

Crymlyn Tip Coed Darcy

Human Health Risk Assessment

St Modwen Developments Ltd
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eNGLOBE

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Prepared by:

pp. 

Peak Environmental Solutions Ltd

Reviewed by:



Andrew Bates

Project Director

Englobe Regeneration UK

Approved by:



Martin Holmes

Operations Director

Englobe Regeneration UK

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1 Introduction and Approach

The human health risk assessment (HH-RA) has been undertaken to consider the risks that are likely to be posed by the restored land after completion of the proposed works detailed in the Englobe Remedial Implementation Plan (RIP) for the site. The RIP works include landform reprofiling and provision of any required/necessary capping layers and a final site wide restoration layer.

The purpose of the risk assessment is to provide supporting technical evidence to assist with the regulatory approval of the RIP works within the town and country planning regime.

For the purposes of the HH-RA, the restored land will be considered as an area of 'public open space' (POS) without immediately adjacent residential land use. The site includes waste materials within the closed 'Coed Darcy Tip' in the eastern area (currently regulated via an environmental permit).

Information on the site layout, site history, currently permitted area, site history, details of past/recent investigation/remedial works, permit surrender requirements and the proposed permit Closure and Aftercare Management Plan (Closure Plan) are detailed elsewhere in EnGlobe's documentation; this information is not repeated by the assessment.

The HH-RA includes an initial preliminary risk assessment (PRA) to identify relevant pollutant linkages (RPLs) and subsequent more detailed considerations of published generic assessment criteria and detailed site-specific human health quantitative numerical modelling. The capping & restoration layers will provide a robust cover over underlying materials, including the waste materials.

The PRA, combined with the detailed generic/quantitative assessments, have been used as the technical basis for the selection of a range of human health assessment criteria (HH-AC); the HH-AC will then be considered by the RIP.

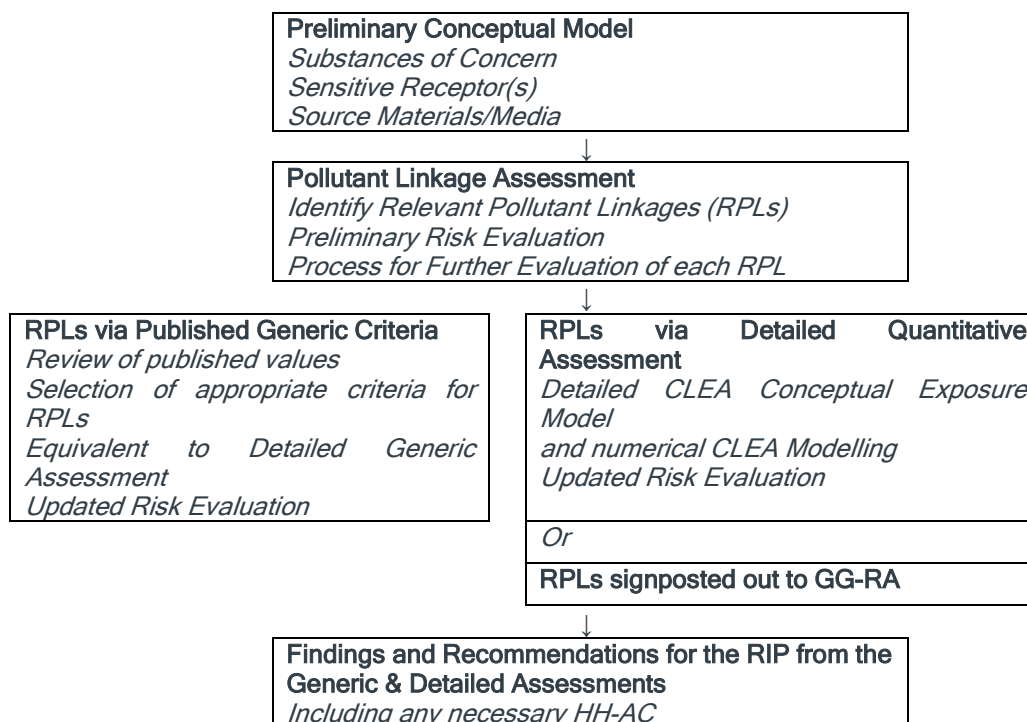
For ground gases, trace gases and vapour-phase volatile organic compound (VOCs), a number of the HH-RA pollutant linkages will be addressed by an appropriate Ground Gas Risk Assessment (GG-RA), which will also include VOCs within 'trace gases'. For selected pollutant linkages, the PRA will signpost out of the HH-RA and refer the reader solely to the GG-RA; for other selected linkages (where the HH-RA may

also be subservient to the GG-RA), additional assessment work is provided in the HH-RA to be used alongside the GG-RA.

Non-aqueous phase liquids (NAPLs) are also documented at the site and NAPL sources will be considered in the PRA; lateral NAPL migration will be mitigated by the RIP works.

The PRA is detailed in Section 2.0, with the detailed assessments and HH-AC discussed in Sections 2.6 & 3.0 and presented in the Appendices.

In summary, the HH-RA has adopted the following overall approach:



The assessment has been prepared under the umbrella management framework provided by non-statutory UK guidance available online gov.uk 'Land Contamination: Risk Management (LCRM)'. The LCRM guidance is based on the now withdrawn CLR-11 'Model Procedures for the Management of Land Contamination'.

The HH-RA has been undertaken within the 2009 SR3 CLEA (contaminated land exposure model) framework. The 2009 CLEA methodology has been amended to take into account relevant conceptual model updates outlined in documents associated with the 2015 LQM/CIEH Suitable for Use Levels (S4ULs), the Phase 1 & 2 2014/21 Category 4 Screening Levels (C4SL) and CLEA model v1.071 with associated handbook Version 1.05. Additional human health guidance for the assessment of VOC-vapour/gas risks has been drawn from guidance provided by the EA, British Standards, SoBRA, CL:AIRE, CIRIA, CIEH and other world-wide sources; selected technical references are provided in Appendix B.

The risk assessment should only be used by competent persons for its intended purpose and it is beyond the scope of this report to present a detailed summary of the risk assessment methodologies, supporting documents and their technical basis. The risk assessment was finalised in December 2022 and should be read in the light of any subsequent changes in legislation, statutory requirements, statutory & non-statutory guidance, relevant research and industry practices.

Selected technical and literature references are provided in Appendix B.



2 Preliminary Conceptual Model

2.1 Overview

The preliminary conceptual model considers contaminants & hazards in source media and their associated exposure/migration pathways through which the contaminants/hazards could impact upon sensitive human health receptors relevant to the restored land. The conceptual model has then been used to identify the plausible relevant pollutant linkages (RPLs).

The pollutant linkage assessment process (*LCRM 'S-P-R assessment'*) considers the following components:

- Receptors** Identify sensitive human health receptor(s)
- Sources** Identify source media and contaminant 'substances of concern'
- Pathways** Identify plausible migration/exposure pathways linking sources to receptor(s)

Note-1: the general term contaminant used to cover LCRM 'source, contaminant and pollutant'

Note-2: 'relevant pollutant linkage' is used in favour of LCRM term 'contaminant linkage'

2.2 Human Health Sensitive Receptors

The PRA considers the following potentially sensitive receptors for the restored land:

Receptors on the Restored Land

- Intermittent Outdoor Worker

There is no planned commercial use of the restored land and there are no plans for permanent site buildings; any outdoor working is likely to be infrequent, probably similar to warden, security and grounds-keeper type roles.

In the absence of a specific scenario for this use, a CLEA-type commercial land use based around intermittent to full-time outdoor working could be adopted.

The outdoor worker excludes groundworkers. Specific risks to groundworkers would be addressed by separate risk assessments and method statements under HS&E obligations.

