GEO-ENVIRONMENTAL ASSESSMENT
THE MACHINE STORE AND PRESSING PLANT
THE OLD VINYL FACTORY, HAYES
PURPLEXED LLP
GEA-19579G-16-230
AUGUST 2016

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

A Geo-Environmental Assessment was requested by Purplexed LLP. The purpose of the assessment was to identify any contaminative or geotechnical issues associated with former land use at *The Machine Store and Pressing Plant, The Old Vinyl Factory, Hayes* which might impact on the site's redevelopment.

SITE DETAILS	
Approximate site area	0.22 ha
Current/previous use	The site is currently derelict. It was previously used as 'The Machine Store and Pressing Plant' for the wider Old Vinyl Factory in Hayes.
Proposed use	The proposed use of the site is understood to comprise a boutique cinema and a residential building including a sub-surface car park.

PHASE 1 NON-INTRUSIVE INVESTIGATION	
Expected geology	Made ground has been encountered during previous site investigations comprising Sand and Gravels of the Lynch Hill Member over London Clay.
Groundwater	The superficial deposits are listed as a Principle Aquifer. The site is not located within a Groundwater Source Protection Zone.
Surface water	The Grand Union Canal is located approximately 200 m north of the site. The River Crane is approximately 900 m south east of the site. The site does not lie within an EA Flood Zone.

PHASE 2 EXPLORATORY INVESTIGATION	
Ground Conditions	The site was covered in hard standing. The underlying geology was sand and gravels (Lynch Hill Gravels) over London Clay.
Contamination	Elevated levels of lead compared to the residential human health screening level were identified within the made ground. Elevated (basic) pH levels were also indicated.
Geotechnical issues	Presence of claystone bands in London Clay should be taken into consideration when piling.

RECOMMENDATIONS	
Geotechnical	Piled foundations are recommended for the hotel and residential block, whilst strip or pad foundations are feasible for the cinema.
Remediation	Building footprints and hardstanding will reduce the risk of exposure to contaminants to future residents. However soft landscaped areas will require clean cover.
Waste classification	Made ground on site is likely to be classified as non-hazardous.

SECTION 1 INTRODUCTION

1.1 Purplexed LLP proposes to develop an area of land located in Hayes, London Borough of Hillingdon for residential and commercial development purposes. The proposed development comprises 'The Pressing Plant' a three screen cinema, and 'The Machine Store', a residential building containing a 6 and 7 storey block above a podium with a two storey sub-surface car park. At ground level the residential building includes a bar and health centre. Idom Merebrook Limited (Merebrook) has been commissioned by Purplexed LLP to undertake preliminary site investigation works and to advise on the geo-environmental implications of the redevelopment of the site for the proposed end use.

1.2 The objectives of the investigation are to:

i. Assess surface and sub-surface ground conditions present at the site;

ii. Identify hazards associated with ground contamination which may place constraints on the site and the proposed development;

iii. Evaluate the risks associated with any identified hazards;

iv. Provide preliminary recommendations for the mitigation of any significant risks identified; and

v. Provide preliminary geotechnical recommendations.

1.3 A Phase 1 (Non-intrusive Investigation) and a Phase 2a (Preliminary Exploratory Investigation) have been undertaken for the subject site.

1.4 This report presents the findings of the geo-environmental investigation and provides an interpretation of the geo-environmental conditions that exist at the site. The contaminative status of the site and the implications with respect to development have been interpreted in accordance with the current government guidance on source-pathway-receptor risk assessment. This report uses a Tier 1 risk assessment to ascribe a conservative qualitative appraisal of the hazards associated with the site.

1.5 This report has been prepared for Purplexed LLP for the sole purpose described above and no extended duty of care to any third party is implied or offered. Third parties making reference to the report should consult Purplexed LLP and Merebrook as to the extent to which the findings may be appropriate for their use.

SECTION 2 PHASE 1 (NON-INTRUSIVE INVESTIGATION)

2.1 INTRODUCTION

2.1.1 Merebrook has previously produced a Phase 1 Environmental Assessment (DS-MER00566-13-58), which should be consulted in conjunction with this report. A summary of the key findings is presented below.

2.2 SITE LOCATION AND SETTING

2.2.1 The site is located to the west of Hayes and Harlington train station in the London Borough of Hillingdon. The wider site is triangular in shape and is approximately 5.6 hectares in size, with the centre of the site located at National Grid Reference TQ 09236 79575. This report covers the development of the proposed Machine Store, adjacent to Blyth Road.

2.2.2 The geology beneath the site consists of Made Ground over Brickearth, Lynch Hill Gravels, London Clay (top of strata 4.6 metres below ground level (m bgl)), Lambeth Group (top of strata approximately 100 m bgl), and the chalk formation (top of strata approximately 130 m bgl). The Lynch Hill gravels are classified as a Principal Aquifer and groundwater flow is in a south easterly direction. The Grand Union Canal is located approximately 200 m to the north of the site. There are no abstraction licenses within 500 m of the site. It is understood, that historically there were six abstractions wells on the site which have since been decommissioned. The site is not located within a Groundwater Source Protection Zone.

2.3 SITE HISTORY

2.3.1 Historic plans show that by 1895, the site was largely undeveloped with a few terraced buildings located along the western boundary. By 1914, the site had been significantly developed with the construction of the gramophone factory. At this time Neptune House formed part of a larger square factory building. By 1993, part of the former gramophone factory was demolished giving rise to the current layout.

2.3.2 The specific parcel history, based on a review of the historic and current maps, dating from 1865 to 2012 is summarised below. Potentially contaminative land uses are shown in **bold**. Copies of key maps used in this review are provided in Appendix 2.

