



**Kirklees Council**

Design & Property Services  
Kirkgate Buildings  
Byram Street  
Huddersfield  
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**Detailed Quantitative Risk Assessment  
Land off Forge Lane  
Thornhill Lees  
Dewsbury  
WF12 9EN**

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## Report Details

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Table of Contents

<b>1</b>	<b>INTRODUCTION .....</b>	<b>1</b>
1.1	Background Information .....	1
1.2	Aims and Objectives .....	2
1.3	Scope of Work .....	2
1.4	Limitations .....	2
<b>2</b>	<b>SITE CHARACTERISATION.....</b>	<b>3</b>
2.1	Environmental Setting .....	3
2.2	Environmental Investigations .....	3
2.3	Receptors .....	3
	2.3.1 Human Health .....	4
	2.3.2 Water Resources .....	4
2.4	Source - Selection of Chemical Constituents of Concern .....	5
	2.4.1 Contaminant Distribution .....	6
	2.4.2 Initial Screening .....	6
	2.4.3 Secondary Screening – Human Health .....	6
	2.4.4 Secondary Screening – Water Resources .....	7
2.5	Source Areas .....	8
	2.5.1 Ammonia as N .....	9
	2.5.2 Ammonium (Ionised Ammoniacal Nitrogen as NH <sub>4</sub> <sup>+</sup> ) .....	9
2.6	Chemical and Toxicological Characterisation .....	9
2.7	Pathways .....	10
	2.7.1 Modelled Pathways .....	10
	2.7.2 Environmental Fate and Transport Pathways .....	10
	2.7.3 Exposure Pathways and Parameters .....	10
<b>3</b>	<b>SELECTION OF THE ASSESSMENT TOOLS .....</b>	<b>12</b>
<b>4</b>	<b>HUMAN HEALTH RISK EVALUATION .....</b>	<b>13</b>
4.1	Methodology .....	13
4.2	Model Run Parameters .....	13
	4.2.1 Building Input Parameters .....	13
4.3	Development of Human Health SSAC .....	13
4.4	Human Health Risk Evaluation.....	14
	4.4.1 <i>In situ</i> Subsurface Soils (Chronic Exposure).....	14
	4.4.2 Soils Re-used during the Redevelopment (Chronic Health Effects) .....	16
	4.4.3 Soils Re-used during the Redevelopment (Medium-term and Acute Exposure) 16	
4.5	Phytotoxicity Assessment.....	17
4.6	Limitations and Assumptions.....	17
<b>5</b>	<b>WATER RESOURCES RISK EVALUATION .....</b>	<b>18</b>
5.1	Methodology .....	18
	5.1.1 Methodology .....	18
	5.1.2 Model Run Parameters.....	18
	5.1.3 Development of Water Resources SSAC.....	18
	5.1.4 Water Resources Risk Evaluation.....	19

<b>6</b>	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>20</b>
<b>7</b>	<b>REFERENCES .....</b>	<b>22</b>
<b>8</b>	<b>STUDY LIMITATIONS.....</b>	<b>25</b>

## Tables

1	Site Specific Assessment Criteria (SSAC) (mg/kg) - <i>In situ</i> Subsurface Soils
2	Site Specific Assessment Criteria (SSAC) (µg/l) - <i>In situ</i> Subsurface Groundwater
3a	Site Specific Screening Criteria (SSSC) (mg/kg) - Soils Re-used during the Redevelopment (no cover layer)
3b	Site Specific Screening Criteria (SSSC) (mg/kg) - Soils Re-used during the Redevelopment (with a cover layer)
4	Exceedances of Site Residents (House) Human Health SSAC (mg/kg) - <i>In situ</i> Subsurface Soils
5	Exceedances of Site Residents (Flat) Human Health SSAC (mg/kg) - <i>In situ</i> Subsurface Soils
6	Exceedances of SSSC (mg/kg) - Soils Re-used during the Redevelopment
7	Results of Risk Assessment for Vapour Release from Soils – Acute Exposure
8	Results of Water Resources Risk Assessment - Groundwater (µg/l)

## Figures

1	Site Location and Environmental Setting
2	Site Layout and Groundwater Elevation Plan
3	Conceptual Site Model Cross Section
4	Modelled Source Area
5	Critical Exceedances of On Site Human Health SSAC (mg/kg) in Soils – <i>In Situ</i> Subsurface Soils -
6	Critical Exceedances of On Site Human Health SSAC (mg/kg) in Soils – Re-Used Soils -

## Appendices

A	Regulatory and Legislative Context
B	Site Specific Redevelopment Plan
C	Sensitivity Testing – Exposure Scenarios
D	Initial Screening
E	Pathway Specific Ranking
F	Pathway Specific Screening
G	Secondary Screening – Water Resources
H	Chemical and Toxicological Input Parameters
I	Sensitivity Testing – Human Health Assessment
J	Sensitivity Testing – Water Resources Assessment
K	Physical and Building Input Parameter Values
L	Human Health Exposure Parameter Data
M	Risk Assessment Methodology
N	Sensitivity Testing – Building Parameters
O	Modelling Outputs
P	Further Sensitivity Testing

## 1 INTRODUCTION

ARCADIS (UK) Ltd (ARCADIS) was commissioned by Kirklees Council to carry out a Detailed Quantitative Risk Assessment (DQRA) at land located off Forge Lane Dewsbury (the site). A site location plan is presented as Figure 1, showing the surrounding land use within a 1km radius. Redevelopment of the site for residential end use has been proposed.

The DQRA was conducted based on recommendations presented in the ARCADIS Phase II Environmental and Geotechnical Site Assessment (representing Stages 3A and 3B of the works as set out in the Site investigation Frameworks Agreement general accordance with the proposal for *Forge Lane, Dewsbury - Stage 1B Assessment (Issue\_04)*, December 2010, ARCADIS document reference 962340001\_04).

A plan showing the site layout is presented as Figure 2.

### 1.1 Background Information

Item	Details
Site status	The western third of the site is predominantly covered by hardstanding associated with demolished structures previously located in this part of the site. The remainder of the site is covered with rough vegetation which is dense in several areas
Previous site use	Mixed commercial / industrial, including gravel pitting, glass works, and iron and steel works
Proposed end-use	Residential
OS National Grid Coordinates	423700, 419708
Elevation	Approximately 40-45m Above Ordnance Datum (AOD)
Previous Reports by ARCADIS	ARCADIS, 2011. Phase II Environmental & Geotechnical Site Assessment and Generic Risk Assessment, Land off Forge Lane, Thornhill Lees, Dewsbury WF12 9EN (ARCADIS Report Ref: 962340101, June 2011)

The site and adjacent land has undergone a series of desk studies and intrusive site investigations since 1997. A detailed summary of environmental investigations undertaken at the site to date is summarised in the previous report issued by ARCADIS (ARCADIS, 2011).

This DQRA has been undertaken following on from the findings of the intrusive works as reported in the Phase II Environmental & Geotechnical Site Assessment Generic Risk Assessment (ARCADIS, 2011) and the information provided in the previous phases of works undertaken. As such, this report should be read in conjunction with the previous environmental reports as the information presented provides the basis for the conceptual understanding of the site.

## 1.2 Aims and Objectives

Outline planning permission was granted for the proposed development in December 2006. It is understood that the reserved matters submission was submitted in December 2010, with a decision pending. Of the various conditions to be discharged, conditions numbers 19 to 23 refer to remediation of the site. Previous assessments conducted have identified the requirement for remediation to render the site suitable for the proposed residential development.

It is understood that the ultimate objective of works at site is to provide information on development constraints relevant to the proposed development that can be passed to a prospective developer to assist in developing remedial options and implementation plans, as required, and abnormal cost estimates

Following the identification of pollutant linkages presenting a potentially unacceptable risk (ARCADIS, 2011), the DQRA has been undertaken as a higher tier assessment with the objectives of:

- Further characterising pollutant linkages at the site using site-specific information.
- Evaluating the significance of the identified impacts (*in situ* soils and groundwater) across the site within the existing legislative framework, through the development of Site Specific Assessment Criteria (SSAC) where appropriate.
- Derive Site Specific Screening Criteria (SSSC) to guide the re-use of excavated material during the redevelopment.

The work was performed in accordance with English legislation and regulatory guidance for the assessment of contaminated land, an overview of which is presented in Appendix A.

## 1.3 Scope of Work

The scope of works was developed with reference to the Department of the Environment Food and Rural Affairs (DEFRA) & Environment Agency's (EA) Contaminated Land Report 11 (CLR 11).

## 1.4 Limitations

ARCADIS' study limitations are presented in Section 7 of this report.

This assessment is based on one round of groundwater sample collection and monitoring. As detailed in the previous phase of works (ARCADIS, 2011), the EA have stated a requirement for three rounds of monitoring to be conducted. The final risk evaluation should be conducted following completion of the additional two rounds of monitoring.

The DQRA does not consider potential risks from bulk ground gases; bulk ground gas protection measures may be required for future development upon the site. This aspect has been further evaluated in the Ground Gas Monitoring Report (ARCADIS, Document ref. 962340125\_01, August 2011).

## 2 SITE CHARACTERISATION

### 2.1 Environmental Setting

The environmental setting of the site is summarised on Figures 1 and 4. Figure 1 identifies potentially sensitive land uses in the vicinity of the site, alongside identified environmental receptors located hydraulically down-gradient of the site. Figure 4 includes simplified profile of the geological conditions, including the depth to groundwater, alongside a conceptual cross section identifying potentially active pollutant linkages for *in situ* subsurface soils and groundwater and soils re-used respectively. The figures have been developed based on information obtained during the previous phases of work and considering the proposed redevelopment of the site. The site is to be redeveloped with a number of two storey detached and semi detached properties. A smaller number of flats are also understood to be included in the scheme. Existing surface water features (pond and stream) are to be retained in the proposed development and a public footpath along the Calder and Hebble Navigation will be constructed. A plan showing the proposed redevelopment layout is presented as Appendix B.

### 2.2 Environmental Investigations

Previous investigations completed at the site have confirmed the presence of made ground to maximum depth of 3.5m below ground level (bgl). Made ground comprised clays, silts, sands and gravels. Made ground was found to be underlain by Alluvium which in turn was found to be underlain by River Terrace Deposits proven to a maximum depth of 10.7m bgl by ARCADIS. Coal Measures were proven underlying the drift deposits to a maximum drilled depth of 40.0m bgl by ARCADIS. Groundwater is present within the shallow natural deposits comprising a single groundwater body at depths between 0.44m and 3.13m bgl (March 2011). The groundwater elevation data collected during the most recent groundwater monitoring visit (March 2011) indicate a generally north to northeasterly flow direction (See Figure 2).

Soil, leachate, sediment, surface water and groundwater samples have been analysed for potential contaminants including Total Petroleum Hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylenes (BTEX), fuel additives, polycyclic aromatic hydrocarbons (PAH), Volatile Organic Compounds (VOC), Semi Volatile Organic Compounds (SVOC), metals and inorganic compounds including asbestos.

Impacts to both shallow soils by a number of Contaminants of Concern (CoC) have been identified at the site. In addition, elevated concentrations of PAH compounds in groundwater sampled from the western part of the site and ammoniacal nitrogen in groundwater from across the site have been measured.

Sediment sampling was conducted to provide information on the sediment quality at the base of the pond.

### 2.3 Receptors

The receptors associated with The Site are presented on Figure 1 and are summarised below.

### 2.3.1 Human Health

The identification of appropriate human health receptors is based on a potential future residential end-use defined by the redevelopment plan.

Based on the intended site use and redevelopment plan, the following are considered potential human health receptors for both in situ subsurface soils and groundwater and soils re-used during the redevelopment:

- Future site resident;
- Maintenance worker visiting the site periodically; and,
- Users of the footpath (e.g. dog walkers).

It is considered appropriate to assess the most sensitive of these receptors, such that the SSAC and SSSC generated are protective of all potential users of the site. Therefore, in order to determine the most sensitive receptor, sensitivity analysis has been undertaken based on the likely exposure scenarios for each receptor. The methodology and results of the sensitivity analysis are presented in Appendix C.

It is noted that allotments are located adjacent to southern and south-western site boundary. Neighbouring residential properties are located beyond the allotments. Given the northerly groundwater flow direction users of the allotments or neighbouring, residents are not considered to be located directly downgradient of the site, and have not been considered as critical receptors within this DQRA.

In addition, construction workers present on-site during redevelopment works have been considered during the DQRA for soils re-used during the redevelopment.

Exposure for construction workers will most likely be acute in nature, i.e. less than one year. This could take the form of short-term exposure (modelled as 15 minutes), such as during ground disturbance during soil excavation works, leading to the potential for release of vapours (Baker *et al*, 2009). As such, further consideration has been given to the short-term exposure to vapours in outdoor air spaces during construction works. Additionally, construction workers could be exposed throughout the construction period, assuming that limited personal protective equipment is used which could prevent direct contact with soil/dust inhalation. It has been assumed that redevelopment works for a site of this size could take 6 months.

### 2.3.2 Water Resources

#### Groundwater

The drift deposits, classified as a Secondary 'A' Aquifer, are considered to be in hydraulic continuity with the underlying Coal Measures, also classified as a Secondary 'A' Aquifer, Therefore the Secondary 'A' Aquifer was considered as a primary water resource receptor in this DQRA.

## Surface Water

Calder and Hebble Navigation is adjacent to the north of the site. Given that water within the canal is generally 1 to 1.5m higher than groundwater resting in nearby monitoring wells the canal is not considered to be in hydraulic continuity with groundwater from beneath the site.

Two surface water features are present on-site: an unnamed pond / marsh area located in the southern part of the site and a drainage ditch which enters the site at the southern site boundary at ground level flowing towards the northern site boundary.

The unnamed pond / marsh area may be in hydraulic continuity with groundwater from beneath the site. The results of the site investigation indicated that the base of the unnamed pond / marsh area is above the groundwater levels measured on site. During periods of heavy rainfall when groundwater levels may rise, it is possible that the groundwater and water within the unnamed pond / marsh area may be in hydraulic continuity. However, surface water samples and sediment samples have been collected from the unnamed pond and analysed for a range of constituents. The results indicated that the surface water samples only contained concentrations of naturally occurring compounds, with none exceeding either ARCADIS in-house GAC or the adopted EQS. This provides additional confidence that the unnamed pond / marsh area are not receptors of concern at the site. While concentrations of certain potential CoC were measured above laboratory MDL in sediments sampled from the pond, there is no evidence of a significant risk to the pond (or from exposure to the pond) based on the following lines of evidence:

- Water quality and risk to the aquatic environment – there were no concentrations of CoC in excess of Environmental Quality Standard (EQS) in surface water samples from the pond; and
- Human health – the pond is unlikely to be used for recreational purposes or fishing meaning the potential for human health receptors to come into regular contact with either the sediments or surface water is minimal.

Based on the above, the pond/marsh area is not considered a plausible receptor.

The drainage ditch becomes deeper as it flows towards the northern site boundary and appears to be culverted beneath the canal. It is considered possible that the drainage ditch is in hydraulic continuity with groundwater beneath the site. Groundwater flow has been inferred towards the north to northeast towards the River Calder, located approximately 450m to the north of the site, flowing north.

## 2.4 Source - Selection of Chemical Constituents of Concern

During previous phase of works (ARCADIS, 2011) the following potential sources were considered further:

- Made ground across the site, with contaminants of concern (CoC) including inorganics, heavy metals and PAHs;
- Other CoC related to former site uses (Glass, steel and iron works) including inorganics, heavy metals, PAH, TPH, PCB and asbestos.
- Asbestos from imported made ground on site;

- Ammoniacal nitrogen in groundwater; and
- Dissolved phase hydrocarbons and PCB in groundwater from adjacent site.

#### 2.4.1 Contaminant Distribution

##### Soils

Each of the constituents was encountered above the laboratory reported method detection limit (MDL) in at least one location in soils from the site. Many of the constituents were encountered at multiple locations, but are naturally occurring.

##### Groundwater

With the exception of PAH and specific inorganic compounds including metals, metalloids and ammoniacal nitrogen, none of the potential CoC in groundwater sampled from the site were measured above laboratory MDL.

#### 2.4.2 Initial Screening

A method of screening has been developed to aid selection of plausible contaminants of concern at the site, taking into consideration the fact that many of the constituents in soil and groundwater can be naturally occurring, and/or of dietary significance.

The first stage in the screening process was to identify each of the constituents which were detected above their laboratory MDL in soil and groundwater. Following this, the frequency and magnitude of the detections were assessed. Those compounds only identified in isolated locations, at what are considered low concentrations have not been assessed further, as indicated in Appendix D, Table D1 and Table D2.

#### 2.4.3 Secondary Screening – Human Health

The second stage of screening considers the likelihood of the potential CoC presenting a risk to human health, based on its dietary significance and likely volatility and toxicity. In addition a number of compounds included such as anions are not considered to present a risk to human health.

##### Dietary Significance

Many of the constituents detected at the site are recommended for inclusion in a daily diet (WHO, 2003). Furthermore, for a number of them the daily intake is set at relatively high level, for example recommended daily intake for calcium for an adult was reported between 1,000mg/day and 1,200mg/day (Office of Dietary Supplements website, accessed June 2011). Where it is known that a constituent is included in the daily dietary intake as part of a healthy diet, these have not been included as plausible CoC within the human health risk assessment.

##### Volatility and Toxicity

The fate and transport of chemicals in the environment depends on many different physical, chemical and biological processes (EA, 2008a). The CoC were assessed for a number of

parameters. These parameters were subsequently used to evaluate each compound in terms of its:

- Toxicity (oral and inhalation pathways),
- Volatility.

The likelihood of a compound presenting a potential risk via certain source-pathway-receptor linkages has been considered by evaluating the volatility and toxicity of compounds and ranking the properties from being a “likely high risk” indicator to a “likely low risk” indicator. The approach adopted for the ranking is presented in Appendix E and the results of the evaluation are presented in Appendix F.

The evaluation was used to inform whether a CoC should be considered for the assessment of risks to human health, which is generally linked to the behaviour of the compound in the environment.

Where a compound exhibits relatively high volatility, and is considered of relatively high toxicity via inhalation pathways this compound was considered further for the human health risk assessment via inhalation pathway.

#### **2.4.4 Secondary Screening – Water Resources**

In terms of potential risks to water resources, it is considered valid to conclude that where a compound is present above laboratory MDL in soil but not in groundwater the potential risk to water resource receptors is not significant. This is considered a valid approach for historically contaminated sites, and where leaching of CoC from soil to groundwater would already be expected to be active (e.g. sites where impermeable hardstanding is absent).

As such, only compounds detected in groundwater at concentrations above laboratory MDL were considered as potential CoC in this risk assessment, and secondary screening undertaken.

#### ***In situ Subsurface Soils and Groundwater***

Measured CoC concentrations in groundwater and leachate were compared with ARCADIS in-house Generic Assessment Criteria (GAC). Where no ARCADIS in-house GAC were available, measured CoC concentrations were compared with Environmental Quality Standards (EQS).

The results are presented in Appendix G and indicated that ammoniacal nitrogen and free ammonia required further consideration as CoC in the water resources risk assessment. The detections of ammonia in excess of the MDL were measured in monitoring wells WS114 and WS115 located along the northern site boundary and WS120 located in the southern part of the site in the vicinity of the marsh area. The highest detections of ammonium (ionised ammoniacal nitrogen as  $\text{NH}_4^+$ ), in excess of 1,000  $\mu\text{g/l}$ , were measured along the northern site boundary.

Concentrations of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene were also measured above ARCADIS' in-house GAC in groundwater sampled from monitoring wells WS102, WS104, WS105, WS107 and WS109. However, it is noted that none of the measured concentrations exceeded the GAC by more than an order of magnitude. It is further noted that the distribution of the identified impacts measured above ARCADIS in-house GAC does not indicate a source, with only sporadic exceedances identified. Based on this, and that PAH are recognised as being of relatively low mobility in the environment, the exceedances of the GAC are not considered to pose a significant risk to the identified water resource receptors:

Based on the above PAH compounds were not included as CoC in this water resources assessment, but ammoniacal nitrogen and ammonia have been considered further.

### ***Soils Re-used during the Redevelopment***

Although the results of the comparison of measured concentrations in groundwater to EQS indicate the site is not significantly impacting upon water resources receptors associated with the site, the movement of material around the site has the potential to re-mobilise some contaminants of concern.

The leachate testing undertaken during the previous phase of works provides a conservative assessment of the concentrations of CoC that could potentially be mobilised from soils. The concentration of each constituent has been compared to water resources GAC or EQS where appropriate. The results are presented in Appendix G and indicate that the measured concentration of PAH and metals exceed the GAC.

Naphthalene and benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene have the potential to leach into groundwater at concentrations above the water resources GAC. However, the concentrations measured in leachate are in the same order of magnitude as the GAC.

The concentrations of arsenic, zinc, vanadium, copper and nickel have the potential to leach into groundwater at concentrations above EQS. The concentrations measured in leachate are all comparable to the respective EQS, as for the PAH.

The potential concentrations measured in leachate samples are considered to be a worst case scenario, therefore, concentrations of these compounds at comparable levels to the EQS provides good evidence that the risk to water resources associated with the site based on *in situ* impacts and the re-use of excavated material is not considered to be significant. This has not been further considered in this assessment.

## **2.5 Source Areas**

A source area has to be defined for the purposes of the controlled waters risk assessment, but not for the purpose of the human health risk assessment. The CoC for which source areas have been defined are ammonia (as N) and ammonium (ionised ammoniacal nitrogen as  $\text{NH}_4^+$ ).

### 2.5.1 Ammonia as N

Total ammoniacal nitrogen as N is the sum of all ammoniacal nitrogen species. The two important species are “free” ammonia (as N) and ammonium (ammoniacal nitrogen present as ionic  $\text{NH}_4^+$ ). The ionisation of ammonia to ammonium is dependent in part on the pH of the groundwater. The laboratory has provided estimated splits between ammonia and ammonium on the basis of the pH recorded in each sample. Ammonia represents a higher toxicity to aquatic life, with an EQS of  $15\mu\text{g/l}$ , in comparison to the EQS of  $500\mu\text{g/l}$  for ammonium. As such, both forms of ammoniacal nitrogen have been assessed as separate CoC.

The detections of ammonia in excess of MDL, were measured in monitoring wells WS114 and WS115 located along the northern site boundary and WS120 located in the southern part of the site in the vicinity of the marsh area. The highest measured concentration of  $780\mu\text{g/l}$  was recorded in groundwater sampled from monitoring well WS114. The source area shown on Figure 4 represents the area of the site where the highest concentrations of ammonia - representing a potential source - have been identified.

It is noted that the area of elevated concentrations of ammonia located in the vicinity of the unnamed pond / marsh area (WS120) was not defined as a separate source area. The primary reason for this is the fact that the surface water samples collected from the unnamed pond / marsh area had measured concentrations of ammonia below laboratory MDL's.

### 2.5.2 Ammonium (Ionised Ammoniacal Nitrogen as $\text{NH}_4^+$ )

The highest detections of ammonium (ionised ammoniacal nitrogen as  $\text{NH}_4^+$ ), in excess of  $1,000\mu\text{g/l}$ , were measured along the northern site boundary. The highest measured concentration of  $9,120\mu\text{g/l}$  was recorded in groundwater sampled from monitoring well WS114. Given that the highest concentrations ammonium were measured in the same locations as the highest concentrations of ammonia, the same source area was adopted.

## 2.6 Chemical and Toxicological Characterisation

Chemical Characterisation	A range of literature sources have been reviewed and chemical properties applicable at $10^\circ\text{C}$ have been adopted where possible. The chemical data from EA (2008a) has been adopted where provided.
Toxicological Characterisation	Where possible toxicological data published by the EA and Department for Environment Food and Rural Affairs (DEFRA) has been used. In the absence of a suitable TOX report, ARCADIS has used the general method of selection outlined in EA (2009b) to find a suitable alternative.

Key chemical and toxicological properties for the CoC are presented in Appendix H.

## 2.7 Pathways

### 2.7.1 Modelled Pathways

In order to assess the risk presented to the identified receptors, the pathways defined as potentially active within the pollutant linkages need to be considered further. Site-specific information is used where possible to assign parameter values for:

- the physical characterisation of the geological and hydrogeological setting of the site;
- physical building properties;
- exposure parameters (assessment of risks to human health).

Based on the results of the previous environmental investigations completed at the site, the unsaturated zone, source zone and aquifer have been conceptualised and are presented on Figure 3.

### 2.7.2 Environmental Fate and Transport Pathways

The following fate and transport pathways have been considered within this DQRA:

- Partitioning of soil or groundwater impacts into soil gas and vertical migration (upwards) towards ground surface.
- Dilution in an overlying air space.
- Off-site migration of impacts in the dissolved phase.

### 2.7.3 Exposure Pathways and Parameters

The following exposure pathways are considered potentially active:

#### **Chronic Exposure**

##### Site resident residing in a house

##### *In situ Subsurface Soils and Groundwater*

- Inhalation of indoor air impacted by a soil or groundwater source
- Inhalation of outdoor air impacted by a soil or groundwater source
- Inhalation of indoor dust impacted by a shallow soil source
- Inhalation of outdoor dust impacted by a shallow soil source
- Direct contact exposure with shallow soils, and dust impacted by a shallow soil source
- Ingestion of produce and soils attached to the produce, grown in shallow impacted soils.

##### *Soils Re-used during the Redevelopment*

- Inhalation of indoor air impacted by a soil source
- Inhalation of outdoor air impacted by a soil source
- Inhalation of indoor dust impacted by a soil source
- Inhalation of outdoor dust impacted by a soil source

- Direct contact exposure with shallow soils, and dust impacted by a shallow soil source
- Ingestion of produce and soils attached to the produce, grown in shallow impacted soils.

#### Site resident residing in a flat

The same exposure pathways are considered potentially active, with the exception of ingestion of produce, assuming that the flats will not have private gardens.

Incidental direct contact exposure pathways with impacted groundwater are not considered to be active for site residents as the depth to groundwater measured in the monitoring well network currently present on-site was in general greater than 1m bgl, which is considered sufficient to prevent incidental direct contact by on-site residents.

### **Medium-term and Acute Exposure**

#### Construction worker

##### *Soils Re-used during the Redevelopment (over 6 month period)*

- Inhalation of outdoor air – vapour emission
- Inhalation of outdoor dust
- Direct contact exposure with soils and dust

##### *Soils Re-used during the Redevelopment (15 minute exposure)*

- Inhalation of outdoor air due to soil disturbance - vapour release (e.g. during construction work, landscaping work) is considered the primary pathway.

Incidental direct contact exposure pathways with potentially impacted groundwater are not considered to be active as it is considered that appropriate management of water during construction (i.e. excavations to be pumped dry, limited potential for direct contact exposure) are assumed to make the pathway inactive for construction workers.

Exposure data have been derived to represent the following receptors, selected in line with the CLEA methodology:

- On-Site Resident: 0 – 6 year old female child; and,
- Construction Worker: 16 – 65 year old female.

### 3 SELECTION OF THE ASSESSMENT TOOLS

This updated DQRA has been undertaken using site-specific information, where available, to derive risk-based assessment criteria, which can be used to assess whether the measured concentrations of CoC on site present potentially unacceptable risks to the identified receptors.

The following modelling tools were selected for the assessment of human health:

Receptor	Media	Selected Modelling Tool
Human Health	Soil	CLEA version 1.06
	Groundwater	RBCA version 2.5
Water Resources	Groundwater	RTW version 3.1

A sensitivity analysis has been carried out, using CLEA 1.06, to assist with selection of parameter values required for the key fate and transport pathways for the human health assessment. The results of sensitivity testing are presented in Appendix I. Sensitivity testing was completed for aliphatics >C5-C6. In addition, a sensitivity analysis has been carried out, using RTW version 3.1, to assist with selection of parameter values required for the water resources risk assessment. The results of sensitivity testing are presented in Appendix J. Sensitivity testing was completed for ammonium. A full listing of the physical parameter values used in the risk assessment is presented in Appendix K.

