

**REPORT
ON
GROUND INVESTIGATION
AT
FORMER BELLROCK NURSERY
GLASGOW**

December 2010

Ref No: H273

Engineer: Scott Bennett Associates (Group 2) Limited



CONTENTS

	<u>Page</u>
1. INTRODUCTION	1 of 36
2. SITE WORK	1 of 36
3. LABORATORY WORK	2 of 36
4. GROUND CONDITIONS	2 of 36
5. COMMENTS ON THE GROUND CONDITIONS IN RELATION TO FOUNDATION DESIGN	3 of 36
6. ENVIRONMENTAL ASSESSMENT	5 of 36
7. REFERENCES	36 of 36

Appendix 1

Site Plan	
Soils Borehole Logs	BH 1 – BH 8
Trial Pit Logs	TP 1 – TP 15
Gas Monitoring Results	Table A

Appendix 2 **Laboratory Test Report**

Laboratory Testing References		
Summary of Test Results	Table 1	Page 1 of 6
Summary of CBR Tests Results	Table 2	Page 2 of 6
Triaxial Test Results		Page 3 - 4 of 6
Oedometer Test Results		Page 5 - 6 of 6

Appendix 3

Chemical and Environmental Test Results



**GROUND INVESTIGATION
REPORT
AT
FORMER BELLROCK NURSERY
GLASGOW**

1. INTRODUCTION

It is proposed to construct a residential development at the site of the former Bellrock Nursery, Glasgow.

At the request of Scott Bennett Associates (Group 2) Limited, Consulting Engineers for the project, a ground investigation was carried out in order to establish the ground conditions at the site to enable recommendations to be made with respect to design and construction of the proposed scheme.

This report presents an interpretation of the information established by observation, boring, sampling and in-situ testing. It should be noted that natural strata vary from point to point and that man made deposits are subject to an even greater diversity. Groundwater conditions are dependent upon seasonal and other factors. Whilst an attempt is made in comprehensive reporting to assess the likelihood or extent of such variations at the site, it should be recognised that there may be conditions pertaining which are not disclosed by the investigation.

Opinions and interpretations expressed herein are outside the scope of UKAS Accreditation.

2. SITE WORK

The field works were carried out during the period 21st to 27th October 2010 and comprised:-

9 No. Light Cable Percussion Boreholes, including 1 No. re-bore, to a maximum depth of 3.80 metres

15 No. Machine Excavated Trial Pits

Details of the boreholes and trial pits including daily progress of hole and casing, descriptions of strata encountered, records of sampling and in-situ testing carried out, observations of groundwater conditions while boring and depths to changes in strata are presented in the exploratory hole records in Appendix 1.



3. LABORATORY WORK

The samples of soil taken during the site works were transported to the laboratory for systematic examination and testing. The characteristics of the soils determined in the laboratory were used to supplement field observations in the preparation of the final exploratory hole records.

Testing was carried out on selected samples to the requirements of the relevant British Standards, or in accordance with current good practice, as appropriate.

The Laboratory Testing References section of Appendix 2 details the tests performed in the laboratory which are UKAS accredited.

Tests marked "Not UKAS Accredited" in this report are not included in the UKAS Accreditation Schedule for our laboratory.

Laboratory Testing Comprised:-

- Classification Tests
- Undrained Triaxial Strength Tests
- Oedometer Consolidation Tests
- California Bearing Ratio Tests
- Chemical Analysis
- Environmental Analysis

The results are presented in summary and detailed Tables and Figures in Appendices 2 and 3.

4. GROUND CONDITIONS

The ground conditions encountered during the investigation comprised topsoil and/or made ground over clay, sand and probable bedrock.

Topsoil was found in Borehole BH7 and Trial Pits TP5, TP7 to TP11, TP13 and TP15 from ground level to depths generally between 0.10 metres and 0.40 metres below ground level (bgl). Locally in Trial Pits TP7 and TP8, the topsoil was found to extend to depths of 0.80 metres and 0.60 metres bgl respectively. Trial Pit TP5 was terminated in the topsoil due to the presence of an electric cable.

Underlying the topsoil and from ground level in the remainder of the exploratory holes, made ground was found to extend to depths between 0.30 metres and 1.20 metres bgl. The made ground predominantly comprised clay or sand with varying proportions of gravel, ash, brick, concrete, glass and burnt shale. Locally in a number of exploratory holes surface layers of tarmac, hardcore and burnt shale were also recorded. Trial Pit TP4 was terminated in the made ground on a concrete obstruction at a depth of 0.40 metres bgl.

Below the topsoil and made ground, the ground conditions encountered to a maximum depth of 3.60 metres bgl generally comprised clay or sand.



The cohesive deposits were recorded in Boreholes BH1, BH2, BH3 and BH8 and Trial Pits TP1, TP2, TP6, TP8 to TP10 and TP12 to TP15. The clay was found to contain varying proportions of sand, gravel and cobbles and was generally described as firm and stiff. However locally in Boreholes BH1 and BH2, Trial Pits TP9, TP13 and TP14, layers of soft clay were recorded. The maximum thickness of the soft clay layer was 1.00 metre in Trial Pit TP9, where the soft cohesive soil was found between 0.60 metres and 1.60 metres bgl. In addition, within Trial Pits TP1, TP2, TP3 and TP10, traces of organic matter were recorded in the upper horizons of the firm clay deposits. Trial Pits TP1, TP2, TP6, TP8 and TP15 were terminated in the cohesive soils.

Granular deposits, comprising sand with varying proportions of clay, gravel and cobbles was recorded below the topsoil and made ground in Boreholes BH4, BH 6, BH6A and BH7 and Trial Pits TP3, TP6 to TP8 and TP10 to TP12. The results of the in-situ penetration tests indicate the sand to be dense. Trial Pits TP3, TP10 and TP12 were terminated in the granular deposits.

All boreholes and Trial Pits TP7, TP9 and TP13 to TP15 were terminated on obstructions, probable bedrock, at depths between 0.70 metres and 3.80 metres bgl. The bedrock was proved for a maximum thickness of 1.40 metres in Borehole 2, where it was recorded between 0.60 metres and 2.00 metres bgl and found to comprise shale.

All exploratory holes except Trial Pit TP1 remained dry during the fieldwork. Within Trial Pit TP1 a water strike was recorded in the made ground at a depth of 0.40 metres bgl.

5. COMMENTS ON THE GROUND CONDITIONS IN RELATION TO FOUNDATION DESIGN

It is not generally advisable to place shallow strip foundations in existing made ground unless it is known to have been a carefully selected material, well compacted under controlled conditions. Clearly this information is not available at this site. Similarly, the topsoil is also considered unsuitable bearing strata. Accordingly, all foundation loads should be transferred below the base of the made ground and topsoil. The findings of the investigation indicate this will involve excavations to depths between 0.10 metres and 1.20 metres bgl.

The ground conditions encountered below the topsoil and made ground generally comprised firm and stiff clay and dense sand. Based on the results of the laboratory and in-situ penetration tests and a visual assessment, an allowable bearing capacity of 100 kN/m² is considered appropriate for the firm and stiff cohesive and dense granular soils.

However within Boreholes BH1 and BH2 and Trial Pits TP9, TP13 and TP14, layers of soft clay were recorded immediately below the made ground between depths of 0.30 metres and 1.60 metres bgl, with the maximum thickness of the soft clay being 1.00 metre in Trial Pit TP9. The soft clay is considered to be unsuitable bearing strata and as a result, it is recommended foundation loads are transferred below the soft clay. As a result, the use of excavate and replace (trench fill) techniques will locally be required.



The ground conditions encountered below the soft clay comprised probable bedrock. Shallow bedrock was also recorded in Borehole BH5 at a depth of 0.60 metres bgl. For foundations formed in competent bedrock there are no anticipated problems regarding bearing capacity or settlement. However where shallow bedrock is recorded, to eliminate the potential for differential settlement, it is recommended all foundation loads for individual buildings are transferred to bedrock.

In addition to the above, within Trial Pits TP1, TP2, TP3 and TP10, traces of organic matter were recorded within the firm clay deposits. Whilst the organic matter content encountered during the investigation is not considered to be problematical, it is imperative all prepared surfaces are carefully inspected to ensure significant quantities of organic matter are not present below proposed foundations.

The flow of groundwater into foundation excavations may be anticipated to be small and it should be possible to control the level of water by open-sump pumping.