- Use by Public

Final arrangements for formal public access to the restored land are to be finalised.

A C4SL land use for public open space for public parks (POS-2) will be adopted.

Receptors on Adjacent/Nearby Land to South and East

- Users and occupiers of adjacent/nearby land to the south and east.

Immediately adjacent land to the south and east is proposed to be POS type land use.

The nearby land will be assumed to potentially include future commercial, residential and POS type land uses.

CLEA/C4SL type commercial, residential and POS land uses could be adopted.

Adjacent/Nearby Land to South and East

- There are no users of potential concern on adjacent/nearby land to north & west.

To the north and west is an extensive natural habitat area known as Crymlyn Bog.

There are no plausible human health receptors of concern associated with the Crymlyn Bog area.

No known public rights of way cross the area.

2.3 Substances of Concern

The substances of concern considered by the assessment are detailed in Table 1.

Table 1 - Substances & Hazards of Potential Concern

Potential Substances of Concern	Non-Volatile or Insufficiently Volatile	Sufficiently Volatile
Total petroleum hydrocarbons Risk banded TPH fractions	Aliphatic & Aromatic C16-C35 fractions are insufficiently volatile	Aliphatic C5-C16 fractions Aromatic C8-C16 fractions (see below)
Benzene, toluene ethylbenzene, xylene isomers (BTEX)	-	BTEX <i>Benzene is solely aromatic C5-6 Toluene is solely aromatic C7-8 Ethylbenzene/Xylenes in Aromatic C8-10</i>
16-PAHs	15-PAHs are considered insufficiently volatile	Naphthalene <i>also in Aromatic 10-12</i>
Phenols	-	Phenols <i>Note: phenol could be taken as Insufficiently-volatile</i>
Other Speciated VOC/SVOC	Speciated SVOCs Typically, insufficiently volatile	Speciated VOCs
Arsenic, cadmium, chromium, copper, inorganic lead, mercury, nickel, selenium, vanadium and zinc	Non-volatile (inorganic species)	-
Easily liberatable cyanide and total cyanide	Non-volatile	-
Asbestos/ACMs	Non-volatile	-
Soil pH (as a soil hazard)	Non-volatile	-
Notes: The rationale with respect to sufficiently volatility is summarised in Appendix B.		
Other Potential Hazards of Concern		
Ground Gases: methane, carbon dioxide, carbon monoxide & H ₂ S. Depleted oxygen		
Trace Gases / VOCs Vapours		

Note-1: Benzene and toluene have their own aromatic C5-C7 & C7-C8 fractions (i.e. there are no other substances in these fractions); ethylbenzene & xylene isomers, 16-PAHs and other PAHs will also be detected within the aromatic C8 to C12+ fractions. It is important to ensure that potential 'double accounting' issues are considered when interpreting TPH/BTEX/PAH results.

Note-2: All banded/speciated GC/MS TPH testing methodologies inherently use Equivalent Carbon (EC) numbers based on boiling point. The carbon banding terminology (e.g. Aromatic C12-C16) used in the assessment is based on EC banding and can be used with all banded TPH testing results, irrespective of whether the testing is compliant with the TPH-CWG methodology.

2.4 Source Materials

The following restored land source materials/layers ('source media') are considered by the preliminary conceptual model.

At Surface / Near Surface (*Surface Materials*)

- Restoration Layer Materials.
- Capping Layer Materials.

Deeper Layers (*Sub-Surface Materials*)

- Waste Deposit Materials.
- Non-Waste Materials.
- Natural Soil Materials.

Liquid, Gas and Vapour Sources/Hazards (*Non-Soil Materials/Hazards*)

- NAPL within sub-surface materials.
- Groundwater (GW) within sub-surface materials.
- Soil Vapour (SVap) within surface materials.
- Soil Vapour (SVap) within sub-surface materials.
- Ground Gases within sub-surface materials.

2.5 Human Health Exposure Pathways

The relevant/plausible exposure pathways for the adopted human health receptors are provided below and are drawn from the standard CLEA/C4SL conceptual models:

For Surface Materials

- Ingestion of surface materials and derived dusts.
- Outdoor dermal contact with surface materials and derived dusts.
- Outdoor inhalation of respirable airborne dusts derived from surface materials.
- Outdoor inhalation of VOC vapours generated by sufficiently volatile substances diffusing out from surface layer materials and mixing with ambient air.
- *Ambient air dust/vapours generated by surface materials could also be inhaled by receptors on adjacent/nearby land after lateral advection and dispersion/dilution.*
- *Includes SVap sources within surface materials.*

For Sub-Surface Materials (including relevant Non-Soil Materials)

- Vertical soil VOC vapour and ground/trace gas migration and mixing with ambient air; soil VOC vapours and ground/trace gases generated by sub-surface source materials, with migration up and through the Surface Materials. Followed by subsequent inhalation by receptors on the restored land; the ambient air vapours/trace/gases could also then be inhaled by receptors on adjacent/nearby land after lateral advection and dispersion/dilution.
- Lateral in-ground unsaturated zone migration (beyond the site boundary) of soil VOC vapours and ground/trace gases generated by sub-surface source materials. Subsequent diffusion to surface and inhalation by receptors on adjacent/nearby land.
- *Includes NAPL, GW, SVap and Ground gas sources within sub-surface materials.*

The EnGlobe controlled waters risk assessment work (see Englobe documentation) has established that groundwater flow is northwards towards Crymlyn Bog. Given the absence of plausible human health receptors within the Crymlyn Bog habitat area, the PRA has not needed to consider human health pathways associated with northerly groundwater flow. The PRA has also not needed to consider human health pathways associated with potential lateral NAPL migration as this will be mitigated by the RIP works.

2.6 Preliminary Linkage Assessment and Risk Evaluation

A pollutant linkage assessment has been undertaken to characterise the RPLs and includes the following elements:

Receptors → Sources → Plausible Pathways → Identified Human Health RPLs

Tables 2 & 3 summarise the sources, the identified RPLs, the preliminary risk evaluation & assessment (PRA) and the recommended next step for each identified RPL.

In summary, the recommendations for the five RPLs identified by the PRA (RPL-1 to RPL-5) are as follows:

RPL-1 for Surface Materials

- *The risks will be addressed via a generic assessment using UK published generic criteria for relevant/applicable land uses(s).*
- *See Section 3.0.*

RPL-2 for VOC Vapours associated with Sub-Surface Materials

- *The risks will be addressed via a detailed CLEA quantitative risk assessment.*
- *See Section 3.0.*

RPLs 3 to 5 for Ground Gas & Trace Gases associated with Sub-Surface Materials

- *The risks posed by these are RPLs are addressed in the GG-RA.*
- *These RPLs are not considered further by the HH-RA.*
- *Please refer to the GG-RA for the risk assessments for these RPLs.*

Notes

- *Note-1: the substances of concern are detailed in Table 1.*
- *Note-2: the human health RPLs requiring detailed CLEA assessment relate to vapour inhalation pathways and the detailed assessment only need to consider sufficiently volatile substances of concern. The rationale with respect to sufficiently volatility is summarised in Appendix B.*
- *Note-3: the risk classification matrix is provided in Table 4.*

Table 2 - Receptors on Restored Land: RPLs and Preliminary Risk Evaluation

Source Materials Averaging Areas	RPL Ref	Human Health Pathways	Consequence	Likelihood	Preliminary Risk Evaluation	RPL of Concern?	Recommended Approach for RPL to address Level of Concern
Surface Materials <i>(Including SVap)</i>	RPL-1	Soil/soil-dust ingestion Outdoor dermal contact Outdoor dust inhalation Outdoor vapour inhalation	Medium	Likely	Moderate Risk	Of concern	Address RPL via a generic risk assessment using UK published generic criteria
Vapours from <i>Sub-Surface Materials</i> <i>Non-Soil Materials</i> <i>(NAPL & GW)</i>	RPL-2	Outdoor vapour inhalation	Mild	Likely	Low to Moderate	Of concern	Address RPL via a detailed CLEA quantitative risk assessment
Ground/Trace Gases from <i>Sub-Surface Materials</i> <i>(Non-Soil Hazard)</i>	RPL-3	Outdoor inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via the GG-RA