A listing of the exposure parameter values used in the risk assessment is presented in Appendix L. The exposure data are taken from Environment Agency (2009b) where possible.

The current non-statutory regulatory technical guidance consulted in undertaking this updated DQRA, updated methodology used and modelling tools available at the time this assessment was undertaken are presented in Appendix M.

## 4 HUMAN HEALTH RISK EVALUATION

### 4.1 Methodology

#### *In situ Subsurface Soils and Groundwater (Chronic Exposure)*

The human health risk assessment has been undertaken using CLEA version 1.06 and RBCA 2.5 to calculate evaluation criteria, or human health SSAC, as outlined in Appendix M. The CLEA software has been used to model exposure *via* soil on site, and RBCA software has been used to model exposure *via* groundwater on site.

#### *Soils Re-used during the Redevelopment (Chronic Exposure)*

The chronic health effects assessment has been undertaken using CLEA version 1.06 to calculate SSSC, as outlined in Appendix M. The CLEA software has been used to model exposure to soil re-used during the redevelopment on site.

#### *Soils Re-used in during the Redevelopment (Medium Term and Acute Exposure)*

The medium-term health effects assessment for the 6 month period has been undertaken using CLEA version 1.06 to calculate SSSC, as outlined in Appendix M. The CLEA software has been used to model exposure to soil re-used during the redevelopment on site.

The acute health effects assessment for the 15 minute exposure has been undertaken using RBCA version 2.5. The potential for workers to be exposed to soil vapours released from open soils was considered further (e.g. during excavation works).

Where appropriate, the SSAC derived for the individual exposure pathways have been combined using the approach outlined in Environment Agency (2009a), with a hazard quotient of 1 across all pathways for an environmental medium.

### 4.2 Model Run Parameters

#### 4.2.1 Building Input Parameters

The redevelopment plan includes flat and houses at a range of different sizes. The smallest flat and house was selected to represent the potential future on-site residential property, as a result of sensitivity testing conducted in line with CLEA methodology and presented in Appendix N. A full listing of building parameters is presented in Appendix K.

### 4.3 Development of Human Health SSAC

#### *In situ Subsurface Soils and Groundwater (Chronic Exposure)*

The SSAC defined for the protection of human health for soils to be left *in situ* and groundwater are presented in Tables 1 and 2 respectively. Example CLEA and RBCA outputs for chronic exposure are presented as Appendix O.

#### *Soils Re-used during the Redevelopment (Chronic Exposure)*

The SSAC developed to assess the in-situ soils can be also used as screening criteria for the on-site material re-use, the SSAC are presented in Table 1. Before re-using the soils on Site, it has been assumed that the soils will be visually screened for asbestos.

#### *Soils Re-used during the Redevelopment (Medium-Term and Acute Exposure)*

The SSSC developed to assess the suitability of the on-site soil material defined for the protection of human health for acute exposure to soil (6 month period) are presented in Table 3.

For assessment of potential acute exposure (and associated health effects) due to ground disturbance (15 minute exposure), the theoretical soil saturation limits were used to represent the likely highest concentrations of CoC in soil. RBCA Toolkit was then used to assess the emission of CoC from surface soils, to approximate the effect if the ground was disturbed (e.g. through excavation of soils). The predicted concentrations of CoC in outdoor air were then compared against WELs.

The CLEA 1.06 model output for soils includes a check as to whether the SSAC is greater than the theoretical concentration at which residual phase begins to form in soil. Where a separate phase is not present, the risk *via* vapour inhalation would not be considered unacceptable since the saturated vapour concentration for a contaminant in soil is not great enough to result in an unacceptable risk *via* vapour inhalation. No apparent evidence of LNAPL was identified on soil or groundwater during the works completed by ARCADIS.

Several of the groundwater SSAC are defined as 'Sol' (solubility) values. The solubility concentration is the maximum theoretical dissolved phase concentration; it defines the point at which no more molecules can dissolve into the water and a separate phase begins to form. The model output 'Sol' denotes the case where the pure component solubility for a contaminant in water is not great enough to result in the selected hazard quotient being reached, or exceeded, for the specified exposure scenario (ASTM, 1995).

Whilst an individual pathway may show an output of 'Sol', it still has the potential to contribute to the overall risk posed to the receptor. This is addressed in the combining of the SSAC for each pathway into a single SSAC for each contaminant for groundwater.

## 4.4 Human Health Risk Evaluation

### 4.4.1 *In situ* Subsurface Soils (Chronic Exposure)

The SSAC derived for residents residing in the houses have been compared to soils sampled within the area of the proposed redevelopment which includes the future houses and SSAC derived for residents residing in the flats have been compared to soils sampled within the area of the proposed redevelopment which includes the future flats (see Appendix B – redevelopment plan).

#### **Residential End Use - House**

For the future site resident scenario residing in a **house**, the following risk evaluation was undertaken:

Pollutant Linkages	Exposure Duration*	Risk Evaluation
Ingestion of produce grown on site, incidental soil ingestion, incidental direct contact, inhalation of dust and inhalation of vapours in indoor and outdoor air impacted by soil source	6 years	Summary of the locations where measured concentrations of CoC in soil exceed SSAC in <b>Table 4*</b> . <b>Figure 5</b> indicates the locations where critical exceedances were measured.

\* A number of the exceedances are driven by direct contact (oral pathways), where a compound exceeds the SSAC based on the direct contact pathway, the depth from which the sample was taken becomes a crucial parameter. Generally, only compounds within near surface soils (<0.5m bgl) are likely to present a potential risk via direct contact pathway for soils remaining *in situ*.

The measured concentrations of a number of CoC exceed the human health SSAC derived for residents residing in a house based on *in situ* subsurface soils. It is noted that a number of these exceedances are near surface soils (<0.5m bgl) and exceed based on direct contact pathways across the area of the site considered to be redeveloped into houses (arsenic, lead, vanadium and benzo(a)pyrene). In addition, the concentration of naphthalene (in two locations) and benzene (in a single location) exceed the human health SSAC derived for residents residing in a house. These exceedances are driven by the inhalation pathway. The measured concentration of benzene and naphthalene in two of these locations are marginally above the SSAC. The measured concentration of naphthalene in the remaining location is considerably higher than the SSAC based on risks from vapour intrusion, however, this location lies outside the proposed development area for houses.

#### Residential End Use - Flat

For the future site resident scenario residing in a **flat**, the following risk evaluation was undertaken:

Pollutant Linkages	Exposure Duration*	Risk Evaluation
Incidental soil ingestion, incidental direct contact, inhalation of dust and inhalation of vapours in indoor and outdoor air impacted by soil source	6 years	Summary of the locations where measured concentrations of CoC in soil exceed SSAC in <b>Table 5*</b> .

\* A number of the exceedances are driven by direct contact (oral pathways), where a compound exceeds the SSAC based on the direct contact pathway, the depth from which the sample was taken becomes a crucial parameter. Generally, only compounds within near surface soils (<0.5m bgl) are likely to present a potential risk via direct contact pathway for soils remaining *in situ*.

The measured concentration of arsenic in one location exceeds the human health SSAC derived for residents residing in a flat based on *in situ* subsurface soils in the area of the site considered to be redeveloped into flats. The measured concentration of arsenic in excess of the SSAC was identified in soil sampled from depths greater than 0.5m bgl. As discussed

above, in general direct contact pathway can be considered active with soils present in the upper 0.5m bgl. Therefore the measured arsenic concentration is not considered to pose a potentially unacceptable level to human health via direct contact pathway.

#### 4.4.2 Soils Re-used during the Redevelopment (Chronic Health Effects)

The same pollutant linkages and exposure durations as *in situ* subsurface soils were considered for soils re-used during the redevelopment for the site resident.

**Table 6** presents the list of exceedances of CoC in soils sampled across the site for the soils re-use. **Figure 6** indicates the locations where critical exceedances were measured.

Concentrations of soil sampled across the site have been compared to SSAC derived for both residents residing in a house and flat considering that soils could be moved around the site during the redevelopment process. In addition, samples from all depths have been considered given that future alterations to the surface level and turning of the soil may result in unacceptable concentrations of other representative CoC being brought to the upper 0.5m bgl. Two sets of SSSC have been provided for use in the site redevelopment, under the assumption that a cover system could be used to manage risks from direct contact exposure or dust inhalation.

A number of CoC concentrations sampled in soils at locations across the site were found to exceed the SSAC for both residential end uses.

#### 4.4.3 Soils Re-used during the Redevelopment (Medium-term and Acute Exposure)

For the construction worker scenario, the following risk evaluation was undertaken:

Pollutant Linkages	Exposure Duration*	Risk Evaluation
Incidental direct contact, inhalation of dust and inhalation of vapours in outdoor air from soil source	0.5 year	A summary of the locations where measured concentrations of CoC in soil exceed the SSSC is presented in <b>Table 3</b> .
Inhalation of volatile compounds due to vapour release	15 minutes	Comparison of predicted outdoor air concentrations, calculated using theoretical soil saturation limits of the CoC, to WELs in <b>Table 7</b> .

For assessment of potential acute exposure (and associated health effects) due to ground disturbance, the predicted concentrations of CoC in outdoor air were compared against WELs. It is noted that only CoC with WELs defined for a short term exposure limit (15 minute reference period) were included in the assessment. These include:

- Ethylbenzene,
- Toluene,
- Xylenes,
- Styrene.

The results of the modelling indicate that the potential for an unacceptable level of acute exposure due to vapour release, on the basis of the theoretical soil saturation limits of the CoC in soils, is not considered to be significant, as shown in Table 7.

Assuming future redevelopment works take half a year, none of the measured concentrations of CoC in soils sampled from across the site have the potential to present an unacceptable risk to construction workers assuming no personal protective equipment is employed to minimise exposure to impacts in soils.

#### **4.5 Phytotoxicity Assessment**

The potential risk to plants from the phytotoxic metals copper, zinc, nickel should be assessed using the values set out within BS 3882:2007, assuming pH 6.0 - 7.0 during re-use of soils during the redevelopment. The values are presented in Table 3.

#### **4.6 Limitations and Assumptions**

The SSSC and SSAC defined to offer protection to the identified human health receptors are based on current best practice. There have been several conservative assumptions adopted in the conceptual model for the derivation of these remedial targets. Modifications to the conceptual model, such as the collection of additional site data, may result in changes to the SSAC or SSSC defined here.

The assessment does not take into consideration the potential for hydrocarbon vapour build-up in enclosed spaces (e.g. excavations), which should be considered during the development works. All works should be conducted with reference to HS(G)66.

## 5 WATER RESOURCES RISK EVALUATION

### 5.1 Methodology

#### 5.1.1 Methodology

The water resources risk assessment has been undertaken using RTW version 3.1. RTW model has been used to back-calculate evaluation criteria, or water resources SSAC, as outlined in Appendix M.

#### 5.1.2 Model Run Parameters

Parameter	Value	Comment
Compliance Point Distance	250m from source	Appendix P, approximately half way between surface water and source
Compliance Criteria	CoC specific	Appendix G
Degradation*	CoC specific	Appendix P
Time Frame	Ogata-Banks solution	In line with RTM methodology
Dispersivity	Longitudinal, transverse and vertical dispersivities have been calculated within the RTW model as 10%, 1% and 0.1% of the compliance point distance respectively	In line with RTM methodology

\* There is limited information on the degradation rate for ammoniacal nitrogen species in the environment, although the generation of nitrate suggests clearly that it is occurring as would be expected under relatively aerobic conditions. An increase in nitrate and nitrite would be expected down-gradient of the source as indicators that attenuation was occurring, but the rate of attenuation is highly site specific. Based site data which indicate that degradation is occurring (the presence of nitrate and nitrite) degradation has been modelled as occurring in the dissolved and sorbed phases. Reference has been made to literature sources to define a degradation half life.

#### 5.1.3 Development of Water Resources SSAC

The SSAC defined for the protection of the identified water resource receptors have been derived and are presented Table 8.

Example RTW output sheets are presented in Appendix O.

The RTM states:

“A simple check that should be undertaken is that the calculated remedial target does not exceed the solubility limit for the contaminant. In this case remediation of the soil would be unnecessary to protect water resources...”

For groundwater, the SSAC have been compared to the theoretical solubility. Where the SSAC exceeds the theoretical solubility and these CoC are not considered to pose unacceptable risks to the identified water resources receptors.

#### **5.1.4 Water Resources Risk Evaluation**

The concentrations of CoC in groundwater have been compared to the SSAC in Table 8.

None of the measured concentrations of CoC in groundwater exceed the water resources SSAC.

## 6 SUMMARY AND CONCLUSIONS

A Detailed Quantitative Risk Assessment (DQRA) has been undertaken for the land of Forge Lane, based on the proposed residential end-use development plan.

The conceptual site model presented in the previous report was further refined in this DQRA, using site specific data, where available. The DQRA considers future on site residents as critical human health receptors. Secondary (a) Aquifer and surface water features located on and around the site were considered as water resource receptors. Site specific assessment criteria (SSAC) were derived for identified critical human health receptors (site residents), and water resource receptors represented by a compliance point distance of 250m.

The conceptual site model also included source-pathway-receptor linkages based on intended use of some/all of the soils excavated from beneath the site during redevelopment works. The SSAC derived for on site residents were considered suitable as screening criteria for on site material re-use. In addition, acute health effects were considered which included the assessment of the potential for vapour release, during the construction works.

### **Water Resources Assessment**

#### ***In situ Subsurface Soils and Groundwater***

- None of the measured concentrations of CoC in soil or groundwater were considered to present a significant risk to water resource receptors.

#### ***Soils Re-used during the Redevelopment***

- Results of leachate testing was used to evaluate potential risks from soils re-use. The results indicate that the measured concentration of a number of PAH and metals have the potential to leach into groundwater at concentrations above the EQS. However, the concentrations measured in leachate were all comparable to the respective EQS, PAH and metals exhibit low mobility in the environment and the potential concentrations measured in leachate samples are considered to be a worst case scenario.
- In conclusion, the result of the comparison indicates that although some of the CoC in soil have limited potential to migrate into groundwater, the concentrations in leachate are not significant and should not prevent re-use of soils during the redevelopment

### **Human Health Risk Assessment**

#### ***In situ Subsurface Soils and Groundwater***

- The potential for unacceptable health effects from the measured concentrations of CoC measured in *in situ* groundwater impacts was not considered to be significant for site residents residing in a flat or house.
- The potential for unacceptable health effects from the measured concentrations of CoC measured in *in situ* subsurface soil in the area of the site proposed to be redeveloped into flats was not considered to be significant for site residents residing in a flat.
- The results of the assessment of *in situ* subsurface soils in the area of the site proposed to redeveloped into houses indicated that two of CoC (benzene and naphthalene) in three locations exceed the SSAC derived for the protection of site residents residing in a house,

based on the vapour intrusion pathway. However, two of the locations only showed marginal exceedances, and the remaining location lies outside of the development area for housing/flats.

- The results of the assessment highlighted a number of locations across the site where PAH and metals in soils exceeded the SSAC driven by direct contact exposure/dust inhalation.

#### ***Soils Re-use***

- The potential for unacceptable medium-term or acute health effects from the measured concentrations of the CoC in soils by future construction workers was not considered to be significant for soils re-use.
- As the SSSC derived for re-use are equivalent to the SSAC, assuming no cover system when soils are re-used, the findings of the assessment are that soils across the site contain PAH and metals at concentrations above the SSSC based on risks from direct contact exposure or dust inhalation.
- The same two CoC which exceeded the SSAC driven by vapour inhalation (benzene and naphthalene) also exceeded the SSSC, as the criteria are the same.

#### ***Conclusion***

The results of the DQRA indicates that further works and screening of soils are required to reduce the risks to human health receptors during redevelopment works.

The potential risks to water resource receptors from measured soil and groundwater concentrations and also from the soil re-use are not considered significant. This assumes that conditions encountered across the site to date are representative of site conditions as a whole.

#### ***Recommendations***

It is recommended that additional groundwater monitoring was undertaken on site. This is to further inform about the potential risks to the identified human health and water resource receptors, and also to fulfil the requirement set by the EA (ARCADIS, 2011).

A Materials Management Plan will be required to provide robust documentation as to how and where soils can be re-used across the site. Two sets of SSSC have been adopted to guide future development works, dependent on whether a cover system to prevent direct contact and dust exposure is employed. The SSSC should be used as screening criteria during soils re-use, and should be incorporated into the Materials Management Plan.

## 7 REFERENCES

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## 8 STUDY LIMITATIONS

**IMPORTANT.** This section should be read before reliance is placed on any of the information, opinions, advice, recommendations or conclusions contained in this report.

1. This report has been prepared by ARCADIS UK Limited (ARCADIS), with all reasonable skill, care and diligence within the terms of the Appointment and with the resources and manpower agreed with Kirklees Council (the 'Client'). ARCADIS does not accept responsibility for any matters outside the agreed scope.
2. This report has been prepared for the sole benefit of the Client unless agreed otherwise in writing.
3. Unless stated otherwise, no consultations with authorities or funders or other interested third parties have been carried out. ARCADIS are unable to give categorical assurance that the findings will be accepted by these third parties as such bodies may have unpublished, more stringent objectives. Further work may be required by these parties.
4. All work carried out in preparing this report has used, and is based on, ARCADIS' professional knowledge and understanding of current relevant legislation. Changes in legislation or regulatory guidance may cause the opinion or advice contained in this report to become inappropriate or incorrect. In giving opinions and advice, pending changes in legislation, of which ARCADIS is aware, have been considered. Following delivery of the report, ARCADIS have no obligation to advise the Client or any other party of such changes or their repercussions.
5. This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report.
6. Whilst this report and the opinions made are correct to the best of ARCADIS' belief, ARCADIS cannot guarantee the accuracy or completeness of any information provided by third parties.
7. This report has been prepared based on the information reasonably available during the project programme. All information relevant to the scope may not have been received.
8. This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of changes in the condition of the site since the time of the investigation.
9. The content of this report represents the professional opinion of experienced environmental consultants. ARCADIS does not provide specialist legal or other professional advice. The advice of other professionals may be required.
10. Where intrusive investigation techniques have been employed they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature of sampling, no investigation technique is capable of identifying all conditions present in all areas. In some cases the investigation is further limited by site operations, underground obstructions and above ground structures. Unless otherwise stated, areas beyond the boundary of the site have not been investigated.
11. If below ground intrusive investigations have been conducted as part of the scope, service tracing for safe location of exploratory holes has been carried out. The location of underground services shown on any drawing in this report has been determined by visual observations and electromagnetic techniques. No guarantee can be given that all services have been identified. Additional services, structures or other below ground obstructions, not indicated on the drawing, may be present on site.
12. Unless otherwise stated the report provides no comment on the nature of building materials, operational integrity of the facility or on any regulatory compliance issues.
13. Unless otherwise stated, samples from the site (soil, groundwater, building fabric or other samples) have NOT been analysed or assessed for waste classification purposes.

# TABLES

Table1  
Site Specific Assessment Criteria (SSAC) (mg/kg)  
- In situ Subsurface Soils -

CoC	Theoretical Soil Saturation Limit	Site Resident (Flat)			Site Resident (House)		
		Oral	Inhalation	Combined	Oral	Inhalation	Combined
<b>Metals</b>							
Aluminium	NVP	1.35E+05	1.40E+5 #	6.88E+04	1.33E+05	1.40E+5 #	6.84E+04
Arsenic	NVP	35	60.1 #	35	32.4	60.1 #	32.4
Cadmium	NVP	24.1	21 #	11.2	5.45	21 #	4.33
Copper	NVP	9.44E+03	8.08E+3 #	4.35E+03	5.32E+03	8.08E+3 #	3.21E+03
Lead	NVP	236	9.78E+4 #	235	233	9.78E+4 #	233
Molybdenum	NVP	337	1.03E+3 #	336	107	1.03E+5 #	107
Nickel	NVP	789	90.1 #	90.1	532	90.1 #	90.1
Vanadium	NVP	792	5.86E+3 #	698	632	5.86E+3 #	571
<b>Aliphatics</b>							
Aliphatics >C5-C6	1,990	2.23E+05	88.2	88.1	2.31E+04	178	176
Aliphatics >C6-C8	1,400	2.23E+05	279	279	6.72E+04	563	558
Aliphatics >C8-C10	902	4.45E+03	71.1	70	3.36E+03	143	137
Aliphatics >C10-C12	551	4.45E+03	346	321	4.25E+03	695	597
<b>Aromatics</b>							
Aromatics >EC8-EC10	6,660	1.78E+03	118	111	352	237	141
Aromatics >EC10-EC12	4,060	1.78E+03	648	475	435	1.29E+03	325
Aromatics >EC12-EC16	1,830	1.78E+03	3.29E+03	1.16E+03	6.38E+02	6.44E+03	580
Aromatics >EC16-EC21	521	1.34E+03	ND	1.34E+03	8.08E+02	ND	808
Aromatics >EC21-EC35	54.8	1.34E+03	ND	1.34E+03	1.23E+03	ND	1.23E+03
<b>PAHs</b>							
Naphthalene	795	1.58E+03	105	98.2	143	205	84.1
Acenaphthylene	2270	402		402	83.3		83.3
Acenaphthene	484	4.04E+03	1.00E+6 #	4.03E+03	766	1.00E+6 #	765
Fluorene	379	3.23E+03	1.00E+6 #	3.22E+03	848	1.00E+6 #	847
Phenanthrene	155	3.23E+03		3.23E+03	1.17E+03		1.17E+03
Anthracene	22.6	3.23E+03	1.00E+6 #	3.23E+03	1.15E+03	1.00E+6 #	1.15E+03
Fluoranthene	210	402	1.00E+6 #	402	270	1.00E+6 #	270
Pyrene	24.4	2.42E+03		2.42E+03	1.56E+03		1.56E+03
Benz(a)anthracene	19	16.2	21 #	9.14	14.6	21 #	8.63
Chrysene	4.89	162	210 #	91.4	141	210 #	84.2
Benzo(b)fluoranthene	13.5	16.2	21 #	9.14	15	21 #	8.76
Benzo(k)fluoranthene	7.63	16	21 #	9.14	15.3	21 #	8.87
Benzo(a)pyrene	10.1	1.62	2.1 #	0.914	1.52	2.1 #	0.883
Indeno(1,2,3-cd)pyrene	0.682	16.2	21 #	9.14	14.8	21 #	8.69
Dibenzo(a,h)anthracene	0.0437	1.62	2.1 #	0.914	1.55	2.1 #	0.892
Benzo(g,h,i)perylene	0.207	2.42E+03		2.42E+03	2.37E+03		2.37E+03
<b>BTEX</b>							
Benzene	8,120	25.8	1.2	1.15	0.476	2.42	0.398
Toluene	7,870	1.98E+04	3.68E+03	3.11E+03	753	7.40E+03	683
Ethylbenzene	5,210	8.88E+03	1.08E+03	963	568	2.16E+03	450
Sum Xylenes	5,670	1.60E+04	358	351	1.04E+03	718	424
<b>Additional VOC</b>							
Carbon Disulphide	16,400	8.91E+03	1.07	1.07	289	2.16	2.15
Dichloromethane	21,700	116	0.251	0.25	0.865	0.506	0.319
Styrene	7,240	661	42.4	39.8	37.2	85.3	25.9
1,2,4-Trimethylbenzene	14,200	4.45E+03	5.15	5.14	1.36E+03	10.4	10.3
<b>Additional SVOC</b>							
Carbazole	246	44.5	1.50E+4 #	44.4	25.3	1.50E+4 #	2.53E+01
2-Methylnaphthalene	4,210	356	111	84.6	93.8	222	66

not selected for this pathway

Where combined SSAC is greater than the theoretical maximum concentration in soil (1kg per kg), 1.0E+06 mg/kg presented as SSAC

*Italics*

Target exceeds theoretical soil saturation limit. Concentrations above the soil saturation limit may indicate the presence of separate phase in soil, but does not necessarily present a significant risk.

NR

No appropriate reference dose identified during review of toxicological data

NVP

Contaminant has only a low vapour pressure in soil

#

Inhalation exposure via dust inhalation only

Table 2  
 Site Specific Assessment Criteria (SSAC) (µg/l)  
 - In situ Subsurface Groundwater -

CoC	Theoretical Solubility Concentration	Site Resident (Flat)			Site Resident (House)			Maximum Measured Concentration (µg/l)	Exceeds SSAC for On-site Resident (Flat)?	Exceeds SSAC for On-site Resident (House)?
		Inhalation of Indoor Air	Inhalation of Outdoor Air	Additive SSAC	Inhalation of Indoor Air	Inhalation of Outdoor Air	Additive SSAC			
PAHs										
Naphthalene	19,000	4,000	Sol	4,000	8,100	Sol	8,100	0.901	No	No
Free Ammonia	610,000,000	13,000	20,000,000	13,000	27,100	20,000,000	27,100	780	No	No

Sol  
 Target acceptable risk is not exceeded at the theoretical solubility concentration.  
 Solubility concentrations are presented for guidance purposes only – these are not SSAC.

