REMEDIAL OPTIONS APPRAISAL, REMEDIATION STRATEGY AND GROUND GAS VERIFICATION PLAN FOR WOODVILLE GARAGE, LLAY

TE1010-TE-00-XX-RP-GE-001-V01

06 DECEMBER 2024

FINAL

Prepared for:

Roof Plus Special Projects

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DOCUMENT CONTROL

Report No. :	TE1010-TE-00-XX-RP-GE-001-V01
Report Status:	FINAL
Project Engineer:	Stuart Milne
Date of Issue:	06/12/2024

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Version No.	Description of Issue / Revision	Date of Issue	Author	Reviewed By	Approved By
1	FINAL	06/12/2024	Stuart Milne	Adrian Read	Adrian Read

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EXECUTIVE SUMMARY

Introduction	Tier Environmental was commissioned by Roof Plus Special Projects to undertake a Remedial Options Appraisal, Remediation Strategy and Verification Plan of Woodville Garage, Llay based on the results of previous Geoenvironmental risk assessments.
Proposed land use	It is proposed that the site will be developed as 3 No. detached two storey residential properties with associated areas of permeable block paving and front and back private garden areas.
Remediation options appraisal and remediation strategy	**Removal of UST/AST, associated infrastructure (including interceptors), and any associated areas of visual/olfactory impacted soils** • Required to mitigate risks via direct contact, dust inhalation and ingestion pathways from potential residual hydrocarbon contamination; • Tanks to be removed by specialist contractor; • Arisings to be placed on visqueen to prevent cross contamination; • Verification samples taken from base and sides of excavation; • Results to be compared against appropriate Generic Assessment Criteria (GACs) protective of future land users (residential with home grown produce land use); • Resultant excavation to be backfilled with suitable materials; • Verification report to be prepared. **600mm Clean Cover System Underlain by Terram Geotextile Membrane** • Required to mitigate risks via direct contact, dust inhalation and ingestion pathways from PAH / TPH impacted soils. • Source(s) of topsoil / subsoil materials to be identified by the contractor; • Tier Environmental to obtain samples of the materials **before** they are imported to site; • Suite of analysis on the samples and frequency of testing to be as per Table 5.1 in this report; • Results to be compared against appropriate GACs protective of future land users (residential with home grown produce land use); • Once imported, hand pits to be excavated in soft landscaped areas on a 1 per 25m grid basis to confirm that the minimum thickness has been achieved and the geotextile membrane is present; • Verification report to be prepared **Implementation of ground gas protection measures for a CS-2 Low Risk Scenario** • Required to mitigate risks from ground gas sources; • Upgraded to a vapour resistant membrane; • Combination of passive subfloor dispersal layer and gas membrane; • Tier Environmental to conduct inspection of the installation process; • Verification report to be prepared **Water Supply Protection** • Due to the known presence of hydrocarbon contamination on site. • Following completion of a Pipeline Risk Assessment, barrier pipe will be required for all proposed water services on site.

1. INTRODUCTION

Tier Environmental was commissioned by Roof Plus Special Projects to undertake a Land Contamination Risk Management (LCRM) Remedial Options Appraisal, Remediation Strategy and Verification Plan for an area of land referred to as Woodville Garage located at Gresford Road, Llay, Wrexham, LL12 0NW (the "site").

The title of this report is in accordance with that described in the Land Contamination Risk Management guidance (available at https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm) which has superseded CLR 11:

- Stage 2 - LCRM Options Appraisal Report
- Stage 3 - LCRM Remediation Strategy

1.1. Proposed Development

Under current proposals the development will comprise the construction of 3 No. two storey detached private residential houses with private front and rear gardens as presented in Appendix A. The majority of surfaces will comprise permeable paved areas with soft landscaping forming new lawn areas in the front at curb side, and part of the rear gardens. As such, in accordance with the *'Updated technical background to the CLEA model'* (Environment Agency, 2009) and *'Suitable 4 Use Levels'* (LQM / CIEH 2015) the proposed generic land use for this development is residential with homegrown produce.

1.2. Previous Reports

Tier Environmental have previously completed 'A Ground Investigation Report for Land at Gresford Road, Llay, Wrexham (Ref: TE1010GIR, dated 11th November 2017).

