Church Road, Garston

Proposed Skate Park

Desk Study & Ground Investigation Interpretative Report

May 2014

For Liverpool City Council

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EXECUTIVE SUMMARY

Introduction	Mouchel has been commissioned by Liverpool City Council to provide a combined desk study and interpretative ground investigation report in relation to the proposed skate park at Church Road, Garston. This report assesses the potential environmental and geotechnical risks and liabilities associated with the proposed development.
Site Setting	The site is located in the Garston area approximately 6km to the south east of Liverpool city centre and covers approximately 2 hectares. The site is currently an unmanaged wooded area located along the top of a former railway sidings. Historically, a sandstone quarry and waterbody were present prior to being infilled. The underlying bedrock is a Principal Aquifer and Stalbridge Dock which connects to the Mersey Estuary is present 61m to the south west.
Ground Investigation	A ground investigation was undertaken to assess the site soils, groundwater and ground gas regime to identify any potential risks to future site users of the proposed skate park as well as to controlled waters, structures associated with the skate park i.e. foundations and adjacent site users. Three cable percussion boreholes with gas / groundwater monitoring installations, eight windowless sampler holes and eight trial pits were excavated at the site. Laboratory chemical and geotechnical testing was also undertaken as well as post fieldwork gas / groundwater monitoring.
Ground Model	The geology encountered comprised made ground up to depths of 13.1m bgl as well as natural gravel, clay and sandstone. No methane or gas flow were detected during the monitoring period. Carbon dioxide was present up to 1% and carbon monoxide up to 1ppm.
Human Health Risk Assessment	Only arsenic was present in excess of the screening value and subsequent statistical analysis indicated that there is not considered to be a risk to human health. The assessment of the gas monitoring results shows that the concentrations of ground gases at the site do not pose a significant risk to site users due to the low concentrations of gas and the absence of flow.
Controlled Waters Risk Assessment	The assessment to consider the risk to the underlying bedrock aquifer and Mersey Estuary from soil leachate at the site indicated elevated concentrations of arsenic, cadmium, copper, zinc, mercury, TPH and PAH at isolated locations across the site. However, given the margin of the exceedences, as well as considering factors such as dilution, degradation and migration, it is unlikely that these exceedences pose a significant risk to the underlying bedrock aquifer or the adjacent Mersey Estuary.
Geotechnical Assessment / Preliminary Design	The nature of the made ground is low strength and high variability so settlement and cracking of the skate park surface could be expected unless these deposits are thoroughly compacted. A minimum 150mm compacted granular layer is recommended beneath the skate park surface to minimise the risk of settlement but this risk cannot be wholly eliminated. Other structures such as ramps and rails would require foundations. These would normally be within the natural ground but this is considered impracticable at this site due to the depth to natural deposits. Foundations within the made ground will need to be designed to spread the load to a low bearing pressure and be tolerant of differential settlement. Significantly loaded raised areas or structures would require the foundation load being transferred to the underlying natural ground by deep foundations. The design sulphate classification for the foundation soils is DS-1. The Aggressive Chemical Environment for Concrete (ACEC) classification for the site is AC-1, assuming mobile groundwater.
Conclusions / Recommendations	There are no remedial measures required with regard to human health, property or the environment. Geotechnical measures are recommended in relation to the construction of the skate park to prevent potential differential settlement and hence cracking to the skate park structures.

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1 Introduction

1.1 Terms of Reference

Mouchel has been commissioned by Liverpool City Council to provide a risk assessment in relation to the proposed skate park at Church Road, Garston. This report assesses the potential environmental risks and liabilities associated with the proposed development and the public open space end use as well as including information pertinent to the geotechnical design.

1.2 Development Proposals/Legislative Context

It is understood that a skate park is to be developed onsite. The construction of the skate park will be subject to planning permission.

The presence of contaminants which may pose a risk to human health or the environment is a material planning consideration. For planning it should be considered whether the site is suitable for its proposed use, and the responsibility for securing a safe development (including cumulative effects of pollution on health, and the potential sensitivity of the proposed development to adverse effects from pollution) rests with the developer and/or landowner. Planning is concerned with the site's proposed use not its current use, where the amount of contamination is required to be low relative to the level of risk. This is the opposite to Part 2A which considers high levels (significant harm) and the current use of the site.

Section 57 of the Environment Act 1995, adds Part 2A (ss.78A-18YC) to the Environmental Protection Act 1990 and contains the legislative framework for identifying and dealing with contaminated land. Where development is undertaken on land which may be affected by contamination, the National Planning Policy Framework, paragraphs 120 to 122 considers pollution and remediation. This links the contaminated land regime within the development process.

For there to be an environmental liability associated with the site there must be a perceived source (a contaminant), a receptor (humans, living organisms or property) and a pathway between them. The potential presence of all of these aspects would result in a complete contaminant linkage.

1.3 Objectives and Scope

The objective of this study is to assess the potential environmental risks and geotechnical abnormals associated with the development of the skate park at the site and its use as a public open space.

The scope of work comprises:-

- A site walkover undertaken by a suitably qualified Environmental Scientist,
- Summary of the information obtained from a Groundsure Report,
- A preliminary risk assessment of the potential environmental risk following the methodology of CLR11 and CIRIA C552,
- Design and undertaking of a preliminary intrusive investigation,
- Completion of a generic quantitative risk assessment with regard to risk to human health and the environment,
- Summary of the geotechnical ground conditions and recommendations in order to facilitate the design of the skate park structures,
- Recommendations for further actions / remediation if required.

2 Desk Study Research

2.1 Site Location

The site is located in the Garston area approximately 6 km to the south east of Liverpool city centre. The site is centred on National Grid Reference (NGR) 340147, 384177 and covers approximately 2.02 hectares.

Figure 1 presents the site location and Figure 2 shows the current site layout.

2.2 Site Setting and Description

A site walkover was undertaken by a qualified Mouchel Geo-Environmental Engineer on 10th December 2013. The site on that day is described below.

The site is currently an unmanaged wooded area located along the top of a section of former rail sidings. The site is typically higher than the surrounding land and is approximately 15m higher than land immediately adjacent to the western boundary. The difference between the site level and surrounding ground level increases from east to west.

The general site topography is relatively uneven. There is a path that extends through the centre of the site in an approximate north east to south west direction. This path is relatively flat and extends into small areas of flat grassland. The land drops away steeply just beyond southern, western and northern sections of the site boundary.

Fly-tipped material was observed in isolated patches across the site. This material included abandoned furniture, shredded tyres, small mounds of brick/hardcore and layers of ash across the central path. Three burnt out areas, indicative of small fires, where also observed on site.

An uncovered manhole, partially filled in, was observed in the north western corner of the site. No other service features were recorded on site.

This area is freely accessible to the public via concrete stairs located adjacent to the end of Dale Street. A ramp, adjacent to these stairs, represents the only point of access for plant machinery that may be used in a future site investigation.

Palisade fencing is present beyond the northern, eastern and western site perimeter. Much of the southern boundary remains unfenced.

2.3 Adjacent Land Use

The table below summaries the adjacent land uses.

Table 1: Summary of Adjacent Land Use

Direction	Surrounding Land Use
North	Derelict land / railway
West	Industrial / Stalbridge Dock
South	Residential
East	Derelict land / church / industrial (gasholder)

2.4 Environmental Designations and Ecology

The Mersey Estuary 398m to the south west is classified as a Site of Special Scientific Interest (SSSI) and 434m to the south west, a Special Protection Area (SPA) and a RAMSAR site.

No invasive weeds such as Japanese Knotweed were noted during the site walkover however, it should be noted that the walkover was not undertaken by a trained ecologist.

2.5 Site History

Historical mapping for the site has been provided as part of the Groundsure Report and is presented in Appendix A.

2.5.1 On Site

The earliest available mapping from 1851 shows that there was a small sandstone quarry present onsite as well as a watercourse / waterbody.

By 1891, the sandstone quarry appeared to be infilled and the waterbody had increased in size covering most of the southern half of the site. The waterbody was labelled 'The Dingle' on the 1891-93 mapping and had been entirely infilled by 1904-05. The site was shown as open land at this time.

Railway lines had been added adjacent to the northern boundary by 1907 with the whole site occupied by railway lines by 1927.

The railway lines in the south eastern half of the site had been removed by 1980 with the remainder removed by 1981-86 when the whole site was labelled as a dismantled railway.

No further changes appear to have been made to the site since the mid 1980s.

2.5.2 Surrounding Area

The earliest available mapping from 1851 shows a corn mill to the immediate east of the site and railway lines to the north west and west. Hiltons Farm was present 250m to the south with Garston village beyond the railway to the north.

By 1891, the farm to the south was no longer present and the railway lines to the north west and west covered a larger area. A large unnamed building was present 250m to the south and residential properties, excavations and ponds to the east.

The corn mill has become a spice mill by 1893 and the excavations and ponds to the east were labelled a brickfield. A manganese mineral works was located 150m to the south east at this time.

By 1904-05, the spice mill was no longer present and a gasworks (which remains currently) had been developed 100m to the east. The brickfield and ponds to the east had been infilled and residential properties had been added to this area at this time. The large unnamed building to the south was labelled a tannery and a smithy was present 150m to the north east of the site.

A saw mill was added 100m to the east by 1907 and had been removed by 1927 when a foundry was added 25m to the east and tanks 50m to the south of the site. A dock (later labelled Stalbridge Dock) had been excavated and developed 100m to the south west and the whole area to the north west and west was occupied by railway lines and sidings.