Table 3a  
Site Specific Screening Criteria (SSSC) (mg/kg)  
- Soils Re-used during Redevelopment -  
(No Groundwater)

CoC	Theoretical Soil Saturation Limit	Site Resident (Flat)			Site Resident (House)			Construction Worker			Plants*	Maximum Measured Concentration (mg/kg)	Exceeds SSSC for Construction Worker?
		Oral	Inhalation	Combined	Oral	Inhalation	Combined	Oral	Inhalation	Combined			
<b>Metals</b>													
Aluminium	NVP	1.35E+05	1.40E+5 #	6.88E+04	1.33E+05	1.40E+5 #	6.84E+04	1.00E+06	1.00E+6 #	1.00E+06		52,500	No
Arsenic	NVP	35	60.1 #	35	32.4	60.1 #	32.4	1.18E+03	3.85E+3 #	1.18E+03		196	No
Cadmium	NVP	24.1	21 #	11.2	5.45	21 #	4.33	735	2.14E+3 #	547		2.41	No
Copper	NVP	9.44E+03	8.08E+3 #	4.35E+03	5.32E+03	8.08E+3 #	3.21E+03	2.86E+05	5.42E+5 #	1.87E+05	<135	1,490	No
Lead	NVP	236	9.78E+4 #	235	233	9.78E+4 #	233	1.14E+04	1.00E+6 #	1.14E+04		7,660	No
Molybdenum	NVP	337	1.03E+3 #	336	107	1.03E+3 #	107	1.02E+04	1.00E+6 #	1.02E+04		23	No
Nickel	NVP	789	90.1 #	90.1	532	90.1 #	90.1	4.12E+04	9.89E+3 #	9.89E+03	<75	85.5	No
Vanadium	NVP	792	5.86E+3 #	698	632	5.86E+3 #	571	2.74E+04	5.09E+5 #	2.60E+04		737	No
Zinc	NVP										<200	1,550	No
<b>Aliphatics</b>													
Aliphatics >C5-C6	1,990	2.23E+05	88.2	88.1	2.31E+04	178	176	1.00E+06	1.00E+06	1.00E+06		0.102	No
Aliphatics >C6-C8	1,400	2.23E+05	279	279	6.72E+04	563	558	1.00E+06	1.00E+06	1.00E+06		0.162	No
Aliphatics >C8-C10	902	4.45E+03	71.1	70	3.36E+03	143	137	1.80E+05	3.11E+05	1.14E+05		0.0815	No
Aliphatics >C10-C12	551	4.45E+03	346	321	4.25E+03	695	597	1.80E+05	6.85E+05	1.43E+05		0.219	No
<b>Aromatics</b>													
Aromatics >EC8-EC10	6,660	1.78E+03	118	111	352	237	141	7.21E+04	1.81E+05	5.15E+04		0.125	No
Aromatics >EC10-EC12	4,060	1.78E+03	648	475	435	1.29E+03	325	7.21E+04	4.23E+05	6.16E+04		0.146	No
Aromatics >EC12-EC16	1,830	1.78E+03	3.29E+03	1.16E+03	6.38E+02	6.44E+03	580	7.21E+04	9.48E+05	6.70E+04		386	No
Aromatics >EC16-EC21	521	1.34E+03	ND	1.34E+03	8.08E+02	ND	808	5.41E+04	ND	5.41E+04		312	No
Aromatics >EC21-EC35	54.8	1.34E+03	ND	1.34E+03	1.23E+03	ND	1.23E+03	5.41E+04	ND	5.41E+04		508	No
<b>PAHs</b>													
Naphthalene	795	1.58E+03	105	98.2	143	205	84.1	6.93E+04	3.49E+04	2.32E+04		582	No
Acenaphthylene	2270	402		402	83.3		83.3	1.74E+04		1.74E+04		4.5	No
Acenaphthene	484	4.04E+03	1.00E+6 #	4.03E+03	766	1.00E+6 #	765	1.74E+05	1.00E+6 #	1.74E+05		939	No
Fluorene	379	3.23E+03	1.00E+6 #	3.22E+03	848	1.00E+6 #	847	1.39E+05	1.00E+6 #	1.39E+05		322	No
Phenanthrene	155	3.23E+03		3.23E+03	1.17E+03		1.17E+03	1.39E+05		1.39E+05		111	No
Anthracene	22.6	3.23E+03	1.00E+6 #	3.23E+03	1.15E+03	1.00E+6 #	1.15E+03	1.39E+05	1.00E+6 #	1.39E+05		28.9	No
Fluoranthene	210	402	1.00E+6 #	402	270	1.00E+6 #	270	1.74E+04	1.00E+6 #	1.74E+04		18.5	No
Pyrene	24.4	2.42E+03		2.42E+03	1.56E+03		1.56E+03	1.05E+05		1.05E+05		13.1	No
Benz(a)anthracene	19	16.2	21 #	9.14	14.6	21 #	8.63	697	1.35E+3 #	459		7.82	No
Chrysene	4.89	162	210 #	91.4	141	210 #	84.2	6.97E+03	1.35E+4 #	4.59E+03		6.08	No
Benzo(b)fluoranthene	13.5	16.2	21 #	9.14	15	21 #	8.76	697	1.35E+3 #	459		9.22	No
Benzo(k)fluoranthene	7.63	16	21 #	9.14	15.3	21 #	8.87	697	1.35E+3 #	459		3.68	No
Benzo(a)pyrene	10.1	1.62	2.1 #	0.914	1.52	2.1 #	0.883	69.7	135 #	45.9		7.43	No
Indeno(1,2,3-cd)pyrene	0.682	16.2	21 #	9.14	14.8	21 #	8.69	697	1.35E+3 #	459		4	No
Dibenzo(a,h)anthracene	0.0437	1.62	2.1 #	0.914	1.55	2.1 #	0.892	69.7	135 #	45.9		1.23	No
Benzo(g,h,i)perylene	0.207	2.42E+03		2.42E+03	2.37E+03		2.37E+03	1.05E+05		1.05E+05		4.52	No
<b>BTEX</b>													
Benzene	8,120	25.8	1.2	1.15	0.476	2.42	0.398	1.05E+03	4.26E+03	840		0.535	No
Toluene	7,870	1.98E+04	3.68E+03	3.11E+03	753	7.40E+03	683	8.04E+05	1.00E+06	7.28E+05		0.0461	No
Ethylbenzene	5,210	8.88E+03	1.08E+03	963	568	2.16E+03	450	3.60E+05	1.00E+06	2.97E+05		0.194	No
Sum Xylenes	5,670	1.60E+04	358	351	1.04E+03	718	424	6.49E+05	5.29E+05	2.91E+05		0.447	No
<b>Additional VOC</b>													
Carbon Disulphide	16,400	8.91E+03	1.07	1.07	289	2.16	2.15	3.61E+05	5.47E+04	4.75E+04		0.0545	No
Dichloromethane	21,700	116	0.251	0.25	0.865	0.506	0.319	4.69E+03	1.22E+04	3.39E+03		0.0494	No
Styrene	7,240	661	42.4	39.8	37.2	85.3	25.9	2.75E+04	6.18E+05	2.63E+04		0.275	No
1,2,4-Trimethylbenzene	14,200	4.45E+03	5.15	5.14	1.36E+03	10.4	10.3	1.80E+05	3.52E+04	2.94E+04		0.298	No
<b>Additional SVOC</b>													
Carbazole	246	44.5	1.50E+4 #	44.4	25.3	1.50E+4 #	2.53E+01	1.80E+03	9.61E+5 #	1.80E+03		1.33	No
2-Methylnaphthalene	4,210	356	111	84.6	93.8	222	66	1.44E+04	2.36E+05	1.36E+04		17.4	No

not selected for this pathway

Where combined SSSC is greater than the theoretical maximum concentration in soil (1kg per kg), 1.0E+06 mg/kg presented as SSAC

- Italics* Target exceeds theoretical soil saturation limit. Concentrations above the soil saturation limit may indicate the presence of separate phase in soil, but does not necessarily present a significant risk.
- NR No appropriate reference dose identified during review of toxicological data
- NVP Contaminant has only a low vapour pressure in soil
- # Inhalation exposure via dust inhalation only
- \* Values set out within BS 3882:2007, assuming pH 6.0 - 7.0 used.

Table 3b  
 Site Specific Screening Criteria (SSSC) (mg/kg)  
 - Soils Re-used during Redevelopment (With a Cover Layer) -

CoC	Theoretical Soil Saturation Limit	Site Resident (Flat)	Site Resident (House)
		Inhalation	Inhalation
<b>Metals</b>			
Aluminium	NVP		
Arsenic	NVP		
Cadmium	NVP		
Copper	NVP		
Lead	NVP		
Molybdenum	NVP		
Nickel	NVP		
Vanadium	NVP		
Zinc	NVP		
<b>Aliphatics</b>			
Aliphatics >C5-C6	1,990	88.2	178
Aliphatics >C6-C8	1,400	279	563
Aliphatics >C8-C10	902	71.1	143
Aliphatics >C10-C12	551	346	695
<b>Aromatics</b>			
Aromatics >EC8-EC10	6,660	118	237
Aromatics >EC10-EC12	4,060	649	1.29E+03
Aromatics >EC12-EC16	1,830	3.30E+03	6.49E+03
Aromatics >EC16-EC21	521	ND	ND
Aromatics >EC21-EC35	54.8	ND	ND
<b>PAHs</b>			
Naphthalene	795	105	207
Acenaphthylene	2270		
Acenaphthene	484		
Fluorene	379		
Phenanthrene	155		
Anthracene	22.6		
Fluoranthene	210		
Pyrene	24.4		
Benz(a)anthracene	19		
Chrysene	4.89		
Benzo(b)fluoranthene	13.5		
Benzo(k)fluoranthene	7.63		
Benzo(a)pyrene	10.1		
Indeno(1,2,3-cd)pyrene	0.682		
Dibenzo(a,h)anthracene	0.0437		
Benzo(g,h,i)perylene	0.207		
<b>BTEX</b>			
Benzene	8,120	1.2	2.42
Toluene	7,870	3.69E+03	7.40E+03
Ethylbenzene	5,210	1.08E+03	2.17E+03
Sum Xylenes	5,670	358	718
<b>Additional VOC</b>			
Carbon Disulphide	16,400	1.07	2.16
Dichloromethane	21,700	0.251	0.506
Styrene	7,240	42.4	85.3
1,2,4-Trimethylbenzene	14,200	5.15	10.4
<b>Additional SVOC</b>			
Carbazole	246		
2-Methylnaphthalene	4,210	111	223

not selected for vapour inhalation

Where combined SSSC is greater than the theoretical maximum concentration in soil (1kg per kg), 1.0E+06 mg/kg target exceeds theoretical soil saturation limit. Concentrations above the soil saturation limit may indicate the presence of separate phases in soil, but does not necessarily present a hazard. No appropriate reference dose identified during review of toxicology. Contaminant has only a low vapour pressure in soil. Inhalation exposure via dust inhalation only. Values set out within BS 3882:2007, assuming pH 6.0 - 7.0 used.

*Italics*

NR  
 NVP  
 #  
 \*

Table 4  
Exceedances of Site Residents (House) Human Health SSAC (mg/kg)  
- In situ Subsurface Soils -

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

CoC	SSAC (mg/kg)	Location	Depth (m)	Concentration (mg/kg)
Arsenic	32.4	CP103	0.50-1.00	134
Arsenic	32.4	TP101	0.20-0.30	38.7
Arsenic	32.4	TP102	0.20-0.30	43.2
Arsenic	32.4	TP103	0.50-0.60	123
Arsenic	32.4	TP104	2.00-2.50	78.9
Arsenic	32.4	TP105	3.50-4.00	63.7
Arsenic	32.4	TP105	1.00-1.50	48.1
Arsenic	32.4	TP108	0.20-0.30	63
Arsenic	32.4	TP109	0.20-0.30	59.1
Arsenic	32.4	TP109	2.60-2.70	60
Arsenic	32.4	TP110	2.20-	58.6
Arsenic	32.4	TP111	0.30-	95.8
Arsenic	32.4	TP112	0.50-	71.1
Arsenic	32.4	TP112	1.40-	54.6
Arsenic	32.4	TP113	0.60-	140
Arsenic	32.4	TP113	1.20-	48.3
Arsenic	32.4	TP114	1.00-	80.9
Arsenic	32.4	TP115	1.00-	70
Arsenic	32.4	TP117	0.40-	128
Arsenic	32.4	TP118	0.30-	176
Arsenic	32.4	TP119	0.50-	196
Arsenic	32.4	TP122	0.30-	49.9
Arsenic	32.4	TP124	0.40-	86.9
Arsenic	32.4	TP125	0.50-	62.4
Arsenic	32.4	WS101	0.50-0.70	84.6
Arsenic	32.4	WS102	0.80-1.00	52.7
Arsenic	32.4	WS107	0.70-1.00	77.9
Arsenic	32.4	WS108	0.60-0.75	58.7
Arsenic	32.4	WS109	2.50-2.80	133
Arsenic	32.4	WS110	0.50-1.00	123
Arsenic	32.4	WS113	1.50-2.00	44
Arsenic	32.4	WS116	0.30-0.60	39.1
Arsenic	32.4	WS118	0.50-0.70	84.3
Arsenic	32.4	WS119	0.30-0.50	81
Arsenic	32.4	WS108	1.00-1.30	125
Lead	233	CP102	0.20-1.00	244
Lead	233	CP103	0.50-1.00	524
Lead	233	TP108	0.20-0.30	497
Lead	233	TP109	2.60-2.70	758
Lead	233	TP110	2.20-	596
Lead	233	TP111	0.30-	2270
Lead	233	TP114	1.00-	444
Lead	233	TP117	0.40-	472
Lead	233	TP119	0.50-	504
Lead	233	TP120	0.30-	364
Lead	233	TP122	0.30-	690
Lead	233	TP124	0.40-	324
Lead	233	TP125	0.50-	7660
Lead	233	WS107	0.70-1.00	682
Lead	233	WS113	1.50-2.00	235
Lead	233	WS118	0.50-0.70	708
Vanadium	571	TP122	0.30-	737
Naphthalene	84.1	TP104	2.00-2.50	582
Naphthalene	84.1	TP105	3.50-4.00	85.3
Acenaphthene	765	TP104	2.00-2.50	939
Benzo(b)fluoranthene	8.76	WS113	1.50-2.00	9.22
Benzo(a)pyrene	0.883	TP103	0.50-0.60	2.05
Benzo(a)pyrene	0.883	TP104	2.00-2.50	3.72
Benzo(a)pyrene	0.883	TP105	3.50-4.00	4.71
Benzo(a)pyrene	0.883	TP108	0.20-0.30	3.66
Benzo(a)pyrene	0.883	TP109	0.20-0.30	2.12
Benzo(a)pyrene	0.883	TP109	2.60-2.70	2.17
Benzo(a)pyrene	0.883	TP110	2.20-	3.18
Benzo(a)pyrene	0.883	TP114	1.00-	5
Benzo(a)pyrene	0.883	TP115	1.00-	2.18
Benzo(a)pyrene	0.883	TP117	0.40-	3.83
Benzo(a)pyrene	0.883	TP120	0.30-	4.68
Benzo(a)pyrene	0.883	TP122	0.30-	1.27
Benzo(a)pyrene	0.883	TP124	0.40-	2.51
Benzo(a)pyrene	0.883	TP125	0.50-	4.94
Benzo(a)pyrene	0.883	WS109	2.50-2.80	2.68
Benzo(a)pyrene	0.883	WS110	0.50-1.00	2.09
Benzo(a)pyrene	0.883	WS113	1.50-2.00	7.43
Benzo(a)pyrene	0.883	WS118	0.50-0.70	3.55
Benzo(a)pyrene	0.883	WS119	0.30-0.50	2.39
Benzo(a)pyrene	0.883	WS108	1.00-1.30	1.63
Dibenzo(a,h)anthracene	0.892	WS113	1.50-2.00	1.23
Benzene	0.398	WS109	2.50 - 2.80	0.535

Exceedance not considered to cause significant risk (further discussed in Section 4.3.2)

Table 5  
Exceedances of Site Residents (Flat) Human Health SSAC (mg/kg)  
- In situ Subsurface Soils -

CoC	SSAC (mg/kg)	Location	Depth (m)	Concentration (mg/kg)
Arsenic	35	WS105	0.80-1.00	45.5

Exceedance not considered to cause significant risk (further discussed in Section 4.3.2)

Table 6  
Exceedances of SSSC (mg/kg)  
- Soils Re-used during the Redevelopment -

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

Exceedances of Site Resident (House) SSSC				
CoC	SSAC (mg/kg)	Location	Depth (m)	Concentration (mg/kg)
Arsenic	32.4	CP103	0.50-1.00	134
Arsenic	32.4	TP101	0.20-0.30	38.7
Arsenic	32.4	TP102	0.20-0.30	43.2
Arsenic	32.4	TP103	0.50-0.60	123
Arsenic	32.4	TP104	2.00-2.50	78.9
Arsenic	32.4	TP105	3.50-4.00	63.7
Arsenic	32.4	TP105	1.00-1.50	48.1
Arsenic	32.4	TP108	0.20-0.30	63
Arsenic	32.4	TP109	0.20-0.30	59.1
Arsenic	32.4	TP109	2.60-2.70	60
Arsenic	32.4	TP110	2.20-	58.6
Arsenic	32.4	TP111	0.30-	95.8
Arsenic	32.4	TP112	0.50-	71.1
Arsenic	32.4	TP112	1.40-	54.6
Arsenic	32.4	TP113	0.60-	140
Arsenic	32.4	TP113	1.20-	48.3
Arsenic	32.4	TP114	1.00-	80.9
Arsenic	32.4	TP115	1.00-	70
Arsenic	32.4	TP117	0.40-	128
Arsenic	32.4	TP118	0.30-	176
Arsenic	32.4	TP119	0.50-	196
Arsenic	32.4	TP122	0.30-	49.9
Arsenic	32.4	TP124	0.40-	86.9
Arsenic	32.4	TP125	0.50-	62.4
Arsenic	32.4	WS101	0.50-0.70	84.6
Arsenic	32.4	WS102	0.80-1.00	52.7
Arsenic	32.4	WS105	0.80-1.00	45.5
Arsenic	32.4	WS107	0.70-1.00	77.9
Arsenic	32.4	WS108	0.60-0.75	58.7
Arsenic	32.4	WS109	2.50-2.80	133
Arsenic	32.4	WS110	0.50-1.00	123
Arsenic	32.4	WS113	1.50-2.00	44
Arsenic	32.4	WS116	0.30-0.60	39.1
Arsenic	32.4	WS118	0.50-0.70	84.3
Arsenic	32.4	WS119	0.30-0.50	81
Arsenic	32.4	WS108	1.00-1.30	125
Lead	233	CP102	0.20-1.00	244
Lead	233	CP103	0.50-1.00	524
Lead	233	TP108	0.20-0.30	497
Lead	233	TP109	2.60-2.70	758
Lead	233	TP110	2.20-	596
Lead	233	TP111	0.30-	2270
Lead	233	TP114	1.00-	444
Lead	233	TP117	0.40-	472
Lead	233	TP119	0.50-	504
Lead	233	TP120	0.30-	364
Lead	233	TP122	0.30-	690
Lead	233	TP124	0.40-	324
Lead	233	TP125	0.50-	7660
Lead	233	WS107	0.70-1.00	682
Lead	233	WS113	1.50-2.00	235
Lead	233	WS118	0.50-0.70	708
Vanadium	571	TP122	0.30-	737
Naphthalene	84.1	TP104	2.00-2.50	582
Naphthalene	84.1	TP105	3.50-4.00	85.3
Acenaphthene	765	TP104	2.00-2.50	939
Benzo(b)fluoranthene	8.76	WS113	1.50-2.00	9.22
Benzo(a)pyrene	0.883	TP103	0.50-0.60	2.05
Benzo(a)pyrene	0.883	TP104	2.00-2.50	3.72
Benzo(a)pyrene	0.883	TP105	3.50-4.00	4.71
Benzo(a)pyrene	0.883	TP108	0.20-0.30	3.66
Benzo(a)pyrene	0.883	TP109	0.20-0.30	2.12
Benzo(a)pyrene	0.883	TP109	2.60-2.70	2.17
Benzo(a)pyrene	0.883	TP110	2.20-	3.18
Benzo(a)pyrene	0.883	TP114	1.00-	5
Benzo(a)pyrene	0.883	TP117	0.40-	2.18
Benzo(a)pyrene	0.883	TP120	0.30-	3.83
Benzo(a)pyrene	0.883	TP122	0.30-	4.68
Benzo(a)pyrene	0.883	TP122	0.30-	1.27
Benzo(a)pyrene	0.883	TP124	0.40-	1.27
Benzo(a)pyrene	0.883	TP125	0.50-	2.51
Benzo(a)pyrene	0.883	WS109	2.50-2.80	4.94
Benzo(a)pyrene	0.883	WS110	0.50-1.00	2.68
Benzo(a)pyrene	0.883	WS113	1.50-2.00	2.09
Benzo(a)pyrene	0.883	WS118	0.50-0.70	7.43
Benzo(a)pyrene	0.883	WS119	0.30-0.50	3.55
Benzo(a)pyrene	0.883	WS108	1.00-1.30	2.39
Dibenzo(a,h)anthracene	0.892	WS113	1.50-2.00	1.63
Benzene	0.398	WS109	2.50 - 2.80	0.535

Exceedances of Site Resident (Flat) SSSC				
CoC	SSAC (mg/kg)	Location	Depth (m)	Concentration (mg/kg)
Arsenic	35	CP103	0.50-1.00	134
Arsenic	35	TP101	0.20-0.30	38.7
Arsenic	35	TP102	0.20-0.30	43.2
Arsenic	35	TP103	0.50-0.60	123
Arsenic	35	TP104	2.00-2.50	78.9
Arsenic	35	TP105	3.50-4.00	63.7
Arsenic	35	TP105	1.00-1.50	48.1
Arsenic	35	TP108	0.20-0.30	63
Arsenic	35	TP109	0.20-0.30	59.1
Arsenic	35	TP109	2.60-2.70	60
Arsenic	35	TP110	2.20-	58.6
Arsenic	35	TP111	0.30-	95.8
Arsenic	35	TP112	0.50-	71.1
Arsenic	35	TP112	1.40-	54.6
Arsenic	35	TP113	0.60-	140
Arsenic	35	TP113	1.20-	48.3
Arsenic	35	TP114	1.00-	80.9
Arsenic	35	TP115	1.00-	70
Arsenic	35	TP117	0.40-	128
Arsenic	35	TP118	0.30-	176
Arsenic	35	TP119	0.50-	196
Arsenic	35	TP122	0.30-	49.9
Arsenic	35	TP124	0.40-	86.9
Arsenic	35	TP125	0.50-	62.4
Arsenic	35	WS101	0.50-0.70	84.6
Arsenic	35	WS102	0.80-1.00	52.7
Arsenic	35	WS105	0.80-1.00	45.5
Arsenic	35	WS107	0.70-1.00	77.9
Arsenic	35	WS108	0.60-0.75	58.7
Arsenic	35	WS109	2.50-2.80	133
Arsenic	35	WS110	0.50-1.00	123
Arsenic	35	WS113	1.50-2.00	44
Arsenic	35	WS116	0.30-0.60	39.1
Arsenic	35	WS118	0.50-0.70	84.3
Arsenic	35	WS119	0.30-0.50	81
Arsenic	35	WS108	1.00-1.30	125
Lead	235	CP102	0.20-1.00	244
Lead	235	CP103	0.50-1.00	524
Lead	235	TP108	0.20-0.30	497
Lead	235	TP109	2.60-2.70	758
Lead	235	TP110	2.20-	596
Lead	235	TP111	0.30-	2270
Lead	235	TP114	1.00-	444
Lead	235	TP117	0.40-	472
Lead	235	TP119	0.50-	504
Lead	235	TP120	0.30-	364
Lead	235	TP122	0.30-	690
Lead	235	TP124	0.40-	324
Lead	235	TP125	0.50-	7660
Lead	235	WS107	0.70-1.00	682
Lead	235	WS113	1.50-2.00	235
Lead	235	WS118	0.50-0.70	708
Vanadium	698	TP122	0.30-	737
Naphthalene	98.2	TP104	2.00-2.50	582
Benzo(b)fluoranthene	9.14	WS113	1.50-2.00	9.22
Benzo(a)pyrene	0.914	TP103	0.50-0.60	2.05
Benzo(a)pyrene	0.914	TP104	2.00-2.50	3.72
Benzo(a)pyrene	0.914	TP105	3.50-4.00	4.71
Benzo(a)pyrene	0.914	TP108	0.20-0.30	3.66
Benzo(a)pyrene	0.914	TP109	0.20-0.30	2.12
Benzo(a)pyrene	0.914	TP109	2.60-2.70	2.17
Benzo(a)pyrene	0.914	TP110	2.20-	3.18
Benzo(a)pyrene	0.914	TP114	1.00-	5
Benzo(a)pyrene	0.914	TP115	1.00-	2.18
Benzo(a)pyrene	0.914	TP117	0.40-	3.83
Benzo(a)pyrene	0.914	TP120	0.30-	4.68
Benzo(a)pyrene	0.914	TP122	0.30-	1.27
Benzo(a)pyrene	0.914	TP124	0.40-	1.27
Benzo(a)pyrene	0.914	TP125	0.50-	2.51
Benzo(a)pyrene	0.914	WS109	2.50-2.80	4.94
Benzo(a)pyrene	0.914	WS110	0.50-1.00	2.68
Benzo(a)pyrene	0.914	WS113	1.50-2.00	2.09
Benzo(a)pyrene	0.914	WS118	0.50-0.70	7.43
Benzo(a)pyrene	0.914	WS119	0.30-0.50	3.55
Benzo(a)pyrene	0.914	WS108	1.00-1.30	2.39
Dibenzo(a,h)anthracene	0.914	WS113	1.50-2.00	1.63

Table 7  
Results of Risk Assessment for Vapour Release from Soils - Acute Exposure

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

Contaminant of Concern	ACUTE EXPOSURE			
	Theoretical Soil Saturation Limit (mg/kg)	Predicted Concentration in Outdoor Air (mg/m <sup>3</sup> ) - 15 minute Exposure Scenario	Workplace Exposure Limit (mg/m <sup>3</sup> ) - 15 Exposure Scenario	Predicted Concentration greater than WEL?
Ethylbenzene	5,210	10	552	No
Toluene	7,870	22	384	No
Xylenes	5,670	9.6	441	No
Styrene	7,240	31	1,080	No

Notes

Predicted concentrations in air taken from RBCA Toolkit 2.5

WEL Workplace Exposure Limit

Table 8  
Results of Water Resources Risk Assessment - Groundwater (µg/l)

CoC	Water Resources SSAC (µg/l)	BH5A	CP101	CP102	CP103	CP104	WS101	WS102	WS103	WS104	WS105	WS106	WS107	WS109	WS110
Ammonium (NH <sub>4</sub> )	30,100	1300	536	428	-	-	-	-	2280	-	487	-	325	1860	-
Free Ammonia as N	902	-	-	-	-	-	-	-	-	-	-	-	-	-	-

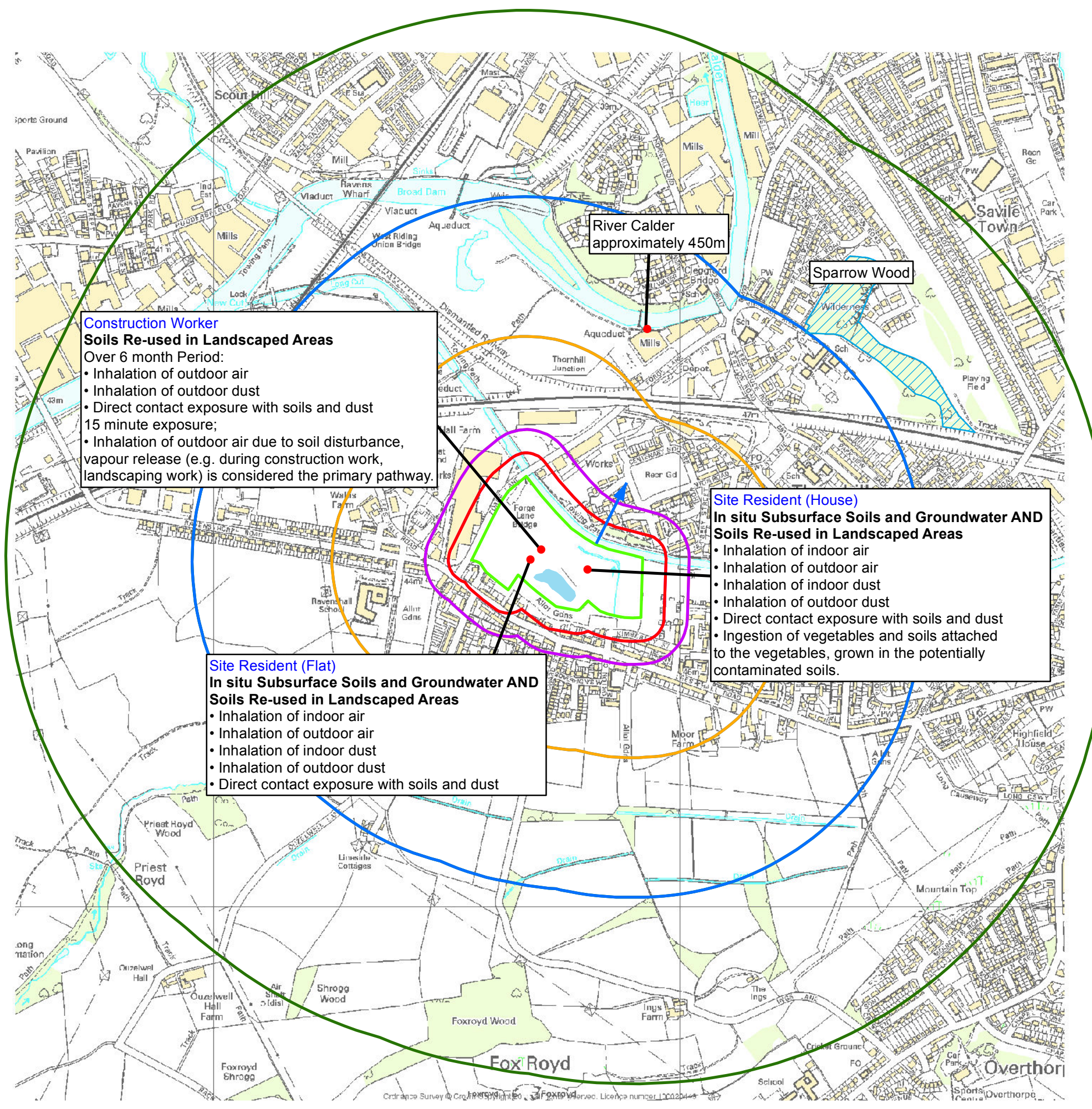
**Notes:**  
- Less than the Method Detection Limit, it is assumed that there is no significant risk.