1.3. Background and Previous Works Summary

The above Tier Environmental Ground Investigation Report, hereafter referred to as the 'GIR' report, included a generic quantitative risk assessment of laboratory chemical analysis data obtained from soil and groundwater to determine potential risks to human health for the proposed land use and the controlled waters environment.

The results of a generic quantitative human health risk assessment have determined the following:

- Made Ground soils should be considered to present a potentially unacceptable risk to human health with respect to benzo(a)pyrene, benzo(b)fluoranthene and aromatic EC21-35 petroleum hydrocarbons for an end land use of residential with home grown produce. A hotspot of elevated dibenzo(ah)anthracene is present within the Made Ground soils in the area of WS5.

The results of a generic quantitative controlled waters environment risk assessment have determined the following:

- Groundwater samples collected from across the Site have identified localised (WS5) naphthalene, fluoranthene, benzene and total petroleum hydrocarbons in concentrations elevated above the most stringent water quality standards. Due to the low sensitivity of the Site and localised nature of the contamination, it is considered that local groundwater should not be considered to present a potentially unacceptable risk to controlled waters; however, localised excavation is recommended.

- No free phase product was measured beneath the site.

The results of a ground gas risk assessment have determined the following:

- Based upon the ground gas assessment, the Site may be classified as a Characteristic Situation 2 – Low Risk. Given the historic land use of the Site as a garage with associated above ground storage tanks, underground storage tanks and a fuel filling area, a potential risk from volatiles generated from unidentified hydrocarbon contamination is considered possible. As a result, it is considered that the gas protection measures should include a volatile resistant membrane.
- It should be noted the 2017 GIR identified the site to be located within a lower probability radon area as less than 1% of homes are above the action level. This assessment has been reviewed further to updated UK Radon mapping produced by the UK Health Security Agency in December 2022. Whilst latest data shows the site to be within an area where the maximum radon potential is between 10-30%, a subsequent site specific report has confirmed the <1% designation and therefore no radon protection measures are required.

1.4. Anticipated Outline Remedial Works

The GIR report included the following outline remediation requirements on the basis of the risk assessment conclusions summarised above. In essence, the outline remedial strategy and verification plan is:

- Clean Cover in Private Garden Areas
    - In order to remove the remaining pollutant linkages, it is considered that the soft landscaped/garden areas of the Site should be covered with a 600mm deep clean cover system (150mm Topsoil layer underlain by 450mm subsoil and a hi visibility Terram geotextile membrane). It is considered that as the proposed development is for residential with privately owned gardens with a potential for home grown produce, that a 600mm clean cover system with a geotextile membrane will provide sufficient thickness for the exposure scenarios typical for such a land use and the geotextile will provide a hi-visibility physical barrier in the unlikely event that any excavations are undertaken to this depth.
    - The source of the aggregates, imported subsoil and Topsoil material should be inspected and tested prior to being brought to site to ensure its chemical suitability and absence of any deleterious materials such as glass, metal, roots, invasive weed species and the like.
    - The depth and chemical suitability of the clean cover soils should be undertaken by a suitably experienced consultant and a verification report produced to discharge any associated planning conditions.
- Water Supply Protection
    - Due to the known presence of hydrocarbon contamination on site, it is recommended that a Pipeline Risk Assessment be completed in order to assess the necessary piping required for implementation for water services on site; however, at this time it is anticipated that barrier pipe will be required for all proposed water services on site.
- Uplift and Disposal of Underground Storage Tanks
    - Before soil removal can take place, it will be necessary to remove any existing and potentially previously unidentified USTs/interceptors on the site, notably in the western area of the Site, as identified during the site walkover.
    - The procedures detailed in the Institute of Petroleum publication "Guidelines for the Uplift of Product from Petrol Filling Stations and Customer Tanks" should be followed. Prior to the commencement of works, the PLO will need to be notified with two weeks' notice.
    - Notwithstanding the above comments, before any work is commenced on the rendering permanently safe of an underground petroleum storage tank, any residual product within the tank (if present, it is understood that the known underground storage tanks have been previously concrete filled) shall be removed as far as is practically possible, this is known as "bottoming". In

addition, it may also be then necessary to treat the base of the tank with a proprietary emulsifier or hydrocarbon adsorbent to ensure, so far as is practicable, that all residual hydrocarbons are removed.

