ST. AMBROSE

Ground Contamination Risk Assessment Report

for

Balfour Beatty

FEBRUARY 2010

Project No.: 5311

Ramboll UK Ltd.
The Capital Building,
12/13 St. Andrew Square,
Edinburgh. EH2 2AF

tel 0131 550 4070
fax 0131 550 4093
edinburgh@ramboll.co.uk

Ground Contamination Risk Assessment Report

ST. AMBROSE

Balfour Beatty

Revision History

Rev	Date	Purpose/Status	Document Ref.	Comments
1A	26th November 09	**Final**	**5311.E.GQRA.1A**	For Issue
1B	4th February 10	**Final**	**5311.E.GQRA.1B**	Updated following CLO comments

Author:	**Checked by:**	**Approved by:**
[redacted]	[redacted]	[redacted]

EXECUTIVE SUMMARY

SCOPE	
Purpose of the report	Ramboll UK Ltd (RUK) was instructed by Balfour Beatty to design a supplementary site investigation and provide an interpretative ground contamination assessment at the proposed St. Ambrose School site in Coatbridge. The proposed development will comprise the construction of St. Ambrose High School including a two-storey school building with associated school pitches, car parking, play areas and soft landscaping.
SITE INFORMATION	
Grid Reference	271546, 665970 ***Site Area (approx.)*** 13.5ha
Current Site Description	Currently the site is occupied by numerous sports pitches to the south of Townhead Road and is in use by the general public as a recreational area. An area of car parking and an access road is present in the northeast of the site.
History	Until the 1980s, the site was used as rough pasture in a mining area with a railway crossing the north of the site and the eastern site boundary and coal pits to the northeast and southeast of the site. During the 1980s, the railway in the north was dismantled and a mineral railway was constructed across the southern area of the site. The site was then used as a landfill from 1945-1972. By the 1990s the site was in use as playing fields following reprofiled and has remained so up to the present day. No further details are available regarding the capping of the landfill and development of the playing fields.
SITE INVESTIGATION	
Previous SI	A preliminary and main intrusive investigation were undertaken on site by URS in 2006 and 2008 respectively.
Activities	The supplementary site investigation works designed by Ramboll to address data gaps comprised 11No. mechanically-excavated trial pits to a maximum depth of 4.10mbgl, 11No. hand-excavated pits to a maximum depth of 1.20mbgl and soil sampling for chemical analysis.
Laboratory Analysis	37No. soil samples (including one duplicate) and 8No. leachate samples were analysed for a typical chemical suite including: pH, selected metals and inorganics, extractable petroleum hydrocarbons (EPH), polycyclic aromatic hydrocarbons (PAHs), phenols and an asbestos screen. Specific samples were also scheduled for foc, speciated hydrocarbons, volatile organic compounds and semi-volatile organic compounds.
GROUND CONDITIONS	
Geology	Made Ground was encountered across the site comprising topsoil, reworked topsoil material and probable landfill material. The Made Ground ranges in thickness between 0.30m and 10.10m. The greatest depths of Made Ground were typically reported in the northern area of the site. Superficial deposits of peat and glacial deposits of clay, sand and silt were encountered underlying Made Ground strata. The solid geology of the Middle Coal Measures, described as interbedded sandstone, mudstone and coal was encountered at depths of between 6.50-23.20mbgl and was recovered as highly weathered sandstone and mudstone.
Hydrology & Hydrogeology	Groundwater was typically recorded at the superficial to solid interface at depths ranging from 12.80 to 23.20mbgl. It is understood that this is the underlying aquifer. Perched shallow groundwater was also reported across the site within the Made Ground and superficial deposits, although typically, perched groundwater was reported above the peat at depths ranging from 1.90 to 4.70mbgl. There are various drains labelled on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the southwest site boundary. On investigation, these are surface ditches, typically dry, which are likely to fill with water during heavy rain. The nearest surface water receptor is therefore Monkland Canal, which runs east to west and lies approximately 350m south of the site and Lochend Loch and Woodend Loch lie approximately 450m west and 650m northwest of the site boundary respectively.

GROUND CONTAMINATION	
Human Health	The risks to Human Health via direct contact with lead and nickel in localised areas across the site are considered to be **LOW / MODERATE** as these materials are at depths proposed to be excavated as part of the cut and fill works. Localised elevated concentrations of PAHs are located in areas of proposed fill where there will be at least 600mm of fill and existing material located above the source strata. Therefore, these localised impacts are unlikely to present a significant risk via direct contact pathways. Risks to Human Health from these impacts are therefore considered to be **LOW**. Risks to human health caused by elevated benzo(a)pyrene in probable landfill and topsoil material across the site and elevated benzo(a)anthracene in topsoil are considered likely to be significant in areas of soft landscaping where there may be an active direct contact pathway. Therefore, the risk to human health from benzo(a)pyrene and benzo(a)anthracene in soft landscaped areas is classified as **MODERATE**.
Controlled Waters	Risks to the Secondary Aquifer underlying the site are classified as **LOW / MODERATE** due to the impacts of manganese, ammonia and PAH reported within the shallow groundwater. Risks to the underlying aquifer from the localised hydrocarbons and marginal impacts of copper and zinc within the shallow groundwater are classified as **LOW**. Due to the significant depths of impermeable deposits including peat and clay overlying the aquifer in the majority of locations across the site it is considered unlikely that significant vertical migration of contaminants will occur. However, due to the potential for mine shafts on site, preferential pathways for vertical groundwater migration may be present. In areas of the proposed soakaways the risks to the underlying aquifer are considered to be **LOW / MODERATE**. The development proposals include increasing the area of hardstanding across the site thus reducing leaching potential and likely pathways through the landfill material. Based on the significant distance to the nearest surface water receptor (Monkland Canal; Lochend and Woodend Lochs all >350m from the site) and the proposed development minimising pollutant linkages, the risks to the surface water receptors are considered to be **LOW**.
Vegetation	Elevated concentrations of lead, nickel, mercury, copper and zinc have been reported in topsoil and probable landfill material when compared to the phytotoxic GAC as defined in The Soil Code (MAFF, 1998). These are considered to represent a **LOW** risk to vegetation on the sports pitches due to the proposed make-up and low permeability membrane proposed. There is considered to be a **LOW/MODERATE** risk to vegetation in planted areas of soft landscaping.
Water Supply Pipes	Elevated concentrations of metals, sulphate and organics have been reported in topsoil and landfill material when compared to the WRAS screening criteria used to assess the potential risks of laying water supply pipes in contaminated ground. There is considered to be a LOW/MODERATE risk of degradation of the pipe construction material and a MODERATE risk to future site users from contaminant ingress into potable water supplies and water consumption.
Ground Gas	Ground gas monitoring visits were undertaken by URS in 2006 and 2008/9 and Geotechnics in 2009. The concentrations reported would classify the proposed development as Characteristic Situation 4 and appropriate ground gas protections measures will be required in the proposed development in accordance with CIRIA 665 (2007) and BS8485 (2008).

RECOMMENDATIONS	
Further Assessment	• A Human Health Detailed Quantitative Risk Assessment (DQRA) is recommended in order to further assess the potential risks caused by site-wide impacts of benzo(a)anthracene in topsoil, benzo(a)pyrene in topsoil and landfill material and hotspots of nickel in landfill material.
Remedial Measures Required	• Ground gas protection measures will be required in the proposed development in accordance with Characteristic Situation 4 (CIRIA C665). A design for these protection measures has been proposed. • Hotspots of lead have also been identified in areas proposed to be excavated as part of the cut and fill works. During enabling works it is recommended that this material is stockpiled separately and subjected to validation testing to establish whether the material is suitable for use. • Elevated phytotoxic contaminants may present a significant risk to vegetation in planted areas such as borders and flower beds. It is therefore recommended that 600mm of imported clean fill material is imported into all planted areas.

Additional Considerations	It is recommended that a suitably qualified Environmental Consultant is on site during the enabling works to ensure that should any areas of apparent contamination be exposed; the material is excavated, stockpiled separately onsite and subjected to validation testing in order to ensure the material is suitable for use. Allowances are also recommended to be made for the removal, treatment and disposal of shallow groundwater should dewatering be required during excavation. An Environmental Specification Report is recommended to ensure the Contractor is undertaking all enabling works in accordance with the recommendations made in this report. A Validation Report will also be required to demonstrate that the enabling works have been carried out according to the Environmental Specification. Laying underground services in potentially contaminated Made Ground materials has the potential to establish preferential flow pathways and therefore materials should be used appropriate to the level of contamination identified on site, particularly with regard to underground mains water supply. It is recommended that wrapped iron pipes laid in trenches filled with inert material should be used for water supply pipes. Consultation with Scottish Water is also advised. The site has been historically redeveloped and used as a landfill, and although not encountered during the site investigations, localised deposits of asbestos-containing materials have the potential to be present in Made Ground across the site. Appropriate health and safety precautions (*i.e.*, provision of appropriate PPE to site development workers, *etc*.) should be adopted during enabling works.

CONTENTS

APPENDICES

1 INTRODUCTION

1.1 Brief

Ramboll UK Ltd (RUK) was instructed by Balfour Beatty to design a supplementary site investigation and provide an interpretative ground contamination assessment at the proposed St. Ambrose School site in Coatbridge.

This report provides a factual summary of the supplementary investigation and an assessment of ground contamination risks based on all available data.

The proposed development will comprise the construction of St. Ambrose High School including a two-storey school building with associated school pitches, car parking, play areas and soft landscaping. The current proposed development plan is provided as Drawing 5311/E/002, Appendix A.

1.2 Background

Ramboll UK understand 1No. desk study (Phase I) and 2No. intrusive site investigations (Phase II) have been undertaken within the site boundary since 2005; available reports and investigations for the site are outlined below:

- *St. Ambrose High Desk Study (URS, 2005);*
- *Preliminary Ground Investigation Report, St. Ambrose High School, Coatbridge (URS, 2006);*
- *Proposed St. Ambrose High School, Ground Investigation Report (URS, 2008); and*
- *Proposed St. Ambrose High School, Additional Gas Monitoring (URS, 2009)*

A review of these reports was undertaken by WSP (2009) on behalf of North Lanarkshire Council's Environmental Department and is detailed in the letters outlined below and provided in Appendix B:

- *Report Review – Proposed St. Ambrose High School, WSP 17th November 2008;*
- *Proposed St. Ambrose, Townhead Report Review Summary and Recommendations, Environmental Services 18th November 2008 (incl. URS response to comments); and*
- *Report Review Follow Up – St. Ambrose High School, WSP 31st August 2009.*

The additional investigation works undertaken by Ramboll and detailed in this report are to supplement the existing site data and provide additional information across the site. This data will inform a full, robust environmental risk assessment for the proposed St. Ambrose School and address the concerns raised by WSP (2009).

1.3 Objectives

The objectives of the supplementary site investigation works and report were to further establish the environmental ground conditions in the area of the proposed soakaways, undertake additional shallow soil analysis to address data gaps within the URS report in order to fully address the risks to Human Health and provide a Ground Contamination Risk Assessment for the proposed development using all available data and address the concerns raised by WSP (2009).

In order to achieve these objectives the following scope of works were undertaken:

- Site investigation comprising:
  - 5No. machine-excavated trial pits to a maximum depth of 3.30mbgl (below ground level) in the areas of the proposed soakaways;
  - 6No. machine-excavated trial pits to a maximum depth of 4.10mbgl across the site;
  - 11No. hand excavated pits to a maximum depth of 1.20mbgl across the site;
  - Soil sampling for chemical laboratory analysis; and
- Factual and interpretative reporting comprising:
  - Generic quantitative risk assessment using both new and existing data to characterise contamination risks associated with the proposed development;
  - Qualitative risk assessment to identify potentially significant ground contamination risks associated with the proposed development and also with regard to the construction phase of the works; and
  - Development of a risk management strategy outlining significant ground contamination risks and recommendations for their mitigation.

All ground contamination assessment work has been completed in accordance with the current UK legislative framework, further details of which are provided in Appendix C.

1.4 Constraints and Limitations

This report has been prepared for the exclusive use of the Balfour Beatty for the purpose of assisting site evaluation in the context of the proposed redevelopment at the time of writing. This report should not be used in whole or in part by any third parties without the express permission of Ramboll UK Ltd. in writing.

Ramboll has endeavoured to assess all information provided to them during this appraisal. This report summarises information provided from a number of external sources and cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon.

2 SITE SETTING

The site of the proposed St. Ambrose High School is located in Coatbridge, Lanarkshire. A site location plan is presented as Figure 2.1 in Appendix A.

2.1 Site Description

The site is located off Townhead Road and is bordered by Townhead Road to the north, a community centre, pavilion and residential properties to the east, Drumpellier Park to the south and a Golf Course to the west.

The site is located at the approximate National Grid Reference (NGR) 271546, 665970 and occupies an area of approximately 13.5Ha. Currently the site is occupied by numerous sports pitches and is in use by the general public as a recreational area. An area of car parking and an access road is present in the northeast of the site. A current site layout plan indicating current topographic levels is included in Appendix A as Drawing 5311/E/003. Proposed areas of cut and fill at the time of writing are shown on Drawing No. NLC-STA-DRG-C-316 in Appendix A.

2.2 Site History

This summary of the site history has been compiled using the available Ground Investigation Reports (URS, 2006; 2008). According to this information, the site remained in use as rough pasture in a mining area with a railway crossing the north of the site and the eastern site boundary and coal pits to the northeast and southeast of the site until the 1890s when the railway in the north was dismantled and a mineral railway was constructed across the southern area of the site.

By 1912 a reservoir was present to the southeast of the site boundary and 2No. tanks were located northeast of the site. Residential developments were constructed to the north of the site by the 1930s and the railway was dismantled.

The site was then used as a landfill from 1945-1972. Information obtained from North Lanarkshire Council indicate that Townhead Landfill received an estimated half million tonnes of domestic refuge from Coatbridge and 77,000 gallons of wet sewage and unspecified residue from Gartsherrie Steel Works were disposed of annually for an unknown period of time. By the 1990s the site was in use as playing fields following remodelling and has remained so up to the present day. No further details are available regarding the capping of the landfill and development of the playing fields.

