised black sandy gravel of brick, glass, wood, concrete, rope, pottery, rag, burnt ash, shoes and bottles with an organic peaty odour noted. This made ground is deemed to be associated with the infilled extraction / water feature with the southern edge encountered within TPK and the eastern edge encountered in TPL.

Deeper made ground was also encountered in BHC which encountered a brick obstruction from a depth of c.1.50m to c.3.10m and is possibly associated with an unrecorded buried structure or service in this area.

There was no visual and/or olfactory evidence of significant ground contamination (i.e. fuel-derived hydrocarbon type contaminants, asbestos, etc.) present within any of the trial pits or boreholes undertaken across the site. However, the presence ash was noted contained within the made ground materials at the locations of BH's 03, 05, 07, 08 & TP03 and also to be contained within the made ground materials associated with the historically recorded extraction / backfilled water feature (TP's K & L).

The underlying drift deposits were confirmed to a maximum depth of c.15.00m bcgl's and generally comprised an initial layer of loose and medium dense sand before encountering generally firm to very stiff (initially soft in places) sandy gravelly clay. At the location of TP01, an isolated shallow band of soft very sandy slightly organic clay was also noted to depths of between c.1.45m and c.2.20m bcgl whilst at the location of BHC, the made ground was underlain by sandy gravelly clay with no natural sand encountered.

Grey and dark brown organic silt was encountered between a maximum depth of c.2.60m and c.3.50m within TP's K & L and is deemed to be the natural material at the base of the historically recorded extraction / backfilled water feature. This was underlain by natural sand then firm clay.

The underlying solid deposits were not encountered during the completion of any fieldworks on site. In addition, as part of the completed Phase 1: DTS, it can be seen that the site is not at risk from the presence of shallow coal workings or mining activities.

9.0 Conclusions & Recommendations (Cont'd)

9.2 Groundwater:-

Occasional minor water ingresses were noted within several of the investigation positions during the intrusive works, at the interface between the Shirdley Hill Sand deposits and underlying Boulder Clay. Significant water ingresses were recorded in TP's K & L from a depth of c.1.00m in the historically recorded extraction / backfilled water feature with standing water recorded at a depth of between c.2.00m and c.2.50m on completion.

In addition, from the results of the groundwater monitoring undertaken standing water levels of between c.0.23m and c.1.72m bcgl have been recorded. These water ingresses are considered to be representative of perched shallow surface water trapped within the initial made ground and underlying Shirdley Hill Sands present below the site as a whole.

From the above, it can be seen that shallow water ingresses may become problematic with regards to future excavations for foundations, service runs, etc. In addition, the presence of shallow water within the layers of made ground and sand can lead to instability, and may result in the development of 'running' sand, should excavations extend into or beyond these deposits. Stability of excavations can be improved by using groundwater control techniques to reduce pore water pressures in permeable layers.

Subsequently, in order to minimise the risk of potential instability below the site, it is recommended that an allowance be made for temporary pumping of water, especially during the wetter periods of the year and when excavating in any granular layers where any groundwater appears to be present below the site.

9.3 Foundation Options:-

When considering the ground conditions across the site, made ground materials were generally identified to depths of between c.0.20m up to c.1.50m bcgl before the underlying natural generally firm to stiff (initially loose in places) drift deposits were encountered. As previously highlighted, an exception to this was noted at the location of TP01, where isolated shallow band of soft very sandy slightly organic clay was noted to depths of between c.1.45m and c.2.20m bcgl and at BHC and the historically recorded extraction / backfilled water feature where deeper made ground was encountered.

Taking into account the above, it is possible that traditional shallow foundations (i.e. strip and/or pads) might be considered for the proposed development, with such foundations taken down through the made ground, initial 'loose' sand deposits, slightly organic clay deposits at TP01 and silt deposits at the base of the historically recorded extraction / backfilled water feature and based wholly within the natural clay deposits, at a minimum depth of c.0.75m below finished ground levels, and designed to a maximum allowable bearing pressure of $70kN/m^2$.

From the results of the intrusive works, this would result in foundations being based at depths of between c.0.90m and c.3.60m bcgl, with footings potentially extending into areas where shallow perched groundwater was noted during the intrusive works. Taking this into account, it would be prudent to allow for the introduction of appropriate groundwater control techniques (i.e. pumping equipment, etc.,) prior to and throughout the duration of construction particularly in the area of the historically recorded extraction / backfilled water feature.

Alternatively, it is understood that ground improvement techniques are also being considered for this site to provide a consistent uniform geotechnical platform onto which the new structure and associated infrastructure (car parking, hardstanding etc.) can be constructed. It is anticipated that vibro-stone columns are currently being considered, although some of the softer deposits present, particularly in the area of the historically recorded extraction / backfilled water feature, may require pre-treatment (such as lime stabilization), before completion of the main ground improvement works.

9.0 Conclusions & Recommendations (Cont'd)

9.3 Foundation Options (Cont'd):-

However, if this option were to be utilised due to the numerous types of ground improvement currently available, it is recommend that the information contained within this report is passed onto the preferred specialist contractor, so they can design and price a suitable scheme, particularly as a detailed design lies out with the scope of this report.

