Table 5.2. Comparison of soil test results to SSAC – metals

Compound	Calculated $SSAC_{oral/derm}$	Number of Tests	Min.	Max.	Number Exceeding SSAC
Western site - residential					
Arsenic	38	12	10	69	1
Cadmium	60	12	<0.1	1	0
Chromium	340	12	17	61	0
Lead	450	12	55	2917	8
Mercury	29	12	<1	3.8	0
Nickel	135	12	19	47	0
Selenium	460	12	0.19	0.27	0
Eastern site - college					
Arsenic	530	23	4	38	0
Cadmium	1400	23	<0.1	7	0
Chromium	5200	23	13	94	0
Lead	750	23	18	6677	5
Mercury	490	23	<0.1	2	0
Selenium	8000	23	0.16	0.62	0
Nickel	1800	23	7	54	0

All units mg kg^{-1}

Table 5.3. Comparison of soil test results to SSAC – organics

Compound	Calculated $SSAC_{oral/derm}$	Calculated $SSAC_{inhalation}$	No. of Tests	Min.	Max.	Number Exceeding SSAC
Eastern site - college						
BTEX						
Benzene	530	9	4	<0.001	0.003	0
Toluene	310,000	1,400	4	<0.001	0.017	0
Ethylbenzene	155,000	NL	4	<0.001	0.003	0
m&p-xylene	325,000	1,500	4	<0.001	0.007	0
o-xylene	325,000	1,500	4	<0.001	0.002	0
Speciated PAH						
Acenaphthene	95,000	*	6	<0.1	0.5	0
Anthracene	450,000	*	6	<0.1	1.4	0
Benzo[a]anthracene	12,000	490,000	6	<0.1	4.6	0
Benzo[a]pyrene	310,000	*	6	<0.1	4.8	0
Benzo[b]fluoranthene	12,000	4,900	6	<0.1	4.4	0
Benzo[k]fluoranthene	1,200	490	6	<0.1	3.6	0
Chrysene	120	49	6	0.2	4.9	0
Dibenzo[ah]anthracene	115,000	49,000	6	<0.1	2.6	0
Fluoranthene	60,000	*	6	<0.1	12	0
Fluorene	60,000	*	6	<0.1	0.4	0
Indeno[123cd]pyrene	1,200	490	6	<0.1	3.5	0
Naphthalene	30,000	1,400	6	<0.1	0.2	0
Pyrene	49,000	*	6	<0.1	9.3	0

Compound	Calculated $SSAC_{oral/derm}$	Calculated $SSAC_{inhalation}$	No. of Tests	Min.	Max.	Number Exceeding SSAC
Speciated TPH[a]						
TPH C6-C8	311,000	2,600	7	<10	<10	0
TPH C8-C10	62,000	3,500	7	<10	<10	0
TPH C10-C12	73,000	NL	7	<10	<10	0
TPH C12-C16	62,000	NL	7	<10	<10	0
TPH C16-C21	47,000	*	7	<10	51	0
TPH C21-C40	47,000	*	7	19	313	0
TPH – total[a]	73,000	NL	9	<20	130	0

All units mg kg^{-1}
a – SSAC for TPH bands based on aromatic fractions
b - SSAC for total TPH based on aromatic fraction C10-C12
NL denotes no limit
* denotes SSAC cannot be determined

Tests for speciated PAH's were not carried out on soil samples from the west of the site, however, 15 No. determinations were made for total PAH's. Since it is not possible to develop SSAC for total PAH (only speciated compounds), we can only comment on the results qualitatively. On that basis, it is considered that the levels of PAH are relatively high and a number of the speciated compounds are likely to exceed SSAC.

The remaining determinants tested for were at or below their limits of detection.

5.5. Phytotoxicity Criteria

Potential phytotoxins are present at levels above PAS100 criteria as follows.

Table 5.4. Comparison of soil test results to PAS100

Compound	PAS100	Number of Tests	Min.	Max.	Number Exceeding PAS100
Western site - residential					
Copper	200	12	47	9138	3
Nickel	50	12	19	47	0
Zinc	400	12	104	689	4
Eastern site – college					
Copper	200	23	12	782	3
Nickel	50	23	7	54	1
Zinc	400	23	49	872	3

All units mg kg^{-1}

5.6. Water Supply Criteria

The organic compounds, TPH and PAH, are present at levels above WRAS criteria across the whole site.