The foundry to the east had been extended by 1951-52 and a molasses depot was present 75m to the south.

By 1960-64, the foundry to the east was labelled a works, the tanks to the south a depot, the saw mill to the east a mill and the manganese mineral works to the south east a works.

The area of residential properties to the immediate south east had been demolished by 1965-67 and the tannery to the south labelled a works.

By 1971, the northernmost part of the former foundry was a scrapyard. The depot to the south was disused and the former manganese mineral works was no longer present. Railway lines located 100m to the north west of the site were part of a container depot at this time.

Residential properties were added to the immediate south east in 1980 where previous ones had been demolished. Some of the railway lines to north west / west had been dismantled and the molasses depot to the south was no longer present.

By 1981-86, the scrapyard had become a tyre depot and the mill to the east was no longer present. Further railway lines / sidings to the north west / west had been dismantled. Garston Way (road) had been added 100m north with factories and works adjacent.

A warehouse was added 150m to the west in 2002 and all the railway lines to the immediate north west / west had been dismantled and the land left derelict. The residential properties to the south east had been demolished and rebuilt in a new (current) layout.

No further significant changes appear to have been made to the surrounding area since the early 2000s.

2.6 Geology

2.6.1 Artificial Ground

The Groundsure Report indicates the presence ground workings within the site area related to an unspecified pit and a waterbody. These are now infilled. As such, made ground is likely to be present due to the previous site use, built up nature of the land compared to the surrounding area as well as these infilled features.

2.6.2 Drift Geology

The drift geology map (BGS Sheet 97, 1:50,000) indicates that there are no drift deposits present underlying the site.

2.6.3 Solid Geology

The solid geology map (BGS Sheet 97, 1:50,000) indicates that the site and the surrounding area is underlain by the Chester Pebble Beds Formation. These are cross stratified sandstone which is fine to coarse grained, commonly pebbly with conglomerates and sporadic siltstones.

2.6.4 BGS Borehole Logs

There are no available BGS borehole logs onsite or within the immediate vicinity as those that are present are all listed as confidential.

2.7 Hydrogeology

The Chester Pebble Beds Formation is classified as a principal aquifer. These are layers of rock or drift deposits that have high intergranular and / or fracture permeability which usually provide a high level of storage and may support water supply / river base flow on a strategic scale.

There are no groundwater source protection zones (SPZs) within 500m of the site.

There is one current groundwater abstraction licence located within 500m of the site. Groundwater is abstracted from a well at King Street, Garston 310m south east for use as a process water.

There is one licensed discharge consent located within 500m of the site. Final / treated sewage effluent is discharged to groundwater via a soakaway located at Weaver Industrial Estate 432m to the south.

2.8 Hydrology

The nearest surface water is Stalbridge Dock located 61m to the south west.

There are no surface water abstractions within 500m of the site.

The site is not located within a flood risk zone.

2.9 Waste Management Facilities and Environmental Permits

There are two current IPPC authorised activities present within 500m of the site. Veolia ES (UK) Ltd operates a waste recovery process involving the distillation of organic solvents 409m to the south. Cheshire Chemicals Ltd operates the same process at their plant located 478m to the south east.

There is one current Part B activity within 500m of the site. Hanson Premix located 372m to the west operates a bulk cement batching process.

There is one historic landfill located within 500m of the site. This is located 368m to the east at Banks Road. There are no details regarding the type or volume of waste deposited.

There are three other current licensed waste sites within 500m of the site. An inert waste transfer station is operated by Bomacks Construction Ltd 268m to the south on Blackburn Street. A household / commercial / industrial waste transfer station operated by Associated British Ports is located 392m to the west. Finally, a vehicle depollution facility is located 473m to the south on Blackburn Street.

2.10 Pollution Incidents

There have been eleven pollution incidents reported within 500m of the site. These are detailed in the table below.

Table 2: Summary of Pollution Incidents

Distance / Direction	Pollutant	Classification
124m south east	Waste - tyres	Category 3 (minor) - air
290m south east	Waste - household / commercial	Category 2 (significant) - land Category 3 (minor) - air
296m north west	Solvents	Category 3 (minor) - water
299m south east	Waste - construction and demolition material, electrical equipment,	Category 2 (significant) - land & air

Distance / Direction	Pollutant	Classification
	commercial and asbestos	
325m north east	Not identified	Category 4 (no impact) - land, air & water
330m south east	Smoke, asbestos, firefighting runoff	Category 2 (significant) - land Category 3 (minor) - air
365m south	Organic chemical / product	Category 3 (minor) - water & land
379m north west	Hydraulic oils	Category 3 (minor) - water
410m south	Organic chemical / product	Category 3 (minor) -water, land & air
413m south	Organic chemical / product	Category 3 (minor) -water, land & air
463m west	Not given	Category 3 (minor) - water

2.11 Current Land Use

There are twenty five potentially contaminative land uses within 250m of the site. These include electricity substations, vehicle repair / testing / services facilities, factory / works and a gas holder station.

There are four current hazardous substance consents within 500m of the site. These relate to British Gas located 167m to the south east, Associated British Ports for storage of ammonium nitrate fertiliser located 313m to the west, Veolia ES (UK) Ltd 437m to the south and Hays Chemicals located 453m to the south.

There are three NIHHS site buffer zones located within 500m of the site. These are 76m south east (British Gas), 224m south east (Coastal Container Services Ltd / Mersey Container Terminals Ltd) and 291m south (Hays Chemicals Ltd).

There are no fuel stations located within 500m of the site.

2.12 Ground Gas and Radon

The presence of an infilled lake on site as well as the previous use of the site as railway sidings means that made ground is likely to be located on site and therefore, ground gas such as methane and carbon dioxide may be present.

The site is not located within a radon affected area as less than 1% of properties are above the action level.

2.13 Ground Stability

The table below summarises the natural hazards findings presented in the Groundsure Report.

Table 3: Summary of Potential Natural Hazards

Natural Hazard	Hazard Potential
Shrink - Swell Clay	Negligible
Landslides	Very Low
Soluble Rocks	Null - Negligible
Compressible Deposits	Negligible
Collapsible Deposits	Very Low
Running Sands	Negligible

2.14 Services Information

Services information was obtained prior to the site investigation; these plans confirmed that no recorded services are present at the site.

3 Preliminary Assessment

3.1 Preliminary Ground Model

The site contains an infilled quarry and infilled lake as well as being previously occupied by railway lines / sidings. As such, there is the potential for contaminated made ground to be present across the whole site.

The surrounding area (within 250m) has contained a variety of current and historic potentially contaminating uses. These include railway line / sidings, a farm, a corn / spice mill, a brickfield (now infilled), a gasworks (now gas holder station), a tannery, a foundry, depots, a saw mill and a scrapyard / tyre depot.

There are no drift deposits present underlying the site so there will be limited or no protection of the underlying principal aquifer.

Stalbridge Dock which links to the Mersey Estuary is present 61m to the south west. This is likely to the lined.

3.2 Potential Contaminant Linkages

The Conceptual Site Model (CSM) has been complied in accordance with BS10175 and CLR11 and builds on the ground model by the identification of sources, pathways and receptors, illustrating the possible contaminant linkages.

For there to be any environmental liability, there must be a source i.e. something capable of causing pollution or harm, a receptor and a viable pathway between them i.e. a contaminant linkage. If one of these elements is missing, there can be no significant risk. If all are present, then the magnitude of risk is a function of the magnitude of the pollutant, the sensitivity of the receptor and the nature of the migration pathway.

It should be noted that any investigation or development of the site could actually create new pathways which could increase the liabilities associated with the site.

3.2.1 Sources

The previous uses of the site include a sandstone quarry (now infilled) and railway lines / sidings (now dismantled). There was also a lake on site (The Dingle) which was subsequently infilled.

The surrounding area has included railway lines / sidings, farm, corn / spice mill, brickfield (infilled), gasworks, manganese mineral works, tannery, foundry, depots, saw mill and scrapyard.

The on and offsite uses may have resulted in contamination being present onsite. The likely contaminants associated with these previous uses include - heavy metals, cyanide, phenols, asbestos, polyaromatic hydrocarbons (PAHs), petroleum hydrocarbons (TPH), acid and alkaline pHs, semi volatile and volatile organic compounds, polychlorinated biphenyls (PCBs) and herbicides.

Furthermore, ground gases such as methane and carbon dioxide may be generated by any fill materials / made ground, particularly if the organic content of this material is high.

Table 4: Source of contamination

Ref	Primary source	Expected distribution	Likely contaminants
S1	Potentially contaminated soil onsite	Due to the presence of an infilled quarry / lake and railway lines / sidings, contaminants could be present across the whole site	Metals, cyanide, phenols, asbestos, polyaromatic hydrocarbons, petroleum hydrocarbons, acid and alkaline pHs, semi volatile and volatile organic compounds, polychlorinated biphenyls, and herbicides.
S2	Potentially contaminated soil offsite	Due to the presence of potentially contaminative uses in the vicinity of the site, contaminants may have migrated onto site.	Metals, cyanide, phenols, asbestos, polyaromatic hydrocarbons, petroleum hydrocarbons, acid and alkaline pHs, semi volatile and volatile organic compounds, polychlorinated biphenyls, and herbicides.

3.2.2 *Receptors*

The most sensitive receptors are considered to be the users of the proposed skate park.

Other receptors include groundwater (principal aquifer), surface water (Stalbridge Dock) and structures associated with the skate park.