In addition, if any deeper pits for large machinery within the commercial units is proposed, these should be constructed with either sheet piles or secant piles to support the excavation walls. These should be based within the underlying natural clay deposits recorded up to a depth in excess of c.15.00m.

From the results of the insitu CBR tests, if any new access roads, areas of hardstanding, car parking, etc., or ground bearing slabs are to be considered without any ground improvement taking place, then based upon the results of these intrusive works a design CBR value of 3.0% is recommended for the natural strata where this is to be used as an undisturbed subgrade.

It is recommended that the sub-grade materials are 'proof rolled' to identify any potential 'soft spots' below this development area, and these can be dealt with introducing an increased thickness of compacted sub-base and/or a geotextile reinforcement. In addition, it may also be prudent to allow for an engineer to attend site during the development works, to confirm the design CBR value of the materials to be utilised prior to construction.

At this stage, when considering the risk to building materials, it is recommended that a concrete design class of DS-1 and ACEC class of AC-2z is used for all foundations and buried concrete outwith the area of TPK

9.4 Hazardous Ground Gas Risk Assessment:-

From the results of the gas monitoring visits, no detectable concentrations of Methane (CH_4) have been recorded. However, concentrations of Carbon Dioxide (CO_2) have currently been recorded up to a maximum level of 4.6%, with negligible flow rates being recorded (<0.1l/hr) on all occasions.

Based on these results, it is felt that the site can be assessed as Characteristic Situation 1 (CS1) indicating that no gas protection would be required for the proposed development.

9.5 Ground Contamination:-

From the results of the contamination screening carried out and the Level 1 Risk Assessment undertaken (Section 8.0), and based on the 'commercial' end use of the site, there is no evidence of site wide heavy or gross contamination which might represent a significant risk to future end-users or Controlled Waters, with the majority of the samples screened falling below the chosen Critical Concentration (C_C) values for this site.

However, contamination has been identified within the trapped water encountered within the historically recorded extraction / backfilled water feature at the location of TPL. Consequently, there is requirement for remediation works, such as treatment, removal, protection measures or further detailed quantitative risk assessment, to be undertaken on this site. There will also be a requirement for the completion of a Remediation Statement and Validation Report.

9.0 Conclusions & Recommendations (Cont'd)

9.5 Ground Contamination (Cont'd):-

In addition to the above, although no significant gross / heavy contamination was identified during the fieldworks, it is deemed prudent to undertake a watching brief during the initial site strip to ascertain that there are no other unknown or unrecorded areas of potential contamination present on this site, particularly at the eastern end where access was restricted during this geo-environmental investigation. If any new areas of potentially contaminated materials are identified then appropriate sampling, screening and risk assessment should be undertaken to determine whether any remedial measures are required.

As part of the development, save for the trapped surface water contained within the historically recorded extraction / backfilled water feature, there is no requirement for any further materials to be removed off site. However, if during the construction works, any of the excavated materials (i.e. made ground, etc.) cannot be accommodated on site, and these materials may need to be removed from site as a waste and disposed of at an appropriate landfill or waste disposal facility. Reference should be made to the notes on off-site disposal within Appendix V, particularly when assessing the likely classification of these materials prior to disposal. Alternatively, consideration may be given to recycling these materials under the new CL:AIRE Definition of Waste: Development Industry Code of Practice.

At this stage, any natural materials (i.e. drift deposits) are likely to be classified as 'inert', provided these materials remain separate from all other materials on site. Finally, although no significantly elevated levels of contamination were identified across the site, it is likely that if the made ground materials are to be removed from site then these materials would be classified as 'non-hazardous', although further testing may be required to confirm this.

In addition, consideration may need to be given to the protection of service pipes for the proposed development from the made ground present, and therefore a supplementary suite of contamination testing may be required in order to meet the requirements of the local utilities service provider for their 'pipe selection risk assessment' (PSRA), once the location and depth of future services have been determined.

When considering the risks to any future maintenance or construction workforce, standard PPE should prove adequate protection against the levels of potential contaminants recorded during these investigation works. Similarly, the results can also be used by the Main Contractor / Project Coordinator, when devising an adequate Site Health & Safety Plan, in accordance with current CDM Regulations. For further guidance reference should be made to the Health and Safety Executive (HSE) document EH40/2005 Workplace exposure limits.

9.6 General Comments:-

For future site works, adequate lateral trench support will be required for excavations, in order to prevent trench wall collapse or over excavations, as well as to create a safe working environment below a depth of 1.20m, and any excavations on this site should remain open for as short a period as possible, since some of these materials may be susceptible to deterioration, if left open to the natural elements for any significant period of time.

It is also recommended for any new developments, adequate surface drainage should be designed and installed by a competent contractor, in order to prevent surface water 'ponding' or collection, during and post construction, particularly where the existing surface drainage system is disrupted or damaged.