5.7. Waste Classification Tests

Measured concentrations of total organic carbon exceed criteria for non hazardous waste in samples from WS2 in the east of the site and WS6 in the west of the site. Soil leachate tests at L/S=10 also failed criteria for non hazardous waste in samples of Made Ground for antimony and WS6 for chromium.

On the basis of these tests, deposits of Made Ground for off site disposal will qualify as non hazardous waste.

Hazardous wastes are present where hydrocarbon concentration exceeds 1000mg kg^{-1}. This is however localised to BH04.

5.8. Nature and Distribution of Contamination

Potential contaminants are present at levels above the calculated SSAC at the following locations and depths.

Table 5.5. Locations and Depths Exceeding Adopted Criteria

Location	Depth (m)	Compound	Concentration	Exposure Route
Western site - residential				
WS5	1.0	Lead	1100	Oral/Dermal
	2.0	Lead	530	Oral/Dermal
WS6	1.0	Lead	1900	Oral/Dermal
	2.0	Lead	670	Oral/Dermal
BH06	1.6	Arsenic	69	Oral/Dermal
	1.5	Lead	2917	Oral/Dermal
	2.5	Lead	2052	Oral/Dermal
	0.5	PAH	1081	Water supply
	1.5	PAH	367	Water supply
	1.5	Copper	9138	Planting
	2.5	Copper	1898	Planting
	0.5	Total PAH	1081	Qualitatively assessed to be elevated
	1.5	Total PAH	367	
BH07	0.5	Copper	275	Planting
	1.5	Zinc	468	Planting
	2.0	Zinc	689	Planting
	0.5	Lead	501	Oral/Dermal
	2.0	Lead	689	Oral/Dermal
Eastern site – college				
WS2	1.0	TPH	130	Water supply
	1.5	TPH	100	Water supply
	2.5	Copper	240	Planting
	1.0	Zinc	530	Planting
WS4	1.0	Nickel	54	Planting
BH02	0.5	Lead	984	Oral/Dermal
	1.5	Lead	1741	Oral/Dermal
	0.5	TPH	374	Water supply
	2.5	TPH	87	Water supply
BH04	0.5	TPH	2832	Water supply
	1.5	PAH	140	Water supply

Location	Depth (m)	Compound	Concentration	Exposure Route
BH05	0.5	Lead	806	Oral/Dermal
	2.0	Lead	6677	Oral/Dermal
	2.5	Lead	3384	Oral/Dermal
	0.2	TPH	194	Water supply
	0.5	TPH	136	Water supply
	2.0	TPH	96	Water supply
	2.5	TPH	90	Water supply
	0.2	Copper	261	Planting
	2.0	Copper	782	Planting
	2.5	Copper	268	Planting
	2.0	Zinc	872	Planting
	2.5	Zinc	856	Planting

All units mg kg^{-1}

Contamination in the form of metals (arsenic, lead, copper and zinc), PAH and TPH are present in Made Ground across the site.

There was no evidence of significant contamination of soils by TPH that could be attributed to the neighbouring former filling station to the southeast.

6. DISCUSSION OF GROUNDWATER TEST RESULTS

6.1. Groundwater Quality Standards

In assessing the levels of compounds in groundwater beneath the site, the results of analyses have been compared to prescribed UK drinking water quality standards (DWS) (ref. 3).

Although the UK DWS are often perceived to be conservative in terms of groundwater risk assessment, they do however provide a useful tool for screening groundwater test data in the context of an aquifer. On that basis, they are used in this instance to determine if a more detailed groundwater risk assessment is required in accordance with the Environment Agency R&D Publication 20 (P20) (ref. 4).

6.2 Discussion of Groundwater Test Results

With the exception of a slightly elevated level of arsenic in water sampled from BH06, no measured concentrations of potential contaminants exceeded the adopted UK DWS.

Specifically, hydrocarbon compounds were not detected even on the boundary with the former filling station on Gray's Inn Road.

6.3. Summary

The site overlies a non aquifer comprising London Clay strata.

Groundwater contamination was not identified with the exception of arsenic in one borehole.

In the context of a non aquifer, P20 risk assessment is not performed on the marginally elevated occurrence of arsenic in BH06.

There is no evidence of groundwater contamination emanating from the former filling station to the southeast.

7. DISCUSSION OF GAS/VAPOUR MONITORING RESULTS

7.1. Gas/Vapour Assessment Criteria

Gas Screening Values (GSV) are compared against guidance contained within CIRIA Publication BR149 (ref. 8) for the development of gas-contaminated land. This guidance assesses data obtained from monitoring and places the gassing regime within one of six Characteristic Situations. These range from CS1 for which special precautions are not required through to a maximum of CS6, which could in extreme cases prevent development entirely.