Table 5: Receptors

Ref	Receptor	Description
R1	Site Users	The site is to be redeveloped as a skate park.
R2	Groundwater (Principal aquifer)	The bedrock beneath the site is classified as a principal aquifer.
R3	Surface Water (Stalbridge Dock)	Stalbridge Dock is located approximately 61m to the south west.
R4	Structures	There may be concrete structures present associated with the skate park such as bowls and ramps.
R5	Adjacent site users	Residential properties are located to the south of the site.

3.2.3 *Pathways creating contaminant linkages*

The potential pathways for contaminants to reach receptors are highlighted and discussed in the table below.

Table 6: Pathways

Ref	Pathway	Description
P1	Dermal contact with contaminants in soil	Site users may come into contact with contaminants present within the soil onsite via dermal contact.
P2	Ingestion of soil / soil dust	Site users may ingest contaminants present in the soil via hand to mouth transfer and ingestion of soil dust.
P3	Inhalation of soil dust / gas / vapours	Site users may inhale soil dust / gas and vapours.
P4	Leaching and migration	Contaminants present on and adjacent to the site may leach / migrate into the principal aquifer underlying the site.

Ref	Pathway	Description
P5	Vertical and lateral migration of soil gas / vapours	Soil gas / vapours onsite may migrate offsite.
P6	Direct contact with contaminants	Structures such as concrete bowls / ramps associated with the skate park may be in direct contact with contaminated soil.

3.3 Risk Evaluation

Each potential contaminant linkage is identified in Table 7 below. Figure 3 provides a visual CSM which outlines the contaminant linkages discussed in the table below.

An evaluation of the risk that each contaminant linkage poses to the site has been undertaken in general accordance with CIRIA guidance document C552, 2001 (as detailed in Appendix B).

The evaluation and the resultant actions identified are based on the available information presented within this report.

Table 7: Risk Evaluation of Potential Contaminant Linkages

1. Hazard Identification		2. Hazard Assessment				3. Risk Estimation		4. Risk Evaluation	5. Managing the Risk
Contaminant Source		**Pathway**		**Receptor**		**Consequence of risk being realised**	**Probability of risk being realised**	**Classification**	**Action required**
S1	Potentially contaminated soil on site	P1	Dermal contact with soil	R1	Site Users	Medium	Low	Moderate / Low	It is possible that harm could arise to these receptors. Investigation is required to clarify the risks and determine the potential liability. Some remedial measures may be required in the long term.
		P2	Ingestion of soil / soil dust			Medium	Low	Moderate / Low	
		P3	Inhalation of soil dust / gas / vapours			Medium	Low	Moderate / Low	
		P4	Leaching and migration	R2	Groundwater - principal aquifer	Medium	Likely	Moderate	
				R3	Surface Water - Stalbridge Dock	Mild	Low	Low	
		P5	Vertical / lateral migration of soil gas / vapours	R5	Adjacent site users	Severe	Unlikely	Moderate / Low	
		P6	Direct contact with contaminants	R4	Structures associated with the skate park	Mild	Likely	Moderate / Low	

1. Hazard Identification		2. Hazard Assessment				3. Risk Estimation		4. Risk Evaluation	5. Managing the Risk
Contaminant Source		**Pathway**		**Receptor**		**Consequence of risk being realised**	**Probability of risk being realised**	**Classification**	**Action required**
S2	Potentially contaminated soil offsite	P4	Leaching and migration leading to P1 / P2 / P3	R1	Site users	Medium	Unlikely	Low	
		P4	Leaching and migration	R2	Groundwater - principal aquifer	Medium	Low	Moderate / Low	

3.4 Potential Waste and Sustainability Considerations

Should any of the material onsite be deemed to pose an unacceptable risk to receptors or be geotechnically unsuitable after a site investigation and assessment of the findings, this material may need to be remediated or removed from site. Material may also need to be removed from site as part of the skate park construction. Should any disposal be necessary, consideration will need to be given to testing of the material for disposal to landfill. Any material to be removed from site will need to be assessed to establish the materials acceptability to landfill by comparison to the concentrations within the Waste Acceptance Criteria (WAC) limits.

Samples can be tested using Waste Acceptance Criteria testing in accordance with testing method BS EN 12457-3 in order to assess the materials acceptability to landfill.

3.5 Safety, Health and Environment Considerations

Site personnel involved with any investigation work should be appropriately qualified with experience of working on potentially contaminated sites. Appropriate personal protective equipment (PPE) should be worn by person working in close proximity to fill materials and a reasonable standard of hygiene maintained.

To eliminate any risk from hand to mouth transfer of potentially harmful material, smoking, eating and drinking should be prohibited within the working area and prior to washing hands.

3.6 Geotechnical Considerations

The probable geology described in Section 2.6 indicates that the sandstone bedrock (Chester Pebble Beds Formation) is directly overlain by Made Ground associated with the infilling of ‘The Dingle’ / quarry as well as the construction of the railway sidings. A substantial thickness of made ground may be present, of variable but unknown content. This is expected to provide low bearing resistance and high settlement beneath any redevelopment of the site. The ground investigation chapters following provide more details.

4 Ground Investigation

4.1 Design Rationale and Scope

The rationale for the investigation was to assess the site soils, groundwater and ground gas regime to identify any potential risks to future site users of the proposed skate park as well as to controlled waters, structures associated with the skate park and adjacent site users. This investigation will also provide information relating to the geotechnical conditions at the site which will assist in determining the foundation design for the skate park structures.

The scope of the investigation was as detailed below:

- Three cable percussion boreholes to a nominal depth of 15m with standard penetration tests (SPTs)
- Eight windowless sampler holes to a nominal depth of 5m with SPTs
- Eight machine excavated trial pits to a nominal depth of 4.5m
- Three gas / groundwater monitoring installations (within cable percussion boreholes)
- Chemical and geotechnical laboratory analysis

4.2 Fieldwork

The intrusive investigation was undertaken by Ian Farmer Associates and monitored by Mouchel. Ian Farmer Associates carried out the drilling of the exploratory holes as well as the logging and soil sampling. Subsequent gas / groundwater monitoring and groundwater sampling of the monitoring installations was carried out by Mouchel.

The investigation was carried out in general accordance with the following standards:

- BS5930:1999 Code of practice for site investigations, as modified by BS14688 for soil and rock descriptions;
- BS10175:2011 Code of Practice for the Investigation of Potentially Contaminated Sites.

- Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination, 2001 (Environment Agency).

The table below summarises the exploratory holes undertaken at the Church Road, Garston site.

Table 8: Summary of Site Activities

Activity	Date Undertaken	Exploratory Hole Reference	Maximum Depth
Cable percussion boreholes with gas / groundwater installations	20th - 24th February 2014	BH01 - BH03	13.30m
Windowless sampler holes	20th - 21st February 2014	WS01 - WS08	5.45m
Machine excavated trial pits	24th February 2014	TP01 - TP08	4.4m

The location of the exploratory holes is shown on the figure provided within the Ground Investigation Factual Report which is presented in Appendix C. The exploratory hole logs are presented in this Factual Report.

The three cable percussion boreholes were installed with gas / groundwater monitoring standpipe with details of these installations summarised in the table below.

Table 9: Gas / Groundwater Monitoring Installation Details

Exploratory Hole Reference	Type of Installation	Depth of Response Zone (m bgl)	Response Zone Stratum
BH01	50mm standpipe	1.00 - 13.00	Made Ground
BH02	50mm standpipe	1.00 - 12.20	Made Ground
BH03	50mm standpipe	1.00 - 6.00	Made Ground

Gas monitoring and groundwater monitoring was undertaken on a three occasions in the month following the completion of the site investigation. Groundwater sampling was carried out during the first monitoring visit.

Details of monitoring programme carried out at the Church Road, Garston site are given in the table below.

Table 10: Gas and Groundwater Monitoring Programme

Exploratory Hole Reference	Monitoring Visit 1 05/03/2014	Monitoring Visit 2 16/03/2014	Monitoring Visit 3 21/03/2014
BH01	Gas / groundwater monitoring, dry - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring
BH02	Gas / groundwater monitoring, insufficient water - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring
BH03	Gas / groundwater monitoring, insufficient - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring

Groundwater sampling was planned during the first monitoring visit but all the installations were either dry or did not recharge after purging so no groundwater samples were obtained from the site.

Copies of the monitoring records are included in Appendix D.

4.3 Chemical Laboratory Testing

Soil samples were obtained during the drilling of the cable percussion boreholes, window sampler holes and excavation of the trial pits.

All soil samples were stored in airtight containers appropriately labelled and transported in cool boxes with ice packs maintained at 4°C, under completed chain of custody documentation. SAL Ltd are appropriately accredited for the analysis required and are an approved supplier under the Mouchel Quality Management System.

The testing suite was based on the types of contaminants expected to be associated with an area of land previously occupied by railway sidings as well as containing an infilled pond and sandstone quarry.

4.3.1 Soils

The table below outlines the soil analysis undertaken on samples taken from the proposed skate park site at Church Road, Garston.

Table 11: Summary of Soil Analysis

Suite Reference	Analysis	No. of Samples Scheduled
Soil Suite	Metals - arsenic, cadmium, chromium, hexavalent chromium, copper, nickel, mercury, lead, selenium, zinc	19
	pH	19
	Asbestos	19
	Total cyanide	19
	Soil organic matter	19
	Total phenols	19
	Speciated 16 PAHs	19
	Total petroleum hydrocarbons (TPHCWG)	19
	PCB 7 congeners	19
	PCB WHO 12	19
	Semi volatile organic compounds (SVOCs)	19
	Volatile organic compounds (VOCs)	19

The results of the soil chemical analysis are presented in Appendix E.