2.3 Geology

Based on the information obtained from previous site investigations (URS, 2006; 2008); the geology underlying the site is understood to comprise Made Ground including topsoil overlying probable landfill material up to a maximum depth of 8.45mbgl. No significant capping layer is present above the probable landfill material. Underlying the Made Ground are superficial deposits of peat, glaciolacustrine clay, silt and sand and glacial till to a maximum depth of 23.2mbgl. These superficial deposits overlie the solid geology of the Middle Coal Measures, reported at depths between 7.40mbgl and 23.20mbgl and comprise sandstone and mudstone with occasional bands of coal.

The site is underlain by several coal seams, some of which have been historically mined by shallow workings. In addition, mine shafts have been identified in and

around the site. The potential geotechnical risks from mining instabilities are not discussed further in this report.

2.4 Hydrogeology & Hydrology

The previous investigations (URS, 2006; 2008) indicate that the solid geology underlying the site is classified as moderately permeable according to the Scottish Environmental Protection Agency (SEPA). This is comparable to the Environment Agency (EA) classification of a Secondary Aquifer. The site is not within a source protection zone.

During the URS investigations in 2006 and 2008, groundwater was typically recorded at the superficial to solid interface at depths ranging from 12.80 to 23.20mbgl. It is understood that this is the underlying aquifer. Perched shallow groundwater was also reported across the site within the Made Ground and superficial deposits, although typically, perched groundwater was reported above the peat at depths ranging from 1.90 to 4.70mbgl.

There are various drains labelled on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the southwest site boundary. On investigation, these are surface ditches, typically dry, which are likely to fill with water during heavy rain. A photograph is included in Appendix A as Figure 2.2. The nearest surface water receptor is therefore Monkland Canal, which runs east to west and lies approximately 350m south of the site and Lochend Loch and Woodend Loch lie approximately 450m west and 650m northwest of the site boundary respectively.

2.5 Flood Risk

The Scottish Environmental Protection Agency's indicative floodplain map shows that the site does not lie within an area of potential risk from river or sea flooding. The nearest area in the vicinity of the site at risk of flooding lies approximately 150m northeast of the site boundary.

2.6 Ground Gas

There is a potential for the build up of potentially hazardous ground gas across the site. The site has previously been used as a landfill and there is a layer of peat across the majority of the site; both of which have the potential to generate potentially hazardous ground gases. In addition, the site is in an area associated with mining and therefore there is a potential for potentially hazardous mine gases to be generated. The source of the very high methane concentrations is the natural peat deposits underlying the site

Due to the potential risks from ground gas in the context of the proposed development, 4No. ground gas monitoring visits were undertaken as part of the initial investigation (URS, 2006) between August and October 2006. Maximum concentrations of 12.6% carbon dioxide, 4.0% methane and a maximum flow rate of 2.5l/hr was recorded during these monitoring visits.

An additional 4No. rounds of monitoring were undertaken following the URS investigation (2008) during August 2008 and maximum concentrations of 30.2% carbon dioxide, 68.7% methane and a negligible flow rate were recorded during these monitoring visits. It is considered unlikely that no flow rate would occur across

the site during all 4No. monitoring rounds therefore the negligible flow rates reported during these visits are considered to be invalid.

An additional 12No. rounds of monitoring were carried out between November 2008 and April 2009. Maximum concentrations of 32.2% carbon dioxide, 75.4% methane and a maximum flow rate of 10.9l/hr were recorded during these monitoring visits.

Based on current guidance, these results would classify the site as Characteristic Situation 4. However, URS argued that the high flow rate reported (10.9l/hr) was a spurious result as it only occurred once, from one borehole and therefore the next highest flow rate reported (1.8l/hr) should be used when classifying the gas regime on the site. Using this flow rate, the site would be classified as Characteristic Situation 3.

This classification was not deemed appropriate by the Environmental Services Department at North Lanarkshire Council as they considered the 10.9l/hr flow rate reported was a valid result and therefore should be incorporated into the ground gas assessment. Therefore the gas regime on site is considered to be representative of Characteristic Situation 4 and appropriate protection measures should be incorporated into the proposed development.

2.7 Previous Ground Investigations

Site investigations were undertaken on site by URS in 2006 and 2008 and interpretation of geoenvironmental ground conditions was provided by URS in 2008. Data from these investigations has been incorporated into this report to inform a full, robust assessment of the potential risks to Human Health and Controlled Waters that may exist on site based on the proposed development.

The preliminary investigation in 2006 comprised:

- 10No. machine-excavated trial pits to depths of 2.30-4.90mbgl;
- 7No. cable percussive boreholes to depths of 5.00-11.50mbgl;
- 4No. rotary boreholes to depths of 26.70-39.00mbgl;
- 4No. rounds of ground gas monitoring;
- Geotechnical and environmental sampling and analysis; and
- Factual Reporting.

The main investigation in 2008 comprised:

- 26No. cable percussive boreholes to depths of 7.05-15.50mbgl;
- 10No. rotary boreholes to depths of 39.40-47.30mbgl;
- 105No. machine-excavated trial pits to depths of 2.00-4.30mbgl;
- Geotechnical and environmental sampling and analysis;
- 1No. round of groundwater monitoring and sampling;
- 4No. rounds of ground gas monitoring; and
- Factual and Interpretative Reporting

A plan illustrating all the exploratory hole locations is included in Appendix A as Drawing 5311/E/001.

2.8 Preliminary Conceptual Model

Risk from contamination is assessed by consideration of possible linkages between contaminant sources and potential receptors which could be harmed or polluted. The key aspect of the UK contaminated land framework is the development of a

conceptual model which illustrates the spatial interaction between the potential sources and receptors on site. Sources, receptors and pathways are defined as:

- A source, *i.e.*, a substance that is capable of causing pollution or harm;
- A pathway, *i.e.* a route by which the contaminant can reach the receptor; and
- A receptor (or target), *i.e.* something which could be adversely affected by the contaminant.

Further details of the current UK contaminated land framework for contamination assessment are provided in Appendix C.

2.8.1 Sources

A review of historical and current land use on site and in the surrounding area has been undertaken. Potential contamination sources and actual sources of contamination (as identified in the previous site investigations) are summarised below:

Table 2-1: Potential/actual sources of contamination

Source	Potential/actual contaminant and/or hazard	Description/properties
Made Ground (Landfill)	Heavy metals, Polycyclic Aromatic Hydrocarbons (PAHs), hydrocarbons, Volatile Organic Compounds (VOCs) Semi-Volatile Organic Compounds (SVOCs), asbestos and ground gas	Elevated concentrations of various contaminants including lead, nickel, arsenic, cyanide, chromium, benzo(a)pyrene, dibenzo(a,h)anthracene and aromatic EC21-35 hydrocarbons were identified in isolated areas of Made Ground across the site. This material is also known to be generating potentially hazardous ground gases. There is a potential for contaminants to exist in areas of site not previous investigated.
Mining including railways	Heavy metals, inorganics, hydrocarbons, PAHs, asbestos and ground gas	Elevated concentrations of various contaminants including lead, nickel, arsenic, cyanide, chromium, benzo(a)pyrene, dibenzo(a,h)anthracene and aromatic EC21-35 hydrocarbons were identified in isolated areas of Made Ground across the site. Some of these contaminants may have been generated as a result of the mining activities on site. In addition potentially hazardous ground gases may be generated from the coal seams and former mining activities on site. There is a potential for contaminants to exist in areas of site not previous investigated.
Peat	Ground Gas	Peat underlies the majority of the site and is known to be generating potentially hazardous ground gases.

2.8.2 Pathways

In order for contaminants to reach potential receptors, there has to be a viable route for the contaminant. Potential pathways considered given the nature of the proposed development and the potential contaminative sources identified:

- Dermal contact with soils;
- Ingestion of soils;
- Inhalation of dust and vapours;
- Plant root up-take;

- Migration of ground gases;
- Contaminant ingress into potable water supply pipes; and
- Leaching and subsequent migration of groundwater.

2.8.3 Receptors

The site-specific receptors that could potentially be affected by the hazards identified in relation to the current and future use of the site for a school with areas of soft landscaping:

Human Health

- Current and future site users; and
- Site development workers.

Environmental

- Moderately Permeable Aquifer (Middle Coal Measures);
- Monkland Canal approximately 350m south of the site boundary;
- Structures and services;
- Adjacent properties; and
- Plants and vegetation.

2.8.4 Summary

The most significant potential pollutant linkages identified are:

- Direct contact with potentially contaminated Made Ground soils by future site users and construction workers;
- Leaching of contaminants into underlying groundwater and subsequent vertical migration into the underlying aquifer or lateral migration into surface water receptors;
- Migration and accumulation of potentially hazardous ground gases in confined spaces resulting in asphyxiation or explosion;
- Inhalation of airborne dust or fibres associated with demolition material within the Made Ground;
- Risk to plants from phytotoxic contaminants; and
- Contaminant ingress into potable water supply pipes and subsequent degradation of pipe material and/or consumption by site users.

3 SITE INVESTIGATION

3.1 Design

The site investigation was designed as a supplementary investigation in order to supplement the existing site data and provide a full assessment of the nature and extent of any ground contamination on site, addressing the concerns raised by WSP (2009). The investigation was undertaken and supervised by Geotechnics Ltd. on behalf of Ramboll UK and exploratory hole logs were produced by a Ramboll Environmental Consultant and logged in accordance with BS 5930.

The objectives of the supplementary site investigation were as follows:

- Identify any potential contaminants and their potential leaching capacity across the site that may be associated with former land-use in areas not previously investigated;
- To provide additional environmental information about the topsoil and shallow Made Ground material across the site;
- Identify any potential contaminants and their potential leaching capacity in the areas of the proposed soakaways; and
- Provide additional information on shallow environmental ground conditions across the whole of the site.

3.2 Site Investigation Activities

The supplementary site works were carried out on the 24th September and the 1st-2nd October 2009 by Geotechnics Ltd. The investigation comprised the following scope of works:

- 5No. machine-excavated trial pits to a maximum depth of 3.30mbgl (below ground level) in the areas of the proposed Soakaway;
- 6No. machine-excavated trial pits to a maximum depth of 4.10mbgl across the site;
- 11No. hand excavated pits to a maximum depth of 1.20mbgl across the site; and
- Soil sampling for chemical laboratory analysis.

The locations of the exploratory holes are shown on Drawing 5311/E/001 in Appendix A. Exploratory hole logs are presented in Appendix D, and laboratory chemical analysis results are presented in Appendix E.

3.3 Limitations

Various limitations were experienced whilst undertaking the site investigation. These included the following:

- The machine-excavated trial pits had to be located outside of the current playing fields to avoid any damage as these pitches are still in use by the general public.

It should be noted that although every effort has been made to ensure the accuracy of the data obtained from the investigation, the possibility exists for variations in ground and groundwater conditions between and around exploratory hole locations. In addition, groundwater levels are likely to vary seasonally and with changes in

weather conditions.

3.4 Laboratory Chemical Analysis

A total of 71No. soil samples were despatched to the Derwent Environmental Testing Services (DETS) laboratory in County Durham. DETS is a UKAS and MCERTS accredited laboratory.

37No. soil samples (plus 1No. duplicate) were scheduled by Ramboll UK for chemical analysis, including the following suite of determinands based on historical site use, the findings of previous site investigations, guidance given in the DoE Industry Profiles and CLR8, and on professional experience:

- Speciated Polycyclic Aromatic Hydrocarbons (PAH) (US EPA priority PAHs);
- Extractable Petroleum Hydrocarbons (EPH);
- Metals (arsenic, cadmium, chromium, copper, nickel, lead, zinc, mercury, boron and selenium);
- Sulphide, Sulphate and Sulphur;
- pH; and
- asbestos in Made Ground strata.

In addition, 8No. soil samples were scheduled for analysis of fraction of organic carbon (foc), 10No. samples were scheduled for speciated Total Petroleum Hydrocarbon (TPH) analysis and 2No. samples were scheduled for Volatile Organic Compound (VOC) and Semi Volatile Organic Compound (SVOC) analysis.

18No. soil samples were also scheduled for leachate analysis, for the suite of determinands as detailed below:

- Metals, Cyanide, pH, Sulphate and Sulphide;
- Phenols;
- Hardness as $CaCO_3$;
- PAHs (USEPA 16No. priority Polycyclic Aromatic Hydrocarbons); and
- Extractable Petroleum Hydrocarbons (EPH).

Laboratory chemical analytical results are presented in Appendix E.

3.4.1 Quality Assurance/Quality Control analysis

Duplicate soil sampling results are illustrated in Table 3-1:

Table 3-1: Comparison of Duplicate Soil Sample Analyses

Determinand	HDP11 (mg/kg)	D1 (mg/kg)
Arsenic	17	17
Cadmium	1.8	2
Chromium	32	57
Chromium (Hexavalent)	< 1	< 1
Copper	200	290
Lead	580	480
Mercury	0.14	0.14
Nickel	120	150
Selenium	0.9	0.9
Zinc	620	600

Determinand	HDP11 (mg/kg)	D1 (mg/kg)
Boron	2.7	2.5
Sulphate (Total)	0.17	0.11
Sulphur (Total)	0.12	0.09
Sulphide	48	44
pH	7.6	7.5
EPH	620	670
Acenaphthene	< 0.1	0.3
Acenaphthylene	< 0.1	< 0.1
Anthracene	0.4	0.7
Benzo(a)anthracene	0.7	0.9
Benzo(a)pyrene	0.9	0.9
Benzo(b)fluoranthene	0.3	0.3
Benzo(k)fluoranthene	< 0.1	< 0.1
Benzo(g,h,i)perylene	0.4	0.5
Chrysene	0.7	0.9
Dibenzo(a,h)anthracene	< 0.1	< 0.1
Fluoranthene	0.8	0.9
Fluorene	< 0.1	0.4
Indeno(1,2,3-c,d)pyrene	0.4	0.7
Naphthalene	< 0.1	< 0.1
Phenanthrene	0.8	1.6
Pyrene	1	1.1
PAH	6.5	9.2

Duplicate sample analysis is used to provide an indication of the precision of the analytical results, *i.e.*, the repeatability of the laboratory analytical process. The results of the duplicate analyses are compared with the original sample data. If the results of the sample and duplicate analyses are similar (*i.e.*, within ±30%), it is generally considered that an acceptable standard of repeatability has been maintained in the sampling and analytical process, and that the results can therefore be described as being precise. Only PAH results show a discrepancy of >30% likely due to variations in coal and clinker identified in this location. Considering the remainder of results are within ±30% results are considered precise.