Table 8  
Results of Water Resources Risk Assessment - Groundwater (µg/l)

CoC	Water Resources SSAC (µg/l)	WS111	WS112	WS114	WS115	WS116	WS117	WS119	WS120
Ammonium (NH <sub>4</sub> )	30,100	667	427	9120	7120	-	-	624	3840
Free Ammonia as N	902	-	-	780	367	-	-	-	285

**Notes:**  
- Less than the Method Detection Limit, it is assumed that there is no significant risk.

# FIGURES



**Construction Worker**  
**Soils Re-used in Landscaped Areas**  
 Over 6 month Period:

- Inhalation of outdoor air
- Inhalation of outdoor dust
- Direct contact exposure with soils and dust 15 minute exposure;
- Inhalation of outdoor air due to soil disturbance, vapour release (e.g. during construction work, landscaping work) is considered the primary pathway.

**Site Resident (House)**  
**In situ Subsurface Soils and Groundwater AND Soils Re-used in Landscaped Areas**

- Inhalation of indoor air
- Inhalation of outdoor air
- Inhalation of indoor dust
- Inhalation of outdoor dust
- Direct contact exposure with soils and dust
- Ingestion of vegetables and soils attached to the vegetables, grown in the potentially contaminated soils.

**Site Resident (Flat)**  
**In situ Subsurface Soils and Groundwater AND Soils Re-used in Landscaped Areas**

- Inhalation of indoor air
- Inhalation of outdoor air
- Inhalation of indoor dust
- Inhalation of outdoor dust
- Direct contact exposure with soils and dust

**LEGEND**

- LOCAL NATURE RESERVE
- SITE BOUNDARY
- SITE BUFFER**
- 50m
- 100m
- 300m
- 600m
- 1000m
- MODELLED RECEPTOR
- GROUNDWATER FLOW DIRECTION

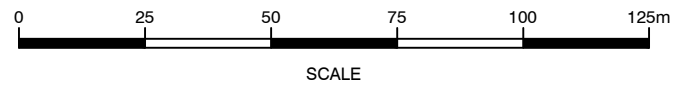
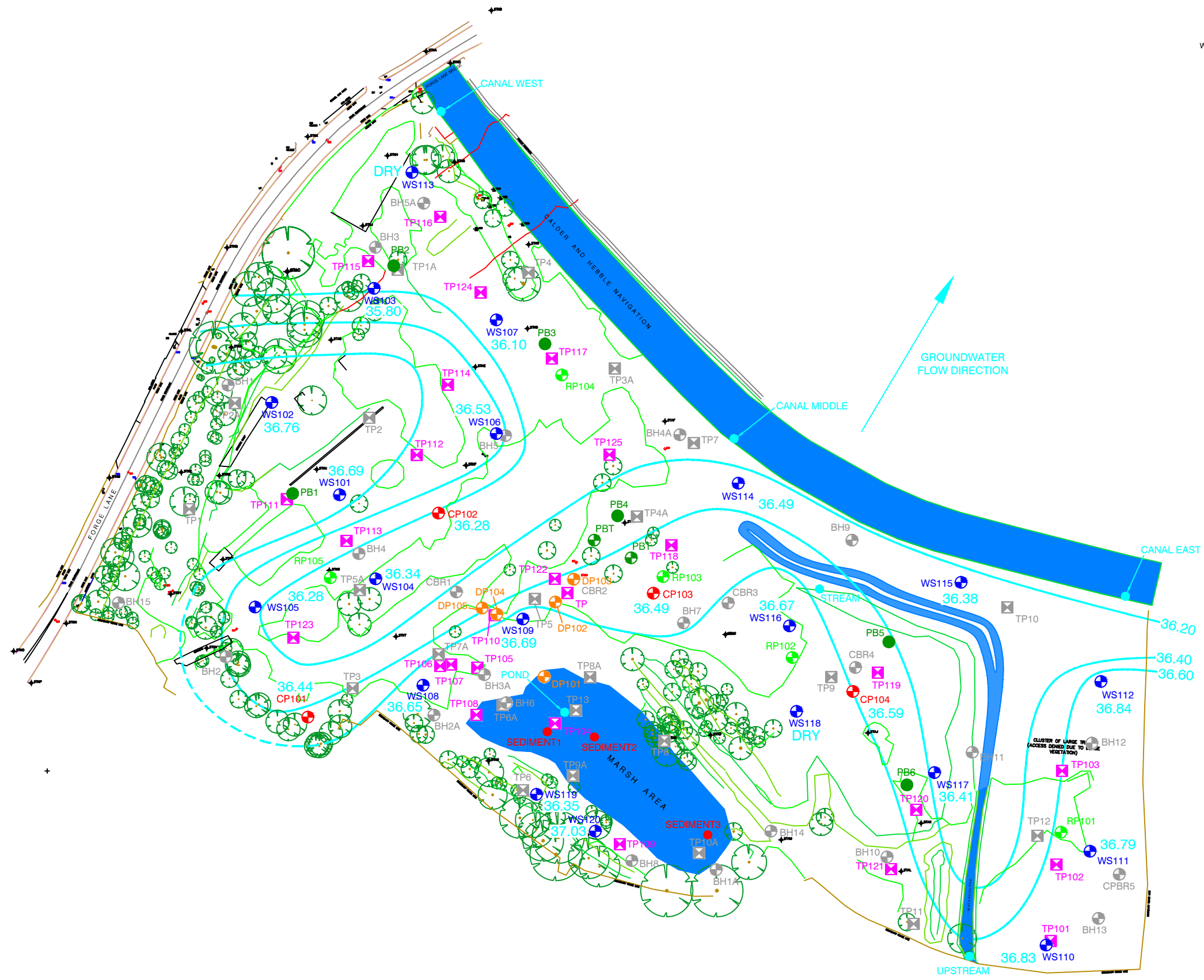
**NOTES**

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.



TITLE: <b>SITE LOCATION AND ENVIRONMENTAL SETTING</b>	
SITE: <b>LAND OFF FORGE LANE</b>	
CLIENT: <b>KIRKLEES COUNCIL</b>	
PROJECT: <b>96234.01</b>	<b>FIGURE 1</b>
DATE: 29/07/11	DRAWN BY: RJM
DRG No.: 962340127 GIS	
SCALE: <b>1 : 9,000</b>	PRINT: <b>A3</b>





**KEY**

- BOREHOLE LOCATION - WINDOW SAMPLE
- BOREHOLE LOCATION - CABLE PERCUSSION
- BOREHOLE LOCATION - DYNAMIC PROBE
- BOREHOLE LOCATION - ROTARY PROBE
- TRIAL PIT LOCATION
- HISTORICAL BOREHOLE - APPROX. LOCATION
- HISTORICAL TRIAL PIT - APPROX. LOCATION
- SURFACE WATER SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION
- APPROXIMATE LOCATION OF PLATE BEARING TEST
- 99.99 GROUNDWATER ELEVATION - MARCH 2011
- GROUNDWATER FLOW DIRECTION

**NOTES**

BASED ON DRAWING BY AECOM.  
DRAWING No: 60140787\_LS013D REV. -  
DATE: 25/11/2009

REV	DATE	COMMENT	CAD
A	03.06.11	PLATE BEARING TEST LOCATIONS ADDED TO PLAN	RJW

**TITLE:** SITE LAYOUT AND GROUNDWATER ELEVATION PLAN

**SITE:** FORGE LANE

**CLIENT:** KIRKLEES COUNCIL

**PROJECT:** 96234.01 **FIGURE 2**

**DATE:** 28/03/11 **DRAWN:** BNB **REV:** A

**DRG.No.:** 962340117-CAD **PRINT:** A3



NOTE: ALL ENTITIES SHOWN ON THIS DRAWING ARE TO BE REGARDED AS APPROXIMATE AND ARE INDICATIVE ONLY. NO MEASUREMENTS TAKEN FROM THIS DRAWING SHOULD BE USED FOR THE LOCATION OF INTRUSIVE INVESTIGATION WORKS ON SITE. SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE. - CONTACT ARCADIS UK IN CASE OF ANY QUERY

**FUTURE RESIDENTIAL USE**

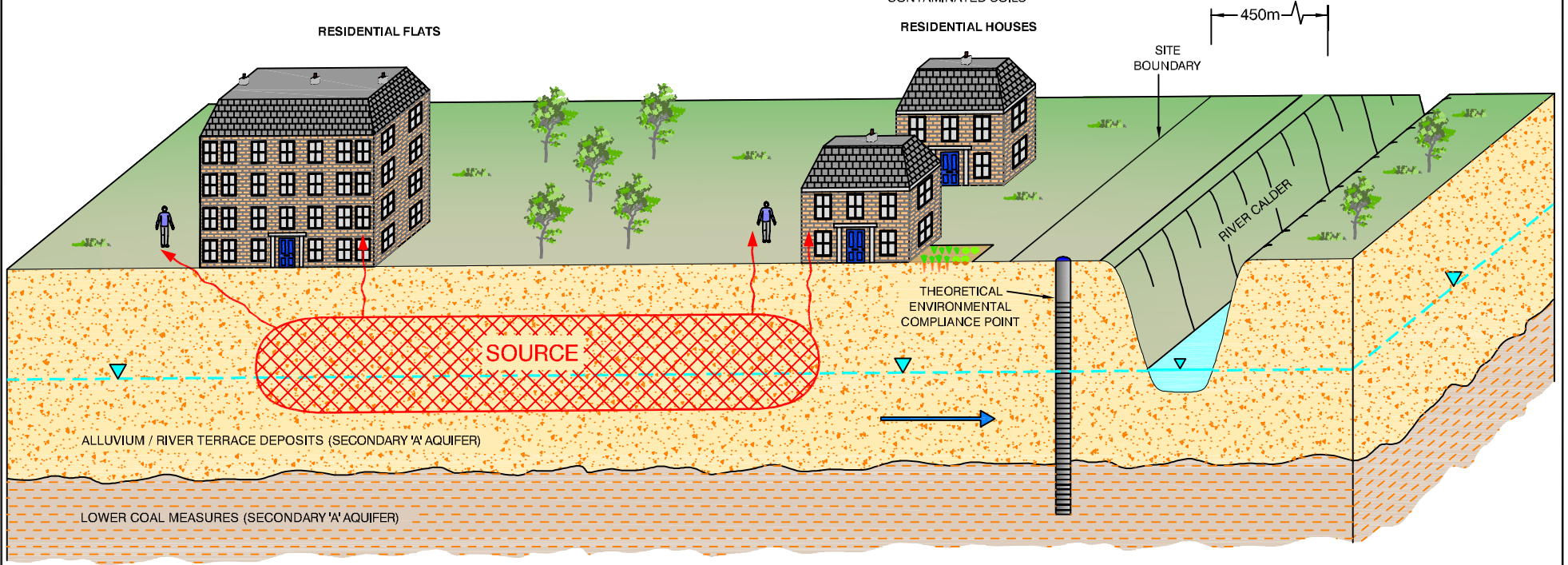
- IN SITU SUBSURFACE SOILS AND GROUNDWATER
- SOIL RE-USED IN LANDSCAPED AREAS

SITE RESIDENT (FLAT)

- INHALATION OF INDOOR AIR
- INHALATION OF OUTDOOR AIR
- INHALATION OF INDOOR DUST
- INHALATION OF OUTDOOR DUST
- DIRECT CONTACT EXPOSURE WITH SOILS AND DUST

SITE RESIDENT (HOUSE)

- INHALATION OF INDOOR AIR
- INHALATION OF OUTDOOR AIR
- INHALATION OF INDOOR DUST
- INHALATION OF OUTDOOR DUST
- DIRECT CONTACT EXPOSURE WITH SOILS AND DUST
- INGESTION OF VEGETABLES AND SOILS ATTACHED TO THE VEGETABLES, GROWN IN THE POTENTIALLY CONTAMINATED SOILS

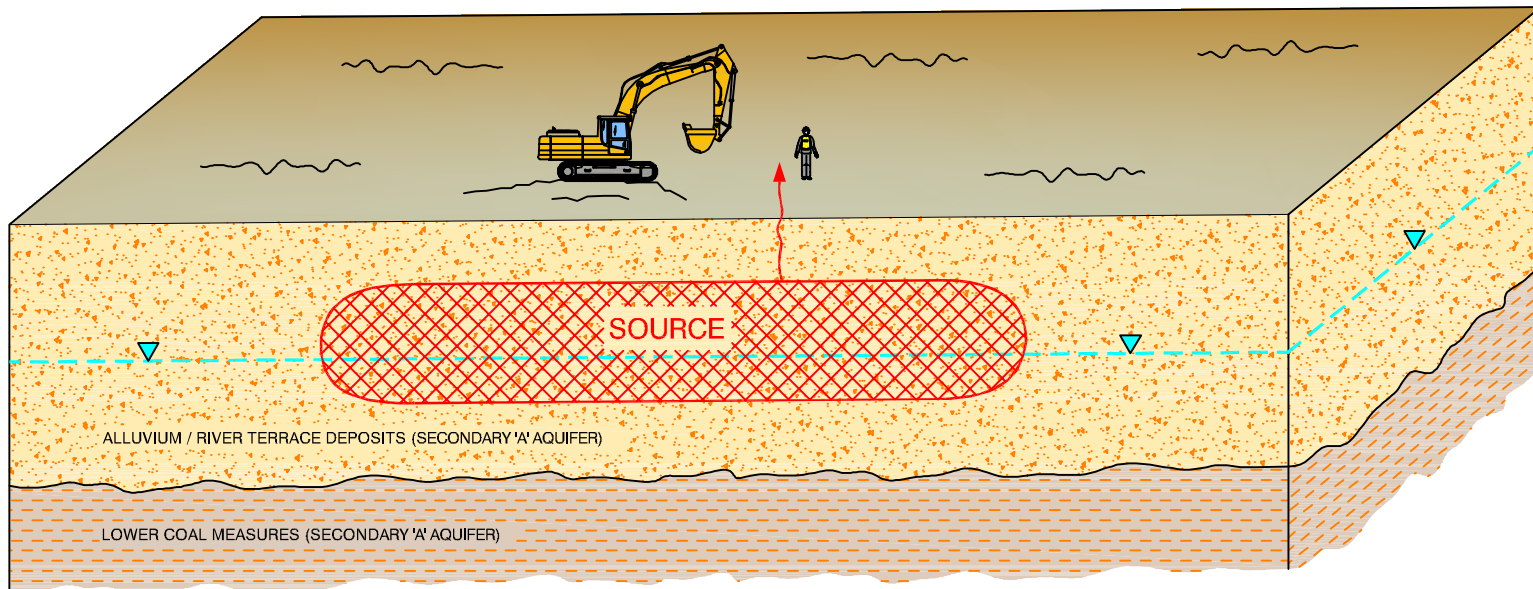


**SITE UNDER REDEVELOPMENT**

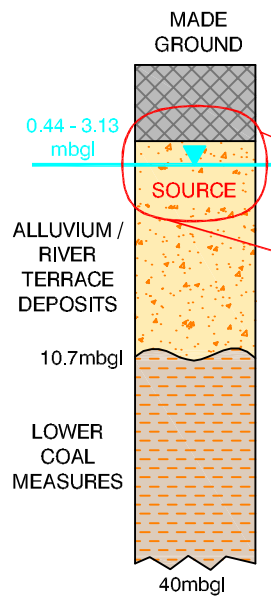
- SOIL RE-USED IN LANDSCAPED AREAS

CONSTRUCTION WORKER

- INHALATION OF OUTDOOR AIR
  - INHALATION OF OUTDOOR DUST
  - DIRECT CONTACT EXPOSURE WITH SOILS AND DUST
- OVER 6 MONTH PERIOD
- INHALATION OF OUTDOOR AIR DUE TO SOIL DISTURBANCE, VAPOUR RELEASE (e.g. DURING CONSTRUCTION WORK, LANDSCAPING WORK) IS CONSIDERED THE PRIMARY PATHWAY
- 15 MINUTE EXPOSURE



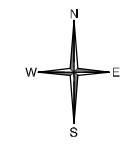
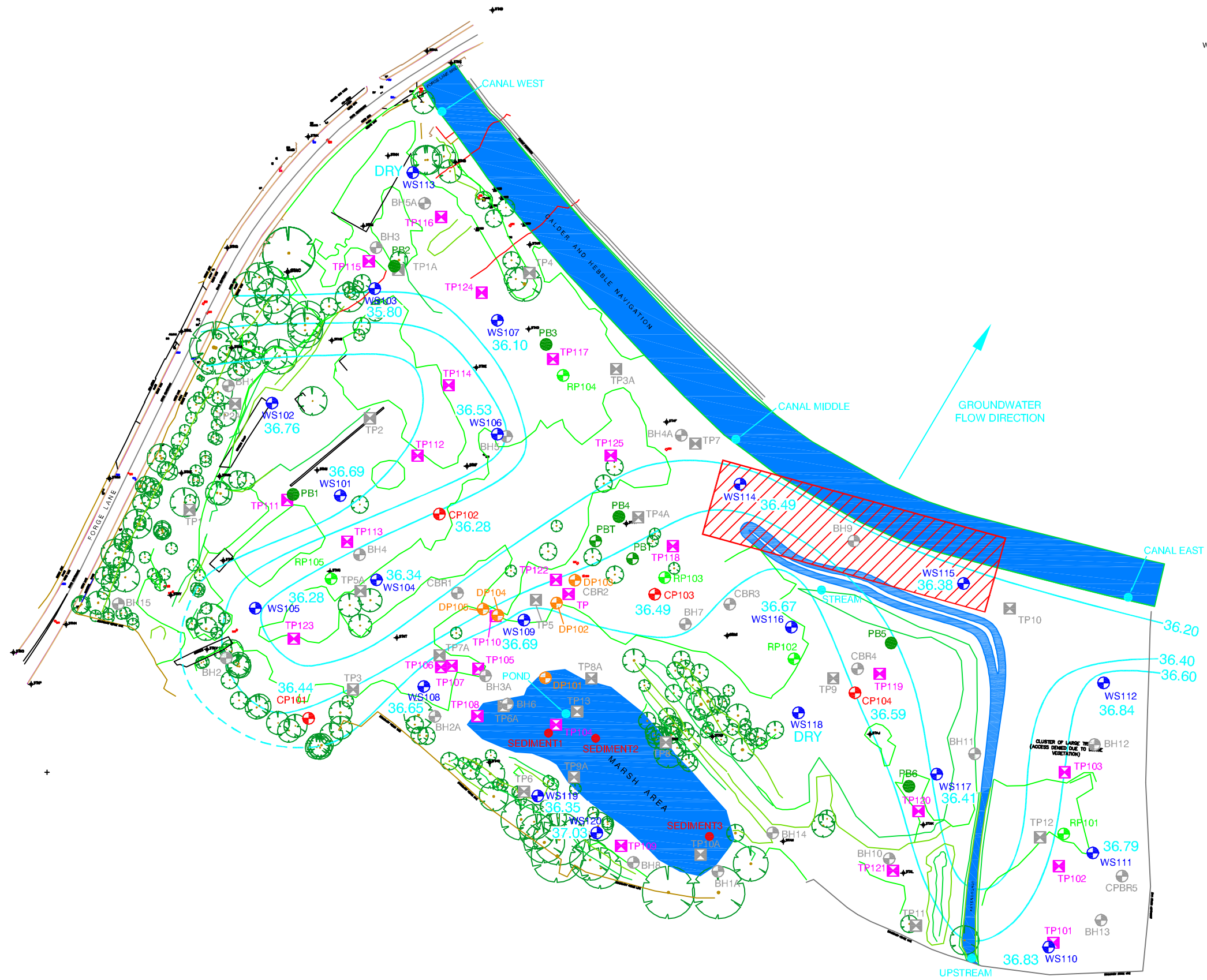
**SITE-SPECIFIC GROUND CONDITIONS**



Conceptual Zone	Physical Characteristics	Justification
Unsaturated Zone	Clayey Gravelly Sand	Considered representative of the most permeable lithology, through which the majority of vapours are likely to migrate.
Source Zone	Clayey Gravelly Sand	Considered representative of the Made Ground and the natural deposits within which the majority of impacts were identified.
Aquifer	Gravelly Sand	Considered representative of the natural deposits, through which the majority of off-site groundwater migration is anticipated to take place.

REV	DATE	COMMENT	CAD

<b>KEY</b> GROUNDWATER LEVEL POTENTIAL VOLATILISATION PATHWAY MIGRATION OF DISSOLVED PHASE IMPACTS		<b>TITLE:</b> CONCEPTUAL SITE MODEL CROSS SECTION <b>SITE:</b> LAND OFF FORGE LANE
<b>PROJECT:</b> 96234.01 <b>DATE:</b> 02/08/11 <b>DRAWN BY:</b> BNB <b>DRG.No.:</b> 962340131-CAD	<b>CLIENT:</b> KIRKLEES COUNCIL <b>PRINT:</b> A3 <b>REV:</b> -	<b>FIGURE 3</b>  Infrastructure · Water · Environment · Buildings Tel +44 (0) 1638 674767 www.arcadis-uk.com



**KEY**

- BOREHOLE LOCATION - WINDOW SAMPLE
- BOREHOLE LOCATION - CABLE PERCUSSION
- BOREHOLE LOCATION - DYNAMIC PROBE
- BOREHOLE LOCATION - ROTARY PROBE
- TRIAL PIT LOCATION
- HISTORICAL BOREHOLE - APPROX. LOCATION
- HISTORICAL TRIAL PIT - APPROX. LOCATION
- SURFACE WATER SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION
- APPROXIMATE LOCATION OF PLATE BEARING TEST
- 99.99 GROUNDWATER ELEVATION - MARCH 2011
- GROUNDWATER FLOW DIRECTION
- MODELLED SOURCE AREA

**NOTES**

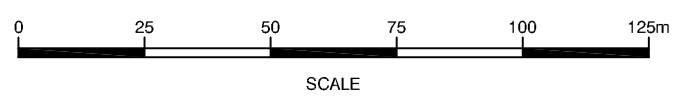
BASED ON DRAWING BY AECOM.  
DRAWING No: 60140787\_LS013D REV. -  
DATE: 25/11/2009

REV	DATE	COMMENT	CAD

TITLE: MODELLED SOURCE AREA  
SITE: FORGE LANE  
CLIENT: KIRKLEES COUNCIL

PROJECT: 96234.01      FIGURE 4

DATE: 28/03/11    DRAWN: BNB    REV: -  
DRG.No.: 962340132-CAD    PRINT: A3



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### LEGEND

- EXCEEDANCE OF HUMAN HEALTH SSAC
- NO EXCEEDANCE
- SOILS SAMPLED WITHIN THE VICINITY OF THE PROPOSED FLATS NOT INCLUDED IN COMPARISON
- SITE BOUNDARY

### NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

TITLE: <b>CRITICAL EXCEEDANCES OF ON-SITE HUMAN HEALTH SSAC (mg/kg) IN SOILS - IN SITU SUBSURFACE SOILS</b>	
SITE: <b>LAND OFF FORGE LANE</b>	
CLIENT: <b>KIRKLEES COUNCIL</b>	
PROJECT: <b>96234.01</b>	<b>FIGURE 5</b>
DATE: <b>02/08/11</b>	DRAWN BY: <b>RJM</b>
DRG No.: <b>962340129 GIS</b>	
SCALE: <b>1 : 1,250</b>	PRINT: <b>A3</b>

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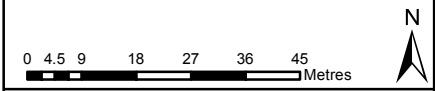


**LEGEND**

- EXCEEDANCE OF HUMAN HEALTH SSSC FOR RESIDENTIAL END USE (HOUSE)
- EXCEEDANCE OF HUMAN HEALTH SSSC FOR RESIDENTIAL END USE (FLAT)
- SITE BOUNDARY

**NOTES**

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.



TITLE: <b>CRITICAL EXCEEDANCES OF ON-SITE HUMAN HEALTH SSAC (mg/kg) IN SOILS - RE-USED SOILS</b>	
SITE: <b>LAND OFF FORGE LANE</b>	
CLIENT: <b>KIRKLEES COUNCIL</b>	
PROJECT: <b>96234.01</b>	<b>FIGURE 6</b>
DATE: 02/08/11	DRAWN BY: RJM
DRG No.: 962340130 GIS	
SCALE: 1:1,250	PRINT: A3

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# APPENDICES

Appendix A  
Regulatory and Legislative Context

## Appendix A Regulatory and Legislative Context

Land contamination is generally dealt with by the following types of regulation:

Acts of Parliament to investigate and remedy harm caused by land contamination;  
Conditions placed upon Planning Permissions for the redevelopment of land; and,  
Acts of Parliament and Regulations for the control of waste.

In England land contamination is identified and dealt with through Acts / Regulations including:

- The Contaminated Land Regulations (2006) (England)
- Part IIA of the Environmental Protection Act (1990);
- The Town and Country Planning Act (1990);
- The Environmental Permitting (England and Wales) Regulations (2007);
- The Pollution Prevention and Control (England and Wales) Regulations (2000) (as amended);
- The Water Resources Act (1991);
- The Water Act (2003);
- The Environmental Damage (Prevention and Remediation) Regulations 2009; and,
- The Groundwater Regulations 1998.

### **Part IIA of the Environmental Protection Act 1990**

Part IIA of the Environmental Protection Act 1990 (which was inserted by Section 57 of the Environment Act 1995) created a regime for the identification and remediation of contaminated land. Section 78A(2) of the Environmental Protection Act 1990 defines contaminated land for the purposes of Part IIA as:

*'any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that;*

- (a) *significant harm is being caused or there is a significant possibility of such harm being caused; or*
- (b) *pollution of controlled waters is being, or is likely to be caused.'*<sup>1</sup>

Harm is defined under section 78A of the Environmental Protection Act as meaning 'harm to the health of living organisms or other interference with the ecological systems of which they form part and, in the case of man, includes harm to his property'. Types of harm are related to specific receptors in order to determine whether they can be regarded as "significant", as defined in Table A of Annex 3 of the DEFRA (2006)<sup>2</sup> statutory guidance.

Part IIA sets the definition of contaminated land within the context of the 'suitable for use' approach. The legal definition of contaminated land is also discussed within Statutory Guidance released by DEFRA (2008)<sup>3</sup>.

The government has recognised the following objectives with regard to contaminated land for England (DEFRA, 2006):

- *to identify and remove unacceptable risks to human health and the environment from contaminated land,*
- *to reduce the pressure on green field land and to encourage the reuse of land that may have been subject to potentially contaminative uses, and*
- *to seek to ensure a proportionate, manageable and economically sustainable approach to the cost burdens faced by individuals, companies and society as a whole.'*

<sup>1</sup> Definition to be amended to "significant pollution of controlled waters is being caused or there is a significant possibility of such pollution being caused" under the Water Act 2003

<sup>2</sup> Environmental Protection Act 1990: Part 2A. Contaminated Land. DEFRA Circular 01/2006

<sup>3</sup> Guidance on the legal definition of contaminated land. DEFRA July 2008

The 'suitable for use' approach underlies these objectives, and is based on the principles of risk assessment, including the concept of the 'pollutant linkage'.

In the event that there are unacceptable levels of risk posed by a site, a remediation notice can be served under the contaminated land regime introduced under Part IIA of the Environmental Protection Act 1990.