4.3.2 Leachate

The table below outlines the soil leachate analysis undertaken on selected soil samples taken from the proposed skate park site at Church Road, Garston.

Table 12: Summary of Leachate Analysis

Suite Reference	Analysis Suite	No. of Samples Scheduled
Leachate Suite	Metals - arsenic, cadmium, chromium, hexavalent chromium, copper, nickel, mercury, lead, selenium, zinc	14
	pH	14
	Total cyanide	14
	Total phenols	14
	Speciated 16 PAHs	14
	Total petroleum hydrocarbons (TPHCWG)	14

The results of the soil leachate chemical analysis are presented in Appendix E.

4.4 Geotechnical Laboratory Testing

A summary of the geotechnical tests scheduled on soil samples taken from the proposed skate park site at Church Road, Garston is given in the table below.

Table 13: Summary of Geotechnical Laboratory Testing

Geotechnical Test	Test Method	No. samples scheduled
Classification/Compaction		
Moisture Content	BS1377: Part 2: 1990; Clause 3	8
Liquid / plastic limits	BS1377: Part 2: 1990	8
Particle Size Distribution	BS1377: Part 2: 1990; Clause 9	16
Recompacted California Bearing Ratio	BS1377: Part 4: 1990; Clause 7.4	8
Determination of dry density/moisture content relationship (2.5kg hammer)	BS1377: Part 4: 1990	8
Chemical (tests on soils and groundwater)		
BRE SD1 Suite – acid soluble / water soluble sulphate, pH, Total Sulphur	TRL Report 447	8

The results of the geotechnical laboratory analysis are presented in Appendix C.

5 Ground Model

5.1 Topography and Geomorphology

The site is typically higher than the surrounding land and is approximately 15m higher than land immediately adjacent to the western boundary. The difference between the site level and surrounding ground level increases from east to west. The general site topography is relatively uneven. The land drops away steeply just beyond southern, western and northern sections of the site boundary.

5.2 Geology

The geology recorded during the investigation was consistent with the expected geology noted during the desk study phase of the investigation.

A brief description of the encountered geology is presented in the sections below. Exploratory hole logs are presented in Appendix C.

5.2.1 Made Ground

Made ground was encountered at each of the exploratory hole locations across the site. The overall proven thickness varied between 6.4m in BH03 in the eastern part of the site and 13.1m in BH01 in the western part of the site. The base of the made ground was proven in the three deep cable percussion holes as well as in WS06 and WS08 which were located in the eastern part of the site.

There were two distinctive types of made ground encountered at the site. The upper made ground comprised a dark grey sand and gravel with clinker, ash, brick and sandstone with occasional wood fragments. This was present from the ground surface in all the exploratory holes with the exception of TP06, TP07 and TP08. These were excavated into the side of the slope in the south eastern part of the site.

The underlying made ground comprised an orange / red brown sand and gravel with cobbles and clayey pockets with sandstone, brick, ash and clinker as well as occasional wood and metal fragments. This material was encountered across the site.

No visual or olfactory evidence of contamination was noted during the investigation.

5.2.2 Natural Ground

Natural superficial deposits comprising a very dense silty sandy gravel was encountered in BH02 only in the central part of the site.

Sandy, gravelly clay was present in both WS06 and WS08 in the western part of the site.

Bedrock was encountered as a weak, medium to coarse grained sandstone that as encountered at 6.4m bgl in BH03 in the east and at 13.1m bgl in the west of the site.

5.3 Groundwater

Groundwater was only encountered in one exploratory hole, BH02, during the site works. This was a strike at 12m at the top of the gravel which rose to 10m after 20 minutes.

BH01 was dry throughout the monitoring period. From the groundwater levels encountered in BH02 and BH03 recorded during the monitoring period, the hydraulic gradient appears to be from east to west towards the River Mersey.

5.4 Chemical Distribution

The concentrations of metals and hydrocarbons vary throughout the made ground across the site. No specific area appears to contain the highest concentrations.

5.5 Ground Gas

The gas monitoring results show that carbon dioxide was recorded up to 1% and carbon monoxide up to 1ppm. Methane, hydrogen sulphide were absent as was any flow.

6 Human Health Risk Assessment

6.1 Soils

6.1.1 Methodology

Based on the Preliminary Risk Assessment and Ground Model (see Section 0) for this site, a Generic Quantitative Risk Assessment for human health has been undertaken in accordance with CLR and SR (SC050021 series) (DEFRA) guidance and comprises the following:

- selection of appropriate generic screening values for human health assessment;
- creation of relevant datasets from which to undertake the assessment;
- assessment of contamination distribution and comparison of site data to screening values using the approach outlined in the CL:AIRE / CIEH guidance;
- assessment of risks to receptors;
- determination of requirements for further investigation or remediation.

Selection of Soil Screening Values

It is understood that the Church Road, Garston site that has been investigated is to be redeveloped as a skate park. As such, the chemical data has been screened against a generic public open space scenario.

The Environment Agency (EA) has not produced any Soil Guideline Values (SGVs) for this land use. Mouchel have developed the public open space scenario based upon the generic allotments scenario with the plant uptake pathways disabled. This scenario considers a 0-6 year old female who visits site regularly but is not living above any contaminant plume that may be present. The model does not include the consumption of site grown vegetables. Time is spent outdoors only, with exposure varying during child development. However, cadmium, which was released by the EA as a SGV in July 2009, is based on a lifetime exposure as cadmium builds up over time in the kidneys. As such, cadmium has been assessed for a public open space land use for a 75 year period (lifetime exposure).

The SOM concentrations averaged 11.9% across the site. As such, all the data has been compared against a public open space scenario at 6% SOM which reflects a more site specific screening value.

A detailed description of the derivation of GAC's has been included in Appendix F.

Creation of Relevant Datasets

It is not known if site levels will change during the works. Therefore all the soil samples from the made ground encountered have been assessed as one population.

6.1.2 Assessment

The human health risk assessment has been carried out in accordance with the CL:AIRE / CIEH guidance.

The purpose of the assessment is to determine whether there is sufficient evidence that the true mean of the population falls below the critical concentration (screening value) i.e. that the site is uncontaminated and suitable for the intended end use.

Statistics are used to assist in answering the key question raised above and to help decide whether to support a particular hypothesis. The Null Hypothesis is the starting point because it is believed to be true but needs to be proved.

In terms of planning, the hypotheses are as follows:

- Null hypothesis (H_0) - the true mean concentration is equal to, or greater than, the critical concentration;
- Alternative hypothesis (H_1) - the true mean concentration is less than the critical concentration.

The null hypothesis needs to be rejected in order to confirm that the land is uncontaminated and suitable for the proposed end use under the planning regime.

Identification of Contaminants of Concern

Potential contaminants of concern (CoC) have been identified where any exceedences of the critical concentrations have been noted.

A screening table displaying the outcome of this initial screening has been produced and is displayed in Appendix G and a summary of this is included in the table below.

Table 14: Identification of Contaminants of Concern

Determinand	Critical Concentration	Range of concentrations	Number of exceedences
Arsenic	130	5 - 140	1 / 19

All concentrations in mg/kg.

* - some detection limits for samples tested were also in excess of the critical concentration.

The following CoC have been identified during this initial screening:

- Arsenic

All the other determinands recorded concentrations that were lower than the critical concentration so have been discounted from any further assessment as there is not considered to be a risk from these contaminants.

Statistical Analysis

As detailed above, exceedences were recorded for arsenic . As such, this CoC was taken forward for further assessment including the use of statistical assessment as detailed with the CL:AIRE / CIEH guidance.

The following steps were undertaken:

- With regard to non-detects, where the proportion of these within the dataset was less than 15%, the non detect value was replaced with the value of the method detection limit. Where the proportion was greater than 15%, the non detect value was replaced with a value representative of half that of the method detection limit as per the guidance.

- Outliers - Grubb's Test was performed to determine if any of the concentrations represented statistical outliers. The dataset has been visually checked and any apparently anomalous readings have been investigated i.e. by checking the field logs and checking the laboratory results for any data entry issues. Unless it could be determined that the outlier was the result of a reporting error or represented part of a separate dataset, the value remained within the dataset for assessment.

Non detects and outliers were dealt with as above and the sample mean was calculated and compared against the critical concentration.

Where the sample mean was greater than the critical concentration, the assessment was stopped as the null hypothesis cannot be rejected i.e. the true mean must be greater than the critical concentration, therefore there is considered to be a risk to human health from this CoC and further action is required to deal with this contaminant.

Where the sample mean was lower than the critical concentration, further statistical analysis was carried out for that CoC.

The table below summarises the outcome of the sample mean comparison with the critical concentration.

Table 15: Sample Mean Concentration

CoC	Sample Mean	Critical Concentration	Outcome
Arsenic	39.32	130	May be possible to reject null hypothesis - true mean may be less than critical concentration

All concentrations in mg/kg.

For arsenic, it may be possible to reject the null hypothesis and determine that the site is suitable for its proposed end use for these determinands. Further statistical analysis including the calculation of the 95% upper confidence level (UCL) of the mean is required.

As part of the further statistical analysis, the following steps were undertaken:

- Normality - The normality of the population was established using probability plots as well as the Shapiro Wilk Test.

- Calculation of the 95% UCL of the mean - where there was no significant departure from normality, the one sample t-test was used and where there was a significant departure from normality, the one sided Chebychev Theorem was used.

The table below summarises the outcome of the 95% UCL assessment for CoC.