Table 1: Summary of the key features shown on historic maps

DATA SOURCE	SITE / SURROUNDINGS
1865 – 1913 (1:2, 500 scale).	Site is noted as located within larger **Brick Field**.
	Railway situated to the south of site.
1914 – 1934 (1:2,500	**Railway sidings** present on site.
	Gramophone factories now present to the east with

DATA SOURCE	SITE / SURROUNDINGS
scale).	associated **tanks**.
1935 – 1964 (1:2,500 scale).	**Gramophone factories** have expanded to the west and onto current parcel. **Tramways** present on site.
	Two large tanks are present on the western boundary of the parcel.
1965 – 1981 (1:2,500 scale).	Tramways no longer present on site.
	No significant change.
1982 – 1991 (1:2,500 scale).	No significant change.
	One tank now present on eastern boundary of parcel.
1992 – 2012 (1:2,500 scale).	Buildings no longer present.
	No tanks adjacent to eastern boundary.

2.4 RADON GAS

2.4.1 The site does not lie within a Radon Affected Area as defined by the Health Protection Agency as 0 – 1 % of the houses are above the action level. Guidance issued by the Buildings Research Establishment (BRE-211) indicates that no radon protection measures are necessary at the site.

2.5 AIR QUALITY

2.5.1 The site lies within a designated Air Quality Management Area (AQMA) for the London Borough of Hillingdon with reference to NO_2.

2.6 PREVIOUS INVESTIGATIONS

2.6.1 Several investigations were conducted in the wider Old Vinyl Factory Site between 1999 and 2014. The findings of these reports can be summarised as follows:

i. None of the potential inorganic contaminants in the samples analysed (between 1999 and 2010) were reported above their respective screening levels for commercial land use;

ii. No elevated contaminants above the screening levels were reported in any of the natural ground samples analysed;

iii. The majority of the potential organic contaminants were reported below their respective screening levels for the residential land use. However, elevated concentrations of PAHs, particularly benzo (a) pyrene, benzo (a) anthracene and dibenzo (a,h) anthracene were reported above the screening levels in two of the samples analysed;

iv. No elevated concentrations of potential contaminants were reported in the groundwater analysed and as such the risk to groundwater was assessed as Low;

v. No elevated ground gases (methane and carbon dioxide) were recorded in boreholes within the Old Vinyl Factory Site and based on the ground gas risk assessment, no ground gas protection measures were recommended. However, volatile organic contaminants were identified at an off-site location (Gatefold Building) to the south east of the Old Vinyl Factory Site;

vi. High concentrations of phytotoxic metals were identified in limited areas (RPS March 2011 ref: RG/HLEI15948.);

2.6.2 Asbestos containing materials were identified within ducts and tunnels beneath the site, as well as hydrocarbons within one of the ducts to the north of the Porterhouse.

SECTION 3 SITE INVESTIGATION RATIONALE

3.1.1 A site investigation rationale has been devised in accordance with the findings of the Phase 1 investigation and the resultant preliminary conceptual site model and risk assessment.

3.1.2 Intrusive sampling locations were chosen on the basis of providing broad spatial coverage of the site as no obvious features suggesting contaminative use were identified which required targeted investigation.

3.2 SITE INVESTIGATION METHODS

3.2.1 An intrusive investigation was carried out by Merebrook between 12 April and 15 April 2016, and 13 May and 16 May 2016 and comprised the following scope of work:

i. Three cable percussion boreholes (MBH01/16 – MBH03/16) to a maximum depth of 30 metres below ground level (m bgl);

ii. Eight shallow hand dug pits (HDP1 to HDP8) to a maximum depth of 1.3 m bgl; and

iii. Three machine-dug trial holes (MTP1601 to MTP1603) to a maximum depth of 1.6 m bgl.

3.2.2 Exploratory hole locations are indicated on drawing 19579g-304-001 in Appendix 1. Logging of exploratory holes was undertaken by a Merebrook Officer. Exploratory hole logs are contained in Appendix 3.

3.2.3 Light cable percussion equipment was used to advance borehole MBH01/16 to MBH03/16. Standard Penetration Tests (SPTs) were performed at approximate one metre intervals. The tests involved driving a steel cone tipped series of rods

into the ground over a distance of 450 mm using the repeated blows of a 63.5 kg weight allowed to free fall over a distance of 760 mm. The total number of blows required for the final 300 mm penetration (the 'N' value) is recorded on the window sample logs.

3.2.4 Installations (with response zones in the River Terrace Gravels) were installed in boreholes MBH02/16 and MBH03/16.

3.2.5 Representative soil samples were taken from various depths and strata to assess the contaminative status of the site. Soil samples were submitted to an MCERTS/ UKAS accredited laboratory for chemical analysis of a broad suite of potential contaminants. The results are provided in Appendix 4.

3.2.6 A programme of geotechnical laboratory testing was performed on selected soil samples obtained from the boreholes, comprising strength tests. Chemical testing was also undertaken to assess the aggressiveness of the ground with respect to buried concrete. The results are provided in Appendix 5.

SECTION 4 GROUND CONDITIONS

4.1 SURFACE GROUND CONDITIONS

4.1.1 The site was surfaced with tile and linoleum within the offices to the north of site, and tiles over concrete within the warehouse area.

4.2 SUB-SURFACE GROUND CONDITIONS

4.2.1 A suspected basement or duct was identified in the north of the site. The extent of this was not delineated.

4.2.2 The sub-surface ground conditions comprised Made Ground overlying sand and gravel, considered to be the Lynch Hill Member, over a stiff bluish grey clay, considered to be London Clay.

4.2.3 A summary of the ground conditions encountered is presented in Table 2, whilst a more detailed assessment of the strata is contained in the following sections of the report.