### **Regulation of Development on Land Affected by Contamination**

Management of risks from contamination in development of land is also regulated in the UK under the Town and Country Planning Act 1990. Land contamination is a material planning consideration within this planning regime. The Local Planning Authority may impose conditions on the development during planning that include preliminary risk assessment, site investigation, risk assessment and remediation. The Environment Agency may use its role as a statutory consultee to provide the Local Planning Authority with advice.

Assessment of risk is again based on the pollutant linkage concept. The aim of risk management in the development should be to render the land suitable for the proposed use and, therefore, to prevent consideration of the site under Part IIA.

ODPM Planning Policy Statement 23 (PPS23): Planning and Pollution Control and its Annex 2: Development on Land Affected by Contamination provides guidance on the relationship between development and the management of risks from land contamination caused by historical use. The Building Regulations 2000, made under the Building Act 1984, also require measures to be taken to protect new buildings and their occupants from the effects of contamination. Guidance on the requirements is provided in Approved Document C - Site preparation and resistance to contaminants and moisture, published by ODPM in 2004.

### **Voluntary Remediation Action**

Voluntary remediation action on contamination resulting from historical activities can often anticipate future remediation requirements, such as through the Planning regime, and is encouraged (DEFRA, 2006), especially where the site is not being assessed under Part IIA.

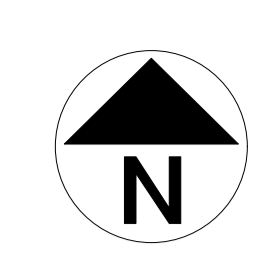
### **Non-statutory regulatory technical guidance documents**

The non-statutory regulatory technical guidance for England on the assessment of land contamination, primarily released as part of the Contaminated Land Exposure Assessment (CLEA) methodology (DEFRA and EA) is currently undergoing a period of significant change. The following documents currently present guiding principles in investigating and assessing potentially contaminated land, which are generally adopted in considering sites within any of the legal frameworks discussed above, or when considering voluntary remediation action:

- *Investigation of potentially contaminated sites – Code of Practice* (British Standard 10175: 2001).
- *Contaminated Land Report CLR11 Model Procedures for the Management of Land Contamination*. (DEFRA and EA, 2004).
- *Human health toxicological assessment of contaminants in soil* Environment Agency Science Report SC050021/SR2 (EA, 2009a)
- *Updated technical background to the CLEA model* Environment Agency Science Report SC050021/SR3 (EA, 2009b)
- *Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values* Environment Agency Science Report SC050021/SR7 (EA, 2008)
- *Groundwater Protection: Policy and Practice*, Environment Agency GP3 Parts 1-4
- *Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination* (EA of England and Wales, 2006) developed in consultation with the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Heritage and Environment Service.
- *Assessing risks posed by hazardous ground gases to buildings* Report C665 (CIRIA, 2007)

- *BS 8485:2007 Code of practice for the characterization and remediation from ground gas in affected developments (British Standards Institution, 2007)*
- *Risk Based Corrective Action (RBCA) Methodology (ASTM designation E1739-95, E2081-00).*
- *DoE Industry Profiles.*

Appendix B  
Site Specific Redevelopment Plan



Recreation Ground

Recreation Ground

- 1000mm high metal railings
- 300mm high metal railings
- 1800mm high timber fence
- 1200mm high timber fence



Appendix C  
Sensitivity Testing – Exposure Scenarios

## Appendix C Sensitivity Testing – Exposure Scenarios

In order to identify the most sensitive potential receptor type associated with the site, the following exposure scenarios have been considered:

### 1. Site Resident

The residential end-use described by the EA (2009b) assumes a development consisting of a two-storey house, a private garden comprising a lawn, flowerbeds and a small fruit and vegetable patch. A family consisting of parents and young children, who make regular use of the garden, are considered as potential receptors for the generic residential end-use. The guidance further concludes that *“when adults and children are likely to be present together, it is usual to consider the child as the critical receptor”*.

As such, the future resident defined as a 0-6 year old female child (EA, 2009b).

### 2. Maintenance worker visiting the site periodically

It is likely that the housing development will employ a maintenance worker (likely to be 16 to 65 years old) on a part-time basis to undertake regular upkeep works such as grass cutting, weeding and general tidying of the housing development. Such works are unlikely to be a daily activity and will vary depending on the time of year, with more undertaken during the summer months than during the winter. Therefore, on balance, it was considered reasonable to assume that the groundskeeper is likely to amount to visits once per week, for up to two hours per visit. The groundskeeper is unlikely to spend any significant time indoors, therefore inhalation of indoor is not considered active.

### 3. Users of the footpath (e.g. dog walkers)

For the users of the footpath, reasonable assumptions have been made regarding the exposure frequency and duration. It is considered that a child (0-6 year old female) visits the footpath 5 visits per week and spends approximately 15 minutes walking within the vicinity of the site.

Based on the above, the likely exposure parameters assumed for each of the potential receptors are presented in Table C1.

The sensitivity analysis results have been undertaken for aliphatic >C5-C6. The results indicate that the site resident scenario is the most stringent receptor, resulting in the lowest SSAC. Therefore, this receptor has been selected as the most suitable for use in the DQRA. The SSAC derived for this receptor type will provide protection to other potential receptors associated with nursing home.

Scenario	Receptor	Age range (years)	Exposure Duration (years)	Frequency to Indoor Air (days per year)	Time Indoors (hours per day)	Frequency to Outdoor Air (days per year)	Time Outdoors (hours per day)	Soil and Dust Ingestion Rate (grams per day)	Soil to Skin Adherence Factor (Indoor) (mg/cm/day)	Maximum Exposed Skin Fraction (Indoor)	Soil to Skin Adherence Factor (Outdoor) (mg/cm/day)	Maximum Exposed Skin Fraction (Outdoor)	Target Level for Aliphatics >C5-C6 in Soil (mg/kg)
Residential Redevelopment	<b>Site Resident</b>	<b>0 - 6</b>	<b>6</b>	<b>365</b>	<b>21.7</b>	<b>365</b>	<b>1</b>	<b>0.1</b>	<b>0.06</b>	<b>0.333</b>	<b>1</b>	<b>0.264</b>	<b>88.1</b>
	Users of the Footpath	0 - 6	6	0	-	260	0.25	0	-	-	-	-	432,021
	Maintenance Worker	16 - 65	49	0	-	52	2	0.05	-	-	0.14	0.08	7,973,187

Notes:

**Bold** Selected as critical receptor

Appendix D  
Initial Screening

Appendix D  
Initial Screening  
Table D1: Soils

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

CoC	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (mg/kg)	Average Concentration (mg/kg)	Considered in further assessment?	Comments
<b>Inorganics</b>							
Chloride	<5	56	51	586	41.7	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Fluoride	<1	56	39	7.71	2.17	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Phosphate	<1	54	1	1.52	1.52	No	A single detection, concentration only relatively higher than MDL. Compound not considered as CoC.
Nitrite	<0.1	56	52	3.98	0.992	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Nitrate	<1	56	41	57.9	9.46	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Ammoniacal Nitrogen as N	<15	31	3	460	199	No	Few detections at relatively low concentrations. Compound not considered as CoC.
Elemental Sulphur	<5	24	18	1140	146	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Total Sulphur	<0.02	22	19	1.55	0.348	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Easily liberated Sulphide	<15	29	6	560	180	Yes	Compound present in few locations however relatively high concentrations with respect to MDL. Carried forward to second stage of screening.
Sulphate	<0.008	17	13	1.67	0.413	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Total Sulphate	<48	29	26	9420	2544	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Total Cyanide	<1	56	10	196	70.6	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
<b>Metals</b>							
Aluminium	<11	59	59	52,500	13,996	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Arsenic	<0.6	59	58	196	57	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Beryllium	<0.01	59	59	8.86	1.71	No	Compound naturally occurring. The distribution and magnitude of measured concentrations does not indicate hot spot areas. Compound not considered as CoC.
Boron, water soluble	<1	59	6	2.71	1.58	No	Few detections and maximum concentration within the same order of magnitude as MDL. Compound not considered as CoC.
Cadmium	<0.02	59	18	2.41	0.7	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Chromium	<0.9	59	59	219	45.3	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Chromium, Hexavalent	<0.6	59	2	5.26	3.01	No	Few detections at relatively low concentrations. Compound not considered as CoC.
Copper	<1.4	59	58	1,490	121	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Iron	<2	59	59	373,000	77,944	No	Compound naturally occurring. The distribution and magnitude of measured concentrations does not indicate hot spot areas. Compound not considered as CoC.
Lead	<0.7	59	58	7,660	442	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Magnesium	<8	59	59	14,600	3,128	No	Compound naturally occurring. The distribution and magnitude of measured concentrations does not indicate hot spot areas. Compound not considered as CoC.
Mercury	<0.14	59	5	1.74	0.592	No	Few detections at relatively low concentrations. Compound not considered as CoC.
Molybdenum	<0.1	59	44	23	5.74	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Nickel	<0.2	59	59	85.5	39.9	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Tin	<0.24	59	49	57.2	10.3	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Vanadium	<0.2	59	59	737	94.3	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Zinc	<1.9	59	58	1,550	148	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
<b>Aliphatics</b>							
Aliphatics >C5-C6	<0.01	56	16	0.102	0.0544	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aliphatics >C6-C8	<0.01	56	28	0.162	0.113	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aliphatics >C8-C10	<0.01	56	25	0.0815	0.0732	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aliphatics >C10-C12	<0.01	56	20	0.219	0.119	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aliphatics >C12-C16	<0.1	56	55	130	33	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aliphatics >C16-C21	<0.1	56	55	134	35	Yes	Compound present in multiple locations. Carried forward to second stage of screening, assessed aliphatics >C16-C35.
Aliphatics >C21-C35	<0.1	56	54	705	120		
<b>Aromatics</b>							
Aromatics >EC8-EC10	<0.01	56	46	0.125	0.059	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aromatics >EC10-EC12	<0.01	56	20	0.146	0.079	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aromatics >EC12-EC16	<0.1	56	54	386	106	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aromatics >EC16-EC21	<0.1	56	54	312	67.6	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aromatics >EC21-EC35	<0.1	56	54	508	131	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Aromatics >EC35-EC44	<0.1	56	52	208	49.3	No	Assessed as aromatics >C21-C35.
Aromatics >EC40-EC44	<0.1	56	49	94.2	19.7		
<b>PAHs</b>							
Naphthalene	<0.009	58	51	582	17	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Acenaphthylene	<0.012	58	36	4.5	0.576	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Acenaphthene	<0.008	58	38	939	38.1	Yes	Compound present in multiple locations. Carried forward to second stage of screening.

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Initial Screening  
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962340126\_01 / September 2011

CoC	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (mg/kg)	Average Concentration (mg/kg)	Considered in further assessment?	Comments
Fluorene	<0.01	58	38	322	15.8	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Phenanthrene	<0.015	58	54	111	7.5	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Anthracene	<0.016	58	39	28.9	2.46	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Fluoranthene	<0.017	58	47	18.5	3.72	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Pyrene	<0.015	58	47	13.1	2.94	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Benz(a)anthracene	<0.014	58	48	7.82	1.77	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Chrysene	<0.01	58	50	6.08	1.43	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Benzo(b)fluoranthene	<0.015	58	51	9.22	1.77	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Benzo(k)fluoranthene	<0.014	58	41	3.68	0.899	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Benzo(a)pyrene	<0.015	58	47	7.43	1.55	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Indeno(1,2,3-cd)pyrene	<0.018	58	40	4	0.943	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Dibenzo(a,h)anthracene	<0.023	58	34	1.23	0.348	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Benzo(g,h,i)perylene	<0.024	58	40	4.52	1.13	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
<b>BTEX</b>							
Benzene	<0.009	23	13	0.535	0.0647	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Toluene	<0.005	23	15	0.0461	0.0254	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
Ethylbenzene	<0.004	23	18	0.194	0.0747	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
p/m-Xylene	<0.014	23	9	0.422	0.0705	Yes	Compound present in multiple locations. Carried forward to second stage of screening, assessed as sum xylenes.
o-Xylene	<0.01	23	3	0.0248	0.0226		
<b>Additional VOC</b>							
Carbon Disulphide	<0.007	23	4	0.0545	0.0347	Yes	Compound present in few locations however relatively high concentrations with respect to MDL. Carried forward to second stage of screening.
Dichloromethane	<0.01	23	6	0.0494	0.0315	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
1,1,2-Trichloroethane	<0.01	23	1	0.0114	0.0114	No	A single detection, concentration within the same order of magnitude as MDL. Not considered as CoC.
Styrene	<0.01	23	11	0.275	0.124	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
1,2,4-Trimethylbenzene	<0.009	23	3	0.298	0.127	Yes	Compound present in few locations, however maximum and average concentration two orders of magnitude higher than MDL.
4-Isopropyltoluene	<0.011	23	1	0.241	0.241	No	A single detection, concentration only relatively higher than MDL. Compound not considered as CoC.
<b>Additional SVOC</b>							
Carbazole	<0.1	23	12	1.33	0.427	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
bis(2-Ethylhexyl) phthalate	<0.1	23	2	0.209	0.1865	No	Relatively low number of detections. Maximum concentration within the same order of magnitude as MDL. Not considered as CoC.
4-Methylphenol	<0.1	23	3	1.04	0.67	No	Relatively low number of detections. Average concentration within the same order of magnitude as MDL. Not considered as CoC.
2-Methylphenol	<0.1	23	3	0.878	0.418	No	Relatively low number of detections. Maximum concentration within the same order of magnitude as MDL. Not considered as CoC.
2,4-Dinitrotoluene	<0.1	23	1	0.27	0.27	No	A single detection an order of magnitude higher than MDL. Not considered as CoC.
2-Methylnaphthalene	<0.1	23	19	17.4	2.19	Yes	Compound present in multiple locations. Carried forward to second stage of screening.
<b>PCBs</b>							
PCB congener 28	<0.003	27	1	0.0197	0.01970	No	Low number of detections at low concentrations compared to MDL. Not considered as CoC.
PCB congener 52	<0.003	27	1	0.00392	0.00392		
PCB congener 101	<0.003	27	1	0.0034	0.00344		
PCB congener 138	<0.003	27	2	0.00543	0.00456		
PCB congener 153	<0.003	27	2	0.00331	0.00325		
PCB congener 180	<0.003	27	1	0.00502	0.00502		
<b>Phenols</b>							
Phenol	<0.01	23	2	0.128	0.07155	No	Low number of detections with low average concentrations compared to MDL. Not considered as CoC.
Cresols	<0.01	23	4	0.181	0.09895		
Xylenols	<0.015	23	2	0.151	0.09290		
1-Naphthol	<0.01	23	2	0.0151	0.01360		
2,3,5-Trimethylphenol	<0.01	23	1	0.315	0.31500		

CoC	Leachate					Groundwater					Considered in further assessment?	Comments
	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)		
<b>Inorganics</b>												
Ammoniacal Nitrogen as N	<200	24	5	10,100	2,354	<200	22	13	7,090	1,736	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Ammoniacal Nitrogen as NH4	<300	24	4	13,000	3,721	<300	22	13	9,120	2,232	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Ammonia, Free / unionised as N	<200	25	1	819	819	<200	22	3	780	477	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Sulphide	<10	18	0	Not detected		<10	22	9	71	31.6	Yes	Detected in groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Fluoride	<500	18	8	1,480	857	<500	22	6	2,240	1,002	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Sulphate	<2000	18	16	546,000	63,181	<2000	22	22	1,270,000	217,886	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Chloride	<2000	18	3	8,100	5,333	<2000	22	22	126,000	29,968	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Nitrite as NO2	<50	18	0	Not detected		<50	22	5	521	254	Yes	Detected in groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Phosphate (ortho) as PO4	<50	18	10	244	135	<50	22	4	365	154	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Nitrate as NO3	<300	18	12	2,160	846	<300	22	11	19,600	4,563	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
<b>Metals</b>												
Aluminium	<2.9	18	18	2,140	238	<2.9	22	7	7,790	1124	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Arsenic	<0.12	18	18	111	20.3	<0.12	22	22	338	17.05	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Beryllium	<0.07	18	2	2.26	1.2	<0.07	22	1	5.68	5.68	No	Limited detections in leachate and single detection in groundwater. Leaching is considered limited. Therefore compound not considered further.
Boron	<9.4	25	4	17.4	14.2	<9.4	22	22	140	83.2	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Cadmium	<0.1	18	3	9.73	3.34	<0.1	22	5	8.92	1.9	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Chromium	<0.22	18	18	65.8	5.86	<0.22	22	22	19	8.98	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Copper	<0.85	18	16	65	6.32	<0.85	22	21	13.3	2.99	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Lead	<0.02	18	17	18	2.15	<0.02	22	18	11.5	0.777	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Molybdenum	<0.24	18	17	17	5.19	<0.24	22	16	7.68	2.41	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Nickel	<0.15	18	18	174	10.9	<0.15	22	22	544	30.5	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Vanadium	<0.24	18	17	48.3	5.41	<0.24	22	19	5.78	2.3	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Zinc	<0.41	18	14	586	44.4	<0.41	22	21	1390	81.2	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Mercury	<0.01	18	4	0.0271	0.0169	<0.01	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. Therefore compound not considered further.
Magnesium	<36	18	16	11,400	2,730	<36	22	22	65,900	24,267	No	Compound naturally occurring. The distribution and magnitude of measured concentrations does not indicate hot spot areas. Compound not considered as CoC.
Iron	<19	18	1	553	553	<19	22	12	67,400	7,175	No	Compound naturally occurring. The distribution and magnitude of measured concentrations does not indicate hot spot areas. Compound not considered as CoC.
Chromium, Hexavalent	<30	18	1.00	47	47	<30	22	1	47	47	No	Single detection in leachate and groundwater. Leaching is considered limited. Therefore compound not considered further.
<b>TPH</b>												
>C10 - C40	<46	18	3	394	191	<10	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. Therefore compound not considered further.
>C10-C12	<10	18	1	60.8	60.8	<10	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. Therefore compound not considered further.
>C12-C16	<10	18	1	254	254	<10	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. Therefore compound not considered further.
>C16-C21	<10	18	2	20.3	19.8	<10	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. Therefore compound not considered further.
>C21-C40	<10	18	3	82.7	72.9	<10	22	0	Not detected		No	Although compound detected in leachate, no detections in groundwater. Leaching is considered limited. It is noted that a concentration of 50µg/l of total aliphatics & aromatics >C5-35 was measured in one sample in groundwater. Given the low number of detections and low concentration this has not been considered further.
<b>PAHs</b>												
Naphthalene	<0.1	18	13	33.9	2.86	<0.1	22	10	0.901	0.239	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Acenaphthylene	<0.011	18	1	0.389	0.389	<0.011	22	4	0.034	0.0276	No	Single detection in leachate and few detections in groundwater at concentrations within the same order of magnitude as MDL.
Acenaphthene	<0.015	18	6	40.3	6.76	<0.015	22	8	0.7	0.163	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.

CoC	Leachate					Groundwater					Considered in further assessment?	Comments
	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)		
Fluorene	<0.014	18	3	7.18	2.41	<0.014	22	6	0.277	0.0811	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Phenanthrene	<0.022	18	6	1.08	0.224	<0.022	22	9	0.375	0.128	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Anthracene	<0.015	18	2	0.16	0.0886	<0.015	22	5	0.106	0.0532	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Fluoranthene	<0.017	18	6	0.0813	0.0424	<0.017	22	7	1.21	0.291	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Pyrene	<0.015	18	6	0.0793	0.0367	<0.015	22	7	1.41	0.318	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Benzo(a)anthracene	<0.017	18	4	0.0349	0.0269	<0.017	22	6	0.428	0.136	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Chrysene	<0.013	18	3	0.0366	0.0276	<0.013	22	6	0.987	0.266	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Benzo(b)fluoranthene	<0.023	18	1	0.0367	0.0367	<0.023	22	5	0.399	0.13	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Benzo(k)fluoranthene	<0.027	18	1	0.0436	0.0436	<0.027	22	4	0.636	0.227	No	Single detection in leachate and relatively few detections in groundwater at low concentrations. Average concentration an order of magnitude higher than MDL.
Benzo(a)pyrene	<0.009	18	3	0.0423	0.0219	<0.009	22	5	0.812	0.229	Yes	Detected in leachate and groundwater at concentrations above MDL. Therefore carried forward to second stage of screening.
Indeno(1,2,3-cd)pyrene	<0.014	18	1	0.028	0.028	<0.014	22	5	0.464	0.136	No	Single detection in leachate and relatively few detections in groundwater at low concentrations. Average concentration an order of magnitude higher than MDL.
Dibenzo(a,h)anthracene	<0.016	18	0	Not detected		<0.016	22	2	0.121	0.0807	No	No detections in leachate and relatively low concentrations in groundwater. Average concentration within the same order of magnitude as MDL.
Benzo(g,h,i)perylene	<0.016	18	1	0.0409	0.0409	<0.016	22	5	0.639	0.181	No	Single detection in leachate and relatively few detections in groundwater at low concentrations. Average concentration an order of magnitude higher than MDL.
<b>Additional SVOCs</b>												
bis(2-Ethylhexyl) phthalate	No leachate testing undertaken					<2	22	1	3.3	3.3	No	Single detection in groundwater, concentration within the same order of magnitude as MDL.
Dibenzofuran	No leachate testing undertaken					<1	22	1	1.1	1.1	No	Single detection in groundwater, concentration within the same order of magnitude as MDL.

Appendix E  
Pathway Specific Ranking

## Appendix E Pathway Specific Ranking

General bands were defined in order to identify the likely risk indicators, and should be considered in identifying comparatively higher and lower risk indicators, rather than determining absolute risk. There are recognised examples of such screening in literature, for example the use of Henry's Law Constant to determine whether a potential CoC is volatile, partially volatile or not volatile.

<i>Mobility</i>					
Solubility (mg/L)			$K_{oc}$ (cm <sup>3</sup> /g)		
>1	Low	Higher value solubility indicates higher mobility of a compound	>1	Low	Higher $K_{oc}$ value indicates that the compound is likely to sorb to soil resulting in lower mobility
>10	Low to medium		>2	Medium	
>100	Medium		>3	Medium to high	
>500	Medium to high		>4	High	
>1000	high				

<i>Degradation (days)</i>		
>1000	Low	Compounds which degrade readily are likely to pose a lower risk to the environment, unless degradation products are potentially more harmful.
>500	Low to medium	
>100	Medium	
>20	Medium to high	
>1	High	

<i>Toxicity (µg/kg.day)</i>		
<1	High	Lower toxicity compounds are less likely to pose significant risk.
>1	High to medium	
>10	Medium	
>100	Medium to low	
>500	Low	

In addition to toxicological data, it has been noted whether a contaminant is likely to be carcinogenic. In the case of chemicals believed to act via non-threshold mechanism (carcinogenic contaminants), the ALARP principle will automatically apply. The ALARP principle ensures that, irrespective of whether a health-based guideline is being breached or not, exposures are kept 'as low as reasonably practicable' (EA, SR2, 2009). This is the case since there is no level below which it can be said that there is no risk. Toxicological criteria for carcinogenic contaminants are considered to be minimal risk levels.

<i>Volatility (Pa)*</i>		
>1000	High	Volatility indicates the likelihood for the compound to volatilise and present a risk via inhalation pathways.
>500	High to medium	
>100	Medium	
>10	Medium to low	
>1	Low	

Volatility was defined mainly using a compound vapour pressure however consideration was also given to the air-water partition coefficient.

Appendix F  
Pathway Specific Screening

	low risk indicator
	low to medium risk indicator
	medium risk indicator
	medium to high risk indicator
	high risk indicator

CoC	Carried through from Initial Screening?		Volatility		Toxicity		Carcinogenic?		Considered for Human Health		
	Soils	Groundwater	Kaw	Vapour Pressure	Oral HCV	Inh HCV	ID/TDI	Comment	Oral	Dust	Vapour
			10°C	Pa	µg/kg.day	µg/kg.day					
<b>Inorganics</b>											
Free Ammonia as N	No	Yes	0.000173	861,260	ND	28.6	TDI	Unlikely Carcinogen	No	No	Yes
Cyanide, Total	Yes	No	ND	ND	800	ND	TDI	Unlikely Carcinogen	No	No	No
<b>Metals</b>											
Aluminium	Yes	Yes	ND	ND	1000	1.43	TDI	Unlikely Carcinogen	Yes	Yes	No
Arsenic	Yes	Yes	ND	ND	0.3	0.002	ID	Likely Carcinogen	Yes	Yes	No
Boron	No	Yes	ND	ND	88	5.7	TDI	Unlikely Carcinogen	Yes	Yes	No
Cadmium	Yes	Yes	ND	ND	0.36	0.0014	TDI	Unlikely Carcinogen	Yes	Yes	No
Chromium (assessed as Chromium III)	Yes	Yes	ND	ND	1500	ND	TDI	Unlikely Carcinogen	No	No	No
Copper	Yes	Yes	ND	ND	140	0.286	TDI	Unlikely Carcinogen	Yes	Yes	No
Lead	Yes	Yes	ND	ND	3.5	3.5	TDI	Unlikely Carcinogen	Yes	Yes	No
Molybdenum	Yes	Yes	ND	ND	5	3.43	TDI	Unlikely Carcinogen	Yes	Yes	No
Nickel	Yes	Yes	ND	ND	12.0	0.006	TDI	Unlikely Carcinogen	Yes	Yes	No
Tin	Yes	No	ND	ND	600	ND	TDI	Unlikely Carcinogen	No	No	No
Vanadium	Yes	No	ND	ND	7	0.286	TDI	Unlikely Carcinogen	Yes	Yes	No
Zinc	Yes	Yes	ND	ND	300	ND	TDI	Unlikely Carcinogen	No	No	No
<b>Aliphatics</b>											
Aliphatics >C5-C6	Yes	No	34.0	36,000	5,000	5,260	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aliphatics >C6-C8	Yes	No	51.0	6,400	5,000	5,260	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aliphatics >C8-C10	Yes	No	82.0	640	270	270	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aliphatics >C10-C12	Yes	No	130	65.0	100	270	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aliphatics >C12-C16	Yes	No	540	4.80	100	270	TDI	Unlikely Carcinogen	No	No	No
Aliphatics >C16-C35	Yes	No	6,400	0.77	2,000	ND	TDI	Unlikely Carcinogen	No	No	No
<b>Aromatics</b>											
Aromatics >EC8-EC10	Yes	No	0.49	640	40.0	55.0	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aromatics >EC10-EC12	Yes	No	0.14	64.0	40.0	55.0	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aromatics >EC12-EC16	Yes	No	0.05	4.80	40.0	55.0	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Aromatics >EC16-EC21	Yes	No	0.01	0.77	30.0	ND	TDI	Unlikely Carcinogen	Yes	No	No
Aromatics >EC21-EC35	Yes	No	6.80E-04	4.40E-04	30.0	ND	TDI	Unlikely Carcinogen	Yes	No	No
<b>PAHs</b>											
Naphthalene	Yes	Yes	6.61E-03	2.31E+00	20.0	0.86	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Acenaphthylene	Yes	Yes	3.58E-03	0.891 (25°C)	5.00	Insufficient data	TDI	Unlikely Carcinogen	Yes	No	No
Acenaphthene	Yes	Yes	5.17E-03	0.31 (25°C)	50.0	60.0	TDI	Unlikely Carcinogen	Yes	Yes	No
Fluorene	Yes	Yes	2.97E-03	0.080 (25°C)	40.0	40.0	TDI	Unlikely Carcinogen	Yes	Yes	No
Phenanthrene	Yes	Yes	1.10E-03	2.31E+00	40.0	Insufficient data	TDI	Unlikely Carcinogen	Yes	No	No
Anthracene	Yes	Yes	1.08E-03	0.001 (25°C)	40.0	300	TDI	Unlikely Carcinogen	Yes	Yes	No
Fluoranthene	Yes	Yes	6.33E-05	1.31E-04	5.00	40.0	TDI	Unlikely Carcinogen	Yes	Yes	No
Pyrene	Yes	Yes	5.67E-05	1.53E-05	30.0	Insufficient data	TDI	Unlikely Carcinogen	Yes	No	No
Benzo(a)anthracene	Yes	Yes	3.17E-05	1.24E-06	0.2	7.00E-04	ID	Likely Carcinogen	Yes	Yes	No
Chrysene	Yes	Yes	3.20E-06	4.52E-08	2	7.00E-03	ID	Likely Carcinogen	Yes	Yes	No
Benzo(b)fluoranthene	Yes	Yes	2.07E-06	6.34E-08	0.2	7.00E-04	ID	Likely Carcinogen	Yes	Yes	No
Benzo(k)fluoranthene	Yes	Yes	1.75E-06	1.64E-08	0.2	7.00E-04	ID	Likely Carcinogen	Yes	Yes	No
Benzo(a)pyrene	Yes	Yes	1.77E-06	2.00E-08	0.02	7.00E-05	ID	Likely Carcinogen	Yes	Yes	No
Indeno(1,2,3-cd)pyrene	Yes	Yes	2.06E-06	2.12E-09	0.20	7.00E-04	ID	Likely Carcinogen	Yes	Yes	No
Dibenzo(a,h)anthracene	Yes	No	5.44E-06	1.66E-10	0.02	7.00E-05	ID	Likely Carcinogen	Yes	Yes	No
Benzo(g,h,i)perylene	Yes	Yes	2.38E-06	1.55E-10	30.0	Insufficient data	TDI	Unlikely Carcinogen	Yes	No	No
<b>BTEX</b>											
Benzene	Yes	No	0.12	6,238	0.29	1.40	ID	Likely Carcinogen	Yes	Yes	Yes
Toluene	Yes	No	0.11	1,731	223	1,400	ID	Likely Carcinogen	Yes	No	No
Ethylbenzene	Yes	No	0.14	553	100	220	ID	Likely Carcinogen	Yes	Yes	Yes
Sum Xylenes	Yes	No	0.10	452	180	60	TDI	Unlikely Carcinogen	Yes	Yes	Yes
<b>Additional VOC</b>											
Carbon Disulphide	Yes	No	0.408	26,500	100	28.3	TDI	Unlikely Carcinogen	Yes	Yes	Yes
Dichloromethane	Yes	No	0.050	30,800	1.3	60	ID	Likely Carcinogen	Yes	Yes	Yes
Styrene	Yes	No	0.099	670	7.7	74.3	TDI	Unlikely Carcinogen	Yes	Yes	Yes
1,2,4-Trimethylbenzene	Yes	No	0.233	270	50	2	TDI	Unlikely Carcinogen	Yes	Yes	Yes
<b>Additional SVOC</b>											
Carbazole	Yes	No	2.09E-05	1.00E-04	0.5	0.5	ID	Likely Carcinogen	Yes	Yes	No
2-Methylnaphthalene	Yes	No	2.10E-02	7	4	4	TDI	Unlikely Carcinogen	Yes	Yes	Yes

Notes:

Kaw (cm<sup>3</sup>/cm<sup>3</sup>)

Vapour Pressure (Pa)

ID

TDI

Oral HCV

Inh HCV

ND

Air-water partition coefficient. This is the constant of proportionality between the concentration of a chemical in air and in water at low partial pressures, at specified temperature and pressure, and below the saturation limits in either air or water. It is calculated from Henry's Law constant, which is the constant of proportionality between water solubility and the partial pressure of the gas phase and is reported in units Pa m<sup>3</sup> mol<sup>-1</sup>.