Table 16: Summary of 95%UCL assessment for CoC

Determinand	Critical Concentration	95%UCL	Outcome
Arsenic	130	84.09	No outliers, not normally distributed - one sided Chebychev Theorem used. Reject the null hypothesis with high level of confidence (p_1 = 0.98)

All concentration in mg/kg.

6.1.3 *Discussion*

The outcome of the statistical analysis has indicated that there is not considered to be a site wide contamination issue with regard to human health.

6.1.4 *Conclusions*

As such, there is not considered to be a significant risk to human health from the soils present at the site.

6.2 Ground Gas

6.2.1 *Methodology*

A ground gas risk assessment will be completed in general accordance with the CIRIA document C665:2007, “Assessing Risks Posed by Hazardous Ground Gases to Buildings”. Reference has also been made to the British Standard BS8485:2007, “Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments” and the Health and Safety Executive document EH40/2005 “Workplace Exposure Limits”.

The assessment will comprise the following:

- Review of results;

- Calculation of Gas Screening Values for methane (CH_4) and carbon dioxide (CO_2);
- Assessment of O_2, CO and H_2S concentrations using EH40/2005;
- Assessment of risks from ground gas; and
- Recommendations for gas protection measures if necessary.

6.2.2 Review of Field Data

Methane, carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide and flow rates were monitored on three occasions over a period of a month following the completion of the site works.

Atmospheric pressure ranged from 1007mb to 1030mb across the monitoring period with both rising and falling pressure trends in the days preceding the visits.

The table below summarises the range of concentrations detected during the monitoring visits. The full monitoring records are presented in Appendix D.

Table 17: Summary of Ground Gas Monitoring Data

Hole Ref	Methane %	Carbon Dioxide %	Oxygen %	Carbon Monoxide ppm	Hydrogen Sulphide ppm	Flow rate l/hr
BH01	All 0	0 - 0.5	20.5 - 20.7	All 0	All 0	All 0
BH02	All 0	0 - 1	19.4 - 20.6	0 - 1	All 0	All 0
BH03	All 0	0 - 0.4	20.7 - 20.8	All 0	All 0	All 0

6.2.3 Calculation of Gas Screening Values

The gas monitoring data obtained during the monitoring visits has been used to give a semi-quantitative estimate of risk for the site. The characterisation process employs the maximum gas concentrations and flow rates to generate Gas Screening Values (GSVs). As the proposed development is a skate park Situation A of CIRIA C665 has been assumed. The Modified Wilson and Card Classification as described in Table 8.5 of CIRIA C665 has been used.

The GSV for the site has been calculated as 0l/hr using the data from the monitoring rounds. This indicates that the site is considered to pose a very low risk and falls within Characteristic Situation 1

6.2.4 *Assessment of Oxygen (O_2), Carbon Monoxide (CO) and Hydrogen Sulphide (H_2S)*

EH40/2005 Workplace Exposure Limits (HSE 2005) has been used to assess the risk to human health from carbon monoxide (CO), hydrogen sulphide (H_2S) and oxygen (O_2). The exposure limits relate to conditions in a workplace and therefore are not directly applicable to soil gas concentrations. However they can be used to identify which gases do not present a risk and which may require further assessment. For the assessment of O_2 concentrations, EH40/2005 makes reference to the Mines and Quarries Act (1954) which states a minimum of 19%v/v. 20.8%v/v is the normal concentration of O_2 in air.

EH40/2005 presents long-term exposure limits (8-hour TWA reference period) and short-term exposure limit (15 minute reference period) for the workplace for both carbon monoxide and hydrogen sulphide.

A summary of the gas concentrations recorded during the three rounds of monitoring and the assessment criteria are presented in table below.

Table 18: Summary O_2, CO and H_2S Results and Assessment Criteria

Parameter	Minimum Recorded Value	Maximum Recorded Value	8-hour TWA Exposure Limit	15-minute exposure limit	Minimum Concentration (Mines and Quarries Act)
Oxygen	19.4	20.8	n/a	n/a	19%
Carbon Monoxide	0	1	30ppm	200ppm	n/a
Hydrogen Sulphide	All 0		5ppm	10ppm	n/a

6.2.5 *Discussion*

The GSV calculated for the site indicates that the site is considered to pose a very low risk from ground gas.

6.2.6 Conclusions

The assessment of the gas monitoring results shows that the concentrations of ground gas at the site do not pose a significant risk to future site users or nearby property due to the low concentrations and absence of flow.

No gas protection measures are required for sites that are classified as Characteristic Situation 1.

7 Controlled Waters Risk Assessment

7.1 Methodology

Based on the Preliminary Risk Assessment and Ground Model for this site, a Level 1 Screening Assessment has been undertaken in general accordance with Environment Agency guidance Environment Agency Remedial Targets Methodology, Hydrogeological Risk Assessment for Land Contamination, 2006.

The methodology comprises:

- identification of potential contaminant linkages;
- selection of appropriate generic screening values for controlled waters;
- screening measured concentrations of leachate and groundwater against the generic screening values;
- assessment of contaminant distribution and risk to receptors;
- identification of contaminants of concern and relevant contaminant linkages;
- identification of potential contaminants and contaminant linkages which are no longer of concern.

7.1.1 Identification of Potential Contaminant Linkages

The bedrock underlying the site is classified as a principal aquifer. The geological mapping shows that there are no superficial deposits overlying the bedrock and the investigation has proven that there are no significant superficial deposits present. Therefore, there is a potential contaminant linkage between the contaminants present in the soil onsite and the underlying aquifer.

Stalbridge Dock which connects to the River Mersey is located 61m to the south west and there is considered to be a potential contaminant linkage between the soils onsite and the surface water.

7.1.2 Selection of Generic Screening Values

The controlled waters receptors in this case are groundwater within the underlying principal aquifer as well as water within the River Mersey. Therefore, UK Drinking Water Standards (DWS) have been used to assess the potential risk to the underlying aquifer and Environment Agency Environmental Quality Standards (EQS) for the potential risk to the river.

7.1.3 Screening - Soil Leachate

A summary of the exceedences of the EQS values for the soil leachate samples is included in the table below. A full table showing the screened results can be found in Appendix H.

Table 19: EQS Screening - Leachate

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
Cadmium	0.2	<0.02 - 0.26	1/14	WS01 0.5m
Copper	5	1.2 - 29	5/14	WS04 0.4m, WS01 0.5m, WS02 0.8m, WS08 0.4m
Zinc	40	<2 - 360	2/14	WS04 0.4m, WS01 0.5m
Mercury	0.05	<0.05 - 0.08	1/14	WS04 0.4m
Alkaline pH	<7	6.3 - 7.7	3/14	WS04 0.4m, WS01 0.5m, WS08 0.4m
TPH aliphatic C21-35	10	<10 - 90	1/14	TP06 0.2m
TPH aromatic C10-12	1.2	<10 - 20	3/14	TP02 2.5m, TP04 0.9m, TP06 2m
Anthracene	0.1	<0.02 - 1.1	1/14	TP04 0.9m

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
Benzo(a)pyrene	0.05	<0.02 - 0.79	6/14	WS08 0.4m, TP02 2.5m, TP04 0.9m, TP05 0.6m, TP08 2m, BH03 3m
Benzo(b+k)fluoranthene	0.03	<0.04 - 2.6	10/14	BH02 6.5m, WS04 0.4m, BH01 8m, WS08 0.4m, TP02 2.5m, TP04 0.9m, TP06 2m, TP05 0.6m, TP08 2m, BH03 3m
Benzo(ghi)perylene / Indeno(123cd)pyrene	0.002	<0.04 - 0.88	8/14	BH02 6.5m, BH01 8m, WS08 0.4m, TP04 0.9m, TP06 2m, TP05 0.6m, TP08 2m, BH03 3m
Fluoranthene	0.1	<0.02 - 5	6/14	BH02 6.5m, BH01 8m, WS08 0.4m, TP04 0.9m, TP05 0.6m, BH3 3m
Naphthalene	1.2	<0.02 - 10	1/14	TP04 0.9m

A summary of the exceedences of the DWS values for the soil leachate samples is included in the table below. A full table showing the screened results can be found in Appendix H.

Table 20: DWS Screening - Leachate

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
Arsenic	10	0.6 - 11	1/14	TP08 2m
Alkaline pH	<6.5	6.3 - 7.7	1/14	WS01 0.5m
TPH aliphatic C21-35	10	<10 - 90	1/14	TP06 2m
Benzo(a)pyrene	0.01	<0.02 - 0.79	9/14	BH02 6.5m, BH01 8m, WS08 0.4m, TP02 2.5m, TP04 0.9m, Tp06 2m, TP05 0.6m, TP08 2m, BH03 3m
Total PAH	0.1	<0.08 - 3.48	10/14	BH02 6.5m, WS04 0.4m, BH01 8m, WS08 0.4m, TP02 2.5m, TP04 0.9m, TP06 2m, TP05 0.6m, TP08 2m, BH03 3m

7.1.4 *Contaminant Distributions and Risk to Receptors*

There are elevated concentrations of arsenic, cadmium, copper, zinc, mercury, TPH and PAHs at isolated locations across the site. However, given the margin of exceedences and once factors such as dilution, degradation and migration are taken into account, it is unlikely that these exceedences will pose a significant risk to the underlying bedrock or the adjacent dock / Mersey Estuary.

7.1.5 *Identification of Contaminants of Concern and Relevant Contaminant Linkages*

There are not considered to be any Contaminants of Concern with regard to controlled waters that require taking forward to detailed quantitative risk assessment. No significant contaminant linkages are considered to exist at the site that pose a risk to controlled waters.