Table 3 - Receptors on Adjacent/Nearby Land: RPLs and Preliminary Risk Evaluation

Source Materials Averaging Areas	RPL Ref	Human Health Pathways	Consequence	Likelihood	Preliminary Risk Evaluation	RPL of Concern?	Recommended Approach for RPL to address Level of Concern
<i>Vertical Migration</i>							
Dusts/Vapours from Surface Materials	Via RPL-1	Advection/dispersion, then Outdoor dust inhalation Outdoor vapour inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via a generic risk assessment using UK published generic criteria
Vapours from <i>Sub-Surface Materials Non-Soil Materials (NAPL & GW)</i>	Via RPL-2	Advection/dispersion, then Outdoor vapour inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via a detailed CLEA quantitative risk assessment
Ground/Trace Gases from <i>Sub-Surface Materials (Non-Soil Hazard)</i>	Via RPL-3	Advection/dispersion, then Outdoor inhalation	Minor	Likely	Low Risk	Limited concern	Address RPL via the GG-RA
<i>Lateral Migration</i>							
Surface Materials	No RPLs	No plausible pathways	-	-	No Risk	No concern	No further Risk Assessment Required
Vapours from <i>Sub-Surface Materials Non-Soil Materials (NAPL & GW)</i>	RPL-4	Lateral in-ground migration then, migration to surface and vapour inhalation	Minor	Likely	Low Risk	Limited concern	Address RPLs via the GG-RA
Ground/Trace Gases from <i>Sub-Surface Materials (Non-Soil Hazard)</i>	RPL-5	Lateral in-ground migration, then, migration to surface/ near-surface to pose hazard	Mild	Likely	Low to Moderate	Of concern	

Table 4 - Qualitative Risk Classification Matrix

Probability (likelihood)	Consequence			
	Minor	Mild	Medium	Severe
High likelihood	Low risk	Moderate risk	High risk	Very High Risk
Likely	Low risk	Low to moderate risk	Moderate risk	High risk
Low likelihood	Very low risk	Low risk	Low to moderate risk	Moderate risk
Unlikely	Very low risk	Very low risk	Low risk	Low to moderate risk
No Pollutant Linkage	No potential risk			



3 Further Assessments and Recommendations

The generic and detailed assessments and the findings for RPL-1 and RPL-2 are provided in Appendix A and B.

Recommendations for RPL-1

The proposed HH-AC for consideration by the RIP for surface materials with respect to the risks posed by RPL-1 are presented in Appendix A Table A1.

If the surface materials are suitably validated to chemical specification criteria that include appropriate consideration of the HH-RA, then the human health risks posed by RPL-1 for the restored land should be very low and can be considered to be acceptable.

Should other speciated VOC/SVOC or inorganic substances of potential concern be encountered in surface materials during the RIP works, then the RIP can draw upon appropriate criteria (or surrogate/proxy criteria) drawn from the S4UL/C4SL/EIC references.

Appendix A also includes further advisory commentary on the use of the RPL-1 HH-AC.

Recommendations for RPL-2

The detailed assessment concluded that the substances of concern in sub-surface materials pose a very low risk via RPL-2 and that the level of risk can be considered to be acceptable.

As such, it is not considered necessary for the RIP to provide soil, soil-vapour, groundwater or NAPL HH-AC for the sub-surface materials with respect to RPL-2.

Appendix A

Human Health Generic Assessment For RPL-1



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APPENDIX-A

A1.0 HUMAN HEALTH GENERIC ASSESSMENT FOR RPL-1

A1.1 Overview

The PRA identified RPL-1 with respect to the surface material sources and receptors on the restored land & adjacent/nearby land. The PRA identified low to moderate risks associated with RPL-1 and considered that these risks were of sufficient potential concern to require further human health assessment via a generic risk assessment approach.

The generic assessment for RPL-1 has been undertaken to address the potential significance of the long term (chronic) risks to human health (and where necessary short term (acute) risks) posed by selected substances of concern that may be present in the final surface materials on the restored site.

The PRA established the following for RPL-1 with respect to the surface material sources, substances of concern, receptors and relevant exposure pathways:

- Surface Materials.
 - Restoration Layer Materials.
 - Capping Layer Materials.
- Substances of Concern.
 - A broad range of inorganic and volatile to non-volatile organic substances.
 - Detailed in Table A1.
 - Note: no plausible Ground/Trace Gas Hazards are associated with surface materials.
- Future Receptors for the Restored Land.
 - Users of the Restored Land.
 - Users/Occupiers of Adjacent / Nearby Land to the East and South.
- Exposure Pathways for Receptors on the Restored Land.
 - Ingestion of surface materials and derived dusts.
 - Outdoor dermal contact with surface materials and derived dusts.
 - Outdoor inhalation of respirable airborne dusts derived from surface materials.
 - Outdoor inhalation of VOC vapours generated by sufficiently volatile substances diffusing out from surface layer materials and mixing with ambient air.
- Exposure Pathways for Receptors on Adjacent /Nearby Land.
 - Outdoor inhalation of respirable airborne dusts (as above, but after lateral advection and dispersion/dilution).
 - Outdoor inhalation of VOC vapours (as above, but after lateral advection and dispersion/dilution).

The generic assessment comprises an initial step of identifying potentially relevant UK published generic criteria for relevant/applicable land uses(s). From these criteria, a range of human health assessment criteria (HH-AC) have then been selected for consideration by the RIP in the setting of any necessary chemical specification criteria for the surface materials on the restored land.

If the surface materials are then suitably validated to the adopted RIP chemical specification criteria (which include appropriate consideration of the HH-RA), then the human health risks posed by RPL-1 for the restored land should be very low and can be considered to be acceptable.

A1.2 Relevant Criteria

Relevant published generic soil criteria can be selected from the following UK resources/references:

- 2015 LQM/CIEH GACs: 'suitable for use levels' (S4UL); latest revision August 2015.
- Current EA/DEFRA GACs: 'soil guideline values' (SGV).
- 2009 EIC GACs; published by CL:AIRE.
- DEFRA funded 'Research Project Phase-1' C4SLs; most recently revised in December 2014.
- SAGTA funded 'Phase-2 Technical Report' C4SLs; most recently published by CL:AIRE in 2021.
- 2020 SoBRA Acute Generic Risk Criteria.
- Higher published values (e.g. greater than 1,000 mg/kg to 10,000 mg/kg [0.1 to 1 % w/w]) should only be adopted as HH-AC after reasonable consideration (taking into account wider project objectives) to prevent excessive contaminant loadings in surface materials.

The available GACs (which include SGVs & S4ULs) are scientifically based screening criteria, generally derived using the EA CLEA computer model in general accordance with the CLEA framework. Should soil concentrations be at or below a GAC relevant to the land use, then the long-term health risks (or short term for any acute risk criteria) may be considered to be minimal/tolerable.

The assessment considers that following 'standard' CLEA/S4UL/C4SL land uses are relevant to the restored land use:

- Public Open Space: Public Parks.
- The conceptual model for this land use is provided by the C4SL methodology.
- The land use is characterised as an area of open space provided for recreational uses, informal sporting activities (but no dedicated sports facilities/pitches) and dog walking. No permanent buildings within this land use.
- The critical receptor for this land use is a female child, with the duration of the exposure duration over CLEA age classes AC 1 to AC 6 (0 to 6 years old).
- The tracking back of soils into residential dwelling and workplaces is considered negligible under the C4SL land use conceptual model.