- Excavation and Offsite Removal of Soils bearing Visual/Olfactory evidence of Impact
    - If the site is to be redeveloped and materials are disposed off-site, then material exported from the site to landfill shall be hauled by a registered waste carrier in accordance with Duty of Care Regulations, 1991 and the Hazardous Waste Regulations, 2005.
    - There will be requirement for the waste producer to provide appropriate Waste Acceptance Criteria (WAC) testing of the Soils for disposal to ensure that the soils are appropriately classified and that the landfill is licensed to receive such soils. Mixing of hazardous and non-hazardous waste is not permitted. For any hazardous wastes, a consignment note shall be completed, signed, and retained by all parties involved. The consignment note shall state the volume of waste, a physical description of the material and statement of its chemical composition. The waste consignment notes shall be kept by the contractor for a period of at least two years. For non-hazardous wastes, a Waste Transfer Note (WTN) shall be completed. The WTN should be signed and a copies should be kept by the contractor for a period of at least two years. Finally, consignment notes and WTNs shall be shown to an enforcement officer from the local council or the Environment Agency, if asked.
    - Asbestos screen testing did not identify asbestos fibres in any of the Made Ground samples tested.
- Ground gas protection measures commensurate with a CS-2 Low Risk scenario with upgraded membrane for volatile resistance.
    - Due to the potential for contamination associated with historic land use as a filling station.

1.5. Objectives

On the basis of the above, the objectives of this report are to:

- To reproduce the Refined Conceptual Site Model derived within the previous Tier Environmental GIR;
- Undertake a Remediation Options Appraisal to address reported:
    - Measured concentrations of benzo(a)pyrene, benzo(b)fluoranthene, aromatic EC21 to EC35 and benzene, and a hot spot of elevated dibenzo(ah)anthracene within the Made Ground soils;
    - Presence of underground storage tanks (USTs) and above ground storage tanks (ASTs) at the site (plus associated infrastructure and interceptors);
    - A Characteristic Situation 2 – Low Risk ground gas scenario. Given the presence of historic storage tanks, underground storage tanks and a fuel filling area, any membrane should be upgraded for volatile resistance.
- Produce a Remediation Strategy and Verification Plan on the basis of the selected viable approaches determined during the Remedial Options Appraisal.

This report, which was designed to meet the requirements of all relevant current guidance including 'Land contamination: risk management' (LC:RM) (which supersedes CLR11) presents the factual information available during this appraisal, interpretation of the data obtained and recommendations relevant to the defined objectives.

1.6. Assumptions

The following assumptions are made in this report:

- It is assumed that ground levels will not change significantly from those described in this report or a shown on proposed development drawings. If this is not the case, then amendments to the recommendations made in this report may be required.
- The ground investigations that have informed this remediation strategy were designed with due consideration of known or suspected constraints (including underground services and access constraints).
- Any references to observations of suspected asbestos-containing materials are for information only and should be verified by a suitably qualified asbestos specialist and/or confirmed by laboratory analysis.
- The use of the term 'Topsoil' within this report is based on a visual identification only and that these materials have not been classified in accordance with BS3882:2015.
- The use of the terms ‘shallow’ and ‘deep’ within this report (from a geotechnical perspective) assume *typically* between ground level to circa 3.00m below ground level (bgl) for ‘shallow’ and greater than 3.00m bgl regarded as ‘deep’;
- The comments and opinions presented in this report are based on the findings of the desk study, ground conditions encountered during intrusive investigation works performed by Tier Environmental and the results of tests carried out within one or more laboratories. There may be other conditions prevailing on the site which have not been revealed by these previous investigations and which have not been taken into account by this report.
- Responsibility cannot be accepted for any conditions not revealed by the previous investigations. Any diagram or opinion on the possible configuration of the findings is conjectural and given for guidance only. Confirmation of intermediate ground conditions should be undertaken if deemed necessary.

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2. SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview.