The vapour pressure of a substance is the pressure its vapour exerts in equilibrium with its solid or liquid phase. It increases rapidly with temperature and is an important controlling factor on the volatility of substance.

Index Dose, for non-threshold toxicity

Tolerable daily intake, for threshold toxicity

Oral Health Criteria Value

Inhalation Health Criteria Value

No data was sourced

Appendix G  
Secondary Screening – Water Resources

CoC	Leachate					Groundwater					EQS	BGS background Concentrations (µg/l)*			Considered in further assessment?	Comments
	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)	Laboratory MDL	Number of Samples Analysed	Number of detections	Maximum Measured Concentration (µg/l)	Average Concentration (µg/l)		Minimum	Maximum	Mean		
<b>Inorganics</b>																
Ammoniacal Nitrogen as N	<200	24	5	10,100	2,354	<200	22	13	7,090	1,736	ND	No data			Yes	Considered as CoC in water resources assessment.
Ammoniacal Nitrogen as NH4	<300	24	4	13,000	3,721	<300	22	13	9,120	2,232	500	<3	12,000	140	Yes	Considered as CoC in water resources assessment.
Ammonia, Free / unionised as N	<200	25	1	819	819	<200	22	3	780	477	15	No data			Yes	Considered as CoC in water resources assessment.
Sulphide	<10	18	0	Not detected		<10	22	9	71	31.6	0.25	No data			No	No detections in leachate indicative of potential for background concentrations present in groundwater. Although maximum concentration in groundwater above EQS, it is within same order of magnitude as MDL.
Fluoride	<500	18	8	1,480	857	<500	22	6	2,240	1,002	1,500	No data			No	Concentrations in leachate and groundwater are comparable with EQS and within background levels. Average concentration below EQS.
Sulphate	<2000	18	16	546,000	63,181	<2000	22	22	1,270,000	217,886	400,000	100	1,790,000	64,300	No	Concentrations in leachate and groundwater are comparable with EQS and within background levels. Average concentration below EQS.
Chloride	<2000	18	3	8,100	5,333	<2000	22	22	126,000	29,968	250,000	2,000	10,700,000	110,000	No	Concentrations in leachate and groundwater are comparable to background levels. No concentrations measured above EQS.
Nitrite as NO2	<50	18	0	Not detected		<50	22	5	521	254	100	<1	1,010	10	No	No detections in leachate. Concentrations in groundwater are limited and are comparable with background levels. Measured concentrations same order of magnitude as EQS.
Phosphate (ortho) as PO4	<50	18	10	244	135	<50	22	4	365	154	30 - 1,000	No data			No	Concentrations in leachate and groundwater are within EQS range and maximum concentrations an order of magnitude lower than high end of range EQS.
Nitrate as NO3	<300	18	12	2,160	846	<300	22	11	19,600	4,563	50,000	<2	50,800	5,040	No	Concentrations in leachate and groundwater are to background levels. No concentrations measured above EQS.
<b>Metals</b>																
Aluminium	<2.9	18	18	2,140	238	<2.9	22	7	7,790	1,124	200	<1	1,550	56	No	Average concentration in leachate below EQS. Although few detections in groundwater, single detection measured at concentration above EQS. Average concentration within background levels.
Arsenic	<0.12	18	18	111	20.3	<0.12	22	22	338	17.05	50	<1	355	3.2	No	Concentrations in leachate and groundwater are comparable with EQS and within background levels. Average concentration below EQS.
Boron	<9.4	25	4	17.4	14.2	<9.4	22	22	140	83.2	2,000	<20	3,442	75	No	Concentrations in leachate and groundwater below EQS and within background levels.
Cadmium	<0.1	18	3	9.73	3.34	<0.1	22	5	8.92	1.9	5	<0.05	29	0.25	No	Few detections in leachate and groundwater at concentrations within the same order of magnitude as EQS. Average concentrations in leachate and groundwater below EQS.
Chromium	<0.22	18	18	65.8	5.86	<0.22	22	22	19	8.98	250	<0.5	386	1.25	No	Concentrations in leachate and groundwater below EQS and within background levels.
Copper	<0.85	18	16	65	6.32	<0.85	22	21	13.3	2.99	28	<0.1	1,261	14	No	Concentrations in leachate and groundwater the same order of magnitude as EQS and mean background concentration. Average concentrations in leachate and groundwater below EQS.
Lead	<0.02	18	17	18	2.15	<0.02	22	18	11.5	0.777	250	<0.1	6,650	10	No	Concentrations in leachate and groundwater below EQS and within background levels.
Molybdenum	<0.24	18	17	17	5.19	<0.24	22	16	7.68	2.41	70	<0.1	67.7	0.54	No	Concentrations in leachate and groundwater below EQS and within background levels.
Nickel	<0.15	18	18	174	10.9	<0.15	22	22	544	30.5	200	<0.2	78	2.73	No	Concentrations in leachate and groundwater the same order of magnitude as EQS. Average concentrations in leachate and groundwater below EQS.
Vanadium	<0.24	18	17	48.3	5.41	<0.24	22	19	5.78	2.3	60	<0.2	33.9	0.92	No	Concentrations in leachate and groundwater below EQS and comparable to background levels.
Zinc	<0.41	18	14	586	44.4	<0.41	22	21	1390	81.2	500	0.06	23,500	102	No	Concentrations in leachate and groundwater are within background levels. Average concentrations in leachate and groundwater below EQS.
<b>PAHs</b>																
Naphthalene	<0.1	18	13	33.9	2.86	<0.1	22	10	0.901	0.239	10	No data			Potentially	PAH compounds discussed in Section 2.4.4.
Acenaphthene	<0.015	18	6	40.3	6.76	<0.015	22	8	0.7	0.163	2,200	No data				
Fluorene	<0.014	18	3	7.18	2.41	<0.014	22	6	0.277	0.0811	1,500	No data				
Phenanthrene	<0.022	18	6	1.08	0.224	<0.022	22	9	0.375	0.128	ND	No data				
Anthracene	<0.015	18	2	0.16	0.0886	<0.015	22	5	0.106	0.0532	11,000	No data				
Fluoranthene	<0.017	18	6	0.0813	0.0424	<0.017	22	7	1.21	0.291	1500	No data				
Pyrene	<0.015	18	6	0.0793	0.0367	<0.015	22	7	1.41	0.318	1100	No data				
Benzo(a)anthracene	<0.017	18	4	0.0349	0.0269	<0.017	22	6	0.428	0.136	0.029	No data				
Chrysene	<0.013	18	3	0.0366	0.0276	<0.013	22	6	0.987	0.266	2.9	No data				
Benzo(b)fluoranthene	<0.023	18	1	0.0367	0.0367	<0.023	22	5	0.399	0.13	0.1	No data				
Benzo(a)pyrene	<0.009	18	3	0.0423	0.0219	<0.009	22	5	0.812	0.229	0.01 - 0.7	No data				

Notes  
\* Shand et al 2007

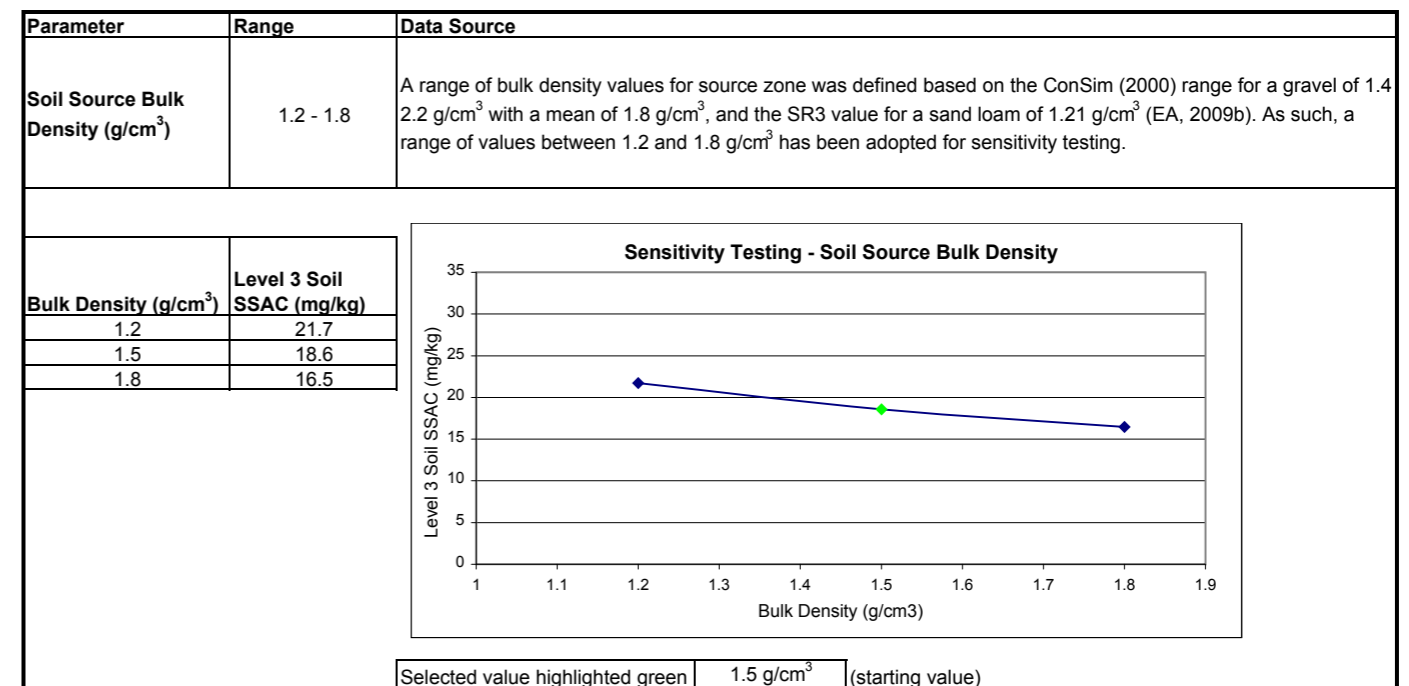
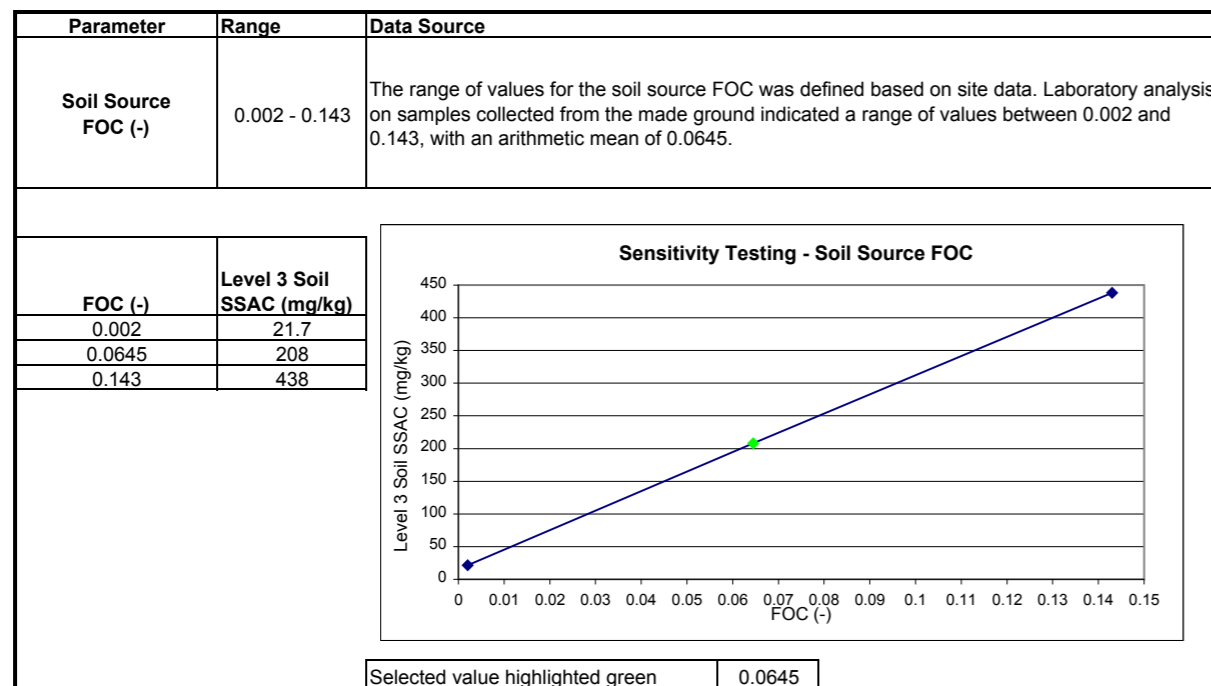
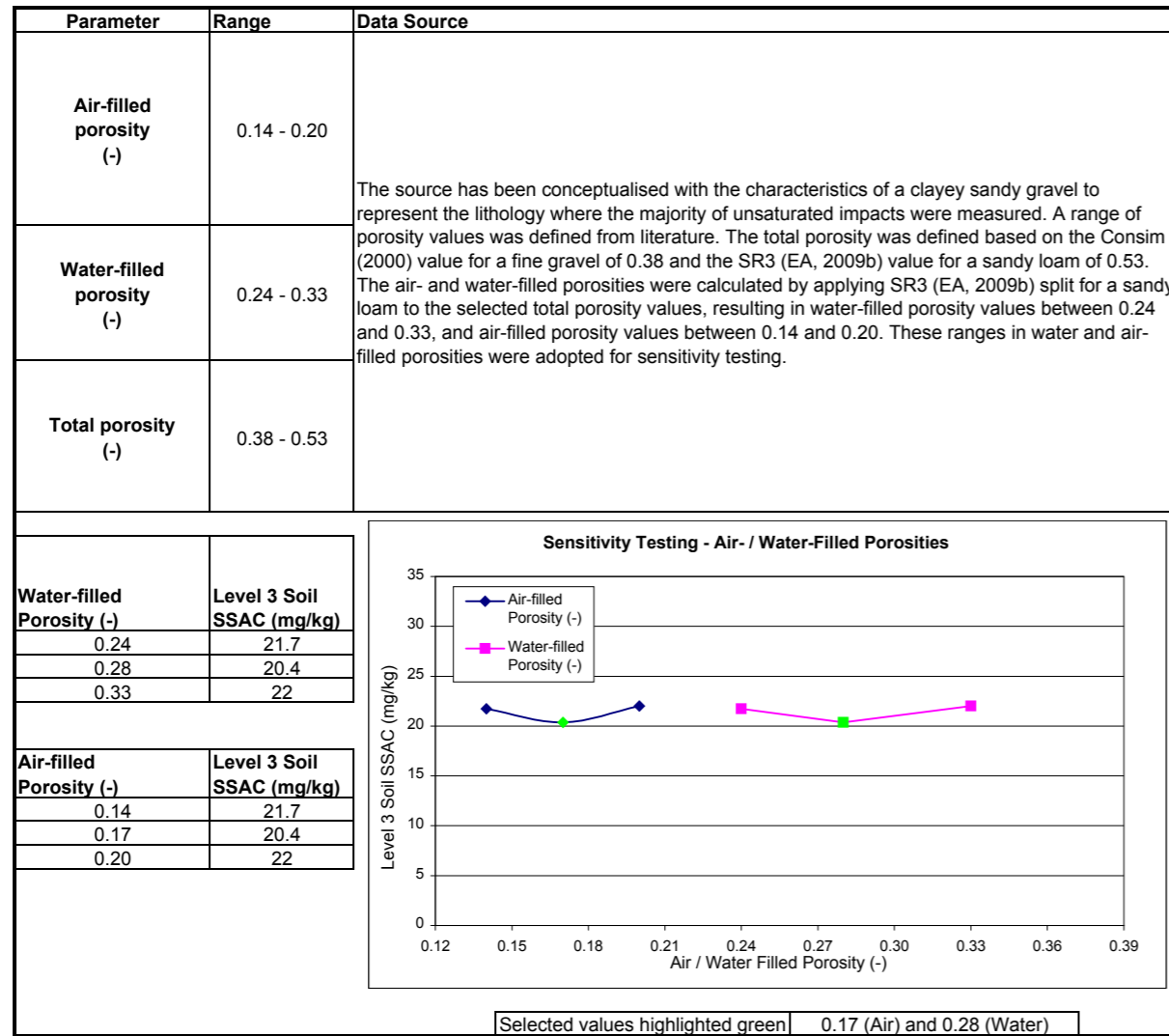
Appendix H  
Chemical and Toxicological Input Parameters