4 GROUND CONDITIONS

4.1 General Stratigraphy

Reference has been made to the supplementary investigation recently undertaken by Geotechnics Ltd. and previous investigations undertaken by URS (2006; 2008). Exploratory hole logs and chemical analysis data from the URS investigation (2006) are presented in Appendix F and data from the URS investigation (2008) are presented in Appendix G for reference.

Exploratory hole logs from the supplementary investigation and logged by Ramboll UK (to BS5930) are presented in Appendix D. An Exploratory Hole Location Plan is included as Drawing No. 5311/E/001 in Appendix A.

The ground conditions encountered during the site investigation works are summarised in Table 4-1 below. Only the dominant soil types are included and summary descriptions have been used:

Table 4-1: Stratigraphic Succession

Strata	Description	Min. Depth encountered (mbgl)	Depth to base (mbgl)	Maximum thickness (m)
Made Ground (Topsoil)	**Silty Sand/Sandy Silt** (dark brown silty fine sand and sandy silt with frequent rootlets and occasional gravel).	0.00	0.00-0.60	0.60
Made Ground (Reworked Topsoil)	**Sandy Gravelly Silt** (dark brown slightly gravelly sandy silt. Gravel is subangular to subrounded fine to coarse of coal, clinker, sandstone, glass and other minor constituents. Sand is fine to medium) **Silty Sand** (dark brown silty fine to medium sand)	0.05	0.10-0.50	0.30
Made Ground (Probable Landfill)	**Sandy Gravel** (red-brown to brown-grey sandy angular to rounded fine to coarse gravel of ash, sandstone, burnt shale, coal, glass, bottles and jars, porcelain, newspaper, slag, wood and numerous other minor constituents depending on location.) **Gravelly Sand** (red-brown to brown-grey gravelly fine to coarse sand. Gravel is angular to rounded fine to coarse gravel of ash, sandstone, burnt shale, coal, glass, bottles and jars, porcelain, newspaper, slag, wood and numerous other minor constituents depending on location.)	0.00	0.90-10.10[1]	9.95
Superficial Deposits	**Peat** (Soft brown to red-brown spongy to amorphous fibrous peat.)	1.40	3.50-9.60	5.50
	Sandy Gravelly Clay (soft to stiff brown to grey gravelly sandy clay. Sand is fine. Gravel is angular to rounded fine to coarse of sandstone, shale, coal, charcoal and quartzite.)	0.00	3.00-23.20	23.20
	Gravelly Sand (grey to orange-brown silty slightly gravelly fine to medium sand. Gravel is subangular to rounded fine to coarse of sandstone and charcoal.)	2.90	3.10-11.90	2.35
	Silt (very soft to firm grey and brown sandy silt. Sand is fine.)	4.00	7.10-13.70	4.20

Strata	Description	Min. Depth encountered (mbgl)	Depth to base (mbgl)	Maximum thickness (m)
Middle Coal Measures (interbedded sandstone, mudstone and coal)	**Sandstone** (moderately strong to strong light grey to white fine to coarse grained sandstone with occasional mudstone laminations.)	6.50-23.20	Not proven	Not proven
	Mudstone (laminated dark grey mudstone with occasional carbonaceous laminations and plant fossils.)	7.40-28.90	Not proven	Not proven
	Coal (Moderately weak to weak dark grey coal with occasional laminations of carbonaceous mudstone.)	15.70-43.60	Not proven	Not proven

[1] Made Ground persists to a maximum of 13.60mbgl in R03 (2006). This is described in drillers logs as "Made Ground (ash, peat and clay)" immediately overlying the bedrock. This description is considered likely to be a Driller's combined description of the Made Ground and underlying superficial deposits and therefore has been omitted from this table.

4.2 Visual and Olfactory Observations of Potential Contamination

During the previous and supplementary site investigations, visual and olfactory observations of potential contamination were observed in a number of exploratory holes, as summarised in Table 4-2. Ash is not included in the table as it was commonly encountered as gravel in Made Ground.

Table 4-2: Visual and Olfactory Evidence of Potential Contamination

Description of Observed Potential Contamination	Exploratory Hole No.	Depth (mbgl)	Description of Strata
Slight organic odour	TP1 (2006)	0.70-0.90	**Made Ground**: Light grey brown **CLAY** with small pockets of fibrous peat and coal.
	TP101 (2009)	0.35-0.45	**Made Ground:** Dark brown to red-brown very gravelly fine to coarse **SAND.**
	TP03 (2009)	2.30-3.00	Soft dark brown to dark grey slightly gravelly silty **CLAY.**
Moderate organic odour	TP04 (2009)	1.50-2.40	Soft very dark brown occasionally mottled grey and black slightly sandy **SILT/CLAY.**
Moderate to heavily decomposed organic material (with moderate to strong rotting odour in TP102)	TP102 (2009)	1.70-3.80	**Made Ground:** Pale to dark grey and orange very sandy **GRAVEL.**
	HDP07 (2009)	1.00-1.10	**Made Ground:** Dark brown to green-brown heavily decomposed organic material.
Moderate hydrocarbon odour	TP102 (2009)	1.70-3.80	**Made Ground:** Pale to dark grey and orange very sandy **GRAVEL.**
	TP101 (2009)	0.80-2.90	**Made Ground:** Firm dark brown to grey-brown gravelly **CLAY.**
	TP238 (2008)	3.40-4.10	**Made Ground:** Dark grey slightly clayey cobbly **SAND** and **GRAVEL.**
Slight hydrocarbon odour	TP102 (2009)	0.90-1.35	**Made Ground:** Firm dark brown very gravelly **CLAY.**
Slag	46No. exploratory holes	Depths ranging from 0.00-6.00	Within **Made Ground** (probable landfill material)
Clinker	22No. exploratory holes	Depths ranging from 0.05-5.20	Within **Made Ground** (probable landfill material)
Tarmacadam	BH202 (2008)	0.05-0.70	**Made Ground**: Brown sandy

Description of Observed Potential Contamination	Exploratory Hole No.	Depth (mbgl)	Description of Strata
			gravelly **CLAY**.
Bitumen	TP231 (2008)	2.90-3.90	**Made Ground:** Dark brown to grey clayey cobbly **SAND** and **GRAVEL.**

4.3 Groundwater Occurrence

Groundwater strikes were encountered typically at the interface between the superficial and solid geology at depths ranging from 10.80mbgl to 23.20mbgl. It is likely that this represents the underlying Secondary Aquifer.

Groundwater strikes were also encountered within the Made Ground across the site, perched over the peat at depths ranging from 1.50mbgl to 4.90mbgl.

Groundwater was also encountered in some of the gravelly clay and silt deposits in localised areas across the site at depths ranging from 2.80mbgl to 11.00mbgl.

No groundwater monitoring was undertaken as part of the supplementary investigation although groundwater monitoring was undertaken during the previous investigations. Wells were installed into the Made Ground and superficial deposits across the site at depths ranging from 0.50-11.50mbgl (URS, 2008). Groundwater was reported in these wells at depths between 1.61-4.91mbgl within Made Ground and between 2.45-8.14mbgl within the superficial deposits. See Section 2.4 for further details of the groundwater regime across the site.

5 GROUND CONTAMINATION ASSESSMENT

This ground contamination assessment has been undertaken in accordance with the current UK framework and comprises a generic quantitative risk assessment as defined in CLR 11. Further details of the legislative framework and CLR11 are provided in Appendix C.

In order to assess the significance of the chemical concentrations reported, generic assessment criteria (GAC) must be selected based on the critical receptors identified at the site. Receptors are considered in relation to Human Health (*e.g.*, people using the site) and Controlled Waters (*e.g.*, water resources).

Potential risks to Human Health from soil impacts are considered using the measured soil concentrations. Potential risks to Controlled Waters are considered using soil leachate concentrations as indicative of the potentially mobile fraction of any soil impact and also measured groundwater concentrations.

5.1 Human Health Assessment

5.1.1 Methodology

Details of the UK framework for human health risk assessment and GAC are provided in Appendix C. GAC are provided for 3 standard land uses only: residential, allotments and commercial.

The site is proposed to be redeveloped as a secondary school (for 11-18 yr olds), with associated playing fields, parking, play areas and soft landscaping. This site has therefore been classified for the purposes of the screening assessment as residential without home-grown produce according to current UK guidance.

Contaminant concentrations below the adopted GAC are considered not to warrant further risk assessment. Where any concentrations are recorded above the GAC consideration of the contaminant distribution is undertaken and statistical analysis used where appropriate.

5.1.2 Soil Screening Analysis

Chemical analysis screening summary tables are held in Appendix H, detailing the measured concentrations of potential contaminants in comparison with the applicable GAC for a residential land use based on current UK guidance (2009). These tables combine chemical data from the initial investigations in 2006 and 2008 (URS) with data from the recent supplementary investigation (RUK, 2009).

Measured concentrations above the recommended GAC are highlighted within the tables (Appendix H) and Table 5-1 provides a summary of these exceedences.

Table 5-1: Summary of Soil Exceedences Compared with Relevant GAC

Determinand	GAC (mg/kg)	No. of Samples (MG and Natural)	No. of Exceedences	Maximum (mg/kg)
Arsenic	35	82	5	71
Lead	450	82	18	6600
Nickel	130	82	3	660

Determinand	GAC (mg/kg)	No. of Samples (MG and Natural)	No. of Exceedences	Maximum (mg/kg)
pH	<5, >9 (pH units)	82	3 (<pH5)	4.53 (min)
Benzo(a)anthracene	6.2	79	5	14
Benzo(a)pyrene	1	79	22	34
Benzo(b)fluoranthene	7.4	79	1	9.3
Chrysene	10	79	1	11
Dibenzo(ah) anthracene	0.93	79	7	5.3
Indeno(1,2,3-c,d)pyrene	4.4	79	3	6.6
Aromatic C21-C35	1300	49	3	1900
EPH	1300*	35	4	6400

*GAC for Extractable Petroleum Hydrocarbons based on that for Aromatic >C21-C35, representing a conservative estimate of the typical hydrocarbon fraction likely to cause harm to human health.

The majority of exceedences detailed in Table 5-1 above are from Made Ground soils only including landfill, topsoil and reworked topsoil, with the following exceptions:

- Acid conditions and elevated hydrocarbons (aromatic C21-C35) concentrations in peat from BH210 (5.3mbgl), TP307 (2.2mbgl) and BH302 (3.3mbgl).
- Elevated EPH, benzo(a)pyrene and dibenzo(a,h)anthracene was reported at 2.8mbgl in the peat from TP01 (2009); and
- Elevated EPH was reported at 2.6mbgl in the organic-rich clay from TP03 (2009).

Asbestos
None of the 46No. samples scheduled for asbestos analysis were found to contain asbestos-containing materials.

Volatile Organic Compounds (VOC) and Semi Volatile Organic Compounds (SVOCs)
None of the 4No. samples scheduled for VOC and SVOC analysis were found to contain concentrations of any VOCs of SVOCs above the laboratory detection limit.

5.1.3 Soil Contaminant Distribution Assessment

Identified metal and hydrocarbon impacts are considered further in relation to vertical and lateral distribution across the site and through statistical analysis, if considered appropriate.

Metals

Arsenic was reported as elevated in 5No. samples of Made Ground considered to be probable landfill material at depths ranging from 0.70mbgl to 5.00mbgl.

Lead was reported at elevated concentrations in 17No. samples of probable landfill material and 1No. sample of reworked topsoil at depths ranging from 0.30mbgl to 5.00mbgl. It is likely that these elevated concentrations are attributable to the ash reported in the probable landfill material reported in these locations and across the site.

Elevated concentrations of nickel were reported in 3No. samples of Made Ground considered to be landfill material at depths ranging from 2.00mbgl to 5.00mbgl.

pH

Acidic conditions ranging from pH 4.53 were reported in 3No. samples of peat from across the site at depths ranging from 2.20-5.30mbgl. Peat is naturally acidic and the pH of this stratum is typically lower than in other strata across the site. However, as the average pH for the peat across the site is 5.83 and within the recommended GAC range for the proposed development therefore there is not considered to be a significant risk from acidic conditions within the peat.

The pH recorded within the shallow soils was within the recommended GAC range for the proposed development.

Polycyclic Aromatic Hydrocarbons

Significantly elevated concentrations of a variety of Polycyclic Aromatic Hydrocarbons (PAHs) were reported in Made Ground (including topsoil and landfill material) from across the site and in 1No. sample of peat from across the site.

More significantly elevated concentrations of PAHs are reported within the topsoil and reworked topsoil and the elevated concentrations within the peat are of a different composition.

Hydrocarbons

Elevated hydrocarbon (EPH) concentrations were reported in 4No. samples. 1No. from probable landfill material in HDP05 at 1.00mbgl, 1No. from reworked topsoil in HDP07 at 0.25mbgl, 1No. from peat in TP01 at 2.80mbgl and the most significant from natural clay in TP03 at 2.60mbgl reported as having a slight organic odour. Speciated data was also obtained from this sample and the concentrations of total aliphatic/aromatic hydrocarbons C5-C35 amounts to 130mg/kg. Therefore, it is considered likely that the elevated hydrocarbons reported are within the heavy-end fraction of hydrocarbons (>C35).

In addition, elevated concentrations of speciated hydrocarbons (Aromatic C21-35) were reported in 3No. samples of peat at 5.30mbgl (BH210), 2.20mbgl (TP307) and 3.30mbgl (BH302).

With the exception of the significantly elevated EPH concentrations is TP03 considered to be attributable to localised source impacts, the other elevated concentrations are considered likely to be representative of the material across the site. Therefore it is considered appropriate to undertake statistical analysis for the probable landfill material, reworked topsoil and peat deposits.