- Commercial use.
- The conceptual model for this land use is provided by CLEA SR3 with some receptor amendments provided by the C4SL methodology.
- This is typically characterised as office/retail workplace with mainly indoor working and some outdoor working (overall light physical work). The critical receptor for this land use is a female worker with exposure duration over CLEA age classes AC 17 (ages 16 to 65).
- Note-1: These land uses include all the active RPL-1 exposure pathways.
- Note-2: The commercial land use includes indoor exposure pathways.
- Note-3: These land uses are considered to be risk protective of the public use of the restored land along with intermittent outdoor working on the land.
- Note-4: Criteria for these land uses will be risk protective of users / occupiers on adjacent land as the active relevant exposure pathways for these receptors are only dust/vapour inhalation (after further advection/dilution).

The generic criteria have generally been calculated within the broad contaminated land exposure assessment (CLEA) methodology framework, with amendments to the CLEA approach adopted within the S4UL and C4SL methodologies.

The 2015 soil S4ULs have been adopted in preference to SGVs as the S4ULs reflect appropriate recent changes to toxicological profiles and exposure conceptual model amendments.

The C4SLs for the Part 2A contaminated land regime provides a limited number of criteria that can be used within the town and country planning regime. The published C4SLs provide criteria that should lie within Part 2A Category 4, but would be expected to be generally closer to the Category 3/4 boundary than 'low/minimal risk' GAC/S4UL/SGV, i.e., the C4SLs describe a 'low level' of risk and are intended to provide a 'higher simple test' for deciding whether land is suitable for use under the planning regime and definitely not Contaminated Land under Part 2A.

The 2015 soil S4ULs have generally been adopted in preference to the published soil C4SL as the S4ULs reflect a lower ('minimal/tolerable' versus 'low') level of risk compared to the C4SL. The exceptions are BaP & lead-Pb (where the C4SL values are adopted) and cyanides & asbestos, which are discussed below. The EIC GACs have been used for a number of other VOCs.

The candidate criteria for the two land uses are presented in Table A1 for a 1% SOM (soil organic matter).

For PAHs, Public Health England (Ref: 2017) generally recommends the use of a coal tar benzo a pyrene (BaP) surrogate marker approach for assessing carcinogenic/genotoxic risks posed by 8 of the 16 PAHs in soils and this approach has been adopted using the available C4SL BaP coal tar criteria.

The adopted easily liberatable cyanide reference criteria are based on a precautionary approach for acute risk via the 2020 SoBRA values for oral pathways (where easily liberatable (free) cyanide is the primary cyanide species of concern). Where both easily liberatable (free) and total cyanide results are available, only easily liberatable (free) cyanide results would normally be used. Where only total cyanide results are available, using the free cyanide criteria would be considered highly risk protective.

The selected phenol HHAC considers potential acute risk exposures. A nominal acid/alkaline soil pH range has also been adopted to flag a potential for skin irritancy via direct dermal contact.

Selected technical references are provided in Appendix B.

A2.0 SELECTION OF HH-AC FOR SURFACE MATERIAL

The proposed HH-AC for consideration by the RIP for surface materials with respect to the risks posed by RPL-1 are presented in Table A1.

The proposed HH-AC for asbestos/ACMs in soil is based on a pragmatic implementation process to allow the RIP to sufficiently demonstrate the absence of visible ACMs and the general absence of detectable ACMs in soil, whilst allowing for some sporadic occurrences of detectable very low asbestos concentrations in soil (but without visible ACMs).

If the surface materials are suitably validated to chemical specification criteria that include appropriate consideration of the HH-RA, then the human health risks posed by RPL-1 for the restored land should be very low and can be considered to be acceptable.

Should other speciated VOC/SVOC or inorganic substances of potential concern be encountered in surface materials during the RIP works, then the RIP can draw upon appropriate criteria (or surrogate/proxy criteria) drawn from the S4UL/C4SL/EIC references.

A3.0 ADVISORY COMMENTARY ON THE USE OF HH-AC

The RIP use of soil criteria based on the HH-ACs must be based on professional good judgement taking into account a range of project/site specific and wider considerations and should not be based solely on the comparison of the HH-ACs with soil data.

There may be additional considerations in the setting of the RIP criteria for surface materials based on risks to other sensitive receptors, such as controlled waters and plants/ecology on the restored land.

It is important that any RIP criteria based on the HH-AC are used carefully when comparing with soil data and that their use appropriately takes into account the adopted sampling strategy and the technical basis of the HH-AC. Any RIP criteria based on HH-AC would be expected to be compared to average or representative source/averaging-area concentrations, rather than maximum or isolated elevated/peak levels. Where a HH AC represents a very low concentration (e.g. near to or less than method detection limit), due consideration should be given to adopting the method detection limit and/or other practical/pragmatic criteria. Background levels in the area may also need to take into account when selecting the RIP criteria.

As previously noted, 'high' concentration published reference values should only be adopted as HH-AC after reasonable consideration (taking into account wider project objectives) to avoid excessive contaminant loadings in materials.

As a general note: an exceedance of an HH-AC should not immediately imply that a substance is not 'compliant' with the criteria or that a substance poses an unacceptable risk to human health; rather an exceedance implies that some form of further consideration may be warranted. A further judgement can be made within a risk appraisal on an appropriate way to address any exceedances (this could include no further action). Where a number of exceedances are identified, further statistical consideration (e.g. using CL:AIRE 2020) and/or quantitative risk assessment may be warranted to determine whether average/representative concentrations are in excess of a risk based criteria. Where all of the detected substance concentrations are less than the HH AC, then this would normally be taken as a very strong indicator that the substance is 'compliant' with the HH AC.

Table A1: RPL-1 Candidate Reference Criteria and Proposed HH-AC in mg/kg

Substance	Reference Criteria		Proposed HH-AC
	POS-2: Parks	Commercial Use	
Arsenic	170	640	170
Cadmium	560	190	190
Chromium (as III)	33,000	8,600	8,600
Copper	44,000	68,000	10,000 (reduced from 25,000) ⁽¹⁾
Lead (inorganic)	1,300	2,300	1,300
Mercury (inorganic)	240	1,100	240
Nickel	800	980	800
Selenium	1,800	12,000	1,800
Vanadium	5,000	9,000	5,000
Zinc	170,000	730,000	10,000 (reduced from 170,000) ⁽¹⁾
Easily Liberatable Cyanide	100 (SoBRA Acute)	100 (SoBRA Acute)	24
Asbestos/ACM in Soil	-	-	No visible ACM, plus: Not identified at Stage-1 OR $\leq 0.001\%$ at Stage-2 With allowance for sporadic $<0.005\%$ w/w Consider Sum-TPH value in RIP based on Hazard Quotient ≤ 1 and TPH composition in surface materials.
Sum TPH Fractions	Hazard Quotient ≤ 1	Hazard Quotient ≤ 1	
Aliphatic TPH C5-6	3,200	95,000	3,200 ⁽²⁾
Aliphatic TPH C6-8	7,800	150,000	7,800 ⁽²⁾
Aliphatic TPH C8-10	2,000	14,000	2,000 ⁽²⁾
Aliphatic TPH C10-12	9,700	21,000	9,700 ⁽²⁾
Aliphatic TPH C12-16	59,000	25,000	10,000 (reduced from 25,000) ^(1,2)
Aliphatic TPH C16-35	160,000	450,000	10,000 (reduced from 160,000) ^(1,2)
Aliphatic TPH C35-44	160,000	450,000	10,000 (reduced from 160,000) ^(1,2)
Aromatic TPH C8-10	3,500	7,200	3,500 ⁽²⁾
Aromatic TPH C10-12	16,000	9,200	9,200 ⁽²⁾
Aromatic TPH C12-16	36,000	10,000	10,000 ⁽²⁾
Aromatic TPH C16-21	28,000	7,600	7,600 ⁽²⁾
Aromatic TPH C21-35	28,000	7,800	7,800 ⁽²⁾
Aromatic TPH C35-44	28,000	7,800	7,800 ⁽²⁾
TPH C44-70	28,000	7,800	7,800 ⁽²⁾
Sum 16-PAHs	-	-	<i>The RIP could use an additional Sum-16 value to help simplify the PAH criteria</i>
Naphthalene	190	1,200	190
Acenaphthylene	83,000	29,000	1,000 (reduced from 29,000) ⁽¹⁾