8 Geotechnical Assessment

This geotechnical assessment is carried out in accordance with BS EN1997 Part 1, based on the Factual Report provided by Ian Farmer Associates. The geotechnical 'characteristic' parameters (defined in EC7 as moderately conservative) are derived from:

- The results of geotechnical laboratory testing,
- Standard Penetration Test 'N' values and the published correlations for undrained shear strength (c_u) and
- Published reference data where no field or laboratory data was available.

8.1 Made Ground

Made ground was encountered in all the exploratory holes at the existing ground level to depth of 13.1mbgl in BH01. The base of the made ground was only proven in BH01, BH02, BH03, WS06 and WS08.

The made ground was generally variable comprising slightly silty to silty, clayey sand and gravel and sandy, slightly gravelly to gravelly clay. The gravel content consisted of angular to subangular fragments of brick, wood, ash, clinker and sandstone. As described in chapter 5.1, there were two distinctive layers within the made ground. –

- An upper layer of dark grey sand and gravel with ash and clinker and rubble
- A lower layer of red brown sand, clay and ash with rubble.

These layers are believed to represent the two principal stages in the history of the site – filling of the inlet from the estuary, then use as railway land

Fifteen PSD testing undertaken on samples from the made ground indicated a Uniformity Coefficient, $U_{c,}$ of greater than 6 indicating that the material is well graded.

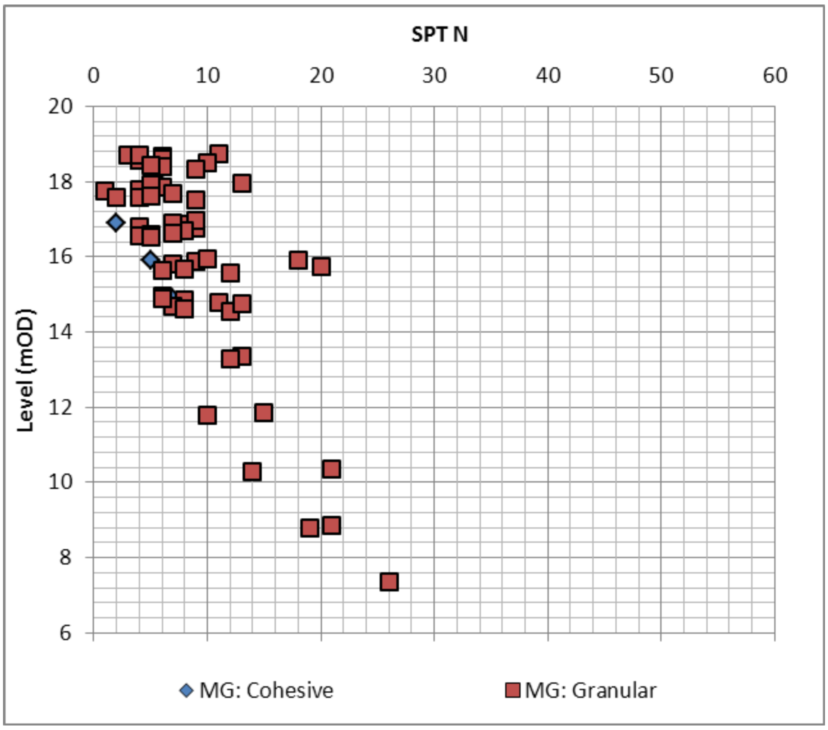
Five compaction tests undertaken on samples from the upper granular made ground indicated optimum moisture content of 11 to 14% and maximum dry density of 1.82 to 1.94Mg/m^3. One compaction test undertaken on a sample from the lower cohesive made ground indicated optimum moisture content of 15% and maximum dry density of 1.85Mg/m^3.

Three California Bearing Ratio tests undertaken on samples from the made ground indicated CBR value between 2.4 to 71.0%

Six moisture content tests undertaken on samples from the granular made ground recorded moisture content of 9.4 to 22%.

Four Atterberg Limit Tests undertaken on samples from the cohesive made ground recorded moisture content of 17 to 23%, liquid limit of 27 to 32%, plastic limit of 14 to 17% and plasticity index of 13 to 15% indicating clay of low plasticity.

Fifty six SPT tests were carried out within the granular made ground. The SPT 'N' values ranged between 1 and 26. The results indicate the density of the granular made ground increases with depth from very loose to very dense. Four SPT test carried out within the cohesive made ground recorded SPT 'N' values ranged between 2 and 7. The 'N' values for both the granular and cohesive made ground are plotted with level in the diagram below. The high figures are suspected to be due to obstructions within the made ground.



8.1.1 Granular Made Ground

Based on material grading and grain shape, PD6694 suggests a critical state friction angle, Φ'_{crit} of 34°. However, due to the variable density, for design purposes a characteristic value Φ' of 31° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

E' = 600(N+6) (kPa)

Using a characteristic SPT N value of 6, a vertical drained Young's modulus, E'_v of 7MPa is indicated.

Where required, a bulk unit weight of $18kN/m^3$ above the water table and $21kN/m^3$ below has been adopted.

8.1.2 Cohesive Made Ground

Based on relationships between SPT N value and undrained shear strength developed by Stroud (1975), adopting the highest plasticity index value of 15% and applying an f_1 value of 5.0, the SPT result indicate an equivalent undrained shear strength, c_u of 25kPa. For design purposes, a characteristic undrained shear strength, c_u of 20kPa will be adopted.

Based on the highest plasticity index, PD6694 suggests a critical state friction angle, Φ'_{crit} of 20°. For design purposes a characteristic value Φ' of 27° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffnesses are derived using the correlation between undrained shear strength and plasticity index by Stroud (1974). Using a characteristic undrained shear strength of 20kPa and the highest plasticity index of 15%, a vertical undrained Young's modulus, E_{uv} and drained Young's modulus, E'_v of 6.5MPa and 5.0MPa have been indicated respectively. The coefficient of volume compressibility, m_v is estimated to be $0.2m^2/MN$.

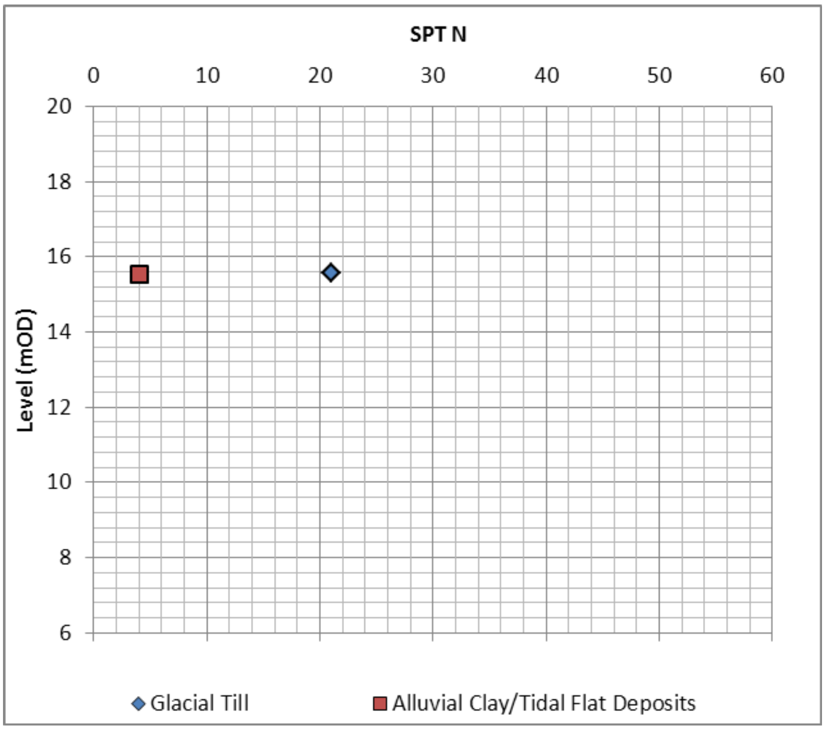
Where required, a bulk unit weight of $17kN/m^3$ above the water table and $17kN/m^3$ below has been adopted.

8.2 Clay

Clay was encountered beneath the made ground in WS06 and WS08. The base of the clay was not proven in WS06.

The clay was described as stiff slightly sandy, slightly gravelly clay in WS06 and firm silty, sandy clay with occasional organic flecks in WS08. The clay has been interpreted as glacial till in WS06 and possible alluvial clay or tidal flat deposits in WS08.

Two SPT tests were carried out within the clay. The SPT ‘N’ values of 4 and 21 were recorded. The ‘N’ values for the clay are plotted with level in the diagram below.



8.2.1 Alluvial Clay / Tidal Flat Deposits

One Atterberg Limit Test undertaken on a sample from the clay recorded moisture content of 23%, liquid limit of 36%, plastic limit of 17% and plasticity index of 19% indicating clay of low plasticity.

Based on relationships between SPT N value and undrained shear strength developed by Stroud (1975), adopting the highest plasticity index value of 19% and applying an f_1 value of 5.0, the SPT results indicate equivalent undrained shear strength, c_u of 20kPa indicating soft consistency. For design purposes, a characteristic undrained shear strength, c_u of 20kPa will be adopted.

Based on the highest plasticity index, PD6694 suggests a critical state friction angle, Φ'_{crit} of 28°. For design purposes a characteristic value Φ' of 27° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffnesses are derived using the correlation between undrained shear strength and plasticity index by Stroud (1974). Using a characteristic undrained shear strength of 20kPa and the highest plasticity index of 19%, a vertical undrained Young's modulus, E_{uv} and drained Young's modulus, E'_v of 6.0MPa and 4.5MPa have been indicated respectively. The coefficient of volume compressibility, m_v is estimated to be 0.2m^2/MN.