GSV's are derived in accordance with CIRIA Publication C659 (ref. 9) from site maximum concentrations of methane, carbon dioxide and flow rate.

7.2. Gas/Vapour Monitoring Results

The gas monitoring data summarised in section 4.7 indicates site maximum concentrations and flow rate and resulting GSV's and a Characteristic Situation as follows.

7.1 Development of Characteristic Situation

Parameter	Site Maximum	GSV	Characteristic Situation
Methane	<0.1%	<0.0003	CS1
Carbon dioxide	1.1%	0.003	
Flow rate	<0.3 l hr^{-1}	-	

Significant vapour concentrations were not detected during the drilling and were below the limit of detection in all instances.

7.3. Summary

Based on gas monitoring data, the site designation is a Characteristic Situation 1 for which no special protection measures are required.

Hydrocarbon vapour contamination is not present.

8. UPDATED CONCEPTUAL SITE MODEL

8.1. General

The site investigation, results of chemical analysis and risk screening assessment presented in the previous section has allowed the conceptual site model developed during previous investigation stages to be updated. This is then used to further assess risks to human health and the environment.

The basis for the model is presented below:

Table 8.1. Updated Conceptual Site Model

Site Summary	Vacant college buildings are presently on site.
Site Description	The site contains former college buildings, which are currently vacant. There is no recorded evidence of previous potentially contaminating site uses. There was, however, a filling station on adjoining land to the southeast and the site did suffer considerable bomb damage during WWII.
Surrounding Area	Surrounding land is in commercial, retail and residential use.
Geology	The site is underlain by variable depths of Made Ground over London Clay.
Hydrogeology	The underlying London Clay is classed as a non aquifer.
Source Characterisation	Made Ground is on site containing a range of metal and organic compound contamination. There is no evidence of contamination migration beneath the site from the adjoining former filling station.
Sources	On site: Made Ground containing elevated concentrations of arsenic, copper, lead, nickel, zinc, TPH and PAH
Pathways	• Dermal contact with soil • Ingestion of soil and soil dusts • Inhalation of soil dusts • Direct contact
Receptors	• Site users (college/residential) • Site workers (construction/maintenance/site investigation) • Water supply • Landscaping

9. RISK ASSESSMENT

9.1. Background

A quantitative risk assessment (QRA) has been carried out as part of this further supplementary investigation, which has developed site specific assessment criteria to establish if soils or groundwater on site present a plausible source of contamination, to assess the risk they pose to human health and the environment, to identify if there is a need to reduce this risk and to allow relevant parties to make risk-based decisions. QRA is based upon the principle of SOURCE, PATHWAY and RECEPTOR (or target); this is termed the SPR-linkage.

For the significant risk to exist, a contaminant present in a source (e.g. Made Ground) must be linked to a receptor (e.g. resident) by a pathway (e.g. by eating soil). The pathway is the route by which the receptor can come into contact with the source. A site-specific assessment is carried out to determine whether the pathways are of sufficient importance to be a significant pollutant linkage (SPL).

When considering remedial options, removal of any one of the three elements of the model would break the pollutant linkage and would almost always represent a satisfactory remedial solution. Remediation does not, therefore, require the removal of contamination. If possible, severing the SPL between the contaminant and the receptor may be sufficient.

The adopted QRA assumes the intended end use is:

- Residential without plant uptake in the west of the site.

  AND

- Non-residential college buildings with basement in the east.

9.2. Critical Receptors

Human Health

A critical receptor is the model of an idealised human target who regularly utilises the site and on which the qualitative risk assessment is based.

Contaminated soil on residential land, proposed in the west of the site, poses the greatest health hazard to a young child under the age of 6 years.

A child is more susceptible to soil contamination than an adult. They have lower bodyweight and lower metabolic rates than adults. Children also have a greater range of pathways to link the receptor (child) to the source (contaminated soil). For example, young children are more tactile than adults and will place objects in their mouth, consequently ingesting contaminants on the object.

Children also spend more time playing on the ground, increasing their dermal contact with the soil.

Their breathing zone is much closer to the ground and as a result can breath in more soil dust, gas or vapour.

Contaminated soil on a commercial-type land use, proposed in the east of the site as college buildings, poses the greatest health hazard to a female adult of a minimum working age of 17 years.

Environment

Critical receptors in the environment generally include controlled waters such as groundwater and surface water features. These often supply drinking water or support sensitive aquatic flora and fauna.