Screening Summary

Exceedences of the above contaminants are typically widespread, with no significant lateral variations in concentrations identified across the site although variations between material types were identified. These elevated concentrations are therefore considered likely to reflect the wider distribution of concentrations through each deposit type across the site, thus statistical analysis is considered appropriate for each material type to further assess the potential risk to Human Health.

Statistical Analysis

The statistical assessments are used to calculate representative concentrations (defined as the 95% Upper Confidence Limit) of those determinands recorded at elevated concentrations across the site. The 95%UCL is then compared to the GAC to determine if there is a significant impact on site. Outlier tests are also completed.

This statistical analysis is completed based on CIEH guidance (2008) and further details of the statistical methods of analysis are provided in Appendix C.

Table 5-2 to Table 5-4 (below) summarises the conclusions of the statistical assessment.

Table 5-2: Summary of identified impacts within Made Ground (probable landfill material)

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Arsenic	35	28.32	None	No significant impact
Lead	450	415	6600mg/kg in BH308 at 2.00mbgl 3600mg/kg in BH210 at 4.00mbgl 1400mg/kg in TP102 at 1.80mbgl	3No. potential hotspots
Nickel	130	97.74	660mg/kg in BH312 at 5.00mbgl	1No. potential hotspot
Benzo(a) anthracene	6.2	2.63	None	No significant impact
Benzo(a)pyrene	1	2.31	None	Potential site-wide impact
Benzo(b) fluoranthene	7.4	2.58	None	No significant impact
Chrysene	10	2.88	None	No significant impact
Dibenzo(a,h) anthracene	0.93	0.74	None	No significant impact
Indeno(1,2,3-c,d)anthracene	4.4	1.43	None	No significant impact
EPH	1300*	1011	None	No significant impact

*Based on conservative GAC values (see note in Table 5-1)

Within the probable landfill material across the site there are identified site-wide impacts of benzo(a)pyrene and localised impacts of nickel in BH312 at 5.00mbgl and lead in BH308, BH210 and TP102 at depths of 2.00mbgl, 4.00mbgl and 1.80mbgl respectively.

Table 5-3: Summary of identified impacts within Made Ground (topsoil and reworked topsoil)

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Lead	450	240	650mg/kg in TP102 at 0.30mbgl	1No. potential hotspot
Benzo(a) anthracene	6.2	8.61	None	Potential site-wide impact
Benzo(a)pyrene	1	5.43	None	Potential site-wide impact
Dibenzo(a,h) anthracene	0.93	0.80	None	No significant impact
Indeno(1,2,3-c,d)anthracene	4.4	4.17	None	No significant impact
EPH	1300*	852	None	No significant impact

Within the topsoil and reworked topsoil material across the site there are identified site-wide impacts of benzo(a)anthracene and benzo(a)pyrene and a localised impact of lead in TP102 at 0.30mbgl.

Table 5-4: Summary of identified impacts within Peat

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Benzo(a)pyrene	1	0.45	34mg/kg in TP01 at 2.80mbgl	1No. potential hotspot
Dibenzo(a,h) anthracene	0.93	0.02	5.7mg/kg in TP01 at 2.80mbgl	1No. potential hotspot
Aromatic C21-35	1300	1289.49	None	No significant impact

Within the peat across the site there are identified localised impacts of benzo(a)pyrene and dibenzo(a,h)anthracene in TP01 at 2.80mbgl.

5.1.4 Soil Summary

The generic screening assessment, contaminant distribution and statistical analysis and assessment following interpretation of the proposed topographic levels across the site have identified the following impacts from those contaminants identified at elevated concentrations in soils across the site.

The following impacts have been identified:

- Localised elevated concentrations of nickel in probable landfill from BH312 (5.00mbgl);
- Localised elevated concentrations of lead in probable landfill material from BH308 (2.00mbgl), BH210 (4.00mbgl) and TP102 (1.80mbgl);
- Localised elevated concentrations of lead in reworked topsoil from TP102 (0.30mbgl);
- Site wide impact of benzo(a)pyrene within probable landfill material and topsoil;
- Site wide impact of benzo(a)anthracene within topsoil material; and
- Localised elevated concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene in peat from TP01 (2.80mbgl).

5.2 Controlled Waters Assessment

5.2.1 Methodology

Details of the methodology used to define GAC are provided in Appendix C.

The GAC adopted for assessment of soil leachate and groundwater are defined based on local environmental receptors.

Typically, shallow groundwater has been encountered on site overlying the peat. In addition there is a moderately permeable aquifer within the solid geology underlying the site. Groundwater within the aquifer is typically located at the solid/superficial interface. The site does not lie within a source protection zone and there are no groundwater abstractions within 250m of the site boundary.

There are various surface drains labelled on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the

southwest site boundary. On investigation, these are surface ditches, typically dry, which are likely to fill with water during heavy rain. A photograph is included in Appendix A as Figure 2.2. The nearest surface water receptor is therefore Monkland Canal, which runs east to west and lies approximately 350m south of the site and Lochend Loch and Woodend Loch lie approximately 450m west and 650m northwest of the site boundary respectively.

Vertical migration into the underlying moderately permeable aquifer is considered to be a potential risk and any leaching during heavy rainfall may enter the drains to the southwest of the site.

The GAC used for groundwater and leachate data is therefore the freshwater Environmental Quality Standards (EQS), or in the absence of EQS, UK Drinking Water Standards (DWS) will be used. The guideline values selected as appropriate GAC for each contaminant are presented in Appendix C.

5.2.2 Leachate Screening Analysis

Leachate analysis for the selected suite of determinands was undertaken on 18No. soil samples submitted for analysis during the supplementary site investigation (RUK, 2009). 21No. soil samples were submitted for leachate analysis during the initial URS investigations in 2006 and 2008. Chemical analysis results screening tables are held in Appendix H, detailing measured concentrations of potential contaminants in comparison with the applicable GAC. Where reported analyses exceed GAC, these are highlighted within the tables. Table 5-5 provides a summary of any exceedances.

Table 5-5: Summary of Leachate Exceedences compared with relevant GAC

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Copper	**1**	26/38	<1	22	3.7
Zinc	**75**	4/38	<1	330	29
Ammoniacal Nitrogen	**200**	6/18	<20	4,900	466
Phenol	**30**	6/35	<0.50	8,800	683
Sulphate	**400,000**	1/35	1,500	540,000	43,000
Anthracene	**0.02**	8/33	<0.01	0.14	0.025
Fluoranthene	**0.02**	9/33	<0.01	0.13	0.030
Sum of 4No. PAH[1]	**0.1**	1/33	0.04	0.11	0.06
Extractable Petroleum Hydrocarbons (EPH)	**90[2]**	1/18	<10	210	36

Minimum, Maximum and Mean concentrations in relation to all data
[1]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene
[2]GAC based on WHO, 2005 values. As no specific GAC is available for EPH(C10-C40) results have been screened to the most conservative GAC (Aromatic C16-21) for speciated hydrocarbons >C10.*
**As recommended by Contaminated Land Officer, North Lanarkshire Council (see email in Appendix B, 14th January 2010)*

All other determinands were either reported below detection limits or were detectable at concentrations below their respective GAC.

5.2.3 Leachate Contaminant Distribution Assessment

Identified metal and hydrocarbon impacts are considered further in relation to vertical and lateral distribution across the site and through statistical analysis, if considered appropriate.

Metals

When compared to the conservative EQS for copper (1ug/l) various samples of landfill material, topsoil and natural strata reported elevated copper concentrations. Due to the widespread nature of these exceedences they are considered likely to be representative of deposits across the site.

4No. samples of probable landfill material reported marginally elevated concentrations of zinc across the site.

Ammoniacal Nitrogen

Ammoniacal Nitrogen is reported to be leaching in elevated concentrations from 6No. samples; 2No. samples of probable landfill material, 3No. samples from natural strata and 1No. sample of topsoil.

Phenol

Phenols were reported as significantly elevated in 6No. leachate samples; 5No. from the probable landfill material and 1No. from natural strata.

With the exception of these 6No. exceedences all other leachate samples analysed for phenols reported concentrations below or at the detection limit. In addition, all soil samples (including those with corresponding elevated concentrations of phenols in leachate) reported concentrations of phenols below detection limit. It is therefore considered unlikely that a source of phenols exists on site which may present a significant risk to Controlled Waters.

Sulphate

Sulphate is reported as marginally elevated in 1No. leachate sample from the probable landfill material.

Organics

Leachate exceedances of anthracene and fluoranthene were reported in 8No. and 9No. soil samples respectively including probable landfill material, natural clay, topsoil and peat. Typically the most significant exceedances (an order of magnitude above the respective GAC) were reported in leachate from the probable landfill material.

1No. sample of the sum of 4No. PAHs was reported to be leaching at concentrations marginally exceeding the GAC (0.11ug/l compared to the GAC of 0.1ug/l) in a sample of reworked topsoil from 0.25mbgl. Considering the marginal and isolated nature of this exceedance it is not considered to present a significant risk to controlled waters and no further assessment is required.

Leachable concentrations of EPH were reported as marginally elevated in 1No. sample from peat.

Screening Summary

Exceedences of the above contaminants are widespread within leachate, with no significant lateral variations in concentrations identified across the site although variations between material types were identified. These elevated concentrations are therefore considered likely to be representative of each deposit type across the site, thus statistical analysis is considered appropriate for each material type to further assess the potential risk to Controlled Waters.

Statistical Analysis

The statistical assessments are used to calculate representative concentrations (defined as the 95% Upper Confidence Limit) of those determinands reported to be leaching at elevated concentrations across the site. The 95%UCL is then compared to the EQS (or DWS where no EQS are available) to determine if there is a significant impact on site. Outlier tests are also completed. This statistical analysis is completed based on CIEH guidance (2008) and further details of the statistical methods of analysis are provided in Appendix C.

Table 5-6 and Table 5-7 (below) summarise the conclusions of the statistical assessment. Due to the limited leachate samples available from the natural strata across the site, statistical analysis is not considered appropriate and therefore Table 5-8 summarises the distribution and extent of impacts within natural strata.

Table 5-6: Summary of identified impacts leaching from Made Ground (probable landfill material)

Contaminant	GAC (ug/l)	Upper Confidence Limit (excluding outliers) (ug/l)	Outliers	Assessment
Copper	1	3.61	22ug/l from BH206 at 2.0mbgl 16ug/l from TP212 at 0.4mbgl	2No. potential hot-spots and potential site-wide impact
Zinc	75	103	None	Potential site-wide impact
Sulphate	400,000	171,000	None	No significant impact
Ammoniacal Nitrogen	200	94.3	800ug/l from HDP07 at 1.00mbgl 4900ug/l from TP102 at 1.80mbgl	2No. potential hotspots
Phenols	30	10.8	6No. ranging from 2,500ug/l to 8,800ug/l	6No. potential hotspots
Anthracene	0.02	0.038	0.14ug/l in TP05 at 2.6mbgl	1No. potential hot-spot and potential site-wide impact
Fluoranthene	0.02	0.060	None	Potential site-wide impact

Within the leachate from the probable landfill material across the site there are identified site-wide impacts of copper, zinc, anthracene, fluoranthene and EPH. Localised impacts of copper, ammonium, phenols and anthracene have also been identified.

Table 5-7: Summary of identified impacts leaching from Made Ground (topsoil and reworked topsoil)

Contaminant	GAC (ug/l)	Upper Confidence Limit (excluding outliers) (ug/l)	Outliers	Assessment
Copper	1	6.32	None	Potential site-wide impact
Ammoniacal Nitrogen	200	126	280ug/l in HP02 at 0.07mbgl	1No. potential hotspot
Fluoranthene	0.02	0.01	0.03ug/l in TP103 at 0.25mbgl	1No. potential hotspot

Within the leachate from the topsoil and reworked topsoil material across the site there are identified site-wide minor impacts of copper and EPH and localised minor impacts of ammoniacal nitrogen in HP02 and PAHs in TP103.

Table 5-8: Summary of identified impacts leaching from Natural Strata

Contaminant	GAC (ug/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Assessment
Copper	1	3/4	<1.6	4	Similar concentrations within the peat and clay deposits
Ammoniacal Nitrogen	200	3/3	220	1,000	Most significant exceedence from the natural clay
Phenols	30	1/4	<0.50	3,000	Only exceedence reported from natural clay
Anthracene	0.02	2/4	<0.015	0.07	Most significant exceedences from the peat
Fluoranthene	0.02	2/4	<0.017	0.09	
EPH	90	1/3	20	210	

Minimum, Maximum and Mean concentrations in relation to all data

5.2.4 Groundwater Screening Analysis

Groundwater monitoring was undertaken by URS on 1No. visit in August 2008. This section provides a full assessment of the potential risks to groundwater based on all available data.

Groundwater samples were collected from 10No. installations. The installations were screened across various strata including Made Ground deposits and underlying superficial strata including the clay, silt and peat. These installations were within the response zone of the shallow groundwater within the superficial deposits, typically perched above the peat. 1No. installation in BH207 was also screened into what is considered likely to be the underlying aquifer at the solid/superficial interface.

Chemical results from groundwater monitoring visits (2008) are presented in Appendix G. Screening tables comparing the groundwater analytical results to their respective GAC are presented in Appendix H. Exceedences of these GAC are highlighted within the tables (Appendix H) and are summarised in Table 5-9 below.