Table 2: Summary of Sub-surface Ground Conditions

STRATA	DEPTH TO TOP RANGE (m bgl)	THICKNESS RANGE (m)
Made Ground	0.0	0.2 – 0.8
Sand and Gravel (Lynch Hill Gravel)	0.5	0.3 – 5.3
London Clay	4.5	> 24.0

4.2.4 **Made Ground**

4.2.4.1 Made ground was present in the majority of exploratory holes across the site and comprised variably cohesive and granular soils. These ranged from 0.2 to 0.8 metres in thickness. The gravels comprised flint and brick with inclusions of concrete.

4.2.4.2 There was no visual or olfactory evidence of contamination.

4.2.4.3 No perched water was encountered within this strata.

4.2.5 **Natural Ground**

4.2.5.1 River Terrace Gravels

4.2.5.2 This strata was variably described as orange brown sandy gravels.

4.2.5.3 There was no visual or olfactory evidence of contamination within this strata.

4.2.5.4 SPTs carried out within the Lynch Hill Gravel recorded 'N' values ranging from 25 to > 50, indicating the presence of typically dense to very dense ground conditions.

4.2.5.5 London Clay

4.2.5.6 This stratum was generally described as stiff bluish grey silty sandy clay.

4.2.5.7 There was no visual or olfactory evidence of contamination.

4.2.5.8 Groundwater was reported within this formation in borehole MBH02/16 at a depth of 9.2 m bgl.

4.2.5.9 Triaxial tests were performed on eighteen undisturbed samples of clay obtained from depths of between 6.5 and 29.0 m bgl in the boreholes. The tests revealed average undrained shear strengths ranging from 78 to 266 kN/m². These results are indicative of stiff and very stiff (high and very high strength) ground conditions.

4.2.5.10 SPTs performed within the London Clay recorded 'N' values of between 12 and 40, indicating predominantly stiff and very stiff (high and very high strength) ground conditions.

SECTION 5 PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

5.1 **FOUNDATIONS**

5.1.1 The proposed development comprises a 3-screen cinema and a residential building containing a six and seven storey block above a podium, with two levels of parking below. The residential block also includes a bar and health centre.

5.1.2 The ground investigation has revealed ground conditions consisting of limited thicknesses of made ground (0.4 – 1.4 m thick) underlain by superficial deposits of Lynch Hill Gravel (3.6 – 5.3 m thick). The London Clay was revealed below the

superficial deposits at depths of between 4.5 and 5.8 m bgl, and was proven to a depth of 30.0 m bgl.

5.1.3 SPTs performed within the Lynch Hill Gravel revealed typically dense and very dense grounds, whilst the London Clay was found to be stiff and very stiff (high and very high strength) in nature.

5.1.4 Based on the ground conditions encountered at the site traditional shallow foundations may be feasible for the cinema. Depending on the proposed structural loads strip or pad foundations founded within the natural gravel could be constructed. Allowable bearing pressures of 250 kN/m² are considered to be achievable for 1 m wide strip footings or 1 m x 1 m square pad footings.

5.1.5 In view of the nature of the residential blocks traditional shallow foundations are unlikely to be suitable to safely support the high structural loads. Similarly, ground improvement is considered unlikely to be suitable. Therefore, it is recommended that a piled foundation solution is adopted.

5.1.6 It is envisaged that either driven or bored / Continuous Flight Auger (CFA) piles could be adopted at the site. Driven piles could possibly be utilised as they have the advantage that no arisings are generated, however, the effects of noise / vibrations are likely to be an issue given the proximity of the existing residential development and railway.

5.1.7 The advantage of using bored / CFA piles is the low noise / vibration of the system, however, arisings are generated by bored / CFA piles. Piles would need to be taken through the made ground and superficial deposits to found within the underlying competent London Clay. Allowance will need to be made for boring through claystone bands within the London Clay.

5.1.8 It is recommended that the advice of a specialist contractor be sought in order to determine the most appropriate / cost effective system and to advise on pile diameters, depths and safe working capacity. A guide to safe working loads for individual bored / CFA piles of varying length and diameter is presented in the table below. Pile calculations have been based on assessing skin friction and end bearing resistance in the undisturbed natural strata. No allowance has been made at this stage for any potential drag down (negative skin friction). This should be assessed and allowed for by the designer.

5.1.9 The calculations assume a pile penetrating into the stiff / very stiff natural clay, whilst no contribution from existing fill materials has been allowed for. A factor of safety of 3.0 has been applied to the calculated ultimate capacities. Greater safe working capacities would be achievable if piles were taken to greater depth thereby benefiting from increased skin friction contribution and possible greater end bearing resistance. As discussed, these values are for guidance purposes only and should be verified by a specialist contractor. In addition, the safe working

loads given are for individual isolated piles. The group effect should be assessed during the design stage.

Table 3: Safe Working Capacities for bored / CFA Piles

Pile Diameter (mm)	Length (m)	Safe Working Capacity (kN)
300	10	120
	15	245
	20	410
450	10	195
	15	390
	20	645
600	10	280
	15	550
	20	900

5.1.10 Due consideration will need to be given to the adoption of a pile testing programme at the site. It is usual practice to carry out load and integrity tests on a proportion of the installed working piles in order to verify acceptability of the design loads. A specialist piling contractor may recommend that a load test be carried out on at least one sacrificial pile installed in advance of the works. The sacrificial pile/piles should not form part of the permanent works and should be tested to failure in order to assess ultimate capacity.

5.2 EXCAVATIONS AND GROUNDWATER

5.2.1 Based on the ground conditions observed at the site, any shallow excavations have the potential to become unstable in the short term, therefore, if man-entry is required, excavations should be supported by shoring or otherwise battered back to a safe angle in order to protect the workforce from possible collapse.