9.0 Conclusions & Recommendations (Cont'd)

9.6 General Comments (Cont'd):-

In addition, for deeper excavations, drainage, service runs or the like that may pass close to or beneath any proposed new foundations, these should be undertaken with care and completed prior to the preparation of any new foundations, so as not to allow any loose or granular material to move or 'flow', thus causing settlement to occur to any new foundations based at a higher level.

An "observational technique" can be applied to the design and construction of this site, and where ground conditions seem to vary from that indicated from the conceptual ground model derived from works to date, then advice from a suitably qualified Engineering Geologist/Geotechnical Engineer should be sought.

END OF REPORT

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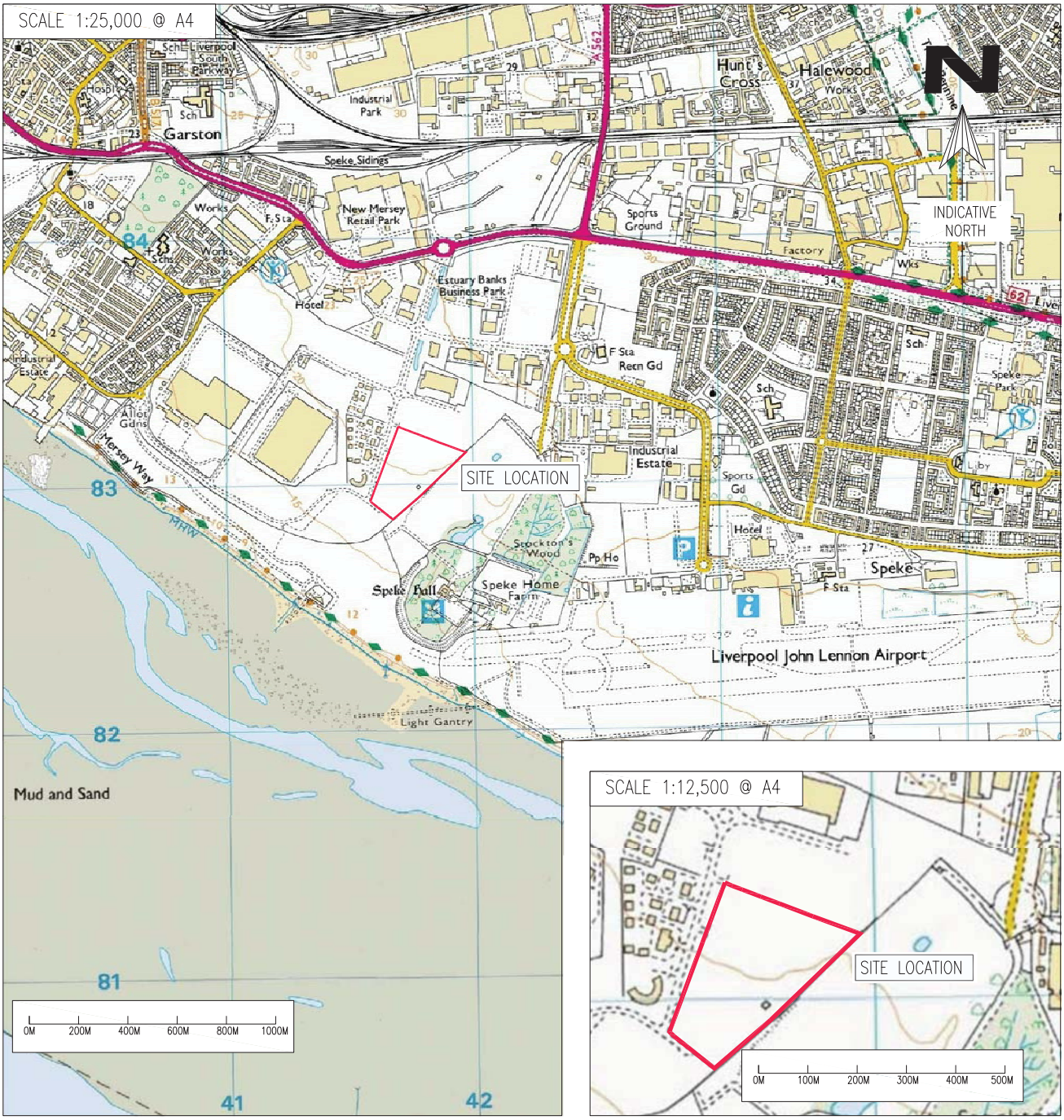
APPENDIX I

Location Plan
Aerial Photograph
Existing & Proposed Site Layout Plans



Client:
ADEPT CONSULTING ENGINEERS LTD

Project Title:	Drawing Title:
Proposed Commercial Development Estaury Boulevard Speke, Liverpool, LS24 8RL	Location Plan

rev.	date	amendments	drawn	chckd

Job Reference:	Drawing Number:	Revision:
16-433	–	–

Drawn by:	Date:	Scale at A4:
P.D	23.05.16	As Shown

Checked by:	Approved by:	
M.P.B	M.P.B	The contractor shall check all dimensions on site before commencement of any works. No dimensions to be scaled off this drawing.

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