Table 5-9: Summary of Water Exceedences compared with relevant GAC

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Maximum (µg/l)	Minimum (µg/l)	Mean (µg/l)
Copper	1	4/10	5.3	<1.6	2.23
Manganese	30	10/10	7,800	1,600	2,802
Zinc	75	3/10	370	<5	75.9
Ammoniacal Nitrogen	200	10/10	16,000	600	4,920
pH	6.5-10	1/10	7.74	6.46	7.09
Nitrites	500	1/10	510	<300	118
Anthracene	0.02	3/10	0.065	<0.015	0.026
Fluoranthene	0.02	9/10	0.46	<0.017	0.143
Benzo(a)pyrene	0.03	6/10	0.29	<0.009	0.993
Sum of 4No. PAH[1]	0.1	6/10	1.06	0.05	0.373
Aliphatics >C21-C35	300[2]	1/10	740	<10	83
Aromatics >C21-35	90	3/10	360	<10	89

Minimum, Maximum and Mean concentrations in relation to all data
[1]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene
[2]GAC based on WHO, 2005 values. As no specific GAC is available for Aliphatic C16-35 results have been screened to the most conservative GAC for Aliphatic speciations (Aliphatic C12-16).*
**As recommended by Contaminated Land Officer, North Lanarkshire Council (email provided in Appendix B, 14th January 2010)*

The laboratory results indicate the following determinands were identified in concentrations above GAC in groundwater:

Metals

4No. groundwater samples reported concentrations of copper exceeding the conservative freshwater Environmental Quality Standard (EQS) of 1ug/l. None of the exceedences were more than an order of magnitude above the GAC although elevated copper concentrations were also reported in leachate from the topsoil and probable landfill material across the site.

Zinc was reported at marginally elevated concentrations in 3No. samples of shallow groundwater across the site. Elevated zinc concentrations were also reported in leachate from the probable landfill material across the site suggesting a mobile, leachable source of zinc may exist in the landfill material.

Manganese was reported as significantly elevated above the EQS of 30ug/l in all samples of groundwater analysed from across the site. Therefore there may be a mobile source of manganese on site.

pH

Marginally acidic conditions were reported in 1No. sample from BH210 and this corresponds to the acidic conditions reported in the peat at this location. Due to the marginal and isolated nature of this exceedance however, the pH is not considered to be a significant risk to Controlled Waters.

Ammoniacal Nitrogen

Significantly elevated ammonium concentrations were reported across the site when compared to the recommended EQS of 200ug/l. Elevated concentrations of ammonium were also found to be leaching from the probable landfill material across the site indicating there may be a potential source of ammonium within the probable landfill material from across the site.

Phenols

Elevated phenols were reported to be leaching from the probable landfill material and natural clay in isolated areas across the site at concentrations exceeding the GAC. However, phenol concentrations in the shallow groundwater were reported below detection limit therefore suggesting that there is not a significant risk to Controlled Waters from phenols.

Nitrites

Nitrites were reported as marginally elevated in 1No. sample of groundwater from BH311. Due to the marginal and isolated nature of this exceedance there is not considered to be a significant risk to Controlled Waters from nitrites.

Organics

Chemical analysis of groundwater indicates elevated concentrations of various PAHs (including anthracene, fluoranthene and benzo(a)pyrene) and heavy-end hydrocarbons within the underlying shallow groundwater.

9No. samples of groundwater reported concentrations of fluoranthene above the EQS of 0.02ug/l. 6No. of these samples also reported elevated concentrations of benzo(a)pyrene and sum of 4No. PAHs and a further 3No. of these reported marginally elevated concentrations of anthracene. Elevated anthracene and fluoranthene concentrations were also reported within leachate samples from across the site and elevated PAHs were also reported within soil samples from the landfill, topsoil and peat across the site. Therefore there is a potential for a leachable, mobile source of PAHs to exist on site.

Elevated concentrations of high-range organics including aliphatics >C21-35 were reported as elevated in localised groundwater from BH205 and aromatics >C21-35 were reported as elevated in localised groundwater from BH202, BH205 and BH211. Marginally elevated hydrocarbon concentrations were reported in only 1No. leachate sample from the peat deposits, and as impacts within the groundwater are localised it suggests the potential for hydrocarbons to leach and mobilise into groundwater is limited.

Concentrations of these contaminants do not indicate any lateral pattern of distribution to suggest a single, isolated source creating a plume of hydrocarbons within the shallow groundwater. Therefore it is considered likely that the material from across the site is leaching these contaminants in similar concentrations mobilising the contaminants into the shallow groundwater.

5.2.5 Controlled Waters Assessment Summary

The generic screening assessment and contaminant distribution assessment of the potential risks to Controlled Waters have identified particular contaminants at elevated concentrations in leachate and shallow groundwater across the site which may present a significant risk to Controlled Waters.

This assessment is based on the shallow groundwater as there are currently no installations appropriately screened into the underlying moderately permeable aquifer; typically located at the superficial/solid geology interface.

The following impacts have been identified:

- Elevated concentrations of copper, zinc and anthracene are leaching at concentrations exceeding the GAC and are impacting the shallow groundwater at similar concentrations;
- Elevated concentrations of ammoniacal nitrogen are reported in leachate, typically from the probable landfill material on site but also from localised areas of natural materials and topsoil on site. Concentrations are typically more significantly elevated within the shallow groundwater on site. The significantly elevated concentrations of ammonia within groundwater are considered likely to be attributable to the breakdown of organic components within the landfill waste and subsequent leaching as no cap was placed above the waste material to minimise leaching. As the landfill is thought to have closed in 1972, it is likely that concentrations of ammonia within leachate would have been significantly higher than at present, thus increasing the concentration of ammonia within the shallow

groundwater across the site. The breakdown of any organic contaminants within the landfill will be reducing over time and this is reflected in the concentrations of ammonia within the leachate;

- Fluoranthene and PAHs (sum of 4No.) are leaching at elevated concentrations most significantly from the probable landfill material across the site but also from localised areas within the topsoil and peat deposits. These contaminants are reported at significantly higher concentrations within the shallow groundwater on site and elevated concentrations of benzo(a)pyrene are also reported in groundwater although no elevated concentrations were reported within leachate (typically reported below detection limit). Higher concentrations of these contaminants within the shallow groundwater rather than leachate are likely due to the decreasing decay of organic matter within the landfill material over time, as discussed above. Benzo(a)pyrene is likely no longer being leached from organic materials within the landfill material as the bacterial decay of this organic material has occurred previously and the impacts from subsequent leaching are revealed only within the groundwater data;
- Concentrations of EPH within leachate are marginally elevated within the peat deposits. However, all speciated TPH leachate data from C5-C35 reported concentrations below detection limit suggesting the only significant impacts are from heavy-end organics greater than C35. In addition, only localised impacts of heavy-end organics (greater than C21) are reported in shallow groundwater across the site. These organics are unlikely to be highly mobile within the water environment, which is demonstrated by the isolated impacts within shallow groundwater;
- Manganese is an essential element in the production of steel and it is known that waste from the Gartcherrie Steel Works was disposed of annually at the former Townhead Landfill, underlying the site. It is likely that leaching of this material within the landfill resulted in migration of manganese into shallow groundwater, therefore explaining the significantly elevated concentrations of manganese across the site. As detailed above, it is likely that manganese represents a finite source and concentrations within the leachate and the shallow groundwater will reduce over time; and
- Phenols were reported as significantly elevated in leachate from 5No. samples of probable landfill and 1No. sample of natural strata. Considering the concentrations of phenols within soils, all other leachate samples and all groundwater samples reported concentrations of phenols below or at the detection limit it is considered unlikely that a significant source of phenols exists on site.

All site wide impacts are considered to be only marginally above the recommended GAC. Only localised impacts have been reported at slightly higher concentrations. The decreased concentrations reported in all strata indicate that there is likely to be only a limited ongoing source of leachable contaminants, which have the potential to impact the underling shallow groundwater.

5.3 Assessment of Phytotoxic Contaminants

5.3.1 Methodology

As landscaped areas are proposed as part of the St Ambrose development, the potential risk to plants from phytotoxic contaminants has been assessed. The GAC selected for this assessment are taken from The Soil Code (MAFF, 1998) as these are

considered to represent the most appropriate guideline values for phytotoxic effects of contaminants on plants.

5.3.2 Screening Analysis

Summary tables screening potentially phytotoxic contaminants are held in Appendix H, detailing the measured concentrations of potential contaminants in comparison with the applicable GAC (MAFF, 1998). These tables combine chemical data from the initial investigations in 2006 and 2008 (URS) with data from the recent supplementary investigation (RUK, 2009).

Measured concentrations above the recommended GAC are highlighted within the tables (Appendix H) and Table 5-10 provides a summary of these exceedences.

Table 5-10: Summary of Soil Exceedences Compared with Phytotoxic GAC

Determinand	GAC (mg/kg)	No. of Samples (MG and Natural)	No. of Exceedences	Maximum (mg/kg)
Arsenic	50	82	2	71
Lead	300	82	26	6600
Nickel	110	82	14	660
Copper	200	82	23	4600
Mercury	1	82	9	8.9
Zinc	300	82	38	4800

The majority of exceedences detailed in Table 5-10 above are from Made Ground, probable landfill material, with the following exceptions:

- Marginally elevated lead and zinc in topsoil from 0.05mbgl in HDP11;
- Marginally elevated zinc in topsoil and reworked topsoil from 0.10mbgl and 0.25mbgl in HDP08 and HDP07 respectively;
- Elevated lead and zinc in reworked topsoil from 0.07mbgl and 0.30mbgl in HDP02 and TP102 respectively;
- Elevated copper, nickel and zinc in peat from 4.00mbgl in TP219;
- Elevated lead and zinc in natural strata (not peat) at 2.45mbgl in TP04 (2009); and
- Marginally elevated copper in natural strata from TP348 at 2.00mbgl.

5.3.3 Phytotoxic Contaminant Distribution Assessment

Identified impacts with regard to phytotoxicity are considered further in relation to vertical and lateral distribution across the site and through statistical analysis, if considered appropriate.

Considering the isolated and marginal nature of the exceedences of phytotoxic metals in natural strata, these exceedences are not considered likely to present a significant risk to plants on site and no further assessment is deemed necessary.

No significant lateral variations in concentrations have been identified across the site although variations in material types have been identified. The majority of exceedences reported are within the probable landfill material, with a lesser number of exceedences from topsoil and reworked topsoil. Statistical analysis is therefore considered appropriate for the probable landfill material and topsoil/reworked topsoil deposits. Exceedences from all depths of Made Ground have been considered for

statistical analysis (even those at considerable depth), due to the extent of cut and fill levels across the site, and the consequent reworking of Made Ground that may result.

Statistical Analysis

Statistical analysis of the data has been undertaken to calculate representative concentrations (defined as the 95% Upper Confidence Limit) of those determinands recorded at elevated concentrations across the site. The 95%UCL is compared to the GAC to determine if there is a significant impact on site. Outlier tests have also been undertaken. The statistical analyses are based on CIEH guidance (2008), further details of which are provided in Appendix C.

Table 5-11 to Table 5-12 (below) summarises the conclusions of the statistical assessment.

Table 5-11: Summary of identified phytotoxic impacts within Made Ground (probable landfill material)

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Arsenic	50	27.8	None	No significant impact
Lead	300	415	6600mg/kg in BH308 at 2.00mbgl 3600mg/kg in BH210 at 4.00mbgl 1400mg/kg in TP102 at 1.80mbgl	3No. potential hotspots and potential site-wide impact
Nickel	110	96.2	660mg/kg in BH312 at 5.00mbgl	1No. potential hotspot
Mercury	1	2.08	None	Potential site-wide impact
Copper	200	253	4600mg/kg in BH210 at 4.00mbgl 2100mg/kg in TP212 at 0.40mbgl	2No. potential hotspots and potential site-wide impact
Zinc	300	700	4800mg/kg in BH210 at 4.00mbgl	1No. potential hotspots and potential site-wide impact

Within the probable landfill material across the site there are identified site-wide impacts of phytotoxic contaminants including lead, mercury, copper and zinc. Localised impacts of nickel in BH312 at 5.00mbgl, lead in BH308, BH210 and TP102 at depths of 2.00mbgl, 4.00mbgl and 1.80mbgl respectively, copper at 0.40mbgl in TP212 and zinc at 4.00mbgl in BH210.

Table 5-12: Summary of identified phytotoxic impacts within Made Ground (topsoil and reworked topsoil)

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Lead	300	240	650mg/kg in TP102 at 0.30mbgl	1No. potential hotspot
Zinc	300	461	None	Potential site-wide impact

Within the topsoil and reworked topsoil material across the site there are identified site-wide impacts of zinc and a localised impact of lead in TP102 at 0.30mbgl.

5.3.4 Phytotoxic Contaminant Summary

The generic screening assessment, contaminant distribution and statistical analysis and assessment have identified the following impacts from those contaminants identified at elevated concentrations in soils across the site when compared to phytotoxic screening values:

- Localised elevated concentrations of lead, nickel, copper and zinc in probable landfill;
- Localised elevated concentrations of lead in reworked topsoil from TP102 (0.30mbgl); and
- Site wide impact of lead, mercury, copper and zinc within probable landfill material and topsoil.

5.4 Potential Risks to Supply Pipes

The soils across the site have been screened to the standards advised in accordance with the Water Regulations Advisory Scheme (WRAS) guidance note, 2002 (9-04-03). Full screening tables are held in Appendix H; Table 5-13 below provides a summary of the exceedences reported.

Table 5-13: Summary of Soil Exceedences compared with relevant WRAS recommended GAC

Determinand	GAC (mg/kg)	No. of exceedences/ No. of samples	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)
Arsenic	**10**	29/82	<3	71	11.3
Cadmium	**3**	4/82	<0.1	9.5	1.11
Lead	**500**	13/82	2	6,600	365
Mercury	**1**	9/82	<0.05	8.9	0.707
Sulphate	**2000**	12/82	0.01	37,000	1,270
Sulphide	**5000**	3/82	<15	3,460	118
pH	**5-8**	22/82	4.53	8.64	7.28
PAH	**50**	6/73	<1.6	130	15.8
Total TPH	**50**	42/49	7.8	3,900	549
Extractable Petroleum Hydrocarbons (EPH)	**50**	33/35	12	6,400	720

Minimum, Maximum and Mean concentrations in relation to all data

The majority of exceedences with regards to WRAS guidance (2002) detailed in Table 5-13 above are from Made Ground soils including landfill, topsoil and reworked topsoil, with the following exceptions:

- Acidic conditions in the peat from 5.3mbgl, 2.2mbgl and 3.3mbgl in BH210, TP307 and BH302 respectively;
- Marginally elevated sulphate in the peat from 4.5mbgl in BH313 and in other natural strata from 2mbgl in TP348;
- Elevated petroleum hydrocarbons in the peat and other natural strata from all samples (with the exception of 2No.);
- Marginally elevated pH from 14mbgl in BH205;
- Marginally elevated arsenic in other natural strata from TP04 at 2.45mbgl.