5.2.2 A basement is proposed beneath the majority of the new structures and is likely to be around 2 – 3 m deep. At these depths the basement excavation will be founded within the Lynch Hill Gravel which contains groundwater. Due to the size and depth of the excavation required, the excavation sides will need to be supported by a permanent structure, such as a contiguous / secant bored pile wall or sheet piled wall, or a temporary structure such as a cofferdam type construction. This will

enable groundwater control measures to be put in place prior to construction of the basement and new buildings. Any permanent or temporary works design will need to allow for groundwater pressures and dewatering.

5.2.3 Groundwater strikes were recorded at depths of 3.5 and 9.2 m bgl in MBH02/16 during the intrusive investigation, whilst resting levels in MBH02/16 and MBH03/16 ranged from 3.04 to 3.29 m bgl. In view of this, it is considered likely that groundwater ingress will occur in shallow excavations, therefore, provision for dewatering during the construction period should be considered.

5.3 FLOOR SLABS

5.3.1 A basement is proposed beneath the majority of the proposed footprints, with a likely formation level in the granular deposits. The basement floor slab will form the underground car parking and based on a formation level within the granular deposits it is considered likely that a ground bearing floor slab could be adopted. In view of the presence of groundwater at relatively shallow depth the basement floor slab may need to be designed to accommodate hydrostatic pressures.

5.4 RETAINING WALLS

5.4.1 As discussed above the basement excavation will need to be supported by a permanent or temporary structure. This is most likely to comprise a sheet pile wall driven into the Lynch Hill Gravel and possibly founded within the stiff clay below. If the sheet pile wall is to form a permanent structure consideration should be given to the potential for corrosion of the wall.

5.4.2 A guide to suitable soil parameters / lateral earth pressure coefficients for use in the preliminary design of a retaining wall is given in the Table 4 below. The parameters given are based primarily on SPT data, classification tests and published information.

Table 4: Summary of Soil Parameters for Preliminary Retaining Wall Design

SOIL	C' (kN/m²)	Φ' (°)	γ_{dry} (kN/m³)	γ'_{sat} (kN/m³)	K_a	K_0	K_p
Made Ground	0	23	17	19	0.39	0.6	3.1
Dense Sand and Gravel	0	41	21	22	0.17	0.3	12.0

Key:

c′ = Cohesion

Φ′ = Angle of shearing resistance

γ'_{dry} = Bulk unit weight (dry)

γ'_{sat} = Bulk unit weight (saturated)

K_a = Active earth pressure coefficient

K_0 = At rest earth pressure coefficient

K_p = Passive earth pressure coefficient

5.5 BURIED CONCRETE

5.5.1 Recommendations given in BRE Special Digest 1:2005 *"Concrete in aggressive ground"* have been followed in order to give recommendations with respect to buried concrete.

5.5.2 Water soluble sulphate analysis was carried out on twenty-two soil samples obtained from depths of between 0.3 and 27.0 m bgl with soil pH determination also carried out on these samples. Water soluble sulphate contents ranged between 0.023 and 0.88 g/l. In accordance with BRE guidelines the characteristic value is calculated by determining the mean of the highest 20 % of results. In this case the characteristic value is 0.78 g/l. On this basis the Design Sulphate Class is DS-2.

5.5.3 The pH values in the soil samples varied between 7.7 and 10.2. The mean of the lowest 20 % of values is 8.0 which represents the characteristic value. Mobile groundwater conditions have been assumed and on this basis the Aggressive Chemical Environment for Concrete (ACEC) class for the site is AC-2.

5.5.4 The London Clay is a pyrite bearing soil. When disturbed and exposed to air and mobile groundwater oxidation can occur leading to the formation of sulphates. In accordance with BRE guidance further chemical testing has therefore been carried out on samples of the London Clay in order to determine total sulphate content and total sulphur content.

5.5.5 The results indicate that pyrite is present within the London Clay, and as such consideration should be given to adjusting the Design Sulphate Class for the site. However, this requirement need only apply where significant disturbance of the London Clay occurs, potentially leading to pyrite being exposed to air and mobile groundwater. Provided there is the minimum of delay between boring piles and placing concrete the London Clay may be considered as undisturbed in this case. Therefore, no adjustment to the initial Design Sulphate Class of DS-2 and the ACEC class of AC-2 is considered necessary.

5.6 ROADS AND PAVED AREAS

5.6.1 For preliminary design purposes it is recommended that a California Bearing Ratio (CBR) value of 2 % is assumed for the made ground. Once the positions of proposed roads and areas of hardstanding have been finalised, *in situ* testing could be undertaken to determine an appropriate design CBR value.

5.7 SOAKAWAYS

5.7.1 The recent ground investigation has revealed the presence of natural granular soils at shallow depth across the site. The granular nature of these soils suggests that these will be suitable for use as a soakage medium, however, the feasibility of drainage via infiltration methods at this site will depend on the design criteria and regulatory requirements, which will include consideration of the thickness of the unsaturated zone, i.e. the depth to groundwater.

SECTION 6 ENVIRONMENTAL ASSESSMENT

6.1 SOIL QUALITY

6.1.1 A total of 10 soil samples were submitted to the laboratory for chemical analysis, including nine samples from made ground and one sample from natural ground. The laboratory chemical analysis certificates are contained in Appendix 4. The results of the analysis are summarised in Table 5.

6.1.2 An initial screening exercise has been undertaken whereby contaminant concentrations recorded in soils have been assessed against *Suitable for Use Levels* (S4ULs) published in 2015 by LQM/CIEH[1]. These precautionary screening levels are designed to be representative of minimal risk to human health in a number of land use scenarios. In this report S4ULs have been selected for a residential land use where the possibility of consumption of homegrown produce does not exist (Table 5) (selected as being the most conservative proposed land use).

6.1.3 An additional set of phytotoxin screening levels have been adopted from 'The Code of Agricultural Practice for the Protection of Soil' Ministry of Agriculture, Fisheries and Food (MAFF), 1993, which are protective of healthy plant growth.