Groundwater should not be permitted to flow over the base of foundation excavations. Where a delay is anticipated between the time of excavations and the concreting of a foundation the formation should be protected by either a blinding layer of concrete or over-site polythene.

The bases of all foundation excavations should be thoroughly inspected on completion to ensure that conditions are as have been assumed in design. Any soft or loose pockets should be removed and replaced by lean mix concrete.

A lightly loaded reinforced concrete ground bearing floor slab should generally perform satisfactorily provided topsoil is removed and the slab is cast on a blanket of well compacted imported granular fill. However as stated above, the localised presence of traces of organic matter within the upper horizons of the cohesive soils should be anticipated. Should the quantity of organic matter within the cohesive soils increase from that encountered during the investigation, then the use of ground bearing slabs may not be possible.

The results of four CBR tests on samples of cohesive deposits indicate a design CBR of less than 2% to be appropriate, necessitating the use of a full capping layer. In addition, where the ground conditions at formation level comprise made ground, then it is likely the local authority will stipulate the adoption of a full capping layer.

The findings of the desk study indicate no anticipated problems regarding the mineral stability of the site.



6. ENVIRONMENTAL ASSESSMENT

6.1 General

This section of the report is concerned with an assessment of the environmental conditions at the site through the refinement of the conceptual site model, based on the data collated during the site investigation.

UK legislation changed in the year 2000 with the implementation of Part IIA of the Environmental Protection Act. This legislation provides a definition of contaminated land as "Land posing significant risk where:

1. Significant harm is being caused, or there is a significant possibility of such harm being caused to the health of living organisms or other interference with the ecological systems of which they form a part (in the case of man this includes harm to property); or,
2. Pollution of controlled waters (Water Environment) is being or is likely to be caused."

The legislation was amended with the introduction of the Contaminated Land (Scotland) Regulations, 2005. The amended regulations removed the reference to 'Controlled Waters' and substituted the term 'Water Environment'. The regulations also introduced various tests of significance of pollution to the Water Environment.

Strictly speaking, Part IIA is concerned with the current use of a site; however, the system is intended to work in tandem with the Planning process, with provision for this being made via Planning Advice Note 33. Thus, sites for which redevelopment is planned will be considered in a similar manner.

Key to the risk assessment will be consideration of the proposed end use of the site. In this case, it is understood that a residential development is proposed at this site. In this respect, a residential with homegrown produce was conservatively assumed for this site.

In accordance with current good practice, a risk-based approach was employed, in accordance with the Contaminated Land Exposure Assessment (CLEA) model. The CLEA Methodology has been developed by the UK Department of Environment, Food and Rural Affairs. It comprises a series of publications that contain technical guidance and algorithms for use in the assessment of land contamination.

Whilst the methodology is not exhaustive, it is considered appropriate that this forms the basis of the approach, given that the CLEA model was produced in the UK and is therefore consistent with our regulatory regime.

In line with the CLEA model, for environmental issues to exist, the presence of complete pollutant linkages in the form of the following three elements is required:

- Source of contamination;
- Target (receptor) which may be harmed; and
- Pathway linking sources to targets.



The identification of a complete pollutant linkage indicates the requirement for further assessment to determine the significance of the linkage and to consider whether remedial action is warranted.

The following sections will further consider the evidence for each of these elements.

6.2 Sources of Contamination

6.2.1 Assessment Criteria – Soils

It is noted that the Environment Agency has revised the CLR7-10 documents and withdrawn the previous Soil Guideline Values (SGVs). Science Report SR3; *Updated technical background to the CLEA model*, which replaces CLR 10 and CLEA Briefing Notes 1 to 4, updates the technical basis of the CLEA model and reconsiders the rationale for the generic landuse scenarios used to derive SGVs. Changes to the model take into account changes identified in the DEFRA statements (Outcome of the "Way Forward" exercise on Soil Guideline Values and Guidance on the legal definition of contaminated land); changes made to the model are as a result of an extensive scientific review; and views received from users of the previous CLEA software models. Changes to the software also take into account comments received on the evaluation of the previous CLEA software versions.

In the first instance, it must be established that it is indeed appropriate to utilise the CLEA model, in assessing an individual site.

Justification for Use of CLEA Model

Science Report SR3, provides an updated estimate as to how much of a substance in soil, children and adults could potentially be exposed to if they live, work and/or play on contaminated sites over long time periods. In particular, it sets out the underlying assumptions that have been made to predict exposure for three standard land use scenarios (residential, allotments and commercial).

In applying one of these landuses, it is important that the assessor has considered whether the conceptual model underpinning the landuse being applied is appropriate. Although they are based on 'typical activities' for each landuse, it is unlikely that they will accurately reflect the conditions found at any one specific site. The assessor must be confident that major differences do not exist between the site under investigation and the underlying conceptual model of the generic land use being applied.

In this case, consideration was given to a residential enduse. The CLEA Report sets out conceptual exposure models for this landuse, which is stated below.

"This generic scenario assumes a typical residential property consisting of a two-storey house built on a ground-bearing slab with a private garden consisting of a lawn, flowerbeds, and a small fruit and vegetable patch. The occupants are assumed to be parents with young children, who make regular use of the garden area".

This is considered to be the most appropriate given the intended end use of the site.



The guidance also states that care must be taken with respect to the applicability of the CLEA Model when assessing sites underlain by made ground. It is our understanding that this relates to the physical properties of soils and the resultant implications for contaminant fate and transportation and exposure characteristics. Critically, the document contains the following advice:

'where made ground comprises a mixture of rubble with a finer matrix of soil, it is the properties of the matrix that are more likely to be relevant to contaminant behaviour'.

With respect to the above statement, we would note that no made ground was encountered on site, with the natural superficial deposits comprising of fine to coarse sand, occasionally with gravel. Prior to all samples being analysed, it is our understanding that they are sieved to remove large particle sizes, with the material tested being of less than sand grade. We have contacted the testing laboratory who have confirmed that the maximum particle size tested is less than 212µm, i.e. fine sand. As such, it is considered that the CLEA model is indeed applicable to this site.

The CLEA UK Soil Guideline Values (SGVs)

These were generic assessment criteria adopted by DEFRA and the Environment Agency for assessing the risks to human health from chronic exposure to contaminated soil. The SGVs were derived from the algorithms contained in the CLEA model. They can be used in support of the application of the statutory regimes addressing land contamination, especially Part IIA of the Environmental Protection Act 1990 and development control under the Town and Country Planning Acts.

These screening values were published (from March 2002) to replace the previous ICRL values (which were withdrawn). However, the SGVs have also been withdrawn, since they no longer reflect the current approach of DEFRA and the Environment Agency. Two updated reports have been published to reflect the current approach - "Human health toxicological assessment of contaminants in soil" and "Updated technical background to the CLEA model". Thereafter, as new individual chemical toxicology (TOX) reports are published, the existing relevant report will be withdrawn. Subsequently, new SGV substance reports are currently being developed to reflect the updated approach using the current CLEA model and software, and will include the following contaminants:

- heavy metals and other inorganic compounds: arsenic, cadmium, chromium, cyanide, lead, mercury, nickel, and selenium;
- benzene, ethylbenzene, toluene and xylenes;
- phenol;
- dioxins and dioxin-like polychlorinated biphenyls (PCBs);
- polycyclic aromatic hydrocarbons (PAHs) - 11 substances.



As all of the new SGVs have yet to be produced, it is understood that it is the current approach of DEFRA and the Environment Agency for practitioners to develop their own assessment criteria using the new CLEA software and handbook. In this respect, Woolgar Hunter has derived a series of screening values using the new CLEA model and new TOX reports, where available. With the exception of lead, as discussed below, it was considered appropriate to utilise these values derived from the new CLEA model as interim screening criteria, in the absence of the new SGV reports. When the Health Criteria Values (HCV) and SGV are updated for lead, DEFRA and The Environment Agency will consider setting the HCV as an intake dose, and not a blood lead level as was previously assumed. This would mean that the CLEA model can be used to calculate SGV. In the absence of the updates, the previous SGV for lead were utilised.