5.4.1 WRAS Contaminant Distribution Assessment

Identified impacts with regard to potential risks to water supply pipes are considered further in relation to vertical and lateral distribution across the site and through statistical analysis, if considered appropriate.

No significant lateral variations in concentrations have been identified across the site although variations in material types have been identified. The majority of exceedences reported are within the probable landfill material; with a lesser number of exceedences from topsoil/reworked topsoil and natural strata. Statistical analysis is therefore considered appropriate for the probable landfill material, topsoil/reworked topsoil deposits and natural strata.

Statistical Analysis

The statistical assessments are used to calculate representative concentrations (defined as the 95% Upper Confidence Limit) of those determinands recorded at elevated concentrations across the site. The 95%UCL is then compared to the GAC to determine if there is a significant impact on site. Outlier tests are also undertaken. The statistical analyses are based on CIEH guidance (2008), further details of which are provided in Appendix C.

Table 5-14 to Table 5-15 (below) summarises the conclusions of the statistical assessment.

Table 5-14: Summary of identified impacts within Made Ground (probable landfill material) when compared to WRAS guideline values

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Arsenic	10	28.3	No	Potential site-wide impact
Cadmium	3	2.48	No	No significant impact
Lead	500	415	6600mg/kg in BH308 at 2.00mbgl 3600mg/kg in BH210 at 4.00mbgl 1400mg/kg in TP102 at 1.80mbgl	3No. potential hotspots
Mercury	1	2.02	None	Potential site-wide impact
Sulphate	2,000	6,540	None	Potential site-wide impact
Total TPH	50	1,230	None	Potential site-wide impact
EPH	50	1,010	None	Potential site-wide impact

Within the probable landfill material across the site there are identified site-wide impacts of contaminants which may affect pipework including arsenic, mercury, sulphate and petroleum hydrocarbons. Localised impacts of lead in BH308, BH210 and TP102 at depths of 2.00mbgl, 4.00mbgl and 1.80mbgl respectively were reported.

Table 5-15: Summary of identified impacts within Made Ground (topsoil and reworked topsoil) when compared to WRAS guideline values

Contaminant	GAC (mg/kg)	Upper Confidence Limit (excluding outliers) (mg/kg)	Outliers	Assessment
Lead	500	240	650mg/kg in TP102 at 0.30mbgl	1No. potential hotspot
Arsenic	10	15.6	None	Potential site-wide impact
PAH	50	66.8	None	Potential site-wide impact
EPH	50	852	None	Potential site-wide impact

Within the topsoil and reworked topsoil material across the site there are identified site-wide impacts of arsenic, PAHs and EPH and a localised impact of lead in TP102 at 0.30mbgl.

Considering the marginal and localised nature of exceedences of sulphate and arsenic in peat and other natural strata, they are not considered to present a significant risk to water supply pipes. However, all samples from peat and other natural strata analysed for petroleum hydrocarbons reported exceedences with the exception of 2No. samples. These are considered to be site-wide impacts within the natural strata.

5.4.2 WRAS Summary

The generic screening assessment, contaminant distribution and statistical analysis and assessment have identified the following impacts from those contaminants identified at elevated concentrations in soils across the site when compared to the WRAS guidelines (2002):

- Localised elevated concentrations of lead in probable landfill and topsoil material;
- Site-wide impacts of arsenic, mercury, sulphate and petroleum hydrocarbons in probable landfill material;
- Site-wide impacts of arsenic, petroleum hydrocarbons and PAHs in topsoil; and
- Site-wide impacts of petroleum hydrocarbons in natural strata.

5.5 Ground Gas Risk Assessment

A ground gas monitoring programme was undertaken by URS as part of the investigations in 2006 and 2008/9. An assessment of the risk presented by any potential ground gas on site was undertaken as part of the *Ground Investigation Report* (URS, 2008) which concluded additional ground gas monitoring would be required. 12No. rounds of ground gas monitoring were undertaken between November 2008 and April 2009 and interpreted within the letter provided in Appendix I (reference 49339729/GLLT0015, May 2009). In addition, during the Geotechnics Ltd. investigation in September-November 2009, 7No. cable percussive boreholes with rotary follow-on were undertaken on Ramboll's instruction in order to provide additional geotechnical data for the site. These boreholes were installed and monitored for ground gas over 4No. visits between October and November 2009.

The section provides a full assessment of all the gas monitoring data available for the site in accordance with CIRIA C665 and BS8485, taking into accounts the comments made by URS. Further details of the assessment methodology are provided in Appendix C.

All available ground gas monitoring data is included within Appendix J. Table 5-16 provides a summary of the maximum and minimum gas concentrations and flow rates reported in each borehole monitored from 2006 to 2009.

Table 5-16: Summary of Ground Gas Monitoring Visits

Borehole	Response Zone	Flow rate (l/hr)*		Peak Gas Concentration (% v/v)						Max. GSV	CS (C665)
				CH_4		CO_2		O_2			
		Max	**Min**	Max	Min	Max	Min	Max	Min		
BH1 (2006)	MG	2.5	0.05	0.1	<0.1	5.8	<0.1	21.6	5.8	**0.145**	**2**
BH2 (2006)	MG	2.4	0.2	4.0	<0.1	12.6	<0.1	3.8	<0.1	**0.302**	**2**
BH3 (2006)	MG	2.2	-0.3	0.1	<0.1	6.2	<0.1	20.8	<0.1	**0.136**	**2**
BH201 (2008)	MG	<0.1	<0.1	<0.1	<0.1	1.7	0.8	18.1	16.8	**0.0017**	**1**
BH202 (2008)	Peat	<0.1	<0.1	68.7	65.3	30.2	20.0	<0.1	<0.1	**0.0687**	**2**
BH203 (2008)	MG	<0.1	<0.1	<0.1	<0.1	1.9	1.5	18.8	18.2	**0.0019**	**1**
BH204 (2008)	Peat	<0.1	<0.1	<0.1	<0.1	2.5	1.9	18.2	17.7	**0.0025**	**1**
BH205 (2008)	MG	<0.1	<0.1	3.7	2.7	4.8	2.9	13.9	13.1	**0.0048**	**1**
BH206 (2008)	MG	<0.1	<0.1	<0.1	<0.1	2.3	1.7	18.4	17.8	**0.0023**	**1**
BH207 (2008)	Silt/Clay /Peat	<0.1	<0.1	<0.1	<0.1	0.8	0.6	20.4	20.1	**0.0008**	**1**
BH208 (2008)	Peat	<0.1	<0.1	10.2	8.3	9.6	6.9	8.9	6.7	**0.0102**	**2**
BH209 (2008)	MG	<0.1	<0.1	<0.1	<0.1	3.7	2.5	16.7	16.1	**0.0037**	**1**
BH210 (2008)	Peat	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	20.6	20.1	**0.0001**	**1**
BH211 (2008)	MG	<0.1	<0.1	<0.1	<0.1	12.3	9.8	10.2	7.8	**0.0123**	**2**
BH213 (2008)	MG	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	20.8	20.7	**0.0001**	**1**
BH301(2008)	MG	<0.1	<0.1	<0.1	<0.1	3.9	2.9	16.1	15.7	**0.0039**	**1**
BH302(2008)	Silt/Clay /Peat	<0.1	<0.1	66.2	62.1	23.3	20.5	0.7	<0.1	**0.0662**	**2**
BH303(2008)	MG	<0.1	<0.1	0.3	0.2	18.4	16.8	1.9	1.1	**0.0184**	**2**
BH304(2008)	Silt/Clay /Peat	<0.1	<0.1	9.1	7.9	5.1	3.9	16.9	16.3	**0.0091**	**2**
BH305(2008)	Silt/Clay	<0.1	<0.1	34.8	28.9	20.0	18.7	10.5	9.7	**0.0348**	**2**
BH306(2008)	MG	<0.1	<0.1	<0.1	<0.1	0.4	0.1	20.7	20.4	**0.0004**	**1**
BH307(2008)	MG	<0.1	<0.1	<0.1	<0.1	13.7	11.7	7.5	6.1	**0.0137**	**2**
BH308(2008)	MG/Peat	<0.1	<0.1	47.4	38.9	23.2	20.7	5.8	4.2	**0.0232**	**2**
BH309(2008)	Peat	<0.1	<0.1	16.8	15.3	21.7	20.5	4.8	4.5	**0.0217**	**2**
BH310(2008)	MG	<0.1	<0.1	<0.1	<0.1	0.6	<0.1	20.7	20.1	**0.0006**	**1**
BH311 (2008)	MG	<0.1	<0.1	<0.1	<0.1	16.8	14.7	3.3	2.3	**0.0168**	**2**
BH312 (2008)	MG/Peat/ Sand/Clay	<0.1	<0.1	<0.1	<0.1	0.8	0.5	19.9	19.5	**0.0008**	**1**
BH313 (2008)	MG	<0.1	<0.1	<0.1	<0.1	12.9	12.9	3.0	3.0	**0.0129**	**2**
BH201 (08/09)	MG	0.2	<0.1	0.2	<0.1	14.2	0.3	19.3	1.1	**0.028**	**2**
BH202 (08/09)	MG	0.2	<0.1	66.9	<0.1	14.5	<0.1	19.7	<0.1	**0.029**	**2**
BH203 (08/09)	MG	0.2	<0.1	3.1	0.1	9.9	1.7	16.5	<0.1	**0.0198**	**2**
BH204 (08/09)	MG	0.2	<0.1	18.6	0.1	16.9	4.2	17.6	7.4	**0.0372**	**2**

Borehole	Response Zone	Flow rate (l/hr)*		Peak Gas Concentration (% v/v)						Max. GSV	CS (C665)
				CH_4		CO_2		O_2			
		Max	**Min**	Max	Min	Max	Min	Max	Min		
BH205 (08/09)	Peat	0.1	<0.1	0.5	<0.1	15.3	5.2	20.1	0.1	**0.0153**	**2**
BH206 (08/09)	MG	0.2	<0.1	0.1	<0.1	15.9	7.4	12.4	1.7	**0.0318**	**2**
BH207 (08/09)	Peat	0.3	<0.1	<0.1	<0.1	21.7	5.0	15.1	5.3	**0.0651**	**2**
BH208 (08/09)	MG	0.1	<0.1	2.8	1.9	7.6	3.5	19.3	9.5	**0.0076**	**2**
BH209 (08/09)	MG	0.1	<0.1	<0.1	<0.1	5.2	0.2	20.6	13.8	**0.0052**	**1**
BH210 (08/09)	Silt/Clay /Peat	0.1	<0.1	75.4	<0.1	22.7	<0.1	17.1	<0.1	**0.0754**	**2**
BH211 (08/09)	Peat	0.3	<0.1	1.0	<0.1	13.0	<0.1	19.4	<0.1	**0.039**	**2**
BH213 (08/09)	MG	0.7	<0.1	<0.1	<0.1	2.1	<0.1	20.9	18	**0.0147**	**1**
BH301 (08/09)	Peat	0.1	<0.1	0.5	<0.1	4.0	<0.1	20.6	<0.1	**0.004**	**1**
BH302 (08/09)	MG	0.2	<0.1	52.5	<0.1	23.5	<0.1	0.5	<0.1	**0.105**	**2**
BH303 (08/09)	MG	0.1	<0.1	9.5	<0.1	18.2	5.7	11.8	<0.1	**0.0182**	**2**
BH304 (08/09)	MG	1.4	<0.1	69.1	<0.1	31.8	<0.1	10.7	<0.1	**0.967**	**3**
BH305 (08/09)	Silt/Clay /Peat	1.8	<0.1	62.1	1.1	32.2	1.3	18.9	3.1	**1.12**	**3**
BH306 (08/09)	MG	0.1	<0.1	1.1	<0.1	5.9	1.6	19.1	<0.1	**0.0059**	**2**
BH307 (08/09)	Silt/Clay /Peat	0.4	<0.1	0.5	<0.1	16.2	5.3	19.5	2.0	**0.0648**	**2**
BH308 (08/09)	Silt/Clay	10.9	<0.1	14.8	<0.1	20.9	2.5	18.7	2.2	**2.28**	**3**
BH309 (08/09)	MG	0.3	<0.1	<0.1	<0.1	3.6	0.8	20.4	17.6	**0.0108**	**1**
BH310 (08/09)	MG	0.2	<0.1	<0.1	<0.1	14.6	0.2	20.4	0.3	**0.0292**	**2**
BH311 (08/09)	MG/Peat	0.1	<0.1	<0.1	<0.1	16.0	1.8	20.3	<0.1	**0.016**	**2**
BH312 (08/09)	Peat	<0.1	<0.1	0.4	<0.1	5.3	0.1	20.9	9.4	**0.0053**	**2**
BH313 (08/09)	MG	0.2	<0.1	<0.1	<0.1	11.5	0.2	20.6	6.5	**0.023**	**2**
BH401 (2009)	Peat	0.8	<0.1	68.0	21.0	10.0	5.1	10.6	0.7	**0.54**	**2**
BH402 (2009)	Peat	16.2	<0.1	69.0	61.0	13.0	9.6	1.0	<0.1	**11.18**	**4**
BH403 (2009)	MG/Peat	0.4	<0.1	20.0	1.5	14.0	4.8	17.0	5.3	**0.08**	**2**
BH404 (2009)	Peat	0.1	<0.1	2.7	<0.1	7.2	2.4	18.7	18.3	**0.0072**	**1**
BH405 (2009)	Peat	1.4	<0.1	15.0	6.1	13.0	2.0	15.0	2.2	**0.21**	**2**
BH405A (2009)	Peat	0.2	<0.1	2.3	<0.1	43.3	2.0	19.6	3.7	**0.087**	**2**
BH406 (2009)	Peat	<0.1	<0.1	0.1	<0.1	11.0	5.6	13.5	2.9	**0.011**	**1**
Worst Case Scenario		**16.2**		**75.4**		**43.3**		**-**		**12.21**	**4**

**Negative flow rates are reported at below detection limit for the purpose of calculating the GSV*

From a review of the available ground gas data the concentrations reported would classify the proposed development as Characteristic Situation 4 based on a worst case scenario, assuming the highest methane concentration (75.4%) and flow rate (16.2l/hr) could occur simultaneously on site. The highest methane concentrations were reported from the natural peat deposits underlying the site.