Table 5: Summary of Soils Chemical Analysis Results

CONTAMINANT	UNITS	MAX	MEAN	No of Tests	SCREENING LEVEL (SL)	No > SL*
HUMAN HEALTH RISK ASSESSMENT						
Asbestos in soil	-	0	0	7	Detected	0
pH	-	10.2	9.14	10	5 – 9	2
Arsenic	$mg.kg^{-1}$	44	20	10	40	1
Cadmium	$mg.kg^{-1}$	0.2	0.2	10	85	0
Chromium (total)	$mg.kg^{-1}$	31	23.5	10	910	0
Hexavalent Chromium	$mg.kg^{-1}$	<4.0	n/a	10	6	0
Lead	$mg.kg^{-1}$	510	258.6	10	310	4
Mercury	$mg.kg^{-1}$	3.9	1.65	10	56	0

[1] Nathanail, C. P., McCaffrey, C., Gillett, A. G., Ogden, R. C. and Nathanail, J. F. 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham. Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3100. All rights reserved. Includes August 2015 nickel update.

CONTAMINANT	UNITS	MAX	MEAN	No of Tests	SCREENING LEVEL (SL)	No > SL*
HUMAN HEALTH RISK ASSESSMENT						
Nickel	$mg.kg^{-1}$	33	23.6	10	180	0
Selenium	$mg.kg^{-1}$	1	1	10	430	0
TPH Aliphatic >EC_5 - EC_6	$mg.kg^{-1}$	0.1	0.1	10	42	0
TPH Aliphatic >EC_6 - EC_8	$mg.kg^{-1}$	0.1	0.1	10	100	0
TPH Aliphatic >EC_8 - EC_{10}	$mg.kg^{-1}$	1	0.28	10	27	0
TPH Aliphatic >EC_{10} - EC_{12}	$mg.kg^{-1}$	2	1.25	10	130	0
TPH Aliphatic >EC_{12} - EC_{16}	$mg.kg^{-1}$	100	16.15	10	1100	0
TPH Aliphatic >EC_{16} - EC_{21}	$mg.kg^{-1}$	560	89.1	10	65000	0
TPH Aliphatic >EC_{21} - EC_{35}	$mg.kg^{-1}$	1300	300.5	10	65000	0
TPH Aromatic >EC_5 - EC_7	$mg.kg^{-1}$	0.1	0.1	10	70	0
TPH Aromatic >EC_7 - EC_8	$mg.kg^{-1}$	0.1	0.1	10	130	0
TPH Aromatic >EC_8 - EC_{10}	$mg.kg^{-1}$	0.1	0.1	10	34	0
TPH Aromatic >EC_{10} - EC_{12}	$mg.kg^{-1}$	3.6	1.46	10	74	0
TPH Aromatic >EC_{12} - EC_{16}	$mg.kg^{-1}$	74	13.23	10	140	0
TPH Aromatic >EC_{16} - EC_{21}	$mg.kg^{-1}$	300	55.6	10	260	0
TPH Aromatic >EC_{21} - EC_{35}	$mg.kg^{-1}$	560	97.2	10	1100	0
Benzene	$mg.kg^{-1}$	<1.0	n/a	10	0.087	0
Toluene	$mg.kg^{-1}$	<1.0	n/a	10	130	0
Ethylbenzene	$mg.kg^{-1}$	<1.0	n/a	10	47	0
Xylene	$mg.kg^{-1}$	<1.0	n/a	10	56	0
Acenaphthene	$mg.kg^{-1}$	0.54	0.15	10	3000	0
Acenaphthylene	$mg.kg^{-1}$	0.1	0.1	10	2900	0
Anthracene	$mg.kg^{-1}$	9.4	1.06	10	31000	0
Benz(a)anthracene	$mg.kg^{-1}$	0.96	0.33	10	11	0
Benzo(a)pyrene	$mg.kg^{-1}$	0.57	0.26	10	3.2	0
Benzo(b)fluoranthene	$mg.kg^{-1}$	0.54	0.26	10	3.9	0
Benzo(ghi)perylene	$mg.kg^{-1}$	0.34	0.8	10	360	0
Benzo(k)fluoranthene	$mg.kg^{-1}$	0.47	0.23	10	110	0
Chrysene	$mg.kg^{-1}$	1.1	0.46	10	30	0
Dibenz(ah)anthracene	$mg.kg^{-1}$	0.1	0.1	10	0.314	0
Fluoranthene	$mg.kg^{-1}$	3.9	1.25	10	1500	0
Fluorene	$mg.kg^{-1}$	0.51	0.15	10	2800	0
Indeno(123-cd)pyrene	$mg.kg^{-1}$	0.27	0.12	10	45	0
Naphthalene	$mg.kg^{-1}$	0.56	0.13	10	2.3	0
Phenanthrene	$mg.kg^{-1}$	9.7	2.29	10	1300	0
Pyrene	$mg.kg^{-1}$	3.2	0.97	10	3700	0
Phenol	$mg.kg^{-1}$	<1.0	n/a	10	440	0
PHYTOTOXICITY RISK ASSESSMENT						
	Units	**Max**	**Mean**	**No of Test**	**Screening Level (SL)**	**No > SL**
Copper	$mg.kg^{-1}$	210	87.9	10	200	0
Nickel	$mg.kg^{-1}$	33	23.6	10	110	0

CONTAMINANT	UNITS	MAX	MEAN	No of Tests	SCREENING LEVEL (SL)	No > SL*
HUMAN HEALTH RISK ASSESSMENT						
Zinc	$mg.kg^{-1}$	120	81.7	10	300	0

6.1.4 **Zootoxic Metals (harmful to human health)**

6.1.4.1 The residential screening level for lead was exceeded in the following samples of made ground: MBH01/16 at 0.6 m bgl, MBH02/16 at 0.3 – 0.9 m bgl, HDP1 at 0.5 – 0.7 m bgl and HDP8 at 0.4 m bgl.