The CLEA methodology is only applicable to long-term or chronic exposure and as such do not apply to other exposure scenarios such as exposure of construction workers. In addition, the published values consider ingestion of soil and soil derived indoor dust. Dermal contact and inhalation routes have been excluded because in the context of the standard land uses, the contribution of these pathways to overall exposure will be much less than 1%. Therefore, the CLEA documents states that:

“In undertaking a site assessment, the assessor should always consider the possibility that inhalation of dust may be a more important exposure pathway; for example, where:

- *The majority of the site is bare for long periods and dry/windy conditions prevail*
- *Activities such as vehicle movements increase dust generation*
- *The contamination itself is present in a dry and or/dusty conditions.”*

Potential risks to construction workers from exposure to dust, from dermal contact and ingestion of contaminated soil are considered to be addressed through the use of good working practice; for example, the keeping of Health and Safety Files that identify any issues of concern and can then be taken into account in the resultant Health and Safety Plans. The keeping of Health and Safety files is mandatory under the CDM Regulations.

The screening criteria are based on the use or proposed use of a site. Thus, the values for a residential end use are more conservative than say for an industrial development. In this case, the proposed development is for new residential properties.

In this respect, all of the test results were compared with the screening criteria for a residential end use.

The CLEA methodology acknowledges that contaminant concentrations vary across a site and that sampling and analysis will introduce measurement errors. As a result, the mean concentration determined from a limited number of samples will have uncertainty associated with it, and will not necessarily equal the true mean concentration at the site.



The methodology sets out a Mean Value Test, which compares the Soil Guideline Value with the upper 95th percentile of the mean measured concentration. Where the Mean Value Test is applied, and the data passes the test, it may be considered that the site requires no further action. Conversely, where a set of data fails the Mean Value Test, a judgement should be made about the benefits of undertaking more comprehensive sampling.

In some data sets, individual concentrations may have been measured at particular locations that are much higher than the rest of the data.

Decisions need to be made on whether these concentrations fall within the maximum of the range of values that can be expected from the sample population, or whether they are indicative of an area of higher contamination (in effect, a different population with a higher mean). Data points that do not fall within the expected distribution of measurements for the sample population are termed “outliers”. The Maximum Value Test can be used to define whether the maximum measured concentration in the soil should be classified as an outlier, and hence whether additional investigation might be warranted in the vicinity to clarify further the extent and nature of the contamination.

The SGVs represent “intervention values”, that is to say, indicators that soil values above these levels might present an unacceptable risk to site users and that further investigation and / or remediation is required.

Screening values have been produced using the new CLEA software for the following contaminants:

- Arsenic
- Cadmium
- Chromium
- Mercury
- Selenium
- Nickel
- Copper
- Zinc
- Ethylbenzene
- Phenol
- Toluene



Screening values have also been derived using the new CLEA software for the following PAHs:

- Naphthalene
- Acenaphthalene
- Fluorene
- Anthracene
- Fluoranthene
- Pyrene
- Benzanthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3 c-d)pyrene

In addition, screening values were also derived using the new CLEA software for petroleum hydrocarbons, which were speciated into the following fractions in accordance with the Environment Agency publication titled “The UK Approach for Evaluating Human Health Risks from petroleum Hydrocarbons in Soils”, Science Report P5-080/TR3, February, 2005.

Table 1: Hydrocarbon Fractions Derived

Aliphatic Fractions	Aromatic Fractions
• Aliphatic EC>6-8	• Aromatic EC>7-8
• Aliphatic EC>8-10	• Aromatic EC>8-10
• Aliphatic EC>10-12	• Aromatic EC>10-12
• Aliphatic EC>12-16	• Aromatic EC>12-16
• Aliphatic EC>16-35	• Aromatic EC>16-21
•	• Aromatic EC>21-35

Formatted: Bullets and Numbering

In calculating screening values for above, the CLEA methodology requires the input of a variety of toxicological, physio-chemical and fate and transportation characteristics. The sources of these parameters were as follows:

Toxicological Data Sources

- CLR Toxicological Profiles – A series of reports prepared by DEFRA containing toxicological information for selected substances.
- Risk Assessment Information System – An online database prepared and maintained by the United States Environmental Protection Agency.



Physio – Chemical Properties

- Environment Agency publication, Draft Technical Report P5-079/TR1, titled '*Review of the Fate and Transport of Selected Contaminants in the Soil Environment*'
- Risk Assessment Information System – An online database prepared and maintained by the United States Environmental Protection Agency.

Fate and Transportation Characteristics

- Risk Assessment Information System – An online database prepared and maintained by the United States Environmental Protection Agency.

Statutory Instrument 1989 No.1263, The Sludge (Use in Agriculture) Regulations 1989

This document was used as a reference to assess the following contaminants, which are potentially phytotoxic at lower concentrations than their human toxicity:

- Copper
- Zinc
- Lead
- Nickel

6.2.2 Assessment – Soils

In the first instance, a Tier 1 screen is undertaken to identify contaminants whose concentrations exceed the screening criteria. In the event of any exceedence being recorded, the Maximum Value Test is then undertaken and any statistical outliers are then removed from the data set prior to undertaking the Mean Value Test (since they have been proven to be part of a separate data set). Any outliers are then subjected to separate risk assessment procedures.

The CLEA methodology requires that contaminant concentrations vary across a site and that sampling and analysis will introduce measurement errors. As a result, the mean concentration determined from a limited number of samples will have uncertainty associated with it, and will not necessarily equal the true mean concentration at the site.

Zoning

According to the guidance, '*where one or more areas of a site appear to have different characteristics from the remainder of the site, the assessor may divide the site into zones of similar character that can be considered independently of each other. Zoning may take into account such characteristics as variations in soil properties or historical, existing or proposed new landuses*'.



With regards to the above, the intrusive investigation revealed that the site is underlain by a mantle of made ground, with the natural superficial deposits consisting of cohesive glacial deposits. Relatively shallow bedrock was encountered in areas of the site. In this respect, it was considered necessary to separate the data collected from the made ground and that from the natural deposits to avoid skewing the data sets.

Summary of Generic Screen

Testing was undertaken on a number of samples from the boreholes and trial pits. The following table presents a summary of the Tier 1 generic screen.



Table 2A: Summary of Tier 1 Screen – Made Ground

Constituent	Units	Tier 1 Screening	No. Samples Analyzed	Range Min	Max	No. Over Tier 1
Arsenic	mg/kg	32.3	10	3.3	14	0
Cadmium	mg/kg	5.17	10	0.5	1.0	0
Chromium (total)	mg/kg	38.0	10	10	92	2
Chromium (VI)	mg/kg	38.0	10	<1	<1	0
Copper (phytotoxic)	mg/kg	200	10	16	85	0
Copper (toxic)	mg/kg	1080	10	16	85	0
Lead	mg/kg	450	10	15	190	0
Mercury	mg/kg	168.6	10	<0.05	0.36	0
Nickel	mg/kg	127.4	10	16	43	0
Selenium	mg/kg	350	10	<0.5	2.1	0
Zinc (phytotoxic)	mg/kg	450	10	47	180	0
Zinc (toxic)	mg/kg	6959	10	47	180	0
Aliphatic EC>5-6	mg/kg	8.84	10	<0.01	<0.01	0
Aliphatic EC>6-8	mg/kg	23.2	10	<0.01	<0.01	0
Aliphatic EC>8-10	mg/kg	5.74	10	<0.01	<0.01	0
Aliphatic EC>10-12	mg/kg	29.77	10	<1.5	4.7	0
Aliphatic EC>12-16	mg/kg	134.98	10	<1.2	22	0
Aliphatic EC>16-35	mg/kg	11779.2	10	<4.9	90	0
Aromatic EC>5-7	mg/kg	3.29	10	<0.01	<0.01	0
Aromatic EC>7-8	mg/kg	3.51	10	<0.01	<0.01	0
Aromatic EC>8-10	mg/kg	9.05	10	<0.01	0.01	0
Aromatic EC>10-12	mg/kg	44.89	10	<0.9	<0.9	0
Aromatic EC>12-16	mg/kg	190.5	10	<0.5	58	0
Aromatic EC>16-21	mg/kg	676.69	10	<0.6	240	0
Aromatic EC>21-35	mg/kg	2147.6	10	<1.4	370	0
Naphthalene	mg/kg	3.78	10	<0.1	0.4	0
Acenaphthalene	mg/kg	1173.5	10	<0.1	15	0
Fluorene	mg/kg	1246.17	10	<0.1	16	0
Anthracene	mg/kg	13775	10	<0.1	19	0
Fluoranthene	mg/kg	2609	10	<0.1	61	0
Pyrene	mg/kg	1946.1	10	<0.1	53	0
Benzantracene	mg/kg	15.56	10	<0.1	25	1
Chrysene	mg/kg	123	10	<0.1	26	0
Benzo(b)fluoranthene	mg/kg	8.96	10	<0.1	19	2
Benzo(k)fluoranthene	mg/kg	101	10	<0.1	12	0
IDPA	mg/kg	10.25	10	<0.1	15	1
Benzo(a)pyrene	mg/kg	1.01	10	<0.1	25	5
Asbestos* ¹	Qual.	n/a	9	ND	D	1



Note to Table

There is no guideline value for use in the assessment of asbestos contamination. In this case, the test involves a visual screen and returns either a positive 'detect' or 'non detect' of asbestos containing material.