The elevated flow rate of 10.9l/hr reported in BH308 was recorded on a single occasion with other flow rates from the same well reported between 0.1l/hr and negative 12.5l/hr (-12.5/l/hr) during all other visits.

Furthermore, there are a number of factors which call into question the data from BH308, in which the apparently anomalous flow rate was recorded. This well is

reported to be screened between 1.00-11.00mbgl, however water level during the first visit was reported to be above the screen (0.78mbgl) which is likely to produce unreliable results. On subsequent monitoring visits, URS reported the bung to be *"jammed down standpipe"* so that groundwater could not be monitored again. Therefore it is likely a combination of interference of groundwater and inappropriate monitoring of this borehole has caused this apparently anomalous result.

The initial results from BH308 suggested the extremely elevated flow rate was an anomalous result. However, during the recent rounds of ground gas monitoring undertaken by Geotechnics Ltd, peak flow rates of up to 16.2l/hr have again been recorded from standpipes with response zones within the peat. Again, these elevated flow rates were only reported in 1No. well (BH402) but on 2No. separate occasions.

Therefore, although typical flow rates across the site are 0.1-1.8l/hr, high flow rates of up to 16.2l/hr have been reported in 2No. boreholes and it has been demonstrated that these high flow rates can occur with simultaneously elevated methane concentrations.

In addition, elevated concentrations of carbon monoxide have also been reported. Typically, concentrations of carbon monoxide range from <1ppm to 3ppm, however, a maximum concentration of 18ppm has been reported on one occasion, from BH405 screened in peat (Geotechnics, 2009).

The proposed development is a sensitive end-use and there is a high risk of ground gas generation from various sources across the site. As a result of these factors and following consultation with North Lanarkshire Council, classification of the site as Characteristic Situation 4 is considered to be appropriate.

6 GROUND CONTAMINATION

6.1 Conceptual Site Model

The information presented in the previous sections of this report have been collated and evaluated to refine the initial conceptual site model for the site. This updated conceptual site model is illustrated in cross-section form in Appendix A, Drawing No. 5311/E/004.

6.1.1 Sources

The following sources of potential contamination have been identified based on the available information from the initial investigations in 2006 and 2008 (URS) and the supplementary investigation in 2009 (Ramboll):

- Potential soil contamination which may pose a risk to Human Health:
    - Localised elevated concentrations of nickel in probable landfill from BH312
    - Elevated localised concentrations of lead reported in probable landfill material in the area of BH308, BH210 and TP102;
    - Localised elevated concentrations of lead, reported in reworked topsoil material in TP102 at 0.30mbgl;
    - Site wide impacts of benzo(a)pyrene within the probable landfill material and topsoil;
    - Site wide impacts of benzo(a)anthracene within the topsoil material; and
    - Localised elevated concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene, reported in TP01 within the peat.

- Potential leachate and groundwater contamination which may pose a risk to Controlled Waters:
    - Marginally elevated concentrations of copper, zinc and anthracene within leachate from across the site, which is impacting the shallow groundwater;
    - Elevated concentrations of ammoniacal nitrogen within the shallow groundwater continuing to leach from materials across the site at slightly elevated concentrations;
    - Fluoranthene and PAHs (sum of 4No.) are leaching at elevated concentrations most significantly from the probable landfill material across the site;
    - Localised elevated concentrations of aliphatic and aromatic C21-35 are reported in shallow groundwater;
    - Elevated manganese within the shallow groundwater across the site, likely a result of leaching from landfill material across the site;
    - Elevated phenols were reported as elevated within leachate samples from isolated areas of landfill material and natural strata; and
    - Elevated ground gas concentrations including methane and carbon dioxide.

- Potential phytotoxic contamination in soils which may pose a risk to plants in soft landscaped areas:

- Localised elevated concentrations of lead, nickel, copper and zinc in probable landfill;
- Localised elevated concentrations of lead in reworked topsoil from TP102 (0.30mbgl); and
- Elevated concentrations of lead, mercury, copper and zinc within probable landfill material and topsoil across the site.

- Potential soil contamination which may present a risk to water supply pipes (WRAS, 2002):

  - Localised elevated concentrations of lead in probable landfill and topsoil;
  - Site-wide impacts of arsenic, mercury, sulphate and petroleum hydrocarbons in probable landfill;
  - Site-wide impacts of arsenic, petroleum hydrocarbons and PAHs in topsoil; and
  - Site wide impacts of petroleum hydrocarbons in natural strata.

6.1.2 Receptors

The site-specific receptors that could potentially be affected by the contamination hazards have been identified in the preliminary conceptual model in Section 2.6.2. Receptors include:

- Future site users – school children, staff and the general public;
- Site development workers;
- Underlying aquifer and surface water features;
- Construction materials;
- Adjacent site users and structures; and
- Site vegetation.

6.1.3 Pathways

The following potential contaminant pathways are considered likely to exist on site given the nature of the site and the contamination sources identified:

Dermal contact with and ingestion of soils;
Plant uptake;

Direct contact pathways and plant uptake will only be active in areas of landscaping with the exception of the sports pitches. The proposed make-up of the pitches includes 250mm-350mm of imported clean fill material which will be separated from the probable landfill material below by a low permeability membrane. Based on these measures across the pitches and the reported concentrations of contaminants, direct contact pathways and plant uptake within the areas of the sports pitches are not considered active.

As the source areas are both localised and site-wide, further consideration is given below as to the location of localised impacts within the proposed development to determine whether these pathways will be active.

The localised elevated concentrations of lead reported in probable landfill material in the area of BH308, BH210 and TP102 and nickel reported in probable landfill material from BH312 were reported in samples at depths exceeding 1.80mbgl. In addition, localised elevated concentrations of lead were also reported in topsoil material in

TP102 at 0.30mbgl. However, these samples are from strata which persist to shallower depths of a minimum of 0.05mbgl and although based on current cut and fill proposals these hotspots are in areas of fill (Drawing NCL-STA-DRG-C-316 in Appendix A), existing site levels will need to be reduced prior to construction. The materials cut from these areas may therefore present a potential risk to Human Health via direct contact pathways.

Localised elevated concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene were reported in TP01 within the peat at a depth of 2.80mbgl. These contaminants are considered to be naturally occurring within the peat and are at a depth considered unlikely to affect future site users via direct contact due to the levels of fill proposed in this area.

Site-wide impacts of benzo(a)pyrene have been identified in the probable landfill and topsoil material across the site and side-wide impacts of benzo(a)anthracene have also been identified in topsoil. These contaminants may therefore present significant risk in areas of soft landscaping via the direct contact pathway to future site users.

When compared to phytotoxic assessment criteria, elevated concentrations of lead, mercury, copper and zinc were reported in Made Ground across the site (including probable landfill and topsoil material). The concentrations of these contaminants reported may present a significant risk to plants and vegetation via plant uptake in areas of soft landscaping.

Ground gas migration;
Inhalation of dusts and vapours;

Leaching and subsequent migration of mobile impacts;

There will be an overall increase in hardstanding across the site and the proposed sports pitches will include a low permeability membrane and surface water drainage system, which will limit rainfall infiltration and the leaching potential of soils. In addition, across the site the probable landfill material is separated from the solid geology (and therefore moderately permeable aquifer) by peat and/or superficial clay, which is likely to restrict the vertical migration of contaminants from the shallow groundwater, into the aquifer below.

In exploratory holes from across the site, the minimum depth of cohesive deposits (including peat and/or clay) separating the Made Ground from the solid geology, is 2.10mbgl and 2.70mbgl reported in BH313 and BH311 respectively (URS, 2008). Typically the depth of cohesive deposits is between 3-10m. However, in rotary boreholes including BH110 (URS, 2008), R03 and R04 (2006), there is between 0-0.4m of natural cohesive strata reported between the Made Ground and solid geology.

Made Ground in R03 and R04 (URS, 2006) is described in drillers logs as "*Made Ground (ash, peat and clay)*" which is considered likely to be a Driller's combined description of the Made Ground and underlying superficial deposits during rotary open-hole drilling. In BH110 (URS, 2008) Made Ground is described as "peat and ash". In all 10No. rotary boreholes undertaken as part of the mining investigation by URS in 2008, no defined peat strata are reported in the borehole logs. Instead, peat is included within the description of Made Ground strata. From the extensive investigations on site, it has been proven that a peat layer underlies the Made Ground in the majority of the site. It is therefore considered likely that this Driller's description of Made Ground includes a combined description of the true Made Ground

material and underlying peat deposits as a result of the highly disturbed nature of rotary arisings and the smearing effect through the core barrel during the rotary open-hole drilling process.

To provide further evidence for this hypothesis, additional boreholes in close proximity to BH110, R03 and R04 have been reviewed. BH308 (33m east of R03) reports 3.8m Made Ground, separated from the solid geology reported at 14.70mbgl by 3.80m peat and 7.10m clay. BH206 (25m southeast of R04) reports 4.55m Made Ground underlain by 2.30m peat and 4.35m clay and solid geology was not reported at the end of the borehole at 11.20mbgl. BH110 lies 36m east of BH310 and 42m west of BH313. These two boreholes report thicknesses of cohesive natural strata between 3.10m and 7.65m including peat and clay deposits.

Therefore it is considered likely that the cohesive deposits across the site are present at a sufficient thickness to mitigate the vertical migration of potential contaminants from shallow groundwater to the underlying aquifer. There are however, 2No. areas adjacent to the northern and eastern site boundaries where potential mine shafts are present (2No. shafts in each area) as shown on the Mason Evans Drawing G2008/473/C/F/04, Appendix A.

In these areas the thickness of cohesive natural strata may have been reduced by mining activities and therefore preferential pathways for the vertical migration of contaminants may be present. In addition, should piling methods extend into the underlying bedrock, preferential pathways for the vertical migration of potential contamination may have been created.

Soakaways are currently proposed in 2No. areas on site, near TP01 in the southwest area of site and underlying the pitch in the southeast corner of site near TP03, TP04 and TP05. In the southeast area of the site, marginal impacts of copper, ammonium, anthracene, fluoranthene and EPH were reported in leachate from probable landfill and natural strata in these areas. Marginally elevated concentrations of lead, dibenzo(a,h)anthracene and EPH were reported in localised soils in this area but these are not considered to be significant.

In samples from TP01 elevated EPH, benzo(a)pyrene and dibenzo(a,h)anthracene were reported in soil samples from the peat in this location. Marginally elevated anthrancene and fluoranthene were reported within leachate from the landfill material and marginally elevated copper, ammonium, anthracene, fluoranthene and EPH were reported in peat. These elevated concentrations are not considered to be significant.

Although the concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene reported in the soils are significant, leachate results reported these contaminants at concentrations below detection limit, therefore suggesting this soil source is not mobile in the water environment. These concentrations of the contaminants reported within leachate are not considered to be significant.

Contaminant ingress into potable water supply pipes and subsequent damage and/or consumption by site users.

Various contaminants which may present a risk to water supply pipes have been reported in probable landfill, topsoil and natural strata across the site when compared to the WRAS screening criteria. Corrosive contaminants including sulphate, organic contaminants including PAHs and petroleum hydrocarbons, toxic contaminants including arsenic, lead and mercury and potentially flammable

methane may all present a significant risk to water supply pipes.

6.2 Qualitative Risk Assessment

Potential pollutant linkages are identified using the source-pathway-receptor framework detailed above. An assessment of the potential significance of each linkage is then made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

This qualitative hazard assessment has been undertaken in accordance with CIRIA C552: *Contaminated Land Risk Assessment, A Guide to Good Practice*. Further details of the methodology used and definition of the risk categories is provided in Appendix C.

Table **6-1** summarises the pollutant linkages and risk ratings associated with the proposed development.

Table 6-1: Hazard Assessment

Hazard / Pollutant	Pathway	Receptor	Potential Severity	Probability Of Risk	Level Of Risk
Localised elevated soil concentrations of lead in topsoil, lead and nickel in landfill material	• Dermal contact • Inhalation of Dusts and Vapours • Ingestion	Future site users	Medium	Unlikely	**LOW**
		Site development workers*	Medium	Low	**LOW / MODERATE**
	• Leaching from soils • Leachate migration • Surface water run-off • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Unlikely	**LOW**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**
Localised elevated soil concentrations of PAHs in peat	• Dermal contact • Inhalation of Dusts and Vapours • Ingestion	Future site users	Medium	Unlikely	**LOW**
		Site development workers*	Medium	Unlikely	**LOW**
	• Leaching from soils • Leachate migration • Surface water run-off • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Unlikely	**LOW**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**

Hazard / Pollutant	Pathway	Receptor	Potential Severity	Probability Of Risk	Level Of Risk
Site-wide impacts of benzo(a)pyrene in landfill material and topsoil and site-wide impacts of benzo(a)anthracene in topsoil	• Dermal contact • Inhalation of Dusts and Vapours • Ingestion	Future site users	Medium	Likely	**MODERATE**
		Site development workers*	Medium	Likely	**MODERATE**
	• Leaching from soils • Leachate migration • Surface water run-off • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Unlikely	**LOW**
	• Plant root uptake	Vegetation in soft landscaped areas	Minor	Likely	**LOW**
Elevated concentrations of lead, nickel, copper, mercury and zinc in topsoil and landfill material across the site when compared to phytotoxic assessment criteria	• Plant root uptake	Soft landscaping (lawns and pitches)	Mild	Low	**LOW**
		Soft landscaping (planted areas)	Mild	Likely	**LOW / MODERATE**
Elevated concentrations of metals, sulphate and organics in topsoil and landfill material across the site when compared to WRAS screening criteria	• Contaminant ingress into potable water supply pipes	Future site users	Medium	Likely	**MODERATE**
		Pipe construction material	Mild	Likely	**LOW / MODERATE**
Marginally elevated copper and zinc within leachate and shallow groundwater	• Leaching from soils • Leachate migration • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Mild	Unlikely	**VERY LOW**
		Secondary Aquifer	Mild	Low	**LOW**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**
Elevated manganese, ammonia and PAH within shallow groundwater and leachate.	• Leaching from soils • Leachate migration • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Low	**LOW / MODERATE**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**

Hazard / Pollutant	Pathway	Receptor	Potential Severity	Probability Of Risk	Level Of Risk
Localised elevated hydrocarbons within shallow groundwater	• Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Unlikely	**LOW**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**
Localised marginally elevated concentrations of EPH, PAH, ammonium and copper within leachate in the areas of the proposed soakaway	• Leaching from soils • Leachate migration • Migration of groundwater	Neighbouring properties	Mild	Low	**LOW**
		Surface water (Monkland Canal; Lochs)	Medium	Unlikely	**LOW**
		Secondary Aquifer	Medium	Low	**LOW / MODERATE**
	• Plant root uptake	Vegetation in soft landscaped areas	Mild	Low	**LOW**
Generation of potentially hazardous ground gas	Ground gas migration	Site users	Severe	Likely	**HIGH**
		Site development workers*	Severe	Likely	**HIGH**

**Given the use of appropriate PPE and health and safety precautions, risk to workers would be reduced to low.*

The risks to Human Health via direct contact with lead and nickel in localised areas across the site including TP102, BH308, BH210 and BH312 are considered to be **LOW / MODERATE** as these materials are at depths proposed to be excavated as part of the cut and fill works.