9.3. Targets and Pathways

Based upon the updated conceptual site model, the following targets and pathways are considered.

9.3.1. Critical Receptors (Direct Contact)

Target 1: Future Site Occupants (residential occupants in the west of the site)

Target 2: Future Site Occupants (college building in the east of the site)

Pathways: Dermal contact, inhalation of soil dust and ingestion of contaminated soil and soil dust.

Source 1: Made Ground containing elevated concentrations of arsenic and lead on the western (residential) site.

Source 2: Made Ground containing isolated elevated concentrations of lead on the eastern (college) site.

Risk Assessment: The identified metals on the western site, which is intended to be developed to residential use, pose risks to human health via oral/dermal exposure to contaminated soils such as in areas of landscaping. It is understood that private gardens are not to be incorporated into the eventual development layout.

Risks from exposure to contaminated soils are mitigated across the college site due to an almost complete cover of buildings that breaks the pathway between source and receptor. A small garden and greenhouse area is proposed, however, development plans indicate these are to incorporate raised planters.

Plausible SPR-linkages are present but can be broken.

9.3.2. Critical Receptors (Potable Water)

Target: Future Site Occupants (residential and college students/staff)

Pathways: Direct contact of mains supply with contaminated soil. Permeation of plastic pipework by organic compounds. Ingestion of potable water from incoming mains supply.

Source 1: Organic compounds, comprising TPH and PAH, are present in Made Ground across the entire site.

Risk Assessment: Concentrations of TPH and PAH exceed the WRAS guideline value and protected services will be required.

Plausible SPR-linkages are present but can be broken.

9.3.3. Site Workers

Target: Construction and maintenance staff.

Pathways: Dermal contact with contaminated soil and soil dust. Inhalation of soil dust. Ingestion of soil and soil dust.

Source 1: Metals and PAH contaminated soils are present across the whole site.

Risk Assessment: Personal protective equipment and site hygiene facilities will be needed during groundworks on site due to the presence of contamination in the ground.

Plausible SPR-linkages are present but can be broken.

9.3.4. Planting and Landscaping

Target: Future landscaping.

Pathways: Direct contact. Soil leaching.

Source 1: Copper, nickel and zinc in Made Ground across the whole site.

Risk Assessment: Potential phytotoxins are present and capping to protect landscaping in the west of the site will be necessary. Protection to planting will not be required in the east of the site since raised planters are planned.

Plausible SPR-linkages are present but can be broken.

9.4. Summary

Risk assessment has been performed and the following SPL-linkages are identified, which requires remedial action:

- Metals and PAH contamination of Made Ground in the west of the site, which represents a risk to on site occupants through direct contact with contaminated soil in areas of landscaping.

- During construction and post development maintenance there are risks to site staff.

- Landscaping in the west of the site could be affected by elevated concentrations of copper, nickel and zinc.

There are no significant or unacceptable risks from gas/vapour or to either groundwater within the underlying major aquifer or surface waters in the surrounding area.

- During construction and post development maintenance there are risks to site staff.
- Landscaping in the west of the site could be affected by elevated concentrations of copper, nickel and zinc.

There are no significant or unacceptable risks from gas/vapour or to either groundwater within the underlying major aquifer or surface waters in the surrounding area.

10. TABULATED RISK ASSESSMENT SUMMARY

The following table summarises all the information that is relevant to the conceptual model and resulting risk assessment.

Risks are defined in terms of:

- Severity of Impact. The terms Serious, Moderate and Negligible are used to describe the severity of impact in the event that a SPR-linkage is realised. These terms are defined in Appendix G.

- Potential Risk. The terms High, Medium and Low are used to describe the risk associated with a particular SPR-linkage and is defined by the completeness of the SPR-link combined with the Severity of Impact (in the event of a link being realised). These terms are defined in Appendix H.

- Remedial or precautionary measures and mitigating factors. Some SPR-linkages may not be realised simply because there may exist *mitigating factors* (e.g. the SPR-link may be present but the pathway distance may be great). Some SPR-linkages may not be readily quantifiable and a *precautionary measures* may be needed (e.g. the presence of ground gas may suggest a low permeability membrane should be included in a floor slab). Finally, *remedial measures* may be the only recourse if mitigating or precautionary measures cannot break the SPR-linkage and the potential risk is High.