Table 2B: Summary of Tier 1 Screen – Natural Deposits

Constituent	Units	Tier 1 Screening	No. Samples Analysed	Recorded Value	No. Over Tier 1
Arsenic	mg/kg	32.3	1	2.1	0
Cadmium	mg/kg	5.17	1	1.2	0
Chromium (total)	mg/kg	38.0	1	7	0
Chromium (VI)	mg/kg	38.0	1	<1	0
Copper (phytotoxic)	mg/kg	200	1	39	0
Copper (toxic)	mg/kg	1080	1	39	0
Lead	mg/kg	450	1	12	0
Mercury	mg/kg	168.6	1	<0.05	0
Nickel	mg/kg	127.4	1	19	0
Selenium	mg/kg	350	1	<0.5	0
Zinc (phytotoxic)	mg/kg	450	1	74	0
Zinc (toxic)	mg/kg	6959	1	74	0
Aliphatic EC>5-6	mg/kg	8.84	1	<0.01	0
Aliphatic EC>6-8	mg/kg	23.2	1	<0.01	0
Aliphatic EC>8-10	mg/kg	5.74	1	<0.01	0
Aliphatic EC>10-12	mg/kg	29.77	1	<1.5	0
Aliphatic EC>12-16	mg/kg	134.98	1	<1.2	0
Aliphatic EC>16-35	mg/kg	11779.2	1	<4.9	0
Aromatic EC>5-7	mg/kg	3.29	1	<0.01	0
Aromatic EC>7-8	mg/kg	3.51	1	<0.01	0
Aromatic EC>8-10	mg/kg	9.05	1	<0.01	0
Aromatic EC>10-12	mg/kg	44.89	1	<0.9	0
Aromatic EC>12-16	mg/kg	190.5	1	<0.5	0
Aromatic EC>16-21	mg/kg	676.69	1	<0.6	0
Aromatic EC>21-35	mg/kg	2147.6	1	<1.4	0
Naphthalene	mg/kg	3.78	1	<0.1	0
Acenaphthalene	mg/kg	1173.5	1	<0.1	0
Fluorene	mg/kg	1246.17	1	<0.1	0
Anthracene	mg/kg	13775	1	<0.1	0
Fluoranthene	mg/kg	2609	1	<0.1	0
Pyrene	mg/kg	1946.1	1	<0.1	0
Benzantracene	mg/kg	15.56	1	<0.1	0
Chrysene	mg/kg	123	1	<0.1	0
Benzo(b)fluoranthene	mg/kg	8.96	1	<0.1	0
Benzo(k)fluoranthene	mg/kg	101	1	<0.1	0
IDPA	mg/kg	10.25	1	<0.1	0
Benzo(a)pyrene	mg/kg	1.01	1	<0.1	0



Discussion of Soil Test Results

Made Ground

As the summary of made ground table shows, various contaminants were found to exceed the screening criteria for a proposed residential enduse. These elevated contaminants are summarised below:

- Chromium (total) – 2 samples;
- Benzanthracene – 1 sample;
- Benzo(b)fluoranthene – 2 samples;
- IDPA – 1 sample;
- Benzo(a)pyrene – 5 samples;
- Asbestos – 1 sample.

The implications of the elevated levels are discussed below.

Natural Deposits

All contaminants screened within the natural superficial deposits were found to be below the screening criteria for the intended enduse of the site.

Total Chromium

Elevated concentrations of total chromium were recorded within two samples from the made ground. The screening criteria for total chromium assumes that the entire concentration is that of hexavalent chromium, which is the most toxic form of chromium and which therefore poses the greatest risk to human health. However, within the two samples that recorded elevated total chromium, the levels of hexavalent chromium were found to be below the screening value, and in each case less than the detection limit of the test. In this respect, risks associated with total chromium are considered to be low.

Asbestos

Asbestos was detected within made ground within borehole BH1 at a depth of 0.50m, although asbestos was not encountered in the remaining samples tested. The type of asbestos was Chrysotile, more commonly known as ‘white asbestos’, which is the most common type of asbestos. Given that the Tier 1 screening for asbestos is either a ‘detect’ or ‘non detect’, no statistical analysis was undertaken for this contaminant. Nonetheless, it is considered reasonable to assume that this represents a ‘hotspot’ of asbestos.

Asbestos is not of a volatile or semi volatile nature, as such, the main potential for exposure will be through contact with the soil or dusts derived from the soil, whereby dermal contact or ingestion could occur. In this respect, risks are considered to be within acceptable levels within any buildings and proposed hardstanding areas, where hardcover will prevent exposure to the soils; effectively breaking the pathway between the contaminated soils and human end users. However, in the areas of proposed soft landscaping, future site users may be directly exposed to these contaminants and in this respect, it is considered that complete pollutant linkages will be present.



At this stage, the layout of the proposed development has not been finalised, as such, the proposed layout of the development will dictate the requirement for any remedial actions to be undertaken to mitigate the risk associated with the localised presence of asbestos fibres.

Statistical Analysis – PAH Exceedences

As previously noted, the recording of an exceedance does not automatically imply that an issue exists. To understand the implications of the exceedances recorded in the soils, statistical tests have been undertaken.

The CLEA methodology requires that contaminant concentrations vary across a site and that sampling and analysis will introduce measurement errors. As a result, the mean concentration determined from a limited number of samples will have uncertainty associated with it, and will not necessarily equal the true mean concentration at the site. To assess such variation, the methodology sets out various statistical tests.

Guidance on appropriate statistical analysis is given in the CL:AIRE/CIEH document titled ‘Guidance on Comparing Soil Contamination Data with a critical concentration; May 2008.

Presence of Outliers – Maximum Value Test

It is important to consider the presence of statistical outlier when reviewing results to ensure that the data is not skewed by the existence of multiple sample populations within the data set.

The CL:AIRE / CIEH document is not prescriptive but instead acknowledges that ‘various outlier tests are available that assessors can use to identify anomalous data in a dataset, each with their own advantages and disadvantages’. The methodology followed in this case was Grubb’s Test which is the example given in Appendix B of the CL:AIRE / CIEH document and also used in the withdrawn CLR7. According to this test the Maximum Test Value (T) is compared with a calculated outlier test value (Tcrit). Where the Maximum Value is greater than the Tcrit value, it is considered statistically possible that the maximum value could belong to a separate population, which may indicate a localised area of contamination.

The results of the Outlier Test are presented in the table below:

Table 3: Summary of Outlier Test Results – Made Ground

Constituent	Outlier Test Statistic	Tcrit Value	Outlier Test Statistic \geq Tcrit	Possible Outlier?
Benzo(a)anthracene	1.59	2.04	No	No
Benzo(a)pyrene	1.57	2.04	No	No
Benzo(b)fluoranthene	1.56	2.04	No	No
IDPA	1.55	2.04	No	No



As the above table shows, the elevated concentrations of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene and IDPA within the made ground are not deemed to represent statistical outliers and therefore are considered to belong to the same sample population and as such, can be subjected to averaging statistics.

Averaging Statistics - Made Ground

The sample population can be subjected to the mean value test. In this test, the generic guideline values are compared with the calculated upper 95th percentile of the mean measured concentration. Where the 95% upper confidence level (UCL) is less than the guideline value, it is considered that no source of contamination has been identified. However, if the concentration is above the guideline value then a source of contamination is considered to be present and further assessment is required of the risks pertaining to this source.

The identification of any complete pollutant linkages indicates that further assessment is required to assess the significance of the pollutant linkage and associated risks, and considers the need for some form of remedial action to break the linkage.