Where required, a bulk unit weight of 17kN/m^3 above the water table and 17kN/m^3 below has been adopted.

8.2.2 *Glacial Till*

Two Atterberg Limit Tests undertaken on samples from the glacial till recorded moisture content of 17%, liquid limit of 29 to 33%, plastic limit of 15 to 16% and plasticity index of 14 to 17% indicating clay of low plasticity.

Based on relationships between SPT N value and undrained shear strength developed by Stroud (1975), adopting the highest plasticity index value of 17% and applying an f_1 value of 5.0, the SPT results indicate equivalent undrained shear strength, c_u of 105kPa indicating stiff consistency. For design purposes, a characteristic undrained shear strength, c_u of 75kPa will be adopted.

Based on the highest plasticity index, PD6694 suggests a critical state friction angle, Φ'_{crit} of 29°. For design purposes a characteristic value of Φ' of 29° will be adopted. Effective cohesion, c' will be taken as 0kPa.

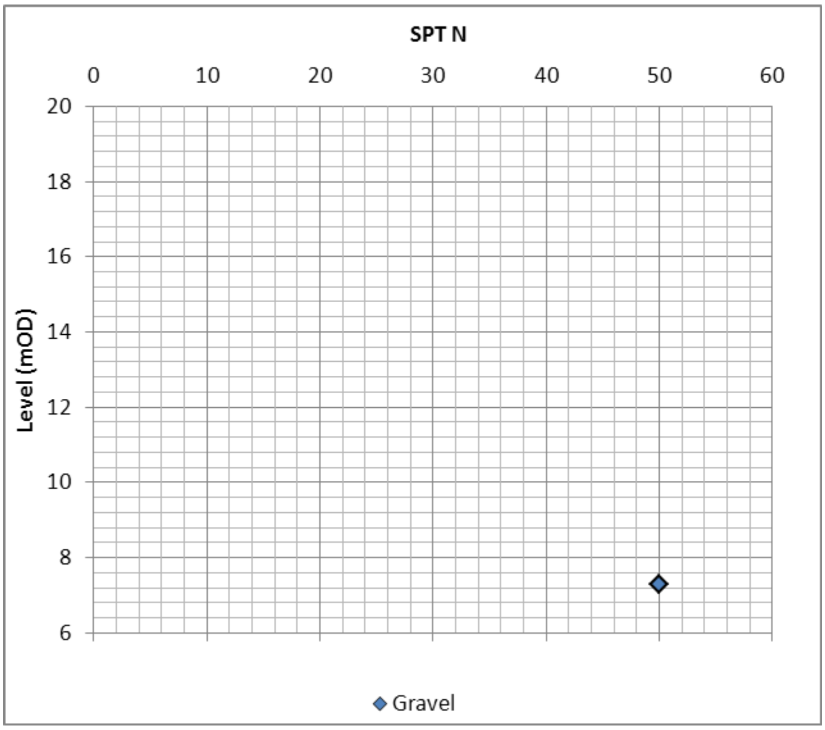
Soil stiffnesses are derived using the correlation between undrained shear strength and plasticity index by Stroud (1974). Using a characteristic undrained shear strength of 75kPa and the highest plasticity index of 17%, a vertical undrained Young's modulus, E_{uv} and drained Young's modulus, E'_v of 24.0MPa and 18.5MPa have been indicated respectively. The coefficient of volume compressibility, m_v is estimated to be 0.05m^2/MN.

Where required, a bulk unit weight of 21kN/m^3 above the water table and 21kN/m^3 below has been adopted.

8.3 Gravel

Natural gravel was only encountered in BH02 at 12.0m bgl. The gravel was described as very dense slightly silty, sandy gravel. The gravel was interpreted as weathered sandstone.

One SPT test was carried out within the gravel. SPT 'N' value of 50 was recorded. The results indicate the gravel is very dense. The 'N' value for the gravel is plotted with level in the diagram below.



Based on material grading and grain shape, PD6694 suggests a critical state friction angle, Φ'_{crit} of 34°. For design purposes a characteristic value Φ' of 34° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

$E' = 1200(N+6)$ (kPa)

Using a characteristic SPT N value of 30, a vertical drained Young's modulus, E'_v of 43MPa is indicated.

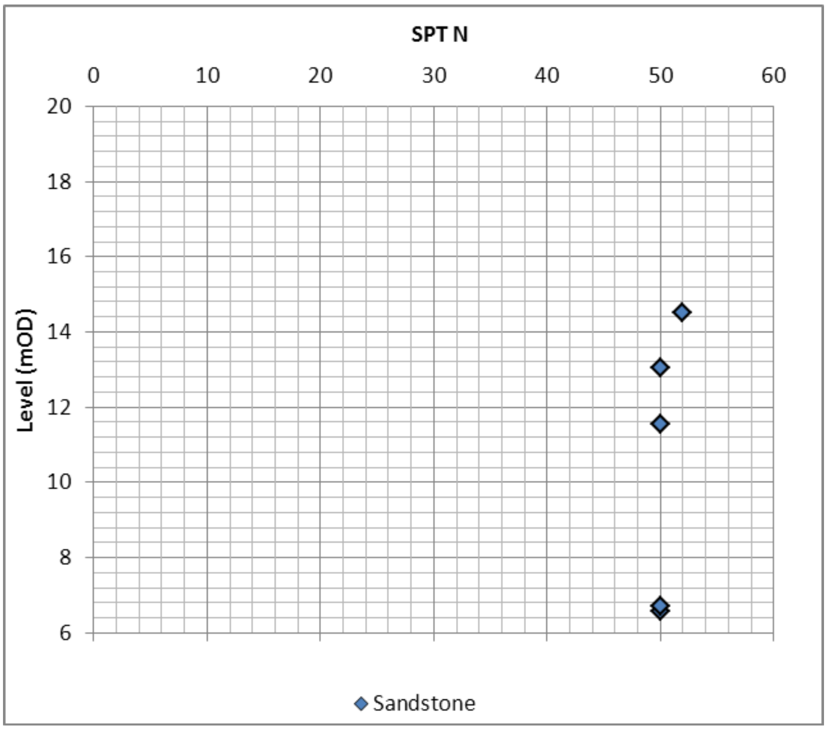
Where required, a bulk unit weight of 18kN/m^3 above the water table and 21kN/m^3 below has been adopted.

8.4 Sandstone

Sandstone was encountered in BH01, BH02, BH03 and WS08. The base of the sandstone was not proven in these exploratory holes.

The sandstone was generally described as very weak to weak red brown medium to coarse grained sandstone.

Four SPT tests were carried out within the sandstone. SPT 'N' values of 50 and 52 were recorded. The results indicate the SPT tests refused within the sandstone. The 'N' value for sandstone is plotted with level in the diagram below.



BS8002 suggests a friction angle, Φ' of 42°. For design purposes a characteristic value Φ' of 40° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

$$E' = 1200(N+6)\ (kPa)$$

Using a characteristic SPT N value of 50, a vertical drained Young's modulus, E'_v of 67MPa is indicated.

Where required, a bulk unit weight of $20kN/m^3$ above the water table and $23kN/m^3$ below has been adopted.

8.5 Groundwater Levels

Groundwater strike was observed in BH02 at 12.0m bgl and rose to 10.0m bgl after 20mins. 50mm slotted standpipes were installed in BH01, BH02 and BH03. Three groundwater monitoring data were available at the time of writing this report and is presented in the table below.

Table 21: Groundwater Monitoring Data

Location	Water Level (m bgl)			Strata type
	05/03/2014	16/03/2014	21/03/2014	
BH01	Dry	Dry	Dry	Made Ground
BH02	10.23	10.14	10.14	Made Ground
BH03	5.93	5.98	5.96	Made Ground

8.6 Geotechnical Characteristic Soil Parameters

Geotechnical 'characteristic' parameters used for the foundation design have been derived from the borehole logs, in-situ test results, laboratory test results, published correlations and reference data. A summary of the recommended characteristic soil parameters are shown in the table below.

Table 22: Summary of Characteristic Design Parameters

Properties	GRANULAR MADE GROUND	COHESIVE MADE GROUND	ALLUVIAL CLAY/ TIDAL FLAT DEPOSIT	GLACIAL TILL	GRAVEL	SANDSTONE
Bulk unit weight, γ_b (kN/m^3)	18	17	17	21	18	20
Saturated unit weight, γ_{sat} (kN/m^3)	21	17	17	21	21	23
Undrained Shear Strength c_u (kN/m^2)	-	20	20	75	-	-
Effective Cohesion c' (kN/m^3)	0	0	0	0	0	0
Peak friction angle, Φ'_{peak} (degrees)	31	27	28	29	38	40
Critical state friction angle, Φ'_{crit} (degrees)	31	27	28	29	34	40
Vertical Undrained Young's Modulus, E_{uv} (MPa)	-	6.5	6.0	24.0	-	-
Vertical Drained Young's Modulus, E'_v (MPa)	7.0	5.0	4.5	18.5	43.0	67.0
Coefficient of Volume Compressibility m_v (m^2/MN)	-	0.2	0.2	0.05	-	-

9 Land Contamination Risks and Remediation Requirements

9.1 Revised Conceptual Model

Based on the findings of the human health and the controlled waters risk assessments, the conceptual model can be revised as described in the sections below and significant contaminant linkages identified if present.