6.1.5 **Phytotoxic Metals (harmful to plant health)**

6.1.5.1 There were no exceedances of phytotoxic metal screening values within the samples analysed.

6.1.6 **Organic Contaminants**

6.1.6.1 There were no exceedances of organic contaminant screening levels within the samples analysed.

6.1.7 **Inorganic Contaminants**

6.1.7.1 Within the made ground samples analysed from BH01/16 at 0.6 m bgl and MTP1602 at 0.7 - 0.9 m bgl, the pH levels were found to be elevated (pH 10.1 and pH 10.2 respectively) This is likely to have been due to the presence of concrete that was noted within these strata.

6.1.7.2 Asbestos was not detected in any of the samples analysed.

6.1.8 **Summary**

6.1.8.1 The made ground at the site is locally impacted by lead, a rare arsenic exceedance and sporadic elevated pH levels.

6.1.8.2 None of the respective screening levels for human health were exceeded within the sample from natural ground and there appears to be little impact on natural soils.

6.2 **GROUNDWATER**

6.2.1 Groundwater level monitoring and sampling was undertaken on 16 May 2016. Resting waters levels were recorded at 3.04 – 3.1m bgl.

6.2.2 Samples were submitted to the laboratory for analysis of a typical contamination suite. Screening levels for groundwater have been derived from the Maximum Allowable Concentrations (MAC) in the Water Supply (Water Quality) Regulations 2010 where prescribed, or for those determinands not included, the 1989 regulations. The laboratory chemical analysis certificate is contained in Appendix 6

and groundwater level data is contained in Appendix 7. A summary of groundwater contaminant concentrations is contained in Table 6.

Table 6: Summary of Groundwater Chemical Analysis Results

CONTAMINANT	UNITS	MAX	MEAN	SCREEN LEVEL (SL)	>SL*
pH	-	8.1	7.8	6.5**	0
Arsenic	$\mu g.l^{-1}$	1.13	0.7	10	0
Cadmium	$\mu g.l^{-1}$	0.05	0.035	5	0
Chromium (total)	$\mu g.l^{-1}$	<5.0	n/a	50	0
Copper	$\mu g.l^{-1}$	2.7	2.4	2000	0
Lead	$\mu g.l^{-1}$	<0.2	n/a	10	0
Mercury	$\mu g.l^{-1}$	<0.05	n/a	1	0
Nickel	$\mu g.l^{-1}$	5.9	4.1	20	0
Selenium	$\mu g.l^{-1}$	1.6	1.25	10	0
Zinc	$\mu g.l^{-1}$	2.5	2.45	5000	0
Cyanide	$\mu g.l^{-1}$	22	16	50	0
Sulphate	$mg.l^{-1}$	156	145.5	250	0
TPH	$\mu g.l^{-1}$	<10	n/a	10	0
BTEX	$\mu g.l^{-1}$	<1.0	n/a	-	0
PAH (total)	$\mu g.l^{-1}$	<0.16	n/a	-	0
PAH****	$\mu g.l^{-1}$	<0.01	n/a	0.1	0
Benzo(a)pyrene	$\mu g.l^{-1}$	<0.01	n/a	0.01	0
Naphthalene	$\mu g.l^{-1}$	<0.01	n/a	-	0
Phenols	$\mu g.l^{-1}$	<10	n/a	0.5	0

Notes: * Samples exceeding screen level
** Minimum value applies (i.e. most acid)
*** Not detected above screening level
*** sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene & indeno(1,2,3-cd)pyrene

6.2.3 There is no evidence of contamination within the groundwater present below this portion of the site.

6.2.4 It is acknowledged that contamination of groundwater by hydrocarbons was present on an off-site land parcel to the east of the subject site. However remediation has subsequently taken place and the Machine Store and Pressing Plant site is noted to be up hydraulic gradient from any residual contamination.

6.3 HAZARDOUS GAS

6.3.1 Gas monitoring has been undertaken on two occasions – 13 May and 9 June 2016. Levels of methane, carbon dioxide and oxygen were recorded in each standpipe, together with associated parameters including borehole flow and ambient air pressure. The results of these gas monitoring rounds are contained in Appendix 7.

6.3.2 The monitoring rounds were undertaken at barometric pressures ranging from 1005 to 1022 mb. Positive flow was recorded within MBH02/16 at 0.4 l hr^{-1}. Over

the two monitoring rounds methane (CH_4) was not detected, carbon dioxide (CO_2) was detected to a maximum of 0.6 % v/v with a corresponding depleted oxygen concentration of 19.8 % v/v.

6.4 WASTE CLASSIFICATION, OFF-SITE DISPOSAL OR RE-USE

6.4.1 Waste Considerations

6.4.1.1 Results obtained indicate that made ground soil arisings would be classified as non-hazardous for waste disposal purposes. No Waste Acceptance Criteria (WAC) analysis has been undertaken as part of the recent investigation. Some landfills may require WAC for waste disposal purposes and confirmation should be sought from the operator as to their site-specific requirements.

6.4.1.2 Natural as-dug arisings (excluding topsoil) could be classed as inert waste without the requirement for WAC testing.

6.4.1.3 Materials, including waste soils which are not to be retained on site, should be removed and disposed of in accordance with all relevant statues including the *Environmental Protection Act 1990*, *The Controlled Waste Regulations 2012* as amended, *The Waste Regulations 2011* as amended, *The List of Wastes Regulations 2005* as amended, *The Hazardous Waste Regulations 2005* as amended, *The Waste Management Regulations 2006* and *The Environmental Permitting Regulations 2010* as amended.