The Mean Value Test returned the following results:

Table 4: Summary of Mean Value Test

Constituent	Tier 1 Value	95% UCL Value	95% UCL >Tier1	Source of Contamination Identified?
Benzo(a)anthracene	15.56	9.63	No	No
Benzo(a)pyrene	1.01	9.59	Yes	Yes
Benzo(b)fluoranthene	8.96	7.42	No	No
IDPA	10.25	6.03	No	No

As the above table shows, the statistical analysis has shown that the made ground does not constitute a source of the elevated levels benzo(a)anthracene, benzo(b)fluoranthene and IDPA and therefore the risk assessment need not proceed any further. However, the statistical analysis has shown the elevated levels of benzo(a)pyrene to be endemic within the made ground across the site for the proposed enduse. The implications of this are discussed in further detail below.

6.2.2.1 Complete Pollutant Linkages - Soil

Assessment of Human Health Contaminants (Benzo(a)pyrene)

Elevated concentrations of benzo(a)pyrene have been detected within the made ground across the site, with recorded values being above the screening criteria for a residential with homegrown produce enduse. The statistical analysis has shown that the elevated levels of this contaminant to be part of the same population, indicating that the concentrations are elevated within the made ground (as opposed to being a localised hotspot) across the site.



Benzo(a)pyrene is not of a volatile or semi-volatile nature, as such, the main potential for exposure will be through contact with the soil or dusts derived from the soil, whereby dermal contact or ingestion could occur. In this respect, risks are considered to be within acceptable levels within any buildings and proposed hardstanding areas, where hardcover will prevent exposure to the soils; effectively breaking the pathway between the contaminated soils and human end users. However, in the areas of proposed soft landscaping, future site users could be directly exposed to these contaminants and therefore, complete pollutant linkages will be present.

Statistical analysis has shown that the elevated concentrations within benzo(a)pyrene are endemic across the made ground. It is therefore considered that some form of remedial activity will be required prior to any re-development at this site, within areas of proposed soft landscaping.

6.2.3 Assessment – Water Environment

6.2.3.1 Assessment Process

Legislative Background

The Water Framework Directive (Directive 2000/60/EC – or ‘WFD’) sets out a legal framework for protecting, improvement and sustainable use of surface water, transitional waters, coastal waters and groundwater across Member States of the EU. In order to prevent pollution, the directive requires the introduction of measures that prevent the entry of hazardous substances, and limit the input of non-hazardous substances, to groundwater. Also of importance is the Groundwater Daughter Directive (Directive 2006/118/EC – or ‘GWDD’).

SEPA is the responsible body for most regulatory regimes dealing with inputs of pollutants to groundwater in Scotland. Where pollutant linkages to the water environment are identified, SEPA is also a consultee for the assessment and remediation of contaminated land through the Development Control and Part IIA regimes, for which local authorities are the competent authority. In the case of designated Special Sites, regulatory responsibility under Part IIA falls to SEPA.

The current approach to assessing contamination risk to the Water Environment is described in the recently published SEPA Position Statement, ‘Assigning groundwater assessment criteria for pollutant inputs’, reference WAT-PS-10-01, version 1.0, March 2010. This describes a methodology for water environment assessment that ensures that, for those regulatory regimes where groundwater quality is, or may be, affected by inputs of polluting substances from point sources, the objectives of relevant European directives are achieved, in particular the requirement of the WFD to prevent or limit the input of pollutants into groundwater.

Article 6(1) of the GWDD requires member states to implement measures to:

- Prevent hazardous substances from entering groundwater; and
- Limit inputs of non-hazardous substances.



It is worth noting that member states are required to determine which substances are hazardous; and that with respect to groundwater, the WAT-PS-10-01 document presents a list of Hazardous Substances that are based on the List 1 substances which came under the 1998 Groundwater Directive.

Receptors

According to the SEPA Position Statement document, the assessor must select the most appropriate receptor(s), based on each individual site.

The Assessment Point for protecting the resource potential was determined using the principles set out in the WAT-PS-10-01 document, in relation to reasonable distance to future potential abstractions.

The ground investigation for this site has revealed a mantle of made ground underlain by cohesive glacial deposits, with the majority of exploratory hole positions remaining dry during the excavation. This is consistent with the conceptual site model, which predicted that the superficial deposits were unlikely to support a continuous shallow groundwater table. Whilst not proven during the intrusive works, the solid geology consist of strata belonging to the Passage Group comprising mainly of sandstones, with fireclays, thin mudstones and coals.

According to the SEPA Position Statement, *“for WFD classification purposes, SEPA has mapped all bedrock aquifers and some extensive sand and gravel aquifers as groundwater bodies. These by definition are capable of providing 10m³/day or supplying 50 people. These groundwater bodies underlie the whole mainland of Scotland and many islands.”* The SEPA website identifies the Passage Group as a ‘groundwater body’, and it is therefore considered that this *“requires protection as a long term resource for human use”*.

In summary, *“SEPA considers that groundwater pollution will occur when an input of a non-hazardous substance causes a breach of an assessment limit at an appropriate assessment point for a receptor.”*

To undertake a successful assessment of the above, the first step is to clearly establish the individual elements i.e. define the receptor(s) that could be impacted and from this, establish appropriate assessment point and assessment limits. The following section outlines this process for this site, with the outcome being summarised in the following table.



Table 5: Assessment Points & Assessment Limits

Potential Receptor	Receptor Present?	Assessment Point	Assessment Limits
Groundwater Body (future resource potential)	Superficial deposits not defined as groundwater body Underlying solid geology (Passage Group) defined as groundwater body	Bedrock defined as potential aquifer, as such assessment point normally set at default distance of 50m Assessment point increased to 250m due to limiting landuse downgradient of site	Resource Protection Values; Minimum Reporting Value; Limit of Test Detection
Surface Water	Yes. Light Burn 580m southeast	Light Burn following dilution	Environmental Quality Standards; Minimum Reporting Value; Limit of Test Detection

With regard to the above, the receptors identified for this site are:

- 1) Bedrock aquifer as a future resource.
- 2) Surface water (the Light Burn).

The assessment of risks to each receptor has been undertaken using the following data:

- Soil leachate analysis undertaken to assess the potential for the soils to impact on the underlying groundwater;
- Groundwater analysis undertaken to assess contaminant concentrations directly;
- Visual and olfactory evidence of contamination.

The following describes the assessment for each of the identified receptors, based on the guidance.



Assessment Points

Receptor 1 – Groundwater (possible future abstraction)

With respect to Receptor 1, the SEPA Position Statement contains the following guidance:

“The assessment point for protecting the resource potential should be identified...at a distance from the source beyond which future developers could reasonably expect to abstract groundwater...at a “default” distance of 50m from the downgradient boundary of the source... The distance between the boundary of the pollutant source and the assessment point can be more than 50m... where present or planned future land use limits the exploitation of the groundwater resource for the foreseeable future. The most likely example is the presence of sewered urban areas. In this instance, the pollution assessment point should be located at the downgradient extent of the limiting land use, subject to a maximum distance of 250m.”

The above statement is considered to apply to this site, which is within a heavily residential area that extends in excess of 250m from the site. Based on this, the assessment point was set at the maximum distance of 250m from the site, for future extraction of groundwater.

Receptor 2 – Surface Water

With respect to Receptor 2, the closest surface water body to the site has been identified as the Light Burn, some 580m southeast, which therefore has been assigned as the closest surface water receptor.

Assessment Limits

“SEPA considers that groundwater pollution will occur when an input of a non-hazardous substance causes a breach of an assessment limit at an appropriate assessment point for a receptor.”

Receptor 1 – Groundwater (possible future abstraction)

For Receptor 1, the SEPA Position Statement classifies contaminants as either ‘Hazardous’ or ‘Non-Hazardous’. Based on this, the assessment hierarchy for groundwater can be summarised as follows, with the test results summarised and discussed below.

Hazardous

1. Resource Protection Value (RPV)
2. Minimum Reporting Value (MRV)
3. Limit of Detection (LoD)

Non-Hazardous

1. Resource Protection Value (RPV)
2. UK Drinking Water Standard (DWS)
3. USEPA Drinking Water Standard (USDWS)

Receptor 2 – Surface Water

According to the SEPA Position Statement, *“Surface waters are defined by the WFD as all inland waters, except groundwater; transitional water, and coastal waters. For these receptors the assessment point is located in the surface water following dilution. The actual point chosen will depend upon the type of surface water.”*



For Receptor 2, the SEPA Position Statement classifies contaminants as ‘Priority Substances (List 1) and ‘Dangerous Substances (List 2)’. In addition, “*where the water is a transitional water, river, stream, or loch, the default assessment limit will be the environmental quality standard (EQS)*”. Further EQS values have also been derived for WFD UK Specific Pollutants. Based on this, the assessment hierarchy for Receptor 2 can be summarised as follows, with the test results summarised and discussed below.