Site name	Land at Gresford Road, Llay
Site address	Gresford Road, Llay, Wrexham, LL12 0NW . A site location plan is included as Drawing No. TE1010.GIR.1 within Appendix A.
National Grid Reference (NGR)	333391, 356219.
Approximate site area	0.11ha
Site shape	The site has a roughly rectangular shape.
Current land use on the site	The site is currently disused. There are currently 2 No. existing structures, comprising a former garage and a derelict bungalow. A crack in the brickwork of the bungalow was noted. The site is largely covered in macadam or concrete, with the exception of the area of land to the south of the garage structure, which is covered in soft garden landscaping. It is understood that the site contains an underground storage tank which has since been backfilled with concrete. The Wrexham Petroleum Licensing Officer did not possess any records of any storage tanks within the Site. Additional unrecorded services should be anticipated.
Surrounding land uses	The site is located within a predominantly residential area, approximately 6km north of Wrexham.
General topography and ground levels	The site is generally flat lying at an elevation of approximately 88.0m AOD.

3. REVISED CONCEPTUAL MODEL

The revised combined conceptual site model and conceptual exposure model, developed for the proposed future land use from the desk study information and subsequent ground investigation and the chemical analysis results presented in the GIR report has been reproduced below.

The potential pollutant linkages identified and a generic quantitative risk assessment are presented in Table 3.1. The terms used in the generic quantitative risk assessment are defined in Appendix C.

Table 3.1 Revised Assessment of Potential Pollutant Linkages.

Source	Potential Contaminants of Concern	Pathway	Receptor	Consequence	Probability	Qualitative Risk Assessment
Benzo(a)pyrene, benzo(b)fluoranthene and aromatic EC21-35 petroleum hydrocarbons contamination within the Made Ground soils from previous Site uses including former refuelling facilities.	Benzo(a)pyrene, benzo(b)fluoranthene and aromatic EC21-35 petroleum hydrocarbons	Direct contact, dust inhalation and ingestion	Future site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
			Adjacent site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Low Likelihood	Moderate / Low Risk
		Migration of mobile contaminants from Made Ground soils to adjacent sites along services and conduits	Adjacent site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
		Migration via water pipes	Future site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
		Lateral and/or vertical migration of mobile contaminants.	Aquifer 1 - Unproductive Strata associated with Till	Minor	Low Likelihood	Low Risk
			Aquifer 2 - Secondary A Aquifer associated with the Scalop Formation	Medium	Low Likelihood	Moderate / Low Risk
			Unnamed tertiary watercourse located approximately 208m southwest	Medium	Unlikely	Low Risk
A hot spot of elevated dibenzo(ah)anthracene.	Dibenzo(ah)anthracene.	Direct contact, dust inhalation and ingestion	Future site users (residential)	Medium	Unlikely	Low Risk
			Adjacent site users (residential)	Medium	Unlikely	Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Unlikely	Low Risk
		Migration of mobile contaminants from Made Ground soils to adjacent sites along services and conduits	Adjacent site users (residential)	Medium	Unlikely	Low Risk
		Migration via water pipes	Future site users (residential)	Medium	Unlikely	Low Risk
		Lateral and/or vertical migration of mobile contaminants.	Aquifer 1 - Unproductive Strata associated with Till	Minor	Unlikely	Very Low Risk
			Aquifer 2 - Secondary A Aquifer associated with the Scalop Formation	Medium	Unlikely	Low Risk
			Unnamed tertiary watercourse located approximately 208m southwest	Medium	Unlikely	Low Risk
Potential unidentified petroleum hydrocarbons within subsurface of the Site.	Hazardous ground gasses (methane, carbon dioxide, hydrogen sulphide, carbon monoxide and depleted oxygen)	Inhalation (indoor and outdoor)	Future site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
			Adjacent site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Low Likelihood	Moderate / Low Risk
		Migration of hazardous ground gases from beneath the site to adjacent sites along services or other preferential conduits	Adjacent site users (residential)	Medium	Low Likelihood	Moderate / Low Risk
		Migration of ground gas / explosion	Buildings and services	Severe	Low Likelihood	Moderate Risk

For definition of the terms used in the qualitative risk assessment, please see Appendix C.