9.2 Discounted Contaminant Linkages

There is no longer considered to be significant contaminant linkages between the contaminants onsite and future site users and controlled waters, as well as between soil gas and future site users and property / structures.

9.3 Remaining Potential Contaminant Linkages

There are not considered to be any remaining potential contaminant linkages with regard to risk to human health, property and the environment.

9.4 Remediation Requirements

9.4.1 Human Health – Soils

There are no remedial requirements identified by these assessments with regard to the risk to human health from contaminants in the soil at the site.

9.4.2 Human Health – Ground Gas

There are no remedial requirements identified by these assessments with regard to the risk to human health from ground gas at the site.

9.4.3 Controlled Waters

There are no remedial requirements identified by these assessments with regard to the risk to controlled waters from soils at the site.

10 Geotechnical Design

10.1 Foundation Analysis and Recommendations

Ground conditions across the site generally comprised thin topsoil and extensive made ground overlying clays and sandstone. Existing ground investigation data indicates that the thickness of the made ground varies significantly from 4.0m to 13.1m. The upper layers of made ground appear to arise from the railway sidings and comprise a mixture of stone and ash railway ballasts. The lower layers appear to be a much older general infill of locally derived sand clay and ash. Both types contain considerable amounts of rubble and some wood. The made ground is also very variable in its relative density, but generally low densities and low stiffnesses were recorded.

It is assumed that the higher sections of the skate structure, along with any ramps and rails will be formed by mass concrete or steel and would induce additional load on the founding material. Normally, it would not be appropriate to found any structure within the made ground, but given the considerable thicknesses of made ground present, this is likely to be the only practicable solution unless piles are adopted. Therefore, for preliminary design, it is assumed that these sections will be founded on spread foundations, within the made ground at a depth 1.0m below ground. Assuming a concentrically loaded foundation and a pad footing width of 1.5m, a safe bearing capacity of 30kN/m^2 is indicated when assessed to BS8004, though that would have to be verified during detail design. Considerable settlement of the made ground is to be expected and any structures should be tolerant of total and differential movements of the order of 50-100mm.

If the skate surface is formed and cast directly on to the made ground ,whether at existing level, in excavated hollows or in placed (and compacted) mounds, then the ground can be expected to settle in a variable and unpredictable manner. The magnitude of the settlement can be reduced by heavy proof rolling of excavated surfaces and full compaction of any placed fills, but medium to long term settlement of the underlying deep fill can still be expected. This could lead to cracking of the skate park surface. It is therefore recommended that the designer allow for a stone blanket layer of at least 150mm beneath the surface and that a geogrid or mesh reinforcement is incorporated into the surface construction to aid dispersal of loads and the effects of differential settlement.

It may be desirable to re-shape the site profile using site won material. Site won material could be classed as a Class 1 General Fill but would need to be selected, screened, crushed and re-compacted in accordance to the acceptability and compaction criteria indicated within Series 600 of the Specification of Highway Works. The material appears to be a little wet of the optimum moisture content, but if screened to yield a free draining material, this should be practical to achieve an acceptable level of compaction. Safe bearing pressure and the settlement performance would depend on the depth of the improvement and will need to be evaluated at detailed design.

Vibro-stone columns could be considered as a ground improvement technique within these ground conditions. The safe bearing pressure and settlement performance would depend on the depth and spacing of the stone columns and advice should be sought through a specialist contractor at detailed design.

Alternately, piles may be adopted to rely on end bearing on the unweathered sandstone. Due to the variability of the made ground, any skin friction contribution from the made ground should be ignored.

Checks will be required at detail design to determine the potential of differential settlement between the higher and lower sections of the skate structure. This will be required to determine the need for structural reinforcement to prevent cracking between the upper and lower sections of the skate structure due to differential settlement.

Any soft spots encountered would need to be over excavated and replaced with compacted granular fill.

Once the general arrangements of the proposal have been established, slope stability checks might be required to ensure that the proposal does not destabilise the existing slope. Unsurfaced slopes are unlikely to be stable if steeper than 1:2. Short surfaced slopes may be stable at a steeper gradient, subject to detailed design of the surfacing.

The loadings of the proposed skate structure should be estimated and the risk of differential settlement evaluated accordingly. The bearing resistance should be assessed in detail when the structural design and applied foundation loads have been completed.

10.2 Concrete Classification

Chemical testing in accordance with BRE Special Digest 1 was carried out on a total of 8 soil samples recovered from the exploratory holes. The range of results is presented in the table below.

Table 23: Results of BRE Special Digest 1 Chemical Testing

Chemical Test	Range of Results	
	Lowest	Highest
Total SO_4 (%)	<0.01%	0.07%
SO_4 in 2:1 Water:Soil (mg/l)	<10mg/l	100mg/l
pH	7.4	9.2
Total Sulphur (%)	<0.01%	0.04%

The aggressiveness of the chemical environment with respect to new buried concrete has been assessed in accordance with BRE Special Digest 1 – Concrete in aggressive ground, 2005. Characteristic values of 100mg/l for soluble sulphate and 7.4 for pH have been determined.

The design sulphate classification for the foundation soils is DS-1. The Aggressive Chemical Environment for Concrete (ACEC) classification for the site, assuming mobile groundwater is AC-1.

10.3 Geotechnical Risk & Uncertainty

The ground is never without uncertainty and risk and therefore in detailed design, the following should be considered:

- Granular and cohesive made ground was encountered in the ground investigation. Due to this variability the characteristic soil properties will be subjected to considerable uncertainty. The detailed design should take account of this uncertainty.
- Depth of made ground varies from 4.0m to 13.1m. Foundation solution should consider variation in thickness of made ground across the site.
- Slope stability checks to determine the risk of slope instability due the proposed skate structure
- Detail settlement checks to determine the risk of differential settlement between different sections of the skate structure.

11 Conclusions

11.1 Ground Model

The site is typically higher than the surrounding land and is approximately 15m higher than land immediately adjacent to the western boundary. The difference between the site level and surrounding ground level increases from east to west. The general site topography is relatively uneven. The land drops away steeply just beyond southern, western and northern sections of the site boundary.

Made ground was encountered at each of the exploratory hole locations across the site. The overall proven thickness varied between 6.4m in BH03 in the eastern part of the site and 13.1m in BH01 in the western part of the site.

Natural superficial deposits comprising a very dense silty sandy gravel was encountered in BH02 only in the central part of the site. Sandy, gravelly clay was present in both WS06 and WS08 in the western part of the site. Bedrock was encountered as a weak, medium to coarse grained sandstone that as encountered at 6.4m bgl in BH03 in the east and at 13.1m bgl in the west of the site.

The gas monitoring results show that carbon dioxide was recorded up to 1% and carbon monoxide up to 1ppm. Methane, hydrogen sulphide were absent as was any flow.

11.2 Human Health Assessment

With regard to potential contamination within the soil at the site, the outcome of the statistical analysis has indicated that there is not considered to be a site wide contamination issue with regard to human health.

The assessment of the gas monitoring results shows that the concentrations of ground gas at the site do not pose a significant risk to future site users or nearby property due to the low concentrations and absence of flow.

11.3 Controlled Waters Assessment

There are elevated concentrations of arsenic, cadmium, copper, zinc, mercury, TPH and PAHs at isolated locations across the site. However, given the margin of exceedences and once factors such as dilution, degradation and migration are taken into account, it is unlikely that these exceedences will pose a significant risk to the underlying bedrock or the adjacent dock / Mersey Estuary.

11.4 Geotechnical Assessment

The preliminary GI has indicated that the site is underlain by between 6.4 and 13.1m of made ground, which appear to a mix of general fill and railway ballast, which in turn overlies a thin layer of firm to stiff clay and then sandstone at depth.

The nature of the superficial materials is that they are of low strength and high variability. Settlement and cracking of the skate surface could be expected unless these deposits are thoroughly compacted. If screened to remove unsuitable materials, the existing fills may be expected to be amenable to reshaping and compaction in accordance with a regular earthworks specification.

A minimum 150mm compacted granular layer is recommended beneath the skate surface, to support the surfacing and minimise the risk of differential settlement leading to cracking of the surface. That risk cannot however be wholly eliminated.

Ramps, rails and other structures associated with the skate park will require foundations. Normally these should bear on to natural ground but at this site, this is considered impracticable. Instead they are expected to be founded within the made ground, but the foundations will have to be designed to spread the load to a low bearing pressure and be tolerant of differential settlement.

For significantly loaded raised areas and structures. It would be necessary to transfer foundation loads to the underlying natural ground by deep foundations unless they are very tolerant of settlement and movement.

12 Recommendations

12.1 Further Intrusive Investigations

No further intrusive investigations are proposed, based on our understanding of the proposed skate park.

12.2 Detailed Quantitative Risk Assessment Requirements

No detailed quantitative risk assessment is required based on our current understanding of the proposed skate park.

12.3 Remedial Requirements

No remedial requirements are anticipated with regard to risk to human health, property or the environment.

12.4 Geotechnical Requirements

The ground conditions are poor and geotechnical measures are recommended in relation to the construction of the skate park to prevent potential differential settlement and hence cracking to the skate park structures and the skate surface.

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Appendix A Groundsure Report

Appendix B C552 Risk Evaluation

Appendix C Ground Investigation Factual Report

Appendix D Gas / Groundwater Monitoring Records

Appendix E Chemical Analysis Results

Appendix F GAC Methodology

Appendix G HHRA Screening

Appendix H Controlled Waters Screening