6.4.1.4 It is a requirement of these regulations that waste sent to landfill should have been subject to measures to reduce the amount of waste, reduce harmful or hazardous properties and facilitate recycling. These requirements may be satisfied by measures such as segregation and screening of wastes to recover suitable fill and material for crushing, segregation of inert materials and putrescible wastes.

6.4.2 Re-use Considerations

6.4.2.1 As a sustainable alternative to off-site disposal, it may be possible to re-use site-won soils provided the following criteria are met:

i. Use of the material will not create an unacceptable risk of pollution to the environment or harm to human health;

ii. The material must be chemically and geotechnically suitable without further treatment;

iii. There must be certainty of use within the scheme;

iv. Material should only be used in the quantity necessary for that use.

6.4.2.2 Provided these criteria are met, the re-use of site-won materials is unlikely to be deemed a waste activity. Production of a *Materials Management Plan* under the

industry *CL:AIRE Code of Practice on the Definition of Waste* represents a robust method of demonstrating that proposed re-use of materials meets the criteria.

SECTION 7 RISK ASSESSMENT

7.1 The potential sources of contamination at the site and the implications with respect to development have been interpreted in accordance with the current government guidance on source-pathway-receptor risk assessment.

7.2 The investigations demonstrate that the former uses of the site have resulted in rare arsenic, sporadic lead contamination and elevated (basic) pH levels within the made ground. These materials are considered for their potential to act as sources for a number of pollutant linkages.

7.3 The potential impacts of contamination sources have been considered with respect to the following receptors:

i. The general public and present site users,

ii. Residents of future development,

iii. Groundwater,

iv. Surface water,

v. Construction workers,

vi. Adjacent land, and

vii. Infrastructure.

7.4 In each case the existence of a pollutant linkage requires a pathway by which the receptor could be exposed to the source. A qualitative assessment of risk is thus considered in the first instance with respect to the site in its current condition and is summarised in the sections below.

7.5 **The general public and present site users**

7.5.1 The site is accessed through a locked construction site, adjacent to the subject site's western boundary. The site is also predominantly covered in hardstanding.

7.5.2 Given that access is restricted and contact with the underlying soils is generally precluded, the risk to the general public and present site users is therefore deemed to be negligible.

7.6 **Residents of future development**

7.6.1 <u>Soil contamination (chemical)</u>

7.6.1.1 Arsenic and lead contamination has been identified within the made ground.

7.6.1.2 The proposed development comprises a large underground basement, with the majority of made ground being removed from site. The proposed development includes very little soft landscaping at ground level, with the majority of amenity space being located at podium or roof level..

7.6.1.3 In the limited areas where soft landscaping is being introduced at ground level, there is a risk of exposure to any retained made ground, and remedial measures comprising the introduction of a clean cover system will be required to mitigate the risk.

7.6.1.4 The risk to future residents is therefore considered to be low, with the introduction of clean cover in areas of soft landscaping.

7.6.2 Asbestos

7.6.2.1 No asbestos fibres or asbestos containing fragments were encountered within the samples sent for analysis. Nevertheless, the buildings are considered to have been built during a period when asbestos containing materials were used for construction and site workers should remain vigilant for the presence of asbestos containing materials.

7.6.2.2 The risk to construction workers and future residents is considered to be low to moderate. The introduction of a clean cover system will mitigate the risk to future residents, however construction workers should be aware of the findings of any asbestos survey and controlled demolition practices will be required.

7.6.3 Hazardous Soil Gas/Vapours (including hydrocarbon vapours/radon)

7.6.3.1 The site does not lie within a radon affected area.

7.6.3.2 CIRIA C665 / BS 8485 (2015) guidance has been followed to assess the recorded soil gas and flow conditions. Based upon the two rounds of gas monitoring undertaken, results indicate that gas protection measures are not considered necessary (Characteristic Situation 1). The development of an underground car park should also provide good ventilation.

7.7 **Controlled waters**

7.7.1 The low levels of soil contamination do not suggest a risk to wider controlled waters via leaching and migration of contamination.

7.7.2 There were no exceedances of the screening levels in the groundwater samples retrieved from MBH02/16 and MBH03/16.

7.7.3 No significant risk to surface waters and groundwater is considered to be present.

7.8 **Construction workers**

7.8.1 Potentially, construction workers are initially at the greatest risk from exposure to hazardous contamination due to excavation works and during the handling of

materials including imported soils. Providing that dust levels are kept within statutory limits and appropriate health and safety procedures are adhered to during the construction phase, the levels of chemical contamination recorded to date are not considered to present an acute risk to human health.

7.9 **Adjacent land**

7.9.1 The low contamination levels found on site are unlikely to present a risk to adjacent land due to the limited contaminant mobility. As such there is not considered to be a significant risk to adjacent land from site-derived contamination.

7.10 **Infrastructure**

7.10.1 There were no elevated concentrations of phytotoxic contaminants detected during the recent site investigation. The investigation of this site has indicated elevated pH (basic) levels within the made ground. Previous site investigations did indicate minor potential contamination within the made ground that could pose a risk to plants. Areas of soft landscaping within the proposed development are understood to be limited. Due to the unsuitable nature of made ground as a growth medium, the provision of suitable topsoil / subsoil will be required in soft landscaped areas.

7.10.2 Limited contamination with the potential to permeate polymeric services has been identified by this investigation, however it is recommended that the utility provider is consulted with respect to their requirements for water supply pipes.

7.10.3 Utility companies apply strict guideline levels on use of polymeric pipes and may consider all made ground unsuitable for typical plastic pipe materials to be used.

SECTION 8 UPDATED CONCEPTUAL MODEL

8.1 Following completion of phases 1 and 2 of the investigation and a qualitative risk assessment, the conceptual model for the site, with relation to pollutant linkages, has been updated. The revised model is presented in Table 7 below.