Priority Substances (List I)

1. Environmental Quality Standards (EQS)
2. Minimum Reporting Value (MRV)
3. Limit of Detection (LoD)

Dangerous Substances (List II)

1. Environmental Quality Standards (EQS)

6.2.3.2 Assessment – Receptor 1 (Groundwater as Future Resource)

The following table summarises the test results with respect to exceedances of the Tier 1 Assessment Limits. Any exceedances will be subjected to further risk assessment to determine compliance at the selected Assessment Point.

Where required, the principals of the further assessment are as stated in the Methodology for the Derivation of Remedial Targets for Soil and groundwater to Protect Water Resources, Environment Agency R&D Publication 20.

No statistical approach was employed in the groundwater assessment, with any elevated contaminants being subject to further assessment.



Table 6: Summary of Soil Leachate Results For Future Groundwater Extraction

Item		Tier 1 Assessment Limit (µg/l)	Max. Leach. Value	No. Leach. Samples	Leach. Exceedences
			Max. G/W Value	No. G/W Samples	G/W Exceedences
Arsenic		10	1 ----- <1	4 ----- 2	0 ----- 0
Cadmium		5.0	<2 ----- <2	4 ----- 2	0 ----- 0
Lead		25	<4 ----- <4	4 ----- 2	0 ----- 0
Mercury		1.0	<0.05 ----- <0.05	4 ----- 2	0 ----- 0
Copper		2000	<2 ----- 4	4 ----- 2	0 ----- 0
Nickel		20	<10 ----- <10	4 ----- 2	0 ----- 0
Zinc		5000	19 ----- 1	4 ----- 2	0 ----- 0
Chromium (total)		50	<5 ----- 5	4 ----- 2	0 ----- 0
Selenium		10	<3 ----- <3	4 ----- 2	0 ----- 0
TPH Aliphatic	EC5-6	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC6-8	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC8-10	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC10-12	1	<1 ----- <1	4 ----- 2	0 ----- 0
	EC12-16	1	<1 ----- <1	4 ----- 2	0 ----- 0
	EC16-35	2	27 ----- <2	4 ----- 2	2 ----- 0
TPH Aromatic	EC5-7	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC7-8	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC8-10	0.1	5.3 ----- <0.1	4 ----- 2	4 ----- 0
	EC10-12	1	1 ----- 2	4 ----- 2	0 ----- 1
	EC12-16	1	10 ----- 25	4 ----- 2	4 ----- 1
	EC16-21	1	30 ----- 29	4 ----- 2	2 ----- 1
	EC21-35	1	51 ----- 17	4 ----- 2	2 ----- 1



Table 6: Summary of Soil Leachate Results For Future Groundwater Extraction (Cont/)...

Item	Tier 1 Assessment Limit (µg/l)	Max. Leach. Value	No. Leach. Samples	Leach. Exceedences
		Max. G/W Value	No. G/W Samples	G/W Exceedences
Naphthalene	0.01	<0.01	4	0
		0.25	2	1
Anthracene	0.01	1.5	4	2
		1.5	2	1
Fluoranthene	0.01	4.3	4	3
		4.3	2	2
Benzo(a)pyrene	0.01	1.2	4	2
		0.87	2	1
Benzo(b)fluoranthene	0.01	1.6	4	2
		1.1	2	1
IDPA	0.01	1.0	4	2
		0.93	2	1
Benzo(k)fluoranthene	0.01	0.64	4	2
		0.48	2	1
Benzo(ghi)perylene	0.01	1.2	4	2
		1.0	2	1



Discussion of Results

As the above summary table shows, various organic contaminants were found to exceed the screening criteria, details of which are given below:

- TPH Aliphatic 16-35 – 2 samples (Leachate);
- TPH Aromatic 8-10 – 4 samples (Leachate);
- TPH Aromatic 10-12 – 1 sample (Groundwater);
- TPH Aromatic 12-16 – 4 samples (Leachate);
- TPH Aromatic 12-16 – 1 sample (Groundwater);
- TPH Aromatic 16-21 – 2 samples (Leachate);
- TPH Aromatic 16-21 – 1 sample (Groundwater);
- TPH Aromatic 21-35 – 2 samples (Leachate);
- TPH Aromatic 21-35 – 1 sample (Groundwater);
- Naphthalene – 1 sample (Groundwater);
- Anthracene – 2 samples (Leachate);
- Anthracene – 1 sample (Groundwater);
- Fluoranthene – 3 samples (Leachate);
- Fluoranthene – 2 samples (Groundwater);
- Benzo(a)pyrene – 2 samples (Leachate);
- Benzo(a)pyrene – 1 sample (Groundwater);
- Benzo(b)fluoranthene – 2 samples (Leachate);
- Benzo(b)fluoranthene – 1 sample (Groundwater);
- IDPA – 2 samples (Leachate);
- IDPA – 1 sample (Groundwater);
- Benzo(k)fluoranthene – 2 samples (Leachate);
- Benzo(k)fluoranthene – 1 sample (Groundwater);
- Benzo(ghi)perylene – 2 samples (Leachate);
- Benzo(ghi)perylene – 1 sample (groundwater).

The implications of these exceedences are discussed below.

TPH Ali 16-35, TPH Aro (8-10, 10-12, 12-16, 16-21, & 21-35) & PAHs (Naphthalene, Anthracene, Fluoranthene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, IDPA, Benzo(ghi)perylene)

The results of the groundwater and soil leachate tests have recorded elevated levels of the above organic contaminants. As previously stated, the superficial deposits do not constitute a groundwater body and therefore do not represent a future groundwater extraction resource; however, the underlying bedrock is shown to represent a future groundwater resource.

With regards to the Water Environment, a complete pollutant linkage comprises of a source (elevated leachable contaminant), a pathway (infiltrating water/pore water) and a receptor (in this case identified as future groundwater extraction 250m southeast within the bedrock). As the shown by the test results, there is the potential for soil leachate results and the superficial groundwater to impact on the bedrock aquifer.



As such, it was necessary to undertake groundwater modelling to assess the level of various contaminants at the assessment point. It was considered prudent to model those TPH fractions and PAHs that exceeded the screening criteria by the greatest margin. A summary of the modelling results are given in the table below:

Table 7: Summary of Groundwater Modelling

Contaminant	Tier 1 Assessment Limit (µg/l)	Recorded Value (µg/l)	Modelled Value at Assessment Point (µg/l)	Is modelled value < Tier 1 Assessment Limit
TPH Aro. 12-16	1.0	25	0.0	Yes
TPH Aro. 16-21	1.0	29	0.0	Yes
TPH Aro. 21-35	1.0	17	3.34×10^{-229}	Yes
Fluoranthene	0.01	4.3	8.45×10^{-230}	Yes
Anthracene	0.01	1.1	0.0	Yes

As the above table shows, the modelled contaminants were found to be significantly below the screening criteria, and in some cases the level of contaminant was found to have completely diluted on reaching the assessment point. Based on this, it is considered that the elevated groundwater and leachable organic contaminants are considered to pose a low risk to the future extraction of groundwater from the bedrock aquifer.

6.2.3.3 Assessment – Receptor 2 (Surface Water)

The following table summarises the test results with respect to exceedances of the Tier 1 Assessment Limits. Any exceedances will be subjected to further risk assessment to determine compliance at the selected Assessment Point.

Where required, the principals of the further assessment are as stated in the Methodology for the Derivation of Remedial Targets for Soil and groundwater to Protect Water Resources, Environment Agency R&D Publication 20.

No statistical approach was employed in the groundwater assessment, with any elevated contaminants being subject to further assessment.