Localised elevated concentrations of PAHs are located in areas of proposed fill with at least 600mm of fill or existing material located above the source strata. Therefore these localised impacts are unlikely to present a risk via direct contact pathways. Risks to Human Health from these impacts are therefore considered to be **LOW**.

Risks to human health caused by elevated benzo(a)pyrene in probable landfill and topsoil material across the site and elevated benzo(a)anthracene in topsoil are considered likely to be significant in areas of soft landscaping where there will be an active direct contact pathway. Therefore the risk to human health from benzo(a)pyrene and benzo(a)anthracene is classified as **MODERATE**. Risks to vegetation in any planted areas caused by plant root uptake of these contaminants are considered to be **LOW.**

Elevated phytotoxic contaminants (including lead, nickel, copper, mercury and zinc) within the Made Ground across the site are considered to present a **LOW** risk to vegetation in the proposed pitch areas. This is due to the proposed make-up of the pitches (including a low permeability membrane and 250-350mm of imported clean fill material) limiting the uptake of contaminants from the Made Ground. However in planted areas such as borders and flower beds the risk to vegetation from plant uptake are considered to be **LOW/MODERATE.**

Risks to potable water supply pipes are considered to be **LOW/MODERATE** with risks to future site users from contaminant ingress into water supply pipes and consumption of contaminated water considered to represent a **MODERATE** risk. Corrosive, toxic, organic and flammable contaminants have been reported in Made Ground at concentrations exceeding WRAS threshold values.

Risks to the underlying Secondary Aquifer from the localised hydrocarbons and marginal impacts of copper and zinc already identified within the shallow groundwater are classified as **LOW**. Due to the significant depths of impermeable deposits including peat and clay overlying the aquifer in the majority of locations across the site it is considered unlikely that significant vertical migration of contaminants will occur. However, potential risks of preferential pathways in the areas of the mine shafts may exist. Therefore risks to the aquifer underlying the site are classified as **LOW / MODERATE** due to the impacts of manganese, ammonia and PAH within the shallow groundwater.

In areas of the proposed soakaways the risks to the underlying aquifer are considered to be **LOW / MODERATE**.

The development proposals include increasing the area of hardstanding across the site thus reducing leaching potential and likely pathways. Based on the significant distance to the nearest surface water receptor (Monkland Canal; Lochend and Woodend Lochs all >350m from the site) and the proposed development minimising pollutant linkages, the risks to the surface water receptors are considered to be **LOW**.

Risks to future site users from the generation, migration and accumulation of potentially hazardous ground gases in confined spaces resulting in asphyxiation or explosion are considered to be **HIGH**.

6.3 Development Considerations

Activities on-site that could affect ground conditions potentially include piling operations, foundation design, earthworks, installation of underground services and provision of drainage infrastructure.

Any piled solution to foundation design should be developed in such a way so that the installation of the piles themselves does not create preferential flow pathways by which potential contamination could mobilise in the unsaturated zone. It is understood that the proposed piling solution includes driven pre-cast piles and bored cast-in-place piles. The use of a pointed or conical driving shoe has been proposed in order to limit any downward migration of potential contaminants during piling.

Contractors should ensure compliance with SEPA guidelines on piling in contaminated land (*Piling and penetrative ground improvement methods on land affected by contamination: Guidance on pollution prevention.* EA, 2001*)*.

Foundation design should take into consideration the potential to encounter aggressive ground conditions beyond those identified during the site investigation.

As the development is proposed to comprise buildings and hard-standing, with associated areas of soft landscaping, infiltration of rainwater may be reduced compared to the present situation, with limited potential for leaching and downward migration of potential contaminants to the underlying groundwater.

It is understood that grouting works are proposed in order to provide mine stabilisation across the site. Any potential migration of grout leachate has the potential to impact Controlled Waters and therefore appropriate methods of grouting should be used to mitigate against this potential risk. Contractors should ensure compliance with BRE publication *"Stabilising mine workings with PFA grouts – Environmental Code of Practise, 2006".*

Soakaways are proposed in 2No. areas of site. The design of these soakaways must take into account the marginal contamination impacts identified in these areas. Although rainfall and surface water infiltration will be encouraged in these areas, the soakaways have been strategically placed towards the south of the site away from the main hub of the landfill to minimise infiltration through the landfill material. In addition, it is considered that the proposed drainage across the entire site will minimise infiltration and leaching through the landfill, therefore improving upon the current situation at the site.

7 RISK MANAGEMENT STRATEGY

7.1 Significant pollutant linkages

Potentially significant pollutant linkages have been identified during the ground contamination risk assessment. These are:

- Risks to Human Health through direct contact pathways with elevated benzo(a)pyrene in probable landfill material across the site;
- Risks to Human Health through direct contact pathways with elevated benzo(a)pyrene and benzo(a)anthracene in topsoil material across the site;
- Risks to Controlled Waters through vertical migration of contaminants including manganese, ammonia, PAH, localised hydrocarbons, copper and zinc from the shallow perched groundwater into the deep aquifer, particularly within the areas of the proposed soakaways and potential mine shafts;
- Risks to Human Health through the generation, migration and accumulation of potentially hazardous ground gases (methane and carbon dioxide) in confined spaces resulting in asphyxiation or explosion;
- Risks to vegetation through plant uptake in planted soft landscaped areas including borders and flower beds; and
- Risks of damage to water supply pipes through contaminant ingress and risks to Human Health through subsequent consumption of potable water by site users.

No risk management strategy is proposed for site development workers as any potential risks should be managed through the implementation of standard health and safety precautions, such as the use of appropriate personal protective equipment (PPE).

7.2 Recommendations

7.2.1 Additional Assessment and Investigation

In order to further assess the potential risks to Human Health caused by the site-wide impacts of benzo(a)anthracene in topsoil, benzo(a)pyrene in topsoil and landfill material and localised hot spots of nickel it is recommended that a Detailed Quantitative Risk Assessment (DQRA) is undertaken in order to derive more appropriate site-specific assessment criteria for these contaminants.

Further investigation into the potential risks to the underlying aquifer including additional groundwater sampling from the shallow groundwater and underlying aquifer across the site may be required in order to further assess the potential risks to Controlled Waters, particularly considering soakaways are proposed in 2No. areas of site.

7.2.2 Proposed Remedial Measures

In addition and based on the information available to date, there is likely to be a requirement for remedial action to progress the development.

The following recommendations are made in order to reduce risks to human health from identified ground gas impacts assuming Characteristic Situation 4:

a) *Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) or beam and block or pre-cast concrete slab;*

b) *All joints and penetrations sealed; and*

c) *Proprietary gas resistant membrane and passively ventilated underfloor subspace or positively pressurised underfloor sub-space with monitoring facility. (in accordance with CIRIA C665)*

Consideration of the point scheme, detailed in BS8485 and superseding the CIRIA recommendations above, should also be given to ensure sufficient mitigation against the build-up of ground gases is provided.

Ramboll have consulted with 2No. leading contractors in the design and installation of ground gas protection systems. Based on the maximum concentrations of methane and carbon dioxide and the maximum flow rate recorded on site an actively ventilated system is considered necessary. Ramboll have received 2No. designs for active ground gas protection systems, considered by the contractors to be compliant with Characteristic Situation 4 and designed to mitigate against the concentrations of ground gas and flow rates reported on site. The proposals for these systems are included in Appendix K.

In addition, hotspots of lead were identified in localised areas across the site, typically at depths exceeding 1.80mbgl. Based on current proposals these impacts are in areas to be filled (*i.e.*, the ground level will be raised) but prior to these works, material from these areas will require excavation in order to obtain finished site levels. This excavated material may present a risk to Human Health via the direct contact pathway and it is not considered appropriate to undertake DQRA modelling for lead due to the limiting variables involved in the calculations for the lead GAC. The GAC for lead of 450mg/kg is therefore considered appropriate for this site. It is proposed that during enabling works, material excavated from the areas where lead hotspots were reported, is stockpiled separately and subjected to validation testing to establish whether the material is suitable for reuse.

Elevated concentrations of phytotoxic contaminants have been reported in Made Ground across the site and it is considered likely that these contaminants may present a risk to plants and vegetation in planted areas such as borders and flower beds. It is therefore recommended that 600mm of imported clean fill material is imported into all planted areas.

There remains the potential for ground conditions to vary in areas not directly investigated.

7.3 Additional considerations for development

Cut and Fill Works
Any excavation works on site may encounter volumes of potentially contaminated groundwater, which was recorded at depths ranging from 1.90mbgl to 4.70mbgl. Allowances are recommended to be made for the removal, treatment and disposal of shallow groundwater should dewatering be required during excavation.

Significant cut and fill works are proposed for the site and there is a potential for contaminated materials not previously identified to be uncovered on site. It is therefore recommended that a suitably qualified Environmental Consultant is on site

during the enabling works to ensure that should any areas of apparent contamination be exposed; the material is excavated, stockpiled separately onsite and subjected to validation testing in order to ensure the material is suitable for use.

Waste Disposal
Any excavation/piling may result in soils that require off-site disposal, if they are unsuitable for reuse on site. All excavated materials will be controlled waste. Further assessment will be required to establish classification (hazardous or non-hazardous) and further chemical testing (and/or pre-treatment) if disposal to landfill is considered. Some form of pre-treatment of those materials to be disposed to landfill (*e.g.*, screening to remove oversized 'clean' demolition material and gravels) may significantly reduce the volume of material liable to classify as hazardous waste.

Environmental Specification
It is recommended that an Environmental Specification Report is produced in order to ensure the Contractor is undertaking all enabling works in accordance with the recommendations above.

Validation Works
Validation sampling will be required from all materials cut from site during enabling works in order to ensure all materials are suitable for use. These results, along with documented evidence to illustrate that the remedial measures detailed above and within the Environmental Specification have been adhered to, will need to be documented in a Validation Report and submitted to the Environmental Department at North Lanarkshire Council.

Underground Services
Laying underground services in potentially contaminated Made Ground materials has the potential to establish preferential flow pathways and therefore materials should be used appropriate to the level of contamination identified on site, particularly with regard to underground mains water supply.

Various contaminants have been reported as elevated when compared to the WRAS screening criteria. In order to protect the mains water supply from contamination in Made Ground strata across the site, it is recommended that wrapped iron pipes are used for potable water supply. In addition, it is noted that arsenic is reported as elevated in Made Ground across the site and *"it is not recommended that water supply pipes be lain in sites where [arsenic] is identified"* WRAS, 2002. Therefore it is also recommended that during installation of the water supply pipes, trenches are over-excavated and filled with inert material in order to remediate the immediate area of the water supply pipes and mitigate any potential damage caused by elevated arsenic contamination. Detailed and early consultation with Scottish Water is strongly recommended in this regard.

It is understood that plastic HDPE pipes are proposed for drainage across the site and it is therefore recommended that trenches dug for the installation of these drainage pipes are infilled with inert material in order to mitigate against any potential damage from contaminants.

Asbestos
No asbestos-containing material (ACM) has been identified on site. However, as the site has been historically redeveloped and used as a landfill, localised deposits of asbestos-containing materials have the potential to be present in Made Ground across the site. Appropriate health and safety precautions (*i.e.*, provision of appropriate PPE to site development workers, *etc*.) should be adopted during enabling works.

8 REFERENCES

BS 5930 (1999) Code of Practice for Ground Investigation

BS 8485 (2007) Code of practice for the characterization and remediation from ground gas in affected developments. British Standards Institute 2007

CIRIA 552 (2001) Contaminated land risk assessment – a guide to good practice. London

CIRIA C665 (2007) Assessing risks posed by hazardous ground gases to buildings. London

Contaminated Land: Applications in Real Environments (CL:AIRE) and Chartered Institute of Environmental Health (CIEH) (2008) Guidance on Comparing Soil Contamination Data with a Critical Concentration (May 2008)

Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) (2002) CLR 8: Potential Contaminants for the Assessment of Land

Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) (2002) CLR 11: The Model Procedures for the Management of Land Contamination

Environment Agency, 2009a SR2 *Human Health toxicological assessment of contaminants in soil* SC050021/SR2 (January 2009)

Environment Agency, 2009b SR3 *Updated technical background to the CLEA model* SC050021/SR3 (January 2009)

Scottish Environmental Protection Agency (SEPA) 2009 www.sepa.org.uk (Accessed throughout November 2009)

Eurocode 7 (2007) Geotechnical Design –BS EN 1997-2:2007

LQM/CIEH (2007) Generic Assessment Criteria for Human Health Risk Assessment. Land Quality Management Ltd and Chartered Institute of Environmental Health

Multimap (2009) www.multimap.co.uk (Accessed throughout November 2009)

Ordnance Survey (2009) www.ordnancesurvey.co.uk (Accessed throughout November 2009)

Planning Policy Statement 25 (PPS25): Development and Flood Risk. December 2006