Table 10.1. TABULATED RISK ASSESSMENT – ORGANIC COMPOUNDS IN SOIL

Source	Receptor	Pathway	Severity of Impact	Risks	Remedial or Pr
Hydrocarbon compounds (TPH and PAH) in Made Ground	Site occupants (western site - residential)	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Low - Medium	• Clean capping in landsca
		Ingestion of potable water	Moderate	Medium	• Protected water supplies
		Vapour intrusion to indoor air via ground slab	Negligible	Low	• Organic compound conti not present
	Site occupants (eastern site - college)	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Low - Medium	• College building cover a
		Ingestion of potable water	Moderate	Medium	• Protected water supplies
		Vapour intrusion to indoor air via ground slab	Moderate	Medium	• Organic compound conti not present
	Potable water supplies	Direct contact	Moderate	Medium	• Protected water supplies
	Services Construction materials	Direct contact	Negligible	Low	• Significant hydrocarbon
	Neighbouring property	Wind erosion Groundwater movement Surface runoff	Moderate	Low - Medium	• Capping of landscaped a • College building cover a
	Construction and maintenance workers	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Medium	• PPE, site hygiene and m • Maintenance of services

Table 10.2. TABULATED RISK ASSESSMENT – METALS IN SOIL

Source	Receptor	Pathway	Severity of Impact	Risks	Remedial or
Arsenic and lead in Made Ground	Site occupants (western site - residential)	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Medium	• Clean capping in land
	Site occupants (eastern site - college)	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Low - Medium	• College building cove
	Potable water supplies	Direct contact	Moderate	Medium	• Protected water supplies
	Services Construction materials	Direct contact	Negligible	Low	• Significant hydrocarb
	Neighbouring property	Wind erosion Groundwater movement Surface runoff	Negligible	Low	• Capping of landscaped a through wind erosion a • College building cove
	Construction and maintenance workers	Direct contact (ingestion, inhalation and dermal contact with soil and soil dusts)	Moderate	Medium	• PPE, site hygiene and m • Maintenance of servi
Copper, nickel and zinc in Made Ground	Plants	Direct contact Soil leaching	Moderate	Low – Medium	• Capping of landscaped a • College building cover a

Table 10.3. TABULATED RISK ASSESSMENT - GROUNDWATER

Source	Receptor	Pathway	Severity of Impact	Risks	Remedial or Precaution
Groundwater contamination not present	All	All	Negligible	Low	• Groundwater contamina

Table 10.4. TABULATED RISK ASSESSMENT - GAS/VAPOUR

Source	Receptor	Pathway	Severity of Impact	Risks	Remedial or Precaution
Soil gas/vapour contamination not present	All	All	Negligible	Low	• Gas/vapour contamin

11. LIABILITY AND RISK

11.1. Current UK Legislation and Liability

Provisions for dealing with contaminated land have been given effect through section 57 of the Environment Act 1995; this adds Part IIA (ss.78A-78YC) to the Environmental Protection Act 1990 and contains legislative framework for identifying and dealing with contaminated land. These sections of the Act and the Contaminated Land (England) Regulations 1999 were brought into force on 1 April 2000.

The law represents nothing more than the application of established principles of liability to the contaminated land situation, however it will mean in practice that Local Authorities will have an express mandate to inspect and enforce against contaminated land. This will potentially result in a greater risk of liability than at present.

Prior to April 2000 there were already a number of legal aspects regarding site liability which could be applied in relation to contamination:

- To prevent a danger to public health either by public accessing of the site or by allowing contamination to migrate off the site (EPA 1990 Clause 79-81).

- To prevent pollution of rivers or groundwater adversely affecting the quality of the water resource (WRA 1991 Clause 85, 76/464/EEC, 80/68/EEC).

In addition to the above criminal liabilities, civil (or tortuous) liabilities exist in common law with respect to four main headings: nuisance, negligence, the rule in Rylands vs. Fletcher and trespass. Parts III of the EPA 1990 has regularised many of these civil liabilities and empowers the Local Authority to issue abatement notices to control any statutory nuisance and recover costs.

Under Part IIa of the EPA 1990, liability for sites identified as "Contaminated Land" under the new legal definition will follow the "polluter pays" principle, or if the polluter cannot be found liability will pass to the owner or occupier.

11.2. Liability and Risk – General

The key environmental issues relevant to ownership, development and occupation of any site are:

- Health and Safety Risks
- Environmental Risks
- Contamination Liability
- Construction Costs
- Effects on Construction and Building Materials.

11.3. Health and Safety Risks

Organic compound and metals soil contamination has been identified in near-surface deposits of Made Ground. Accordingly, there are potential risks to future site users where development is for residential purposes and areas requiring remedial action are identified in the west of the site.