Table 8: Summary of Soil Leachate Results For Surface Waters – Light Burn

Item		Tier 1 Assessment Limit (µg/l)	Max Leach. Value Max G/W Value	No. Leach. Samples No. G/W Samples	Leach. Exceedences Leach. Exceedences
Arsenic		50	1 ----- <1	4 ----- 2	0 ----- 0
Cadmium		0.15	<2 ----- <2	4 ----- 2	0 ----- 0
Lead		7.2	<4 ----- <4	4 ----- 2	0 ----- 0
Mercury		0.05	<0.05 ----- <0.05	4 ----- 2	0 ----- 0
Copper		28	<2 ----- 4	4 ----- 2	0 ----- 0
Nickel		20	<10 ----- <10	4 ----- 2	0 ----- 0
Zinc		75	19 ----- 1	4 ----- 2	0 ----- 0
Chromium (total)		3.7	<5 ----- 5	4 ----- 2	4 (4 LOD) ----- 2 (1 LOD)
Selenium		20	<3 ----- <3	4 ----- 2	0 ----- 0
TPH Aliphatic	EC5-6	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC6-8	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC8-10	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC10-12	1	<1 ----- <1	4 ----- 2	0 ----- 0
	EC12-16	1	<1 ----- <1	4 ----- 2	0 ----- 0
	EC16-35	2	27 ----- <2	4 ----- 2	2 ----- 0
TPH Aromatic	EC5-7	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC7-8	0.1	<0.1 ----- <0.1	4 ----- 2	0 ----- 0
	EC8-10	0.1	5.3 ----- <0.1	4 ----- 2	4 ----- 0
	EC10-12	1	1 ----- 2	4 ----- 2	0 ----- 1
	EC12-16	1	10 ----- 25	4 ----- 2	4 ----- 1
	EC16-21	1	30 ----- 29	4 ----- 2	2 ----- 1
	EC21-35	1	51 ----- 17	4 ----- 2	2 ----- 1



Table 8: Summary of Soil Leachate Results For Surface Waters – Light Burn (Cont/)...

Item	Tier 1 Assessment Limit (µg/l)	Max Leach. Value	No. Leach. Samples	Leach. Exceedences
		Max G/W Value	No. G/W Samples	Leach. Exceedences
Naphthalene	2.4	<0.01	4	0
		0.25	2	0
Anthracene	0.1	1.5	4	2
		1.5	2	1
Fluoranthene	0.1	4.3	4	2
		4.3	2	1
Benzo(a)pyrene	0.05	1.2	4	2
		0.87	2	1
Benzo(b/k)fluoranthene	0.01	1.84	4	2
		1.58	2	1
IDPA/Benzo(ghi)perylene	0.001	2.2	4	4 (2 LOD)
		1.93	2	2 (1 LOD)

Discussion of Results

As the relevant summary table shows, the following contaminants were found to exceed the screening criteria:

- Chromium (Total) – 4 samples (4 LOD, Leachate);
- Chromium (Total) – 2 samples (1LOD, Groundwater);
- TPH Aliphatic 16-35 – 2 samples (Leachate);
- TPH Aromatic 8-10 – 4 samples (Leachate);
- TPH Aromatic 10-12 – 1 sample (Groundwater);
- TPH Aromatic 12-16 – 4 samples (Leachate);
- TPH Aromatic 12-16 – 1 sample (Groundwater);
- TPH Aromatic 16-21 – 2 samples (Leachate);
- TPH Aromatic 16-21 – 1 sample (Groundwater);
- TPH Aromatic 21-35 – 2 samples (Leachate);
- TPH Aromatic 21-35 – 1 sample (Groundwater);
- Anthracene – 2 samples (Leachate);
- Anthracene – 1 sample (Groundwater);
- Fluoranthene – 2 samples (Leachate);
- Fluoranthene – 1 sample (Groundwater);
- Benzo(a)pyrene – 2 samples (Leachate);
- Benzo(a)pyrene – 1 sample (Groundwater);
- Benzo(b/k)fluoranthene – 2 samples (Leachate);
- Benzo(b/k)fluoranthene – 1 sample (Groundwater);
- IDPA/Benzo(ghi)perylene – 4 samples (2 LOD, Leachate);
- IDPA/Benzo(ghi)perylene – 2 samples (1 LOD, Groundwater);



The implications of these exceedences are discussed below.

Chromium (Total), TPH Ali 16-35, TPH Aro (8-10, 10-12, 12-16, 16-21, & 21-35) & PAHs (Anthracene, Fluoranthene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, IDPA and Benzo(ghi)perylene)

The results of the groundwater and soil leachate tests have shown the potential for the above contaminants to impact on the water environment. As previously stated, the closest surface water feature to the site is the Light Burn, which is located 580m to the southeast. As such, this feature was identified as a potential receptor.

As previously stated, a complete pollutant linkage for the Water Environment consists of a source (elevated leachable contaminant), a pathway (infiltrating water/pore water/shallow groundwater) and a receptor (in this case identified as the Light Burn, after dilution, 580m southeast).

The groundwater modelling exercise undertaken with respect to risks to future groundwater extraction at a distance of 250m to the southeast, has shown the contaminants to either completely have diluted or diluted to very low values, substantially below the relatively screening criteria.

Based on the results of the previous modelling, it is considered that the elevated contaminants will have either reduced to values significantly below the screening criteria, or will have completely diluted on reaching the Light Burn. In this respect, the elevated organic contaminants are therefore considered to pose a low risk to the surface water receptor.

6.3 Soil Gas

6.3.1 Introduction

On completion of the boreholes, monitoring standpipes were installed within boreholes BH1, BH4, BH6, BH7 and BH8. A subsequent period of gas monitoring was undertaken between 2 November 2010 and 22 November 2010. Due to vandalism of the standpipes, only one monitoring round could be undertaken within all boreholes, with the exception of BH8 in which two rounds were carried out. However, it is understood that the installation within BH8 has also been vandalised. The concentration and flow of methane, carbon dioxide and oxygen were recorded during each round, together with the ambient atmospheric pressure.



The recorded gas levels were compared with guidelines presented in the following publications:

- BRE (1991) Construction of new buildings on gas – contaminated land. Building Research Establishment Report 212.
- Card GB (1995) Protecting development from methane. CIRIA Report 149
- DoE (1991) Waste Management Paper No 27. The control of landfill gas. Department of the Environment, HMSO, London.
- Department of Environment, Transport and the Regions (1997) Passive venting of soil gases beneath buildings, Guide for Design Volume I.
- Wilson SA and Card GB (1999) Reliability and risk in gas protection design. Ground Engineering Paper, February 1999.
- CIRIA (2006) Assessing Risks Posed by Hazardous Ground Gases to Buildings, Report C665.
- British Standards (2007) Code of practise for the characterisation and remediation from ground gas in affected developments, BS 8485:2007.

The BRE guidance presents the most simple assessment method. According to this guidance, for methane concentrations in the ground in excess of 1% by volume, gas protection measures are required. Where carbon dioxide concentrations fall between 1.5% and 5.0% by volume, consideration should be given to the inclusion of gas protection measures. For carbon dioxide concentrations greater than 5%, protection measures are mandatory.

In addition, this guidance indicates that the presence of asphyxiant gases reduces the oxygen content by dilution to such an extent that life cannot be supported. The risks associated with these compounds are best assessed by monitoring the oxygen content of the air. The concentration of oxygen in air should not be less than 17%v/v.

The Wilson and Card paper (1999) notes that ‘the scope of gas protection measures is specified solely on the basis of the maximum measured gas concentrations, with no consideration given to its spatial distribution and frequency of the readings, borehole flow rates, estimated surface emission rate; or the nature of the gassing source’. This paper goes on to present a holistic approach for the design of gas protection measures. The paper notes that “the most important aspect of relating the gas regime below a site to the risks it poses to development, is the surface emission rate, ie how quickly the gas is coming out of the ground. The lower the surface emission rate, the lower the risk”.

Subsequent to this guidance, additional advice is provided in the DEFRA, Partners in Technology document, titled ‘Passive Venting of Soil Gases Beneath Buildings Research Report, Guide for Design, Volume I’.

The DEFRA, Partners in Technology document takes cognisance of the fact that the gas flow rate has an important role in assessing the risks posed from soil gases. This document produces a soil gas classification scheme, based on gas concentration and flow; and provides recommendations for appropriate protection measures.

The most recent, CIRIA publication C665 recommends assessment of gas conditions through the calculation of Gas Screening Values. The Gas Screening Values follow the DEFRA approach in that they are based on gas concentrations and flow rates.



The gas monitoring results have been considered against the most-recent CIRIA publication and the BS8485: 2007, both of which suggest the calculation of Gas Screening Values.

The monitoring results have been considered against these threshold concentrations.