Acenaphthene	84,000	29,000	1,000 (reduced from 29,000) ⁽¹⁾
Fluorene	63,000	20,000	1,000 (reduced from 20,000) ⁽¹⁾
Phenanthrene	2,000	6,200	1,000 (reduced from 2,000) ⁽¹⁾
Anthracene	520,000	150,000	1,000 (reduced from 150,000) ⁽¹⁾
Fluoranthene	23,000	6,300	1,000 (reduced from 6,300) ⁽¹⁾
Pyrene	54,000	15,000	1,000 (reduced from 15,000) ⁽¹⁾
Benzo(a)anthracene	77 Via BaP (C4SL)	21 Via BaP (C4SL)	21 ⁽³⁾
Chrysene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Benzo(a)pyrene			
Indeno(1,2,3-cd)pyrene			
Dibenz(a,h)anthracene			
Benzo(ghi)perylene			
Total Phenols	440	440	440
Other VOC/SVOC/Inorganics	S4UL/C4SL/EI C	S4UL/C4SL/EI C	If required, the RIP can use other S4UL/C4SL/EIC values
Soil pH (as skin irritant)	5 to 9	5 to 9	Within normal soil range 5 to 9 ⁽⁴⁾

Notes: (1) reduced down to prevent excessive contaminant loadings; (2) where practicable, the speciated TPH fraction criteria should be used in conjunction with a sum-TPH value; use the 'unreduced' criteria number in the calculation; (3) C4SL (marker for 8 genotoxic PAHs), do not sum the 8-PAH, only compare against BaP; (4) applies to soils and not applicable in the case of crushed aggregates and concrete.

Appendix B

RPL-2 Detailed Assessment



ENGLOBE

APPENDIX - B

RPL-2 DETAILED ASSESSMENT

B1.0 HUMAN HEALTH DETAILED ASSESSMENT FOR RPL-2

B1.1 PRA Overview for RPL-2

The PRA identified RPL-2 for outdoor VOC vapour inhalation with respect to sub surface sources and receptors on the restored land & adjacent/nearby land. The PRA identified low to moderate risks associated with RPL-2 and considered that these risks were of sufficient potential concern to require further human health assessment via a CLEA detailed risk assessment approach.

The RPL-2 detailed assessment has been undertaken to address the potential significance of the long term (chronic) risks to human health posed by relevant sufficiently volatile organic substances of concern in the sub-surface materials on the restored land.

The PRA established the following for RPL-2 with respect to the surface material sources, substances of concern, receptors and relevant exposure pathways:

- Sub-Surface Materials.
- Waste Deposit Materials.
- Non-Waste Materials.
 - Natural Soil Materials.
- Plus: NAPL, groundwater and soil vapour within sub-surface materials.
 - Substances of Concern.
- Sufficiently volatile organic substances.
- Detailed in Table B1, including BTEX, naphthalene and volatile TPH fractions.
 - Future Receptors for the Restored Land.
- Users of the Restored Land.
- Users/Occupiers of Adjacent / Nearby Land to the East and South.
 - Exposure Pathways.
 - Vertical soil VOC vapour migration and mixing with ambient air.
- Soil VOC vapours generated by sub-surface source materials, with migration up and through the Surface Materials.
- Followed by subsequent inhalation by receptors on the restored land.
- The ambient air VOC vapours could also then be inhaled by receptors on adjacent/nearby land after lateral advection and dispersion/dilution.

B1.2 Outline of Detailed Assessment Methodology

The RPL-2 detailed assessment comprises an initial step of identifying whether sufficient levels of soil vapours (as mg/m³ in unsaturated zone soil pores) could theoretically be generated 'at source' by the sub-surface sources to be able pose a risk to the receptors via

outdoor vapour inhalation. This initial step has then been used to decide if additional modelling is then necessary for provide soil source modelling outputs (in mg/kg) and groundwater source modelling outputs (as mg/l) and to address NAPL sources.

The outcome of the detailed assessment has then been used to provide recommendations (and criteria, if/where necessary) for consideration by the RIP with respect to RPL-2 and sub surface sources.

The detailed assessment has been undertaken within the 2009 DEFRA/Environment Agency (EA) SR3 CLEA (contaminated land exposure model) framework. The 2009 CLEA methodology has been amended to take into account relevant conceptual model updates outlined in documents associated with the 2015 LQM/CIEH Suitable for Use Levels (S4ULs), the 2014 DEFRA funded Category 4 Screening Levels (C4SL) and DEFRA CLEA model v1.071 with associated CLEA handbook Version 1.05. Additional human health guidance for the assessment of VOC-vapour/gas risks has been drawn from guidance provided by the EA, British Standards, SoBRA, CL:AIRE, CIRIA, CIEH and other world-wide sources. Selected technical references are provided in Appendix B1.

The detailed assessment first step includes the following elements:

1. Substances of concern.
2. Selection of health criteria values (HCV) and chemical parameters.
3. Conceptual exposure model (CEM) that details the required pathway-specific exposure and fate & transport parameters.
4. Soil $\rightarrow$ vapour source modelling using an Excel CLEA compliant spreadsheet model.
5. Review of findings and recommendations for next step in the assessment of RPL-2.

The findings of the detailed assessment should only be used by competent persons for its intended purpose. It is beyond the scope of the assessment to present a detailed explanation of the underlying conceptual models, methodologies, supporting documents and their technical basis.

B1.3 CLEA Modelling Software

The modelling has been undertaken using a bespoke Excel spreadsheet model that is compliant with the S4UL/CLEA-SR methodologies/algorithms and provides outputs benchmarked to the soil S4UL GACs and the SoBRA Groundwater GACs (both of which were generated using the EA CLEA Excel based model).

The bespoke CLEA model was developed by Peak Environmental Solutions Limited (PESL) and has been in use now for over a decade and has been benchmarked and updated over that time to keep in line with the UK good-practice approach to human health risk assessment. The bespoke model will be referred to as CLEA-PESL/2021 in this report.

A summary of the residential/commercial use benchmarking against selected published S4UL soil criteria and SoBRA groundwater criteria is provided at the end of Appendix B2 and demonstrates a very good correlation with the EA model; minor discrepancies are due to the significant figure rounding approach adopted by S4UL and SoBRA.

B2.0 CONCEPTUAL EXPOSURE MODEL

B2.1 Overview

The baseline outdoor vapour inhalation CEM is drawn from the current S4UL conceptual approaches, including default/baseline receptor & pathway assumptions and associated HCV, MDI and physiochemical parameters. The S4UL approach reflects the original CLEA guidance & conceptual exposure models detailed in SC050021 SR2, SR3, SR4 & SR7 and the associated original toxicological and soil guideline documents. The S4UL approach incorporates appropriate risk protective amendments to the CLEA approach drawn from the 2014 C4SL methodology and provided in EA Excel CLEA Model v1.071 & associated User Manual v1.05.