Appendix H  
 Chemical and Toxicological  
 Input Parameters

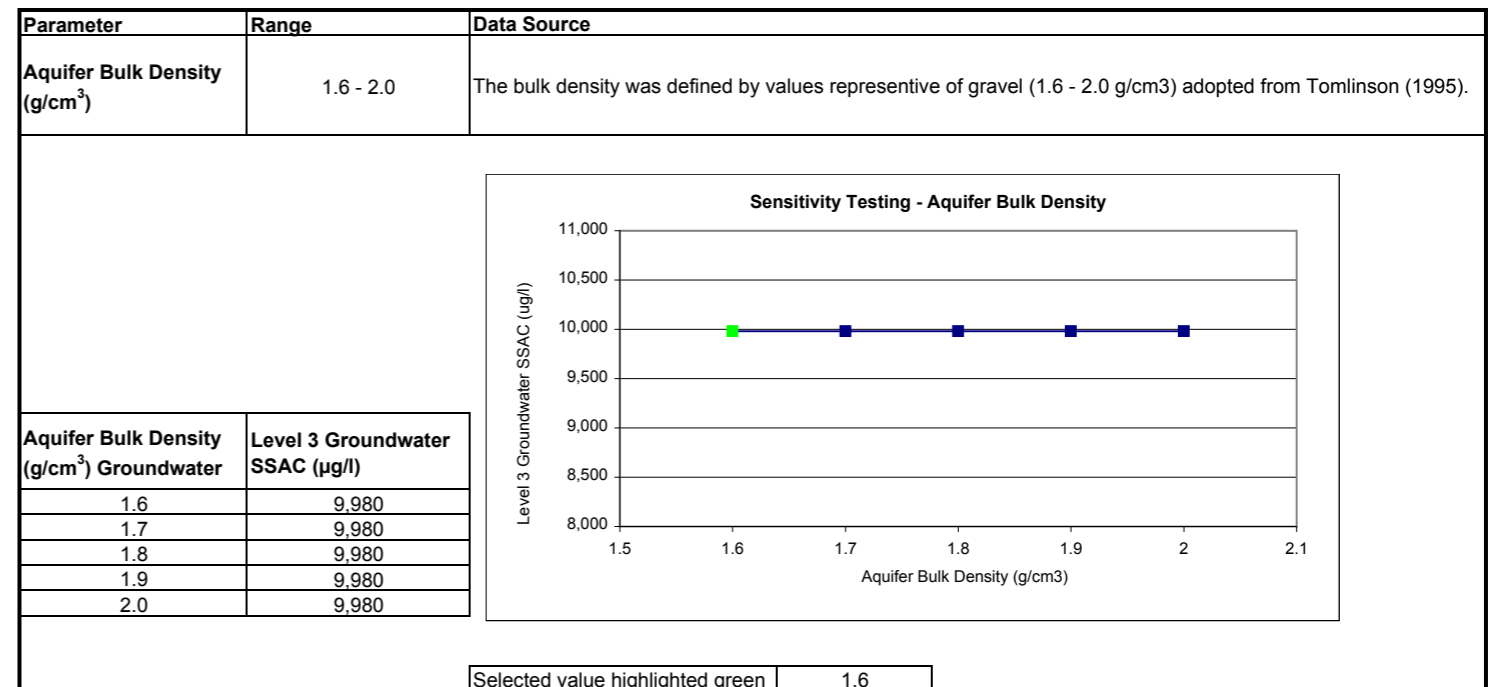
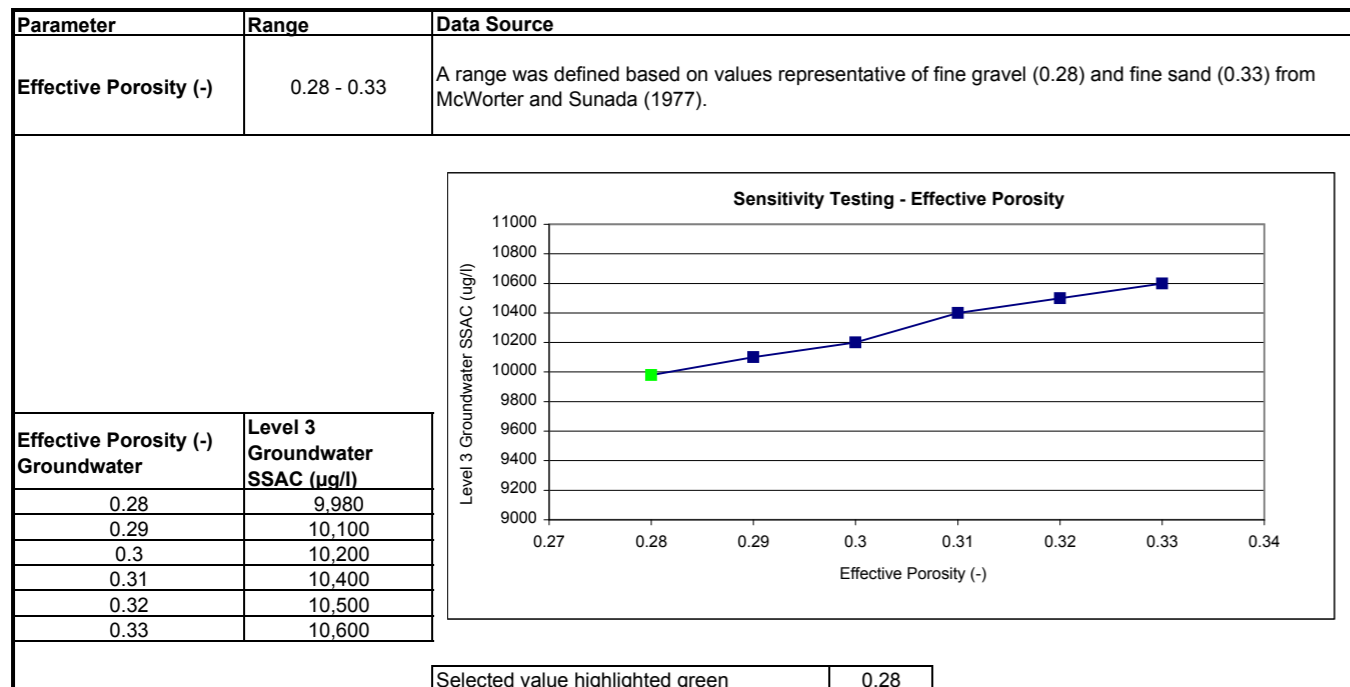
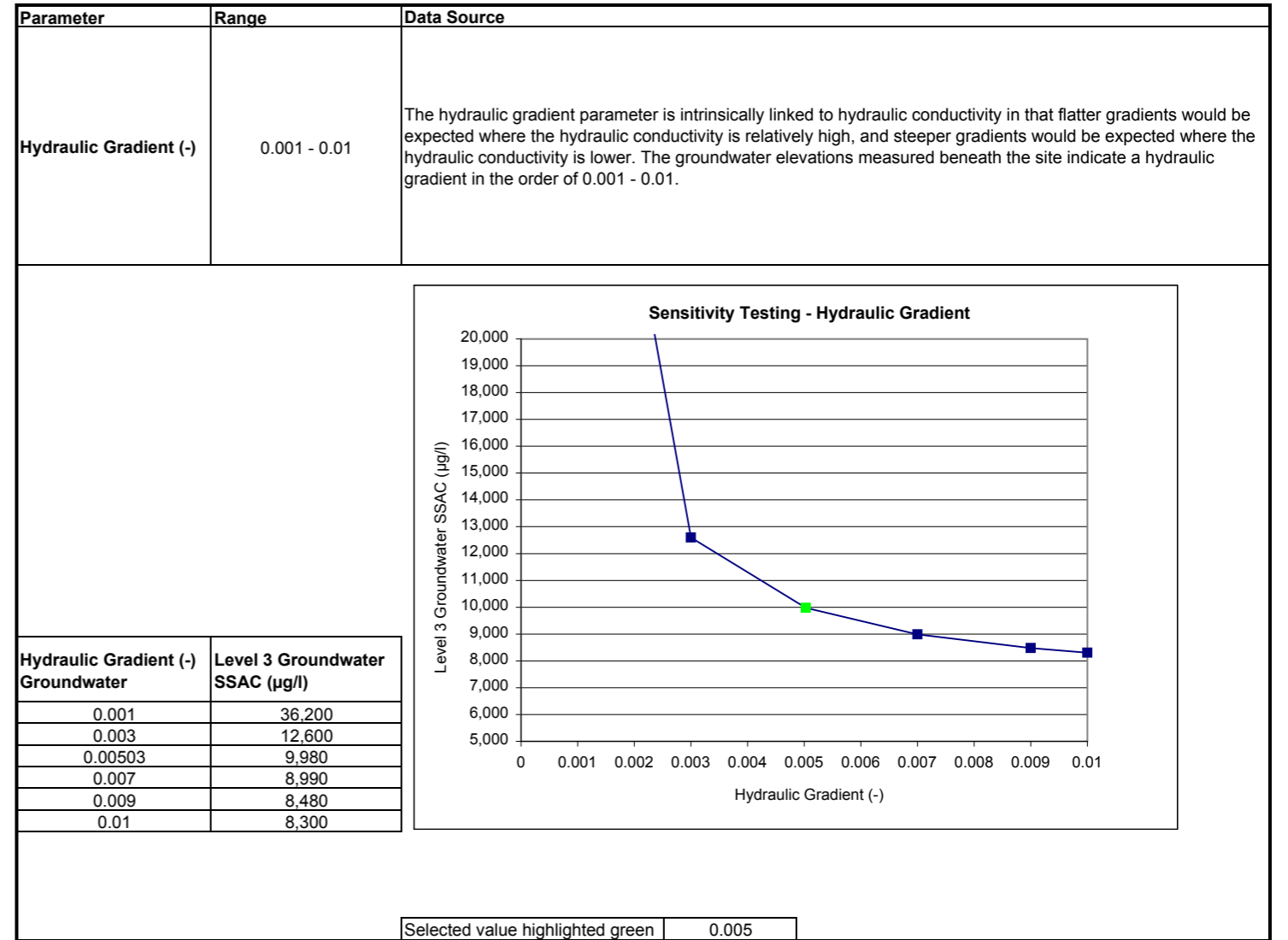
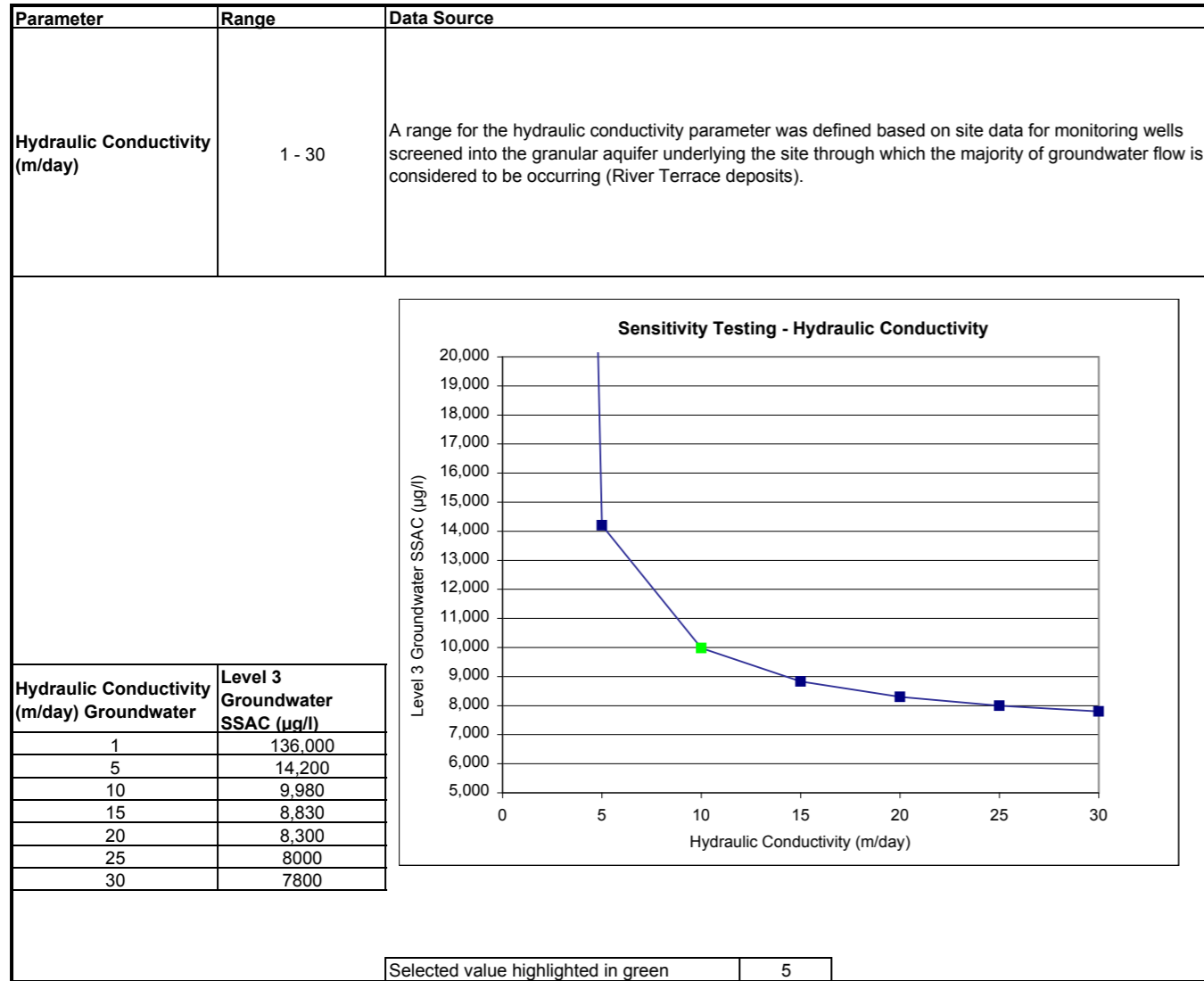
Chemical Name	Inhalation HCV		Inhalation MDI for adults $\mu\text{g day}^{-1}$	Air-water partition coefficient ( $K_{aw}$ ) $\text{cm}^3 \text{cm}^{-3}$	Diffusion coefficient in air $\text{m}^2 \text{s}^{-1}$	Diffusion coefficient in water $\text{m}^2 \text{s}^{-1}$	Relative molecular mass $\text{g mol}^{-1}$	Vapour pressure Pa	Water solubility $\text{mg L}^{-1}$	$K_{oc}$ Log ( $\text{cm}^3 \text{g}^{-1}$ )	$K_{ow}$ Log (dimensionless)	Sub-surface soil to indoor air correction factor (dimensionless) *
	Type	$\mu\text{g kg}^{-1} \text{BW day}^{-1}$										
Aliphatic >C5-C6	TDI	5.26E+03	3.68E+05	3.40E+01	1.00E-05	1.00E-09	8.10E+01	3.60E+04	3.60E+01	2.90E+00	3.30E+00	10.0
Aliphatic >C6-C8	TDI	5.26E+03	3.68E+05	5.10E+01	1.00E-05	1.00E-09	1.00E+02	6.40E+03	5.40E+00	3.60E+00	4.00E+00	10.0
Aliphatic >C8-C10	TDI	2.70E+02	1.89E+04	8.20E+01	1.00E-05	1.00E-09	1.30E+02	6.40E+02	4.30E-01	4.51E+00	4.80E+00	10.0
Aliphatic >C10-C12	TDI	2.70E+02	1.89E+04	1.30E+02	1.00E-05	1.00E-09	1.60E+02	6.50E+01	3.40E-02	5.40E+00	5.60E+00	10.0
Aliphatic >C12-C16	TDI	2.70E+02	1.89E+04	5.40E+02	1.00E-05	1.00E-09	2.00E+02	4.80E+00	7.60E-04	6.70E+00	6.80E+00	10.0
Aromatic >EC8-EC10	TDI	5.50E+01	3.85E+03	4.90E-01	1.00E-05	1.00E-09	1.20E+02	6.40E+02	6.50E+01	3.20E+00	3.10E+00	10.0
Aromatic >EC10-EC12	TDI	5.50E+01	3.85E+03	1.40E-01	1.00E-05	1.00E-09	1.30E+02	6.40E+01	2.50E+01	3.40E+00	3.50E+00	10.0
Aromatic >EC12-EC16	TDI	5.50E+01	3.85E+03	5.40E-02	1.00E-05	1.00E-09	1.50E+02	4.80E+00	5.80E+00	3.70E+00	3.90E+00	10.0
Naphthalene	TDI	8.60E-01	2.80E+00	6.62E-03	6.52E-06	5.16E-10	1.28E+02	2.31E+00	1.90E+01	2.81E+00	3.34E+00	10.0
Benzene	ID	1.40E+00	NR	1.16E-01	8.77E-06	6.64E-10	7.81E+01	6.24E+03	1.78E+03	1.83E+00	2.13E+00	10.0
Ethylbenzene	TDI	2.20E+02	1.30E+02	1.39E-01	7.04E-06	5.31E-10	1.06E+02	5.53E+02	1.80E+02	2.65E+00	3.15E+00	10.0
Sum xylenes	TDI	6.00E+01	1.40E+02	1.04E-01	7.03E-06	5.30E-10	1.06E+02	4.52E+02	1.91E+02	2.66E+00	3.16E+00	10.0
Carbon disulphide	TDI	2.83E+01	0.00E+00	4.08E-01	1.04E-05	8.28E-10	7.61E+01	2.65E+04	2.10E+03	2.06E+00	2.00E+00	1.0
Dichloromethane	ID	6.00E+00	NR	5.00E-02	1.01E-05	1.15E-09	8.49E+01	3.08E+04	2.12E+04	1.11E+00	1.25E+00	1.0
Styrene	TDI	7.43E+01	5.20E+01	9.88E-02	7.10E-06	8.10E-10	1.04E+02	6.70E+02	3.00E+02	2.57E+00	3.05E+00	1.0
1,2,4 Trimethylbenzene	TDI	2.00E+00	0.00E+00	2.33E-01	6.77E-06	7.20E-10	1.20E+02	2.70E+02	7.52E+01	3.57E+00	3.72E+00	1.0
2 Methylnaphthalene	TDI	4.00E+00	0.00E+00	2.10E-02	5.40E-06	7.20E-10	1.42E+02	7.00E+00	2.43E+01	3.51E+00	3.94E+00	1.0
Ammonical Nitrogen	TDI	2.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0
Aluminium	TDI	1.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0
Arsenic	ID	2.00E-03	NR	NR	NR	NR	NR	NR	1.25E+06	NR	NR	1.0
Cadmium (pH 7)	TDI	1.40E-03	2.00E-02	NR	NR	NR	NR	NR	1.62E+06	NR	NR	1.0
Copper	TDI	2.86E-01	2.80E-01	NR	NR	NR	NR	NR	0.00E+00	NR	NR	1.0
Lead	TDI	3.50E+00	4.00E+00	NR	NR	NR	NR	NR	0.00E+00	NR	NR	0.0
Molybdenum	TDI	3.43E+00	0.00E+00	NR	NR	NR	NR	NR	0.00E+00	NR	NR	1.0
Nickel	TDI	6.00E-03	6.00E-02	NR	NR	NR	NR	NR	2.50E+06	NR	NR	1.0
Vanadium	TDI	2.86E-01	1.50E+00	NR	NR	NR	NR	NR	0.00E+00	NR	NR	1.0
Acenaphthene	TDI	6.00E+01	6.00E-02	5.17E-03	4.21E-06	6.40E-10	1.54E+02	3.10E-01	3.93E+00	3.28E+00	3.92E+00	10.0
Fluorene	TDI	4.00E+01	6.00E-02	2.97E-03	3.60E-06	6.10E-10	1.66E+02	8.00E-02	1.90E+00	3.49E+00	4.18E+00	10.0
Anthracene	TDI	3.00E+02	6.00E-02	1.08E-03	3.24E-06	7.74E-10	1.78E+02	1.00E-03	7.00E-02	3.70E+00	4.45E+00	10.0
Fluoranthene	TDI	4.00E+01	6.00E-02	6.29E-05	5.01E-06	4.11E-10	2.02E+02	1.31E-04	2.30E-01	4.26E+00	5.13E+00	1.0
Benz[a]anthracene	ID	7.00E-04	NR	3.16E-05	4.60E-06	3.80E-10	2.28E+02	1.24E-06	3.80E-03	4.89E+00	5.91E+00	1.0
Chrysene	ID	7.00E-03	NR	3.18E-06	4.57E-06	3.77E-10	2.28E+02	4.52E-08	2.00E-03	4.74E+00	5.73E+00	1.0
Benzofl[fluoranthene	ID	7.00E-04	NR	2.05E-06	4.36E-06	3.62E-10	2.52E+02	6.34E-08	2.00E-03	5.02E+00	6.08E+00	1.0
Benzofk[fluoranthene	ID	7.00E-04	NR	1.74E-06	4.36E-06	3.62E-10	2.52E+02	1.64E-08	8.00E-04	5.17E+00	6.26E+00	1.0
Benzofa]pyrene	ID	7.00E-05	NR	1.76E-06	4.38E-06	3.67E-10	2.52E+02	2.00E-08	3.80E-03	5.11E+00	6.18E+00	1.0
Indeno[123-cd]pyrene	ID	7.00E-04	NR	2.05E-06	4.17E-06	3.51E-10	2.76E+02	2.12E-09	2.00E-04	4.94E+00	5.97E+00	1.0
Dibenz[ah]anthracene	ID	7.00E-05	NR	5.40E-06	4.08E-06	3.40E-10	2.78E+02	1.66E-10	6.00E-04	5.27E+00	6.38E+00	1.0
Carbazole	ID	5.00E-01	NR	2.09E-05	3.90E-06	7.03E-10	1.67E+02	1.00E-04	1.80E+00	4.05E+00	3.72E+00	1.0
Aromatic >EC16-EC21	NR	ND	0.00E+00	1.30E-02	1.00E-05	1.00E-09	1.90E+02	7.70E-01	5.10E-01	4.20E+00	4.70E+00	10.0
Aromatic >EC21-EC35	NR	ND	0.00E+00	6.80E-04	1.00E-05	1.00E-09	2.40E+02	4.40E-04	6.60E-03	5.11E+00	6.10E+00	1.0
Acenaphthylene	TDI	5.00E+00	6.00E-02	3.58E-03	4.40E-06	7.53E-10	1.52E+02	8.91E-01	1.61E+01	3.34E+00	4.00E+00	10.0
Phenanthrene	TDI	4.00E+01	6.00E-02	1.10E-03	3.30E-06	5.90E-10	1.78E+02	1.60E-02	4.68E-01	3.71E+00	4.46E+00	10.0
Pyrene	TDI	3.00E+01	6.00E-02	5.64E-05	5.01E-06	4.15E-10	2.02E+02	1.53E-05	1.30E-01	4.21E+00	5.08E+00	1.0
Benzofghi]perylene	TDI	3.00E+01	6.00E-02	2.36E-06	4.22E-06	3.56E-10	2.76E+02	1.55E-10	2.64E-04	5.62E+00	6.81E+00	1.0
Toluene	TDI	1.40E+03	5.20E+02	1.15E-01	7.78E-06	5.88E-10	9.21E+01	1.73E+03	5.90E+02	2.31E+00	2.73E+00	10.0

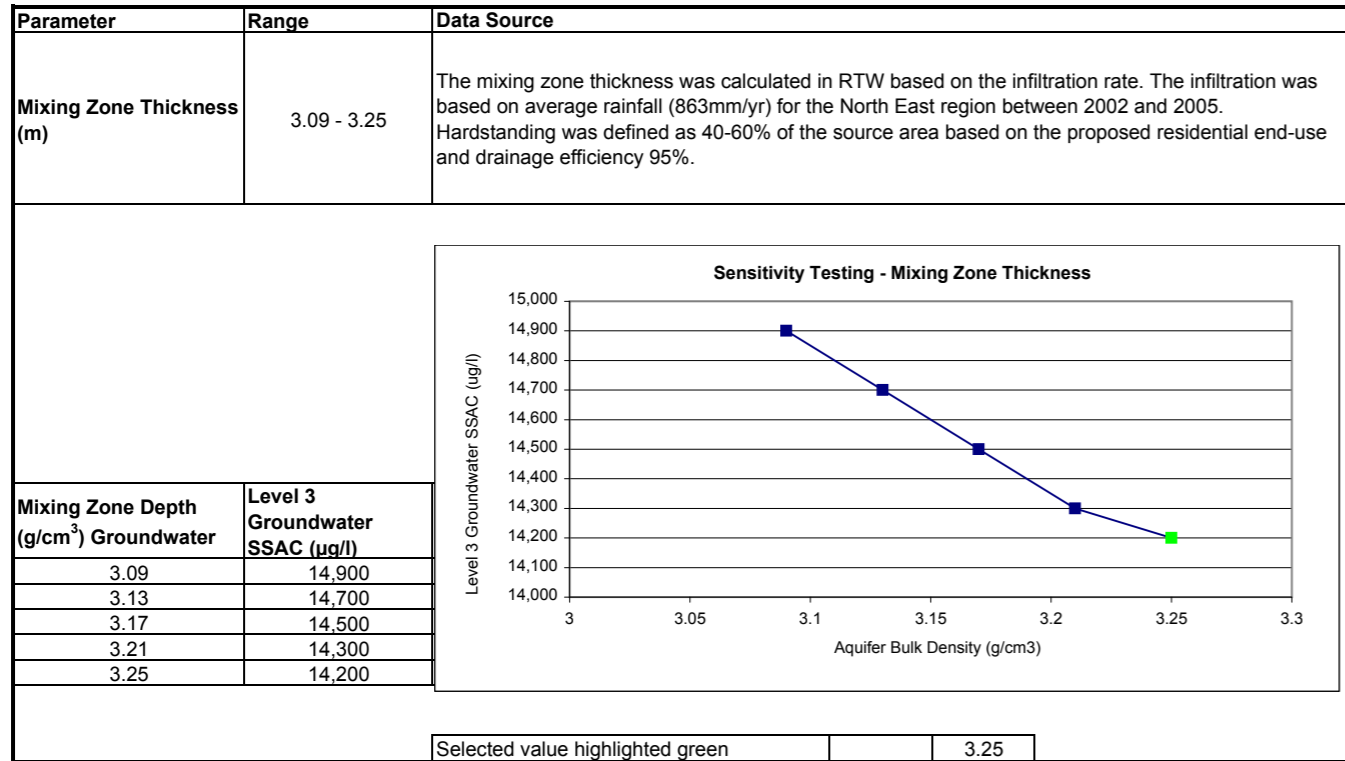
\* It is acknowledged that, for volatile petroleum hydrocarbons, the use of Henry's Law constant to predict the concentration of petroleum hydrocarbons in soil gas overpredicts the concentration by at least an order of magnitude (eg. EA, 2009a; Baker et al., 2009; Hartman, 2002). As such, for the vapour pathways modelled within in the CLEA model, the subsurface soil to indoor air attenuation factor was set to 10 for the volatile petroleum hydrocarbons.

Appendix I  
Sensitivity Testing – Human Health Assessment



Appendix J  
Sensitivity Testing – Water Resources Assessment





Parameter	Value	Source
<b>Unsaturated Zone Parameters</b>		
Lithology	Clayey Gravelly Sand	Site data.
Distance to building foundation from soil source (m)	0.35	Site data.
Distance to on-site building foundation from groundwater (m)	0.85	
Distance to ground surface from soil source (m)	0.5	
Distance to ground surface from groundwater (m)	1	
Vapour permeability (m <sup>2</sup> )	3.04 x 10 <sup>-12</sup>	Calculated in line with guidance (EA, 2009b) <sup>[1]</sup>
Air content in capillary fringe	0.01	Literature value for Sandy Loam (RISC) <sup>[2]</sup>
Thickness of capillary fringe (cm)	10	
<b>Source Zone Parameters</b>		
Lithology	Clayey Gravelly Sand	Site data.
Total porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.45	See Appendix I
Water content (cm <sup>3</sup> /cm <sup>3</sup> )	0.28	
Air-filled porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.17	
Residual soil water content (cm <sup>3</sup> /cm <sup>3</sup> )	0.1	Calculated in line with guidance (EA, 2009b) <sup>[1]</sup>
Soil bulk density (g/cm <sup>3</sup> )	1.5	See Appendix I
Fraction of organic carbon (-)	0.0645	See Appendix I
<b>Aquifer Parameters</b>		
Lithology	Gravelly Sand	Site data.
Hydraulic Conductivity (m/day)	10	See Appendix J
Hydraulic Gradient (-)	0.005	
Source Length (m)	20	
Source Width (m)	100	
Saturated Aquifer Thickness (m)	10	Site data.
Mixing Zone Depth (m)	3.25	See Appendix J
Bulk Density (g/m <sup>3</sup> )	1.6	
Effective Porosity	0.28	
<b>Outdoor Air Model Dimensions</b>		
Mean annual wind speed at 10m (m/s)	5	EA, 2009b <sup>[1]</sup>
Air dispersion factor at 0.8m (g/cm <sup>2</sup> s per kg/m <sup>3</sup> )	97	Calculated based on data for 2ha source area near Manchester (EA, 2009b) <sup>[1]</sup>
Air dispersion factor at 1.6m (g/cm <sup>2</sup> s per kg/m <sup>3</sup> )	160	
Fraction of site cover (m <sup>2</sup> /m <sup>2</sup> )	0.75	Estimated based on the site usage for commercial / residential end use (EA, 2009b) <sup>[1]</sup>
	0.25	Estimated construction worker exposure during site redevelopment works
<b>On-Site Outdoor Air Box Model Dimensions - Construction Workers</b>		
Box Height - Air Mixing Zone Height (m)	1.6	The height of 16-65 year old female (EA, 2009b) <sup>[1]</sup>
Wind speed (m/s)	3.01	Wind speed calculated at 1.6m above ground level based on method presented in RISC-HUMAN methodology. <sup>[3]</sup>
<b>On-site and Off-site Outdoor Air Box Model Dimensions - Residential Receptors</b>		
Box Height - Air Mixing Zone Height (m)	0.9	The height of 16-65 year old female (EA, 2009b) <sup>[1]</sup>
Wind speed (m/s)	2.39	Wind speed calculated at 0.9m above ground level based on method presented in RISC-HUMAN methodology. <sup>[3]</sup>
<b>On-Site Building Dimensions (Residential Property - House)</b>		
Building Type	House	See redevelopment plans (Appendix B)
Cross sectional area of building (m <sup>2</sup> )	73.6	See redevelopment plans (Appendix B)
Foundation Perimeter (m)	34.3	Calculated assuming square building footprint
Living space height (above ground) (m)	4.8	Small terraced house (EA, 2009b) <sup>[1]</sup>
Living space height (below ground) (m)	0.0	
Living space air exchange rate (hr <sup>-1</sup> )	0.5	Value selected from EA (2009b) - suitable for a residential building.
Pressure difference (soil to enclosed space) (Pa)	3.1	Small terraced house (EA, 2009b) <sup>[1]</sup>
Foundation Depth (m)	0.15	
Floor crack area (cm <sup>2</sup> )	686	Calculated based on redevelopment plans (see Appendix B)
Crack fraction	0.000932	
Porosity in foundation cracks	0.45	Defined source porosity
Water content in foundation cracks	0.28	
<b>On-Site Building Dimensions (Residential Property - Flat)</b>		
Building Type	Flat	See redevelopment plans (Appendix B)
Cross sectional area of building (m <sup>2</sup> )	50.2	See redevelopment plans (Appendix B)
Foundation Perimeter (m)	28.3	Calculated assuming square building footprint
Living space height (above ground) (m)	2.4	Bungalow (EA, 2009b) <sup>[1]</sup>
Living space height (below ground) (m)	0.0	
Living space air exchange rate (hr <sup>-1</sup> )	0.5	Value selected from EA (2009b) - suitable for a residential building.
Pressure difference (soil to enclosed space) (Pa)	2.6	Bungalow (EA, 2009b) <sup>[1]</sup>
Foundation Depth (m)	0.15	
Floor crack area (cm <sup>2</sup> )	566	Calculated based on redevelopment plans (see Appendix B)
Crack fraction	0.00113	
Porosity in foundation cracks	0.45	Defined source porosity
Water content in foundation cracks	0.28	

Notes:

<sup>[1]</sup> Environment Agency, 2009b. Updated technical background to the CLEA model. Science Report – SC050021/SR3.

<sup>[2]</sup> Spence L & BP Oil, 2001. Risk-Integrated Software for Clean-ups, RISC User's Manual

<sup>[3]</sup> Van Hall Institute, 1998, RISC-HUMAN version 3.0.

Appendix L  
Human Health Exposure Parameter Data

Appendix L  
Human Health Exposure Parameter Data

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

Exposure Parameter	Units	Site Resident	Construction Worker
Lifetime	years	75	75
Body Weight	kg	13.3	70
Inhalation Rate	m <sup>3</sup> /hour	0.494	0.617
Exposure Duration	years	6	0.5
<b>Inhalation of Indoor Air</b>			
Exposure Frequency	events/year	365	-
Time Indoors	hours/day	21.7	-
<b>Inhalation of Outdoor Air</b>			
Exposure Frequency	events/year	365	125
Time Outdoors	hours/day	1	9
<b>Direct Contact with Soil</b>			
Ingestion Rate	g/day	0.1	0.05
Soil to Skin Adherence Factor (indoor)	mg/cm.day	0.06	-
Soil to Skin Adherence Factor (outdoor)	mg/cm.day	1	0.14
Maximum Exposed Skin Fraction (indoor)	-	0.33	-
Maximum Exposed Skin Fraction (outdoor)	-	0.265	0.08

Notes:

Exposure parameter values presented for a 16-65 year old female and a 0-6 year old female child, representing a typical construction worker and resident respectively (EA, 2009b).

RBCA Exposure Factors – adjusted to account for difficulty with using toxicity data as an acceptable air concentration as opposed to a dose

Indoor Air – On Site Resident Exposure Frequency = 365 days/year

Outdoor Air – On Site Resident Exposure Frequency = 16.8 days/year

Appendix M  
Risk Assessment Methodology

## Appendix M Risk Assessment Methodology

### Non-statutory Regulatory Technical Guidance

The following documents, which have been consulted in undertaking this DQRA, present guiding principles in assessing potentially contaminated land:

General	<ul style="list-style-type: none"> <li>Model Procedures for the Management of Land Contamination, DEFRA &amp; EA (R&amp;D Publication CLR 11).</li> </ul>
Human Health	<ul style="list-style-type: none"> <li>Human health toxicological assessment of contaminants in soil. Environment Agency Science Report SC050021/SR2 (EA, 2009a),</li> <li>Updated technical background to the CLEA model. Environment Agency Science Report SC050021/SR3 (EA, 2009b),</li> <li>Compilation of data for priority organic pollutants for derivation of Soil Guideline Values. Environment Agency Science Report SC050021/SR7 (EA, 2008a).</li> </ul>
Water Resources	<ul style="list-style-type: none"> <li>Remedial Targets Methodology (RTM): Hydrogeological Risk Assessment for Land Contamination (EA, 2006).</li> </ul>

### Calculating Evaluation Criteria

#### Human Health

In order to derive human health evaluation criteria, or SSAC, an assessment of the level of human exposure to the CoC is undertaken, deriving a predicted daily average intake for each exposure pathway assessed. The predicted average daily intake is compared to an acceptable daily intake, or a health criteria value. This ratio of exposure to toxicity is defined as a Hazard Index, and for an individual chemical and exposure pathway:

$$HI_{ij} = ADE_{ij} / TDSI_{ij} \quad (\text{Threshold Compounds})$$

$$HI_{ij} = ADE_{ij} / ID_{ij} \quad (\text{Non-Threshold Compounds})$$

$HI_{ij}$  Hazard index for chemical i, exposure pathway j.