6.3.2 Results

As previously stated, limited gas monitoring rounds were undertaken due to the monitoring standpipes being vandalised; as such, a maximum of two monitoring rounds were undertaken within one installation. For a residential development, the guidance recommends a minimum of six rounds be undertaken; thus, a full assessment could not be made. However, an initial assessment has been made based on the rounds undertaken to date.

Methane was recorded within BH6, BH7 & BH8, when a level of 0.1% was detected. No methane was recorded during the monitoring rounds within BH1 & BH4.

Carbon dioxide was found to be less than the lower threshold limit of 1.5%, with values of 0.1% recorded during each monitoring round.

No depleted levels of oxygen were recorded, with the values varying between 20.1% and 20.5%.

Gas flow rates were found to range between 0.0l/hr and 1.0l/hr, with the greatest flow rate recorded during the second monitoring round in BH8.

To calculate the Gas Screening Value (GSV) a flow rate of 1.0l/hr was utilised, together with the highest concentration of carbon dioxide or methane, which were both 0.1%. The calculation is shown below:

$$\begin{aligned}\text{GSV} &= \frac{\text{max flow rate} \times \text{max concentration of soil gas}}{100} \\ &= \frac{1.0 \times 0.1}{100} \\ &= 0.0011/\text{hr}\end{aligned}$$

With reference to the guidance contained in both BS 8485 and CIRIA document C665, a Gas Screening Value of 0.0011/hr, would equate to Characteristic Situation 1. This category is considered to be of Very Low Risk and typically the source of soil gas relates to soils with low organic content or 'typical' made ground. The guidance indicates that for sites assigned Characteristic Situation 1, no special design requirements are required.

Based on the gas results obtained to date, no gas protection measures will require to be incorporated into the design of the proposed structures at this site; however, it is considered likely that the Regulator will seek further gas monitoring information to confirm matters in this respect.



6.4 Waste Classification

As a general note, any excavated material and excess spoil should always be classified prior to removal from site, as required by Duty of Care Legislation, 1990. This includes both material removed as part of earthworks/regrading works and spoil generated from foundation excavations. Thus, all waste must be described and classified prior to removal. Site plans; exploratory hole records and chemical analysis results should be sent to a licensed waste disposal contractor for confirmation of the material classification prior to disposal off-site.

Waste Acceptance Criteria (WAC) testing was not undertaken as part of the investigation. Should it be necessary to remove soil from the site, and depending on the soil test results from the investigation, a waste disposal contractor may require WAC testing to be undertaken prior to disposal off-site.

6.5 Water Supply Pipes

The assessment for water supply pipes is provided by the Water Regulations Advisory Scheme (WRAS), in their publication titled 'The Selection of Materials for Water Supply Pipes to be Laid in Contaminated Land', reference 9-04-03, October 2002. The guidance figures presented in this document were loosely based on the ICRL guidelines, which were withdrawn over six years ago. In the light of this, there is widespread feeling within the contaminated land industry that the WRAS guidance is not based on current good practice and that there is a need for updated guidance to be produced. This was acknowledged by the Association of Geotechnical & Geoenvironmental Specialists in their publication entitled 'AGS Position on Guidance on Water Supply Pipe Materials for Contaminated Land', July 2009.

It is known that some utility companies are attempting to update their guideline values; for example, Anglian Water has produced a document entitled 'Information for Developers About Contaminated Land and Ground Condition Assessment', dated January 2009.

In order to assess the potential risk to site users utilising water supply pipes, a series of soil samples were scheduled for environmental analysis. These results were assessed against the guideline values produced in the Anglian Water guidance, albeit with cognisance also given to the WRAS guidance.



Table 9: Summary of Water Supply Results

Contaminant	Screening Value (mg/kg)	Max Value (mg/kg)	No. over Screening Value
Sulphide	250	680	1
Arsenic	10	14	1
Boron	3	1.8	0
Cadmium	3	1.2	0
Chromium (hexavalent)	25	<1	0
Chromium (total)	250	92	0
Cyanide (free)	10	0.2	0
Cyanide (complexed)	50	0.3	0
Copper	100	85	0
Lead	150	190	1
Mercury	1	0.36	0
Nickel	70	43	0
Selenium	3	2.1	0
Acidity	pH <5*	9.9	0
Total PAH	20	360	4
Naphthalene	5	0.4	0
Anthracene	10	19	2
Phenanthrene	10	47	2
Fluoranthene	10	61	2
Pyrene	10	53	2
Benzo(a)pyrene	1	25	5
Petroleum Hydrocarbons	50	760	5

With regards to the Anglian and WRAS guidance, various levels of inorganic and organic contaminants were found to exceed the screening criteria. As such, it is considered that the water supply pipes required to serve the proposed development at this site will require to be either ductile iron or polythene/aluminium/polythene construction.

An elevated level of arsenic was recorded within TP12. For any water supply pipe passing through this area, it is also recommend that the water supply pipe trenches be excavated 'double width' and back filled with clean inert granular material.

6.6 Summary of Environmental Conditions

The intrusive investigation encountered a mantle of made ground underlain by natural cohesive deposits. Relatively shallow bedrock was also encountered in areas of the site.

Based on the proposed enduse of the site, the soils were screened against a residential with homegrown produce enduse. Elevated levels of total chromium, benzanthracene, benzo(b)fluoranthene, IDPA and benzo(a)pyrene were recorded as total concentrations within the made ground. Risks posed by the total chromium are considered to be low, based on the levels of chromium VI from the same sample.



Statistical analysis has shown that the made ground does not represent a source of the elevated levels of benzantracene, benzo(b)fluoranthene and IDPA, as such, no further action is required with regard to these contaminants. However, the statistical analysis has also shown that the made ground represents a source of the elevated levels of benzo(a)pyrene; as such, it is considered that some form of remedial action will be required across the proposed soft landscaped areas at this site. In addition, asbestos fibres were detected locally within the made ground in BH1. Remedial action will also be required should soft landscaping be proposed in this area.

The risk to the Water Environment was assessed through groundwater and soil leachate testing. Elevated levels of various organic contaminants were recorded within both the groundwater and soil leachate tests. However, groundwater modelling has demonstrated that the levels of these contaminants will have reduced to values significantly below the screening criteria. Risks with respect to the water environment are therefore considered to be low.

Due to vandalism of the monitoring installations, a sufficient amount of gas monitoring rounds could be undertaken. Based on the limited results undertaken to date, gas protection measures will not require to be incorporated into the design of the proposed structures at this site. Additional gas monitoring is therefore likely to be required.

Graphical representation of the revised conceptual site model is shown as Figure 1.



STUDY LIMITATIONS

In reviewing this report, the following points should be borne in mind:

1. The study conducted and this report has been prepared for the sole use and reliance of the client and their advisors. The report shall not be relied upon, or transferred to any other parties without written authorisation from the authors. If any unauthorised third party comes into possession of this report, they rely upon it at their own risk and the authors owe them no duty of care and skill.
2. The opinions and advice set out in this report relates specifically to the current site and proposed development as detailed herein. They should not be transferred to other sites, schemes, without prior consultation with the authors.
3. The findings and opinions conveyed herein, are based on information obtained from a variety of sources, detailed in the report and which are believed to be reliable. Nevertheless, we cannot guarantee the reliability of such information.
4. The report is not a comprehensive site characterisation and should not be construed as such. Exploratory investigations by their very nature, can examine only a small part of a site. Ground conditions can vary around and between the exploratory hole positions.
5. Any costs presented in this report are indicative only are shown for basic cost analysis to be undertaken. The details may fluctuate depending on market circumstances and timescales and before a contractual situation is concluded, confirmed costs must be obtained.
6. We do not provide legal advice and the advice of lawyers may also be required to understand the implications of any liabilities associated with the site.
7. This investigation has been undertaken in line with legislation and best management practices, current and applicable at the time of writing this report.
8. The report does not consider issues in relation to archaeology, flora and fauna. Specialist advice may be required in respect of these issues.



REFERENCES

1. BS5930:1999 Code of Practice for "Site Investigation" British Standard Code of Practice, British Standards Institution, London
2. BS1377:1990 Parts 1 to 9 British Standard "Methods of Test of Soils for civil engineering purposes". British Standards Institution, London.
3. BS10175:2001 Investigation of potentially contaminated site – Code of Practice.
4. Building Research Establishment, 1991 (New Edition 1996), BRE Digest 363 "Sulphate and acid resistance of concrete in the ground.