The S4UL methodology, which was published after the C4SL, continues the CLEA GAC/SGV approach based around 'tolerable'/'minimal' risk levels. This compares with the 'low level' of risk adopted by the C4SL methodology, which potentially provides a less cautious approach compared to the S4UL methodology. As such, the S4UL methodology only adopted C4SL changes to the CLEA-SR3 approach that were in keeping with the 'tolerable'/'minimal' risk ethos used in GAC/SGV calculation.

Justifications for the underlying S4UL conceptual approach are provided by the current S4UL documentation, which includes the main 2015 hard-copy publication, plus online FAQs and errata at www.lqm.co.uk/publications/s4ul. A detailed discussion of the S4UL/CLEA/C4SL conceptual approaches is beyond the scope of this appendix and the reader is assumed to be appropriately conversant with these methodologies. Additional detailed information on the CLEA conceptual models and pathways are provided by the CLEA Info-Maps available on the SoBRA website (sobra.org.uk/resources/other-publications/).

The CEM provides the modelling parameters, characterises the substances of concern, the critical receptor, the exposure scenario, ground conditions, source terms and averaging areas. To match the input requirements of the pathway algorithms, the CEM consists of the following elements:

- Critical receptor characteristics (worst case adopted).
- Pathway exposure models and parameters.
- Source terms & soil type properties.

Any relevant amendments and/or deviations to the baseline S4UL conceptual approach are provided in the following sections, along with additional commentary on the S4UL/C4SL conceptual approaches where relevant. A S4UL/CLEA/C4SL standard approach of considering a non-diminishing source has been adopted.

The full set of modelling parameters are included in Appendix B2.

B2.2 Substances of Concern, Health Criteria & Chemical Parameters

The sufficiently volatile substances of concern are detailed in Table B1. The rationale for sufficiently volatility is provided in the additional technical notes in Appendix B3.

The UK published HCV used in the CLEA modelling are adult tolerable daily intakes (TDI) for threshold substances and index doses (ID) for non-threshold substances, both drawn from the S4UL/C4SL methodologies.

The average adult mean daily intake (MDI) for the threshold health criteria are generally drawn from the S4UL/C4SL methodologies. For the TPH fractions, more reasonable MDIs have been

adopted in favour of the highly cautious (equivalent to 50% of the TDI) nominal MDI values adopted by the S4UL approach. The rationale for the adopted MDIs for the TPH fractions is provided in Appendix B3.

The chemical specific parameters required for the CLEA modelling are predominantly drawn from S4UL methodology, with additional parameters where required from EA-SR7, EA-TOX/SGV, EIC and C4SL resources.

Table B2 summarises the sources of the toxicological data, MDI and physiochemical parameters used in the CLEA modelling. The adopted parameters are presented in Appendix B2.

Table B1 - Detailed Assessment Human Health Substances of Concern

PRA Substance Group	Modelled Substances: Sufficiently Volatile
Risk banded TPH fractions	Aliphatic C5-C16 fractions Aromatic C8-C21 fractions
BTEX	BTEX <i>Benzene is solely aromatic C5-6; Toluene is solely aromatic C7-8</i> <i>Ethylbenzene/ Xylenes also in Aromatic C8-10</i>
16 PAHs	Naphthalene <i>Also in Aromatic C10-12</i>
Phenol	Phenol <i>Note: could be taken as Insufficiently-volatile</i>
Notes: - Benzene and toluene have their own aromatic C5-C7 & C7-C8 fractions (i.e. there are no other substances in these fractions); ethylbenzene & xylene isomers, PAHs will also be detected within the aromatic C8 to C12+ fractions. - All banded/speciated GC/MS TPH testing methodologies inherently use Equivalent Carbon (EC) numbers based on boiling point. The carbon banding terminology (e.g. Aromatic C12-C16) used in the assessment is based on EC banding and can be used with all banded TPH testing results, irrespective of whether the testing is compliant with the TPH-CWG methodology.	

Table B2 - Sources of Chemical Specific Parameters

Substances of Concern	Toxicity Type	HCV, MDI & Physiochemical Parameters
Aliphatic C5-C16 fractions Aromatic C8-C16 fractions	Threshold TDI	S4UL/TPHCWG See Appendix B3 for MDI calculations
Benzene	Non-Threshold ID	C4SL/EA Only substance in Aromatic C5-7 fraction
Toluene	Threshold TDI	S4UL/EA Only substance in Aromatic C7-C8 fraction
Ethylbenzene	Threshold TDI	S4UL/EA Substances also within Aromatic C8-10
Xylenes	Threshold TDI	
Naphthalene	Threshold TDI	S4UL/EA Substance also in Aromatic C10-12 For soil-vapour, could be considered via Aromatic C10-12 fraction
Phenol	Threshold TDI	S4UL/EA

B2.3 Critical Receptor Characteristics

The exposure characteristics for the adopted critical receptor is based on the standard S4UL exposures models. The S4UL baseline scenarios represent a CLEA-SR3/C4SL hybrid approach where selected changes to the CLEA-SR3 conceptual models have been adopted from the C4SL conceptual approach, (i.e. namely those that fit with the ethos of GAC/SGV calculation under the CLEA framework).

A principle change for vapour pathways under C4SL (and adopted by S4UL) was a revision of the CLEA-SR3 inhalation rates across all CLEA age classes. The C4SL/S4UL inhalation rates are based on 2011 mean USEPA values, which replaced the 2009-SR3 CLEA values (these were based on 2006 USEPA draft review values). The female child daily inhalation rates went down (increasing model outputs) and the female adult daily inhalation rates went up (decreasing modelling outputs).

To provide a 'worst case' assessment for the initial vapour source modelling, the adopted critical receptor is as follows:

- Young Female Child.
- Aged to 0 to 6: CLEA age classes AC 1 to 6.
- S4UL/C4SL body weights & daily inhalation rates.
- Full outdoor occupancy on the restored land.
- 24 hours per day, 365 days per year.
- Occupancy under a POS-2 or commercial land use would be significantly lower.
- The child receptor will be risk-protective for adult receptors on the restored land.
- The child receptor will be risk-protective for receptors on adjacent/nearby land.

The remainder of the baseline S4UL conceptual exposure models and receptor characteristics remain unchanged and have been adopted by the assessment. The adopted critical receptor characteristics are presented in the modelling results in Appendix B2.

B2.4 Outdoor Vapour Inhalation Pathway Model

A restored land area of 12 hectares has been adopted for the outdoor air vapour inhalation pathway, with the source modelled under all of the restored land area. No lateral vapour dilution or further advection has been considered for the receptors on adjacent/nearby land (i.e. risk protective). Note: larger site areas will generate higher outdoor VOC vapour ambient air concentrations from sub surface soils; this means that the CLEA model will provide lower soil vapour modelling outputs as the site area increases.

Cardiff has been adopted as the closest and most appropriate of the available CLEA SR3 locations for providing the necessary wind characteristics for the ambient air element of the outdoor air vapour inhalation pathway model.

A CLEA 'sandy loam soil' (as used for the S4UL/C4SL generic criteria) has been adopted for the modelling. Of the available standard soil types, the CLEA sandy loam soil (which is actually a hybrid sandy loam / loamy sand soil type) provides the next lowest modelling outputs after a CLEA 'sand soil'. Although a CLEA sand soil may superficially seem a better fit for granular non-natural materials, our experience is that the CLEA sandy loam soil (~ 70% coarse / 30% cohesive/fines) provides a more balanced modelling approach more in keeping with the range of sub surface materials, rather than using perfectly uniform CLEA sand with a very limited cohesive/fine fraction (<5% by weight).