Table 7: Revised Conceptual Model

POSSIBLE POLLUTANT LINKAGE			RISK CHARACTERISATION
POTENTIAL SOURCES	**PATHWAYS**	**RECEPTORS**	
Heavy metals and hydrocarbons (made ground)	Contact with contaminated soil	Human health (current users)	**No risk identified** No significant contamination identified and no plausible pathway given current hardstanding.
	Ingestion and inhalation of contaminated soil and dust	Human health (current users)	
Heavy metals and hydrocarbons (made ground)	Contact with contaminated soil	Human health (future residents)	**Low risk identified** Elevated levels of lead and elevated pH (basic) levels identified within the made ground. However the proposed development is predominantly hardstanding with limited areas of soft landscaping. Clean cover required in areas of soft landscaping.
	Ingestion and inhalation of contaminated soil and dust	Human health (future residents)	
Heavy metals and hydrocarbons (made ground)	Contact with contaminated soil	Human health (construction workers)	**Low risk identified** Elevated levels of arsenic, lead and elevated pH (basic) levels identified within the made ground. The adoption of health and safety procedures will mitigate potential risk.
	Ingestion and inhalation of contaminated soil and dust	Human health (construction workers)	
Asbestos (made ground)	Ingestion and inhalation of contaminated soil and dust	Human health (future residents and construction workers)	**Low to Moderate risk** No asbestos fibres or asbestos containing materials identified within the made ground. Buildings are considered to be constructed during a period that asbestos containing materials were utilised.
Contamination (all forms)	Vertical migration to aquifer	Controlled waters	**Low risk identified** No significantly leachable contamination identified.
Contamination (all forms)	Horizontal migration to surface water	Controlled waters	**Low risk identified** The closest surface water feature to site is 200 m to the north. No contamination was detected within the groundwater samples. Soil contamination does not appear to be particularly mobile. Groundwater flow is towards the south east.
Hydrocarbons	Direct contact	Plastic water pipes	**Low to Moderate risk identified** Potential for localised areas of minor contamination on the site as per previous site investigations. Majority of made ground will be removed to accommodate basement car park. Utility providers should be contacted with respect to water supply pipes.

POSSIBLE POLLUTANT LINKAGE			RISK CHARACTERISATION
POTENTIAL SOURCES	PATHWAYS	RECEPTORS	
Hazardous Gas/Vapours In soil	Ingress into buildings and voids	Human health (future residents and construction workers)	**Low risk identified** The site does not lie within a radon affected area. Based on the two rounds of gas monitoring undertaken the study site has been classified as very low risk, Characteristic situation 1 and no gas protection required.
Adjacent Land	Horizontal migration	Future residents/adjacent land	**Low risk identified** No significantly leachable contamination identified

SECTION 9 PRELIMINARY REMEDIATION STRATEGY

9.1 The identified risks at the site can be mitigated by removal of either the source, pathway or receptor. With reference to the conceptual model for the site a remediation strategy, based on source or pathway removal, has been designed.

9.2 The chemical analysis results indicate the made ground is impacted by arsenic, lead and occasional elevated (basic) pH levels, with the potential to impact upon human health.

9.3 The development plan shows that the majority of the site will be covered with buildings and hardstanding. These structures will remove the pollution pathway and reduce the possibility of exposure to the identified contamination. However any soft landscaped public open space areas should be remediated with a clean cover thickness of 300 mm, comprising 150 mm of topsoil and 150 mm of subsoil, thereby reducing the risk to future users.

9.4 Material imported for the formation of domestic gardens and landscaped areas should be obtained from a validated source. The validation should incorporate an assessment of the provenance of the material and chemical analysis.

9.5 Potential risks to construction workers have been identified and the adoption of appropriate Health and Safety procedures will ensure that risks to operatives from hazardous materials at the site are minimised. Operatives should not be allowed to eat, drink or smoke on site except in designated areas and should be required to wash all exposed skin at the end of each shift. Operatives should be informed of the potential hazards at the site and should be required to report any observations of suspect material.

9.6 Materials, including waste soils which are not to be retained on site, should be removed and disposed of in accordance with all relevant statues including the *Environmental Protection Act 1990*, *The Controlled Waste Regulations 2012* as amended, *The Waste Regulations 2011* as amended, *The List of Wastes Regulations 2005* as amended, *The Hazardous Waste Regulations 2005* as

amended, *The Waste Management Regulations 2006* and *The Environmental Permitting Regulations 2010* as amended.

9.7 It is recommended that this report is submitted to the regulators (Local Authority EHO and Planners, Environment Agency Planning Liaison and NHBC) for approval prior to commencement of the works.

9.8 Any observations of ground conditions atypical of those already described should be reported to Merebrook immediately so that an assessment of appropriate action can be made.

SECTION 10 CONCLUSIONS

10.1 Ground conditions revealed from the site investigation have encountered variable thicknesses of made ground (up to 0.8 m bgl) underlain by Lynch Hill Gravels over London Clay.

10.2 Piled foundations are recommended for the residential block, whilst consideration could be given to adopting strip or pad foundations for the cinema. A basement is proposed beneath the majority of the proposed residential footprints, with a likely formation level in the granular deposits. The basement floor slab will form the underground car parking and it is considered likely that a ground bearing floor slab could be adopted. Buried concrete classes DS-2 and AC-2 will apply for foundation concrete, whilst a CBR value of 2 % should be assumed for preliminary design of roads and hardstanding.

10.3 The investigation has identified rare arsenic and elevated lead concentrations in the made ground, when compared to the residential screening values. Elevated (basic) pH levels have also been identified within the made ground. The proposed development includes predominantly hard standing and a sub-surface level car park with only limited areas of soft landscaping. The car park and associated hard surfaces will effectively cap the area, breaking any pollutant linkages. In the limited areas of soft landscaping, there will be a requirement for 300 mm of clean cover.

APPENDIX 1 ▪ Drawings