$ADE_{ij}$  Average daily intake for chemical i, exposure pathway j.

$TDSI$  or  $ID_{ij}$  Reference dose for chemical i, exposure pathway j.

Hazard indices above 1.0 indicate the potential for adverse health effects and suggest the need to undertake a further level of investigation or action. The human health SSAC are defined using a hazard index of 1.0 at the point of exposure and back-calculating, using fate and transport models where necessary, to determine the contaminant level which is acceptable beneath The Site in soils and/or groundwater.

Where appropriate the SSAC derived for the individual exposure pathways are then combined following the approach outlined in Science Report 3 (Environment Agency, 2009b), to give an additive SSAC which results in a sum hazard quotient of 1.0 across all modelled pathways for an environmental medium.

**Water Resources**

In order to estimate the risk to water resource receptors, fate and transport algorithms are used to predict a concentration at a defined receptor point, which is then compared to an appropriate water quality standard. A predicted concentration in excess of the water quality standard suggests the need to undertake a further level of investigation or action. Water resources SSAC are defined using a water quality standard at the point of compliance, then back-calculating to determine the contaminant level which is acceptable beneath The Site in soils and/or groundwater.

The SSAC can be compared to the measured concentrations of the CoC to evaluate whether unacceptable risks are present, and with which pollutant linkage or linkages the unacceptable risks are associated.

**Modelling Tools**

Modelling tools are developed to enable the calculations associated with fate and transport, exposure modelling and risk evaluation to be undertaken by risk assessors in a time-efficient manner, and producing defensible and consistent outputs.

**Human Health**

There are a number of modelling tools that have been developed to help quantify the potential risk posed to human health receptors, and can be adapted to incorporate the guidance presented within the EA guidance on assessing potential chronic health effects from land contamination. These include:

CLEA 1.06	CLEA 1.06 is an excel-based modelling tool implementing the guidance within the Contaminated Land Exposure Assessment (CLEA) methodology released by the EA. It enables quantification of levels and calculation of SSAC for CoC present in soils beneath a site. The model can also estimate the risk from measured concentrations from additional source media, including soil gas, but not from groundwater. The model is deterministic.
SNIFFER v.1.02	This excel-based modelling tool was developed by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) in 2003, and implements the guidance presented within the "Method for Deriving Site Specific Human Health Assessment Criteria for Contaminants in Soil" (SNIFFER, 2003). Since the Environment Agency of England and Wales released the updated guidance as part of the CLEA methodology in January 2009, the assumptions inherent within the SNIFFER model mean that it is less easy to adapt to the UK methodology for assessing land contamination. However, SNIFFER does not model vapour intrusion and vapour emission using appropriate sub-models – which are pathways of concern.

RISC v.5	<p>Risk Integrated Software for Clean-ups (RISC - version 5) is a proprietary modelling tool. Although originally based on the Risk Based Corrective Action (RBCA) methodology (ASTM International (ASTM) Designation E1739-95 and E2081-00), its flexibility allows it, in part, to be adapted to implement the guidance published by the Environment Agency.</p> <p>The tool can be used to model on-site exposure to a range of source media, including groundwater. The vapour migration pathway to indoor air is assessed via the Johnson and Ettinger sub-model, as recommended by the CLEA methodology.</p>
RBCA 2.5	<p>Risk Based Corrective Action Toolkit for Chemical Releases (RBCA – version 2.5) is a second proprietary modelling tool that incorporates the Risk Based Corrective Action (RBCA) methodology. It can be adapted to an extent to implement the guidance published by the Environment Agency, and the vapour migration pathway to indoor air is assessed via the Johnson and Ettinger sub-model, as recommended by the CLEA methodology. However the model compares the predicted air concentration to a defined acceptable air concentration, rather than calculating a dose and comparing to a tolerable daily soil intake for inhalation pathways. This requires alteration of the exposure duration within the model to ensure that the assumptions inherent in the CLEA methodology are incorporated into the assessment of the vapour migration pathways.</p>

### **Water Resources**

There are two commonly used modelling tools that have been developed to implement the guidance presented within the EA's Remedial Targets Methodology. These are:

RTW v.3.1	<p>The Remedial Target Worksheet (RTW) version 3.1 is an excel-based model tool produced by the EA to implement the guidance presented in the hydrogeological risk assessment methodology. RTW assesses the potential risk to a defined receptor point using a tiered analysis process (Level 1 soils – partitioning, Level 2 soils – dilution, Level 3 soils and groundwater – attenuation). RTW is a deterministic model.</p>
ConSim v.2.5	<p>Contamination Impact on Groundwater: Simulation by Monte Carlo Method, version 2.5 (ConSim), was developed by Golder Associates in association with the EA. ConSim is a probabilistic modelling tool, which implements the hydrogeological risk assessment guidance in a similar manner to RTW. However, ConSim allows a more detailed assessment of vertical migration pathways in the unsaturated zone, and, as such, is a useful tool for sites where groundwater is present at a considerable depth.</p>

Appendix K  
Physical and Building Input Parameter Values

Parameter	Value	Source
<b>Unsaturated Zone Parameters</b>		
Lithology	Clayey Gravelly Sand	Site data.
Distance to building foundation from soil source (m)	0.35	Site data.
Distance to on-site building foundation from groundwater (m)	0.85	
Distance to ground surface from soil source (m)	0.5	
Distance to ground surface from groundwater (m)	1	
Vapour permeability (m <sup>2</sup> )	3.04 x 10 <sup>-12</sup>	Calculated in line with guidance (EA, 2009b) <sup>[1]</sup>
Air content in capillary fringe	0.01	Literature value for Sandy Loam (RISC) <sup>[2]</sup>
Thickness of capillary fringe (cm)	10	
<b>Source Zone Parameters</b>		
Lithology	Clayey Gravelly Sand	Site data.
Total porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.45	See Appendix I
Water content (cm <sup>3</sup> /cm <sup>3</sup> )	0.28	
Air-filled porosity (cm <sup>3</sup> /cm <sup>3</sup> )	0.17	
Residual soil water content (cm <sup>3</sup> /cm <sup>3</sup> )	0.1	Calculated in line with guidance (EA, 2009b) <sup>[1]</sup>
Soil bulk density (g/cm <sup>3</sup> )	1.5	See Appendix I
Fraction of organic carbon (-)	0.0645	See Appendix I
<b>Aquifer Parameters</b>		
Lithology	Gravelly Sand	Site data.
Hydraulic Conductivity (m/day)	10	See Appendix J
Hydraulic Gradient (-)	0.005	
Source Length (m)	20	
Source Width (m)	100	
Saturated Aquifer Thickness (m)	10	Site data.
Mixing Zone Depth (m)	3.25	See Appendix J
Bulk Density (g/m <sup>3</sup> )	1.6	
Effective Porosity	0.28	
<b>Outdoor Air Model Dimensions</b>		
Mean annual wind speed at 10m (m/s)	5	EA, 2009b <sup>[1]</sup>
Air dispersion factor at 0.8m (g/cm <sup>2</sup> s per kg/m <sup>3</sup> )	97	Calculated based on data for 2ha source area near Manchester (EA, 2009b) <sup>[1]</sup>
Air dispersion factor at 1.6m (g/cm <sup>2</sup> s per kg/m <sup>3</sup> )	160	
Fraction of site cover (m <sup>2</sup> /m <sup>2</sup> )	0.75	Estimated based on the site usage for commercial / residential end use (EA, 2009b) <sup>[1]</sup>
	0.25	Estimated construction worker exposure during site redevelopment works
<b>On-Site Outdoor Air Box Model Dimensions - Construction Workers</b>		
Box Height - Air Mixing Zone Height (m)	1.6	The height of 16-65 year old female (EA, 2009b) <sup>[1]</sup>
Wind speed (m/s)	3.01	Wind speed calculated at 1.6m above ground level based on method presented in RISC-HUMAN methodology. <sup>[3]</sup>
<b>On-site and Off-site Outdoor Air Box Model Dimensions - Residential Receptors</b>		
Box Height - Air Mixing Zone Height (m)	0.9	The height of 16-65 year old female (EA, 2009b) <sup>[1]</sup>
Wind speed (m/s)	2.39	Wind speed calculated at 0.9m above ground level based on method presented in RISC-HUMAN methodology. <sup>[3]</sup>
<b>On-Site Building Dimensions (Residential Property - House)</b>		
Building Type	House	See redevelopment plans (Appendix B)
Cross sectional area of building (m <sup>2</sup> )	73.6	See redevelopment plans (Appendix B)
Foundation Perimeter (m)	34.3	Calculated assuming square building footprint
Living space height (above ground) (m)	4.8	Small terraced house (EA, 2009b) <sup>[1]</sup>
Living space height (below ground) (m)	0.0	
Living space air exchange rate (hr <sup>-1</sup> )	0.5	Value selected from EA (2009b) - suitable for a residential building.
Pressure difference (soil to enclosed space) (Pa)	3.1	Small terraced house (EA, 2009b) <sup>[1]</sup>
Foundation Depth (m)	0.15	
Floor crack area (cm <sup>2</sup> )	686	Calculated based on redevelopment plans (see Appendix B)
Crack fraction	0.000932	
Porosity in foundation cracks	0.45	Defined source porosity
Water content in foundation cracks	0.28	
<b>On-Site Building Dimensions (Residential Property - Flat)</b>		
Building Type	Flat	See redevelopment plans (Appendix B)
Cross sectional area of building (m <sup>2</sup> )	50.2	See redevelopment plans (Appendix B)
Foundation Perimeter (m)	28.3	Calculated assuming square building footprint
Living space height (above ground) (m)	2.4	Bungalow (EA, 2009b) <sup>[1]</sup>
Living space height (below ground) (m)	0.0	
Living space air exchange rate (hr <sup>-1</sup> )	0.5	Value selected from EA (2009b) - suitable for a residential building.
Pressure difference (soil to enclosed space) (Pa)	2.6	Bungalow (EA, 2009b) <sup>[1]</sup>
Foundation Depth (m)	0.15	
Floor crack area (cm <sup>2</sup> )	566	Calculated based on redevelopment plans (see Appendix B)
Crack fraction	0.00113	
Porosity in foundation cracks	0.45	Defined source porosity
Water content in foundation cracks	0.28	

Notes:

<sup>[1]</sup> Environment Agency, 2009b. Updated technical background to the CLEA model. Science Report – SC050021/SR3.

<sup>[2]</sup> Spence L & BP Oil, 2001. Risk-Integrated Software for Clean-ups, RISC User's Manual

<sup>[3]</sup> Van Hall Institute, 1998, RISC-HUMAN version 3.0.

Appendix N  
Sensitivity Testing – Building Parameters

Appendix N  
Sensitivity Testing - Building Parameters  
N1. Buildings Considered

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

	Smallest Flat	Largest Flat	Smallest House	Largest House
Building footprint (m <sup>2</sup> )	50.2	64	73.6	120.4
Building perimeter (m)	28.3	32	34.3	43.9
Air exchange (l/hr)	0.5	0.5	0.5	0.5
Building height above ground (m)	2.4*	2.4*	4.8**	4.8**
Building height below ground (m)	0	0	0	0
Pressure difference (Pa)	2.6*	2.6*	3.1**	3.4***
Foundation thickness (m)	0.15	0.15	0.15	0.15
Floor Crack Area (cm <sup>2</sup> )	566	640	686	878
Crack fraction (-)	0.00113	0.001	0.000932	0.000729

\* The building height and pressure difference values for a bungalow seem appropriate for a flat and have been adopted.

\*\* The building height and pressure difference values for a small terraced house have been adopted.

Appendix N  
Sensitivity Testing - Building Parameters  
N2. Sensitivity Results

Detailed Quantitative Risk Assessment  
Land off Forge Lane, Dewsbury  
962340126\_01 / September 2011

	Soil SSAC (mg/kg)			
	Smallest Flat	Largest Flat	Smallest House	Largest House
Aliphatics >C5-C6	88.1	94.3	176	203
Benzene	98.2	103	84.1	88
Naphthalene	1.15	1.22	0.398	0.406

\* Building includes basement  
 Most stringent building type, selected for further assessment.

Appendix O  
Modelling Outputs



RBCA SITE ASSESSMENT

Site Name: Forge Lane  
 Site Location:

Completed By: Emily Cray  
 Date Completed: 28-Jul-11

Job ID: 96234.01 IA Flat

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-5  
 Target Hazard Quotient 1.0E+0

Groundwater DAF Option:

SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)

CONSTITUENTS OF CONCERN		Representative Concentration (mg/L)	<input type="checkbox"/> Groundwater Ingestion / Discharge to Surface Water			<input checked="" type="checkbox"/> Groundwater Volatilization to Indoor Air			<input type="checkbox"/> Groundwater Volatilization to Outdoor Air			Applicable SSTL (mg/L)	SSTL Exceeded ? "■" if yes	Required CRF Only if "yes" left
			On-site (0 m)	Off-site 1 (0 m)	Off-site 2 (0 m)	On-site (0 m)	Off-site 1 (0 m)	Off-site 2 (0 m)	On-site (0 m)	Off-site 1 (0 m)	Off-site 2 (0 m)			
CAS No.	Name		None	None	None	Residential	None	None	None	None	None	(mg/L)		
91-20-3	Naphthalene *	1.0E+0				4.0E+0						4.0E+0	<input type="checkbox"/>	<1
7664-41-7	Ammonia	1.0E+0				1.3E+1						1.3E+1	<input type="checkbox"/>	<1

\* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent solubility value. NA = Not applicable. NC = Not calculated.

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		Ammonia		from Level 1
Target Concentration	C <sub>T</sub>	1.50E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value)

	Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C <sub>0</sub>	1.00E+00	mg/l	
Half life for degradation of contaminant in water	t <sub>1/2</sub>	1.50E+03	days	
Calculated decay rate	λ	4.62E-04	days <sup>-1</sup>	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+02	m	
Plume thickness at source	Sy	3.25E+00	m	
Saturated aquifer thickness	da	1.00E+01	m	
Bulk density of aquifer materials	ρ	1.60E+00	g/cm <sup>3</sup>	
Effective porosity of aquifer	n	2.80E-01	fraction	
Hydraulic gradient	i	5.00E-03	fraction	
Hydraulic conductivity of aquifer	K	1.00E+01	m/d	
Distance to compliance point	x	2.50E+02	m	
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	9.00E+99	days	time variant options only
<i>Parameters values determined from options</i>				
Partition coefficient	Kd	6.50E-01	l/kg	see options
Longitudinal dispersivity	ax	2.50E+01	m	see options
Transverse dispersivity	az	2.50E+00	m	see options
Vertical dispersivity	ay	2.50E-01	m	see options

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	1.79E-01 m/d
Retardation factor	Rf	4.71E+00 fraction
Decay rate used	λ	4.62E-04 d <sup>-1</sup>
Rate of contaminant flow due to retardation	u	3.79E-02 m/d
minant concentration at distance x, assuming one-way vertical dispersion	C <sub>ED</sub>	1.68E-02 mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	6.01E+01

Remedial Targets

Remedial Target	Value	Unit	For comparison with measured groundwater concentration.
Remedial Target	9.02E-01	mg/l	

Select Method for deriving Partition Co-efficient (using pull down menu)

User specified value for partition coefficient

Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	6.50E-01	l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon in aquifer	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for related species	K <sub>oc,n</sub>		l/kg	
Sorption coefficient for ionised species	K <sub>oc,i</sub>		l/kg	
pH value	pH			
acid dissociation constant	pKa			
Fraction of organic carbon in aquifer	foc		fraction	
Soil water partition coefficient	Kd	6.50E-01	l/kg	

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

	Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	ax	4.50E+01	2.50E+01	6.88E+00
Transverse dispersivity	az	4.50E+00	2.50E+00	6.88E-01
Vertical dispersivity	ay	4.50E-01	2.50E-01	6.88E-02

Note values of dispersivity must be > 0  
 For calculated value, assumes ax = 0.1 \* x, az = 0.01 \* x, ay = 0.001 \* x  
 Xu & Eckstein (1995) report ax = 0.83(log<sub>10</sub>x)<sup>2.414</sup>; az = ax/10, ay = ax/100 are assumed

Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	#N/A
Completed by:	#N/A
Date:	#####
Version:	1

## Hydrogeological risk assessment for land contamination Remedial Targets Worksheet , Release 3.1

**Date of Workbook Issue: October 2006**

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

**Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.**

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.  
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Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

**IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).**

### Details to be completed for each assessment

<b>Site Name:</b>	Forge Lane		
<b>Site Address:</b>	Thornhill Lees, West Yorkshire, WF12 9EN		
<b>Completed by:</b>	Emily Cray		
<b>Date:</b>	18-Aug-11	<b>Version:</b>	1
<b>Contaminant</b>	Ammonia		
<b>Target Concentration (C<sub>T</sub>)</b>	0.015	mg/l	<b>Origin of C<sub>T</sub>:</b> EQS

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

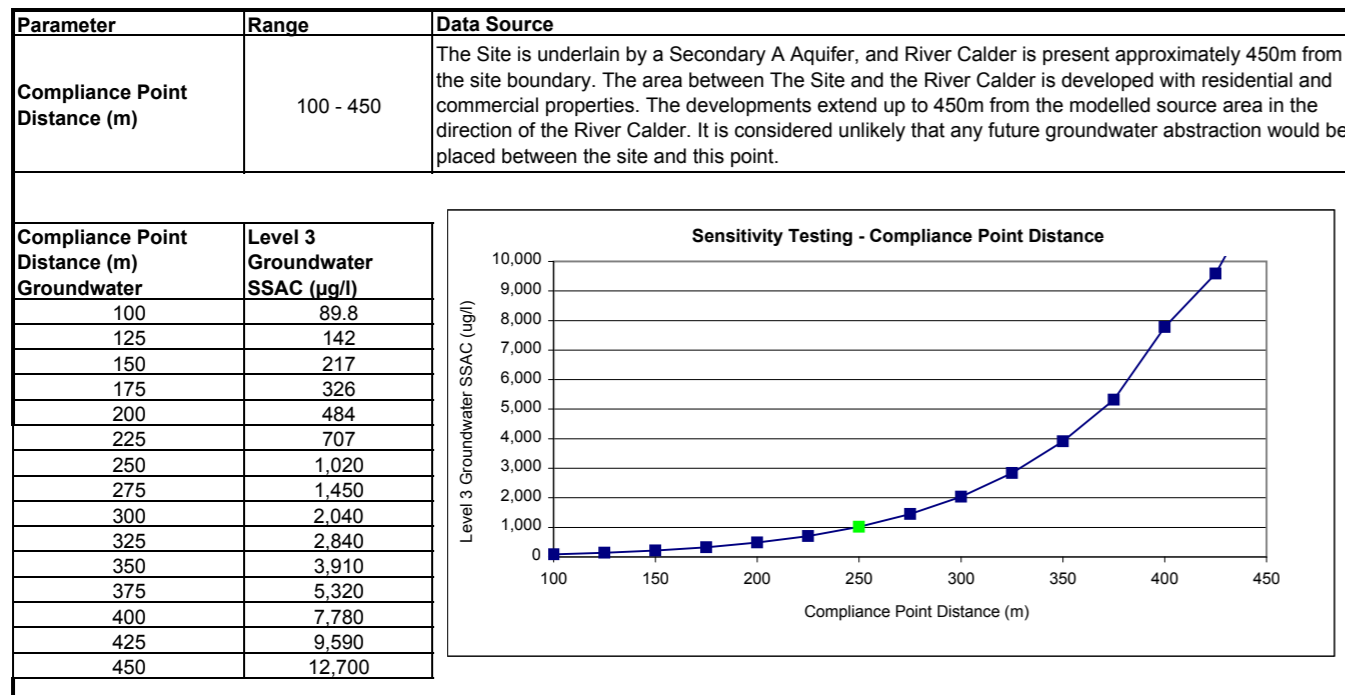
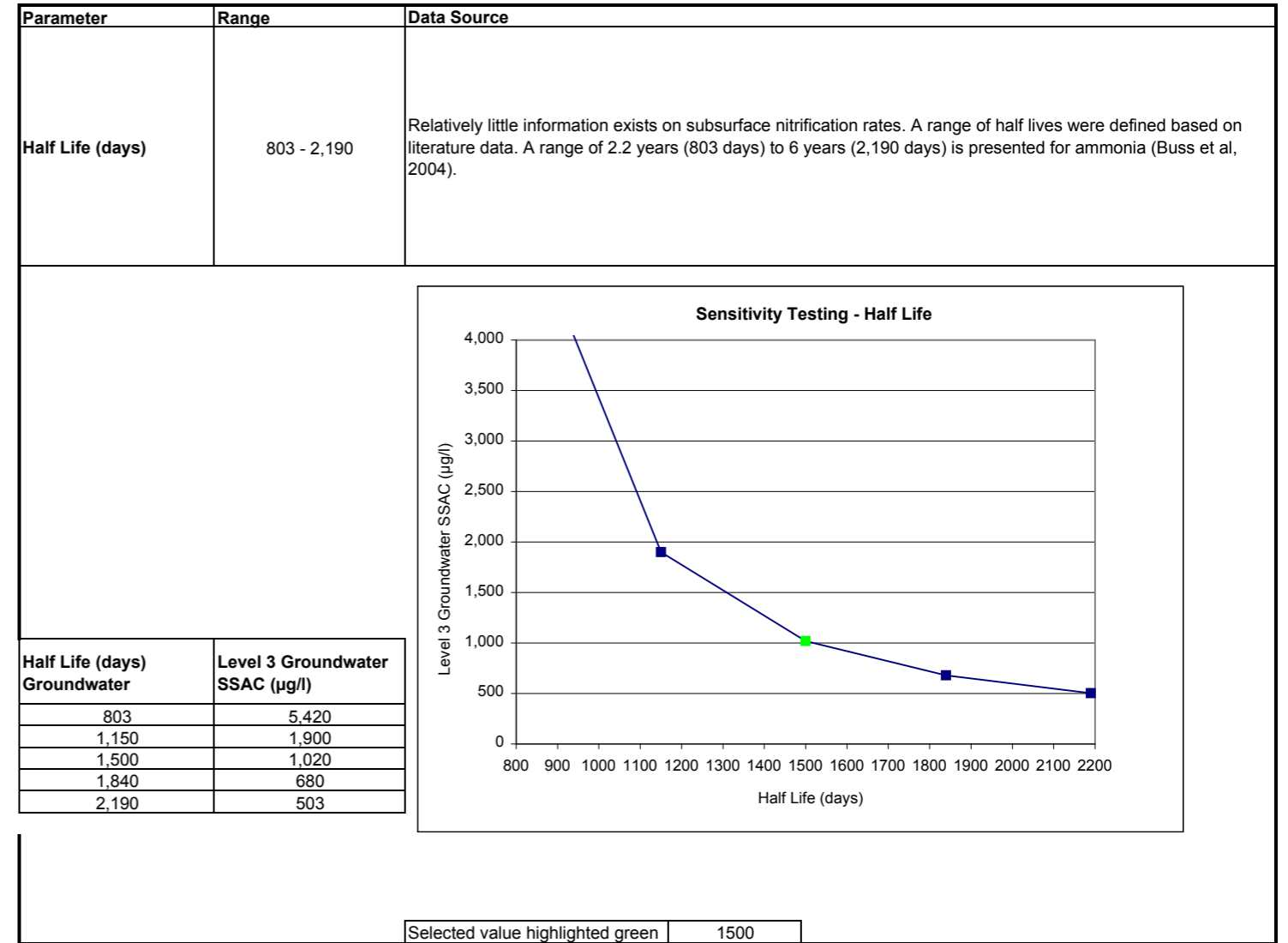
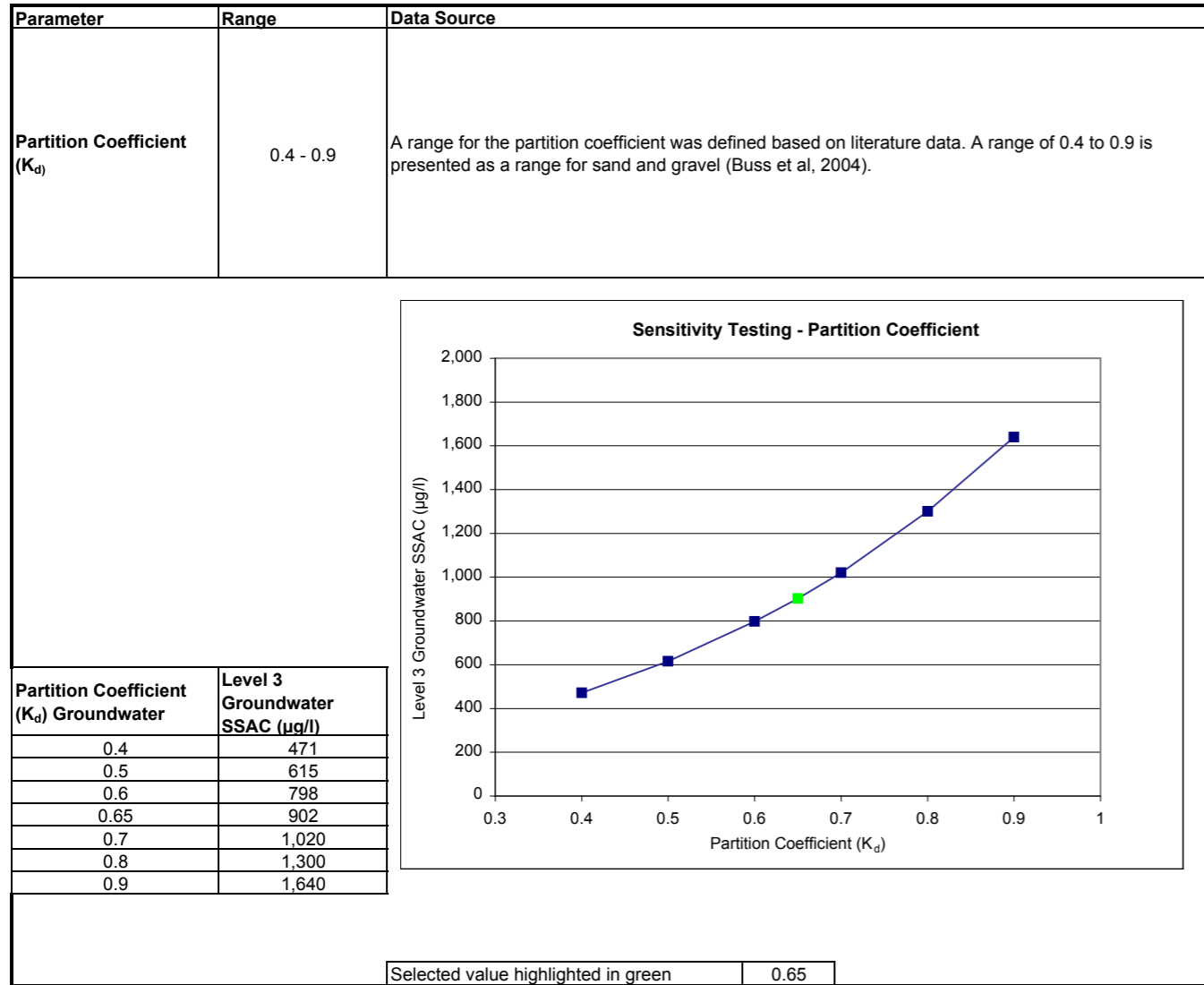
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Appendix P  
Further Sensitivity Testing



Selected value highlighted green	250m
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