The soil vapour modelling outputs are not dependant on soil SOM; so, although the modelling sheets in Appendix B2 provides a SOM value of 1%, this parameter will not affect the soil vapour modelling outputs. The theoretical soil vapour saturation limits ($C_{sat\ vap}$, see next section) are not dependent on either SOM or the soil type. The required specific soil properties are presented in Appendix B2.

The minimum modelled source depth is 1 m (at the approximate top of the sub-surface materials), with further modelling outputs provided for 2.5 m, 5 m and 10 m source depths. Note: the predicted in ground soil vapour levels are all on the same depth-dependant diffusion curve governed by the CLEA sub-surface soil-vapour diffusion model.

As the source separation is ≥ 1 m, the CLEA 'sub-surface' soil model has been used for the outdoor air vapour inhalation pathway (see CLEA SR4 equation 4.1).

The outdoor air vapour inhalation conceptual model is summarised in Table B3, with the required specific detailed pathway parameters provided in Appendix B2.

Table B3 - Summary of the Outdoor Vapour Inhalation Conceptual Model

Modelling Element	Outdoor Vapour Inhalation Sub-Surface Source
Modelled Area	12 Hectares
Conceptual Approach	Modelled vertically: source beneath all the restored land
Soil Types	CLEA Sandy Loam and CLEA Sand
Source Separation	1 m, 2.5 m, 5 m and 10 m
Wind Characteristics	CLEA Wind database values for Cardiff
CLEA Receptor Height for Wind Characteristics	Child: 0.8 m

B2.5 Soil Vapour Saturation Limits

The CLEA methodology includes a number of checks to highlight partitioning boundary conditions that can be used to assist in the interpretation of the CLEA modelling outputs.

For soil vapour source modelling, the saturated soil vapour concentration ($C_{sat-vap}$, at ambient soil temperature) is a fundamental substance-specific physiochemical saturation limit that is not dependant on soil type, soil SOM or the source of the vapours (i.e. $C_{sat-vap}$ applies to soil, soil-vapour, groundwater and NAPL sources).

The $C_{sat-vap}$ provides a theoretical upper limit for a vapour concentration in the soil pore for a substance that cannot be exceeded. In real soils, the achievable upper saturated vapour limit would be expected to be significantly lower than the $C_{sat-vap}$ concentration. The substance specific $C_{sat-vap}$ concentration is calculated using inherent chemical-specific properties via SR3 Equation 5.13 using a nominal CLEA ambient soil temperature of 283K (9.85°C).

Under the CLEA approach, relying on a CLEA vapour-driven criteria (e.g. for vapour, soil and groundwater) that requires the source soil vapour concentrations to be $>C_{sat-vap}$ would be expected to overestimate the risks posed by the substance. Where a CLEA vapour-driven modelling criteria is based on a source soil vapour concentration $>C_{sat-vap}$, then under the CLEA approach, it is unlikely that the substance could pose an unacceptable risk via the modelled CSM.

The density of air at STP is $\sim 1.2 \text{ kg/m}^3$ ($\sim 1,200,000 \text{ mg/m}^3$); as such it also needs to be remembered that at a CLEA model output vapour concentration of $120,000 \text{ mg/m}^3$ would equate to about 10% by weight of air at STP. In addition, model outputs of soil vapour concentrations in excess of $1,000,000 \text{ mg/m}^3$ are theoretically problematic in real soils, irrespective of the $C_{sat-vap}$ concentration.

The substance specific $C_{sat-vap}$ concentrations are provided in Table B4, with the modelling parameters provided in Appendix B2.

B3.0 CLEA MODELLING RESULTS

The CLEA modelling outputs are summarised in Table B4 and presented in full in Appendix B2. The values have been rounded as appropriate, with values in provided brackets where they are above theoretical saturation limits.

The results above vapour saturation must be used with caution, taking into account the discussion on saturation limits in the previous section.

Table B4 - Soil Vapour Outdoor Air Modelling Outputs in mg/m³

Substance	Csat-Vap	1 m	2.5 m	5 m	10 m
Benzene (Aro C5-C7)	207,000	2,040	5,090	10,200	20,400
Toluene (Aro C7-C8)	67,700	>Sat (971,000)	>Sat (2,420,000)	>Sat (4,850,000)	>Sat (9,710,000)
Ethylbenzene	24,900	>Sat (56,400)	>Sat (141,000)	>Sat (282,000)	>Sat (564,000)
Xylene Isomers	21,400	>Sat (41,800)	>Sat (105,000)	>Sat (209,000)	>Sat (418,000)
Naphthalene	126	>Sat (556)	>Sat (1,390)	>Sat (2,780)	>Sat (5,560)
Aliphatic TPH C5-C6	75,400	>Sat (2,190,000)	>Sat (5,470,000)	>Sat (10,940,000)	>Sat (21,900,000)
Aliphatic TPH C6-C8	14,600	>Sat (2,190,000)	>Sat (5,470,000)	>Sat (10,940,000)	>Sat (21,900,000)
TPH Aliphatic C8- C10	17,600	>Sat (128,000)	>Sat (321,000)	>Sat (642,000)	>Sat (1,280,000)
TPH Aliphatic C10-C12	2,180	>Sat (128,000)	>Sat (321,000)	>Sat (642,000)	>Sat (1,280,000)
TPH Aliphatic C12-C16	130	>Sat (128,000)	>Sat (321,000)	>Sat (642,000)	>Sat (1,280,000)
TPH Aromatic C8-C10	16,300	>Sat (20,300)	>Sat (50,700)	>Sat (101,000)	>Sat (203,000)
TPH Aromatic C10-C12	1,770	>Sat (20,200)	>Sat (50,400)	>Sat (101,000)	>Sat (202,000)
TPH Aromatic C12-C16	73	>Sat (19,500)	>Sat (48,700)	>Sat (97,400)	>Sat (195,000)
Phenol	460	104	259	>Sat (518)	>Sat (1,040)

B4.0 REVIEW OF FINDINGS

The modelling has been undertaken for a worst-case, young female child receptor occupying the site and breathing outdoor air for 24 hours a day, 365 days a year.

Any adult or child receptor using the restored land will have dramatically lower exposure times/duration, and therefore lower associated risks via RPL-2. The RPL-2 risks posed to

users/occupiers of adjacent/nearby land will also be significantly lower due to additional lateral advection/dilution of vapour concentrations and lower exposure times/duration compared with the worst case receptor.

Even by adopting a worst-case receptor, the CLEA modelling outputs in Table B4 for TEX and the TPH fractions are all significantly above the Csat-vap concentrations; from this it can be concluded that the TEX substances and TPH fractions in sub-surface are highly unlikely to be able to pose an unacceptable risk via RPL-2 to the sensitive receptors identified by the PRA.

For phenol, the CLEA modelling outputs range from 104 to 1,040 mg/m³ (with outputs 5 m/10 m above Csat-vap). These levels of phenol are not feasible in soil vapours and it can be reasonably concluded that phenol is very unlikely to be able to pose an unacceptable risk via RPL-2 to the sensitive receptors identified by the PRA.

For benzene, the CLEA modelling outputs range from 2,000 to 20,000 mg/m³. The Englobe works and summary of past works (see Englobe documentation) also indicate that only very low levels of benzene have been identified in sub-surface materials and it is not feasible for the soil vapour to exhibit these benzene concentrations. From this, it can be reasonably concluded that benzene is very unlikely to be able to pose an unacceptable risk via RPL-2 to the sensitive receptors identified by the PRA.

From the findings of the detailed assessment, it is concluded that the selected sufficiently volatile organic substances of concern in sub-surface materials pose a very low risk via RPL-2 and that the level of risk can be considered to be acceptable.

The low risk posed by RPL-2 is further supported by VOC vapour data within past works (see Englobe documentation) where in-ground Total VOC (TVOC) concentrations measured in 2018 within the main closed 'Coed Darcy Tip' area were of the order of 150 mg/m³ (mainly comprising aliphatic C5-C6 hydrocarbons). These levels are two orders of magnitude below Csat-vap for these hydrocarbons (as would be expected) and many orders of magnitude below their CLEA modelling outputs.

Given all these factors, it is not considered necessary for the RIP to provide soil, soil-vapour, groundwater or NAPL HH AC for the sub-surface materials with respect to RPL-2.

Should other speciated VOCs of potential concern be identified in sub-surface materials, then the RIP can draw upon the CLEA modelling process provided by Appendix B to identify whether these substances have the potential to pose an unacceptable risk via RPL-2.

There may also be additional considerations in the setting of the RIP criteria for sub-surface materials based on risks to other sensitive receptors, such as controlled waters.

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APPENDIX B2: CLEA MODELLING OUTPUTS

To be provided in Final version.

APPENDIX B3: ADDITIONAL CLEA TECHNICAL NOTES

VOLATILITY AND TOXICITY SCREENING

The USEPA screening mechanism for the identification of compounds likely to have sufficient volatility or toxicity to present a risk via vapour intrusion is described in the CIRIA C682 document and taken from the USEPA guidance, referenced in the main report. The screening accounts for likely volatility using Henry's law constant and likely toxicity using a modified health criteria value.

Sufficient Volatility Screening

The first stage of the screening considers Henry's law constant. Other existing guidance documents, e.g. SNIFFER and USEPA (both referenced in the main report) indicate that if a compound has a dimensionless Henry's law constant of less than 0.0004 then it is considered to be a risk via vapour intrusion and emission pathways. The USEPA screening mechanism follows the same principle and recommends the use of properties appropriate for 10°C.

In addition to organic substances, chemical reactions involving cyanide may also form gases. However, the cyanide compounds typically found on brownfield sites are generally iron complexed with a low potential to form gases. This means that the risk posed by cyanide gas is likely to be negligible and will not be considered by the risk assessment.

Sufficient Toxicity Screening

Screening for sufficient toxicity requires information about the toxicity of the compound via inhalation exposure. The theoretical saturated soil vapour concentration of the pure compound is calculated and compared with a modified health criteria value based on inhalation exposure.

The theoretical saturated soil vapour concentration of the pure compound is calculated using the method detailed in SR3. The modified health criteria value is calculated by modifying the TDSI or ID (in $\mu\text{g/kg/bw/day}$) to an acceptable air concentration (in $\mu\text{g/m}^3$) and compared with the calculated vapour phase concentration.

If the calculated vapour phase concentration is less than the modified HCV then it is likely that the toxicity of the compound relating to the vapour intrusion and exposure pathway will not present a significant risk to human health. For compounds with a very low toxicological threshold for vapour inhalation or where a compound is close to failure then professional judgement and other lines of evidence may be used to inform the decision.

ADOPTED TPH INHALATION MDI

The MDIs for the TPH fractions provided by the S4UL methodology are based on the '50% rule' using the respective oral/inhalation TDIs. This is acknowledged in the 2015 S4UL main document to be a 'highly cautious' approach for deriving generic assessments that should be reviewed on site-specific basis.

If the 50% TDI rule for MDI calculation was adopted across the board for inhalation modelling, then it would provide an implied average annual concentration of $\sim 24 \text{ mg/m}^3$ ($24,000 \text{ ug/m}^3$) of TPH in background ambient air. This is clearly impossible for the UK.

For the site-specific risk assessment, a more nuanced (but still risk protective) approach has been adopted for the setting the TPH fraction inhalation MDIs. This is based on:

Aliphatic fractions

- MDI at 5% of the inhalation TDI.

- 5% adopted as the aliphatic TDIs are relatively high compared with the aromatic TDI.
- For example: at 5% of the TDI for Ali C12-16: MDI = 5% of (0.29 x 70) = ~ 1 mg/day.
- The implied average annual background air concentration would be 50 ug/m³ [1000/20], which although very unlikely in the UK, is suitably risk protective.
- At MDI = 10% of TDI, the implied average annual background air concentration would be 100 ug/m³, which is clearly unfeasible for a single TPH fraction in the UK.
- Implied air concentrations for the fractions provided below.
- Calculations use the 'standard adult' weighing 70 kg and breathing 20 m³/day.

Aromatic fractions

- MDI at 10% of the inhalation TDI.
- 10% adopted as the aromatic TDIs are relatively low compared with the aliphatic TDI.
- Note: the S4UL/EA published Benzene & Toluene MDI values adopted.
- Implied air concentrations for the fractions provided below.

The adopted MDIs at 5% and 10% of their respective TDI are consistent with the TEX and PAH MDI to-TDI ratios and provide a practical means to allow for a more reasonable risk-protective contribution to exposure from background intake.

This approach provides the following adult inhalation MDIs and implied annual average background air concentrations (in brackets):

Aliphatic fractions

- | | | | |
|--------------------------|------------|----------------------------|--------|
| • MDI Aliphatic C5-6 | 18 mg/day | (0.9 mg/m ³) | 5% TDI |
| • MDI Aliphatic C6-8 | 1 8 mg/day | (0.9 mg/m ³) | 5% TDI |
| • MDI Aliphatic C8-C10: | 1 mg/day | (0.05 mg/ m ³) | 5% TDI |
| • MDI Aliphatic C10-C12: | 1 mg/day | (0.05 mg/ m ³) | 5% TDI |
| • MDI Aliphatic C12-C16: | 1 mg/day | (0.05 mg/ m ³) | 5% TDI |
| • MDI Aliphatic C12-C16: | 1 mg/day | (0.05 mg/ m ³) | 5% TDI |
| • MDI Aliphatic C16-C35: | 7 mg/day | (0.35 mg/ m ³) | 5% TDI |

Aromatic fractions

- | | | | |
|-------------------------|-------------|-----------------------------|-------------|
| • MDI Aromatic C5-7 | 0.2 mg/day | (0.01 mg/m ³) | Benzene MDI |
| • MDI Aromatic C7-8 | 0.52 mg/day | (0.026 mg/m ³) | Toluene MDI |
| • MDI Aromatic C8-C10: | 0.42 mg/day | (0.021 mg/ m ³) | 10% TDI |
| • MDI Aromatic C10-C12 | 0.42 mg/day | (0.021 mg/ m ³) | 10% TDI |
| • MDI Aromatic C12-C16: | 0.42 mg/day | (0.021 mg/ m ³) | 10% TDI |
| • MDI Aromatic C16-C21: | 0.21 mg/day | (0.011 mg/ m ³) | 10% TDI |
| • MDI Aromatic C21-C35: | 0.21 mg/day | (0.011 mg/ m ³) | 10% TDI |

At these MDI values, the implied average annual ambient air concentrations summed across the TPH fractions provides a total of $\sim 2,470 \text{ ug/m}^3$. So even at 5% and 10% of respective TDIs, the adopted MDIs still provide a very high (but risk protective) implied annual average background air concentration of $\sim 2.5 \text{ mg/m}^3$.

The implied fraction average annual ambient air concentrations detailed above also provided higher MDI values (some by many orders of magnitude) than would be given by the TPH fraction 'total daily intake' values in Table 17.5 of the 2015 S4UL main document.

Note: for site-specific risk assessments, CLEA-SR2 recommends that the MDI should be considered negligible if no data or information is available on likely background exposure (SR2 Section 3.4.1), so the site-specific approach adopted for the TPH MDI is more risk protective than EA guidance.

Overall, the approach for TPH is considered to significantly over-estimate the inhalation MDI contributions and provide a suitably protective assessment for the inhalation modelling for the TPH fractions.