4. REMEDIAL OPTIONS APPRAISAL

The information presented in the previous GIR report summarises the physical conditions of the site, the nature of the soils / materials, the contamination status of the Made Ground soils and presents an overview of the controlled waters regime. For completeness, however, it would be prudent to refer to the previous ground investigation reports, should additional information be required. The following section identifies the remediation strategy that could be utilised to effectively manage/mitigate the identified pollutant linkages associated with the soils at the site. In determining the most effective remediation option(s) for the site, consideration needs to be given to a number of techniques, stating (where appropriate) the suitability and limitations of each chosen method.

4.1. Ground Gas Risk Considerations

The Tier Environmental GIR report stated:

'Ground gas monitoring was performed on 6 No. occasions on 8th June 2017 and 15th August 2017. A conservative Gas Screening Value (GSV) has been calculated assuming a maximum flow rate of 27.4l/hr and a maximum carbon dioxide concentration of 10.0% v/v. This has produced a GSV of 2.74l/hr, which places the site in a Characteristic Situation 3 - Moderate Risk Scenario in accordance with CIRIA C665. This is based on the flow rates that are considered to be due to groundwater pumping. It is therefore considered that the Site should be categorised as CS2 (low risk) based on the maximum recorded carbon dioxide concentration of 10% v/v, the Site is considered to be CS2 (low risk). The results of the human health risk assessment determined that the membrane should be upgraded to a volatile resistant membrane due to the historic land use as a filling station and potential for unrecorded contamination across site.'

Wholesale removal of ground gas sources from beneath the site is not viable, sustainable or practicable and as such, Tier Environmental have taken into consideration BS8485:2015+A1:2019 and the guidance within CIRIA C665 and CIRIA 735 in preparing a separate ground gas verification plan in Section 6 of this report.

Considerations for Radon

It should be noted the 2017 GIR identified the site to be located within a lower probability radon area as less than 1% of homes are above the action level. This assessment has been reviewed further to updated UK Radon mapping produced by the UK Health Security Agency in December 2022. Latest data shows the site to be within an area where the maximum radon potential is between 10-30% which would require full radon protection measures.

The joint UKHSA-BGS digital Indicative Atlas of Radon in the United Kingdom presents an overview of the results of detailed mapping of radon potential, defined as the estimated percentage of homes in an area above the radon Action Level, from which this 10-30% value has been derived. UK Radon states that:

"The Atlas presents a simplified version of the Radon Potential Dataset for the United Kingdom with each 1-km grid square being classed according to the highest radon potential found within it, so is indicative rather than definitive."

Further to a site specific radon search, included in Appendix G, the site is confirmed to be within an area where less than 1% of homes are above the action level and therefore no protection measures are required.

4.2. Remedial Options Appraisal

The following elements have been considered for the site with respect to remedial options, where necessary/appropriate, during the feasibility and options appraisal stage:

- degree to which risks need to be reduced or controlled;
- time within which the remediation strategy is required to take effect;
- practicability of implementing and, where appropriate, maintaining the strategy;
- technical effectiveness of the strategy in reducing or controlling risks;
- longevity of the strategy - i.e. the potential for the proposed remediation technologies to mitigate against contaminant rebound;
- sustainability of the strategy (i.e., how well it meets other environmental objectives, for example on the use of energy and other material resources, and avoids or minimises adverse environmental impacts in off-site locations, e.g. neighbouring residents, or on other environmental compartments, such as air and water);
- cost of the strategy; benefits of the strategy – all remediation strategies should deliver direct benefits (the reduction or control of unacceptable risks) – but many have merits that extend well beyond the boundaries of the site; and
- legal, financial and commercial context within which the site is being handled including the specific legal requirements that remediation has to comply with, and the views of stakeholders on how unacceptable risks should be managed.

Due consideration has been given for possible feasible options, as presented in the tables below to effectively evaluate the practicality, effectiveness, durability and sustainability of potential remedial solutions.

It is also considered that all risks to construction/maintenance workers will be effectively managed via the measures detailed in Section 9.5 of the Tier Environmental GIR Report. As such, risks to construction/maintenance workers fall outside the remit of this Remedial Options Appraisal.

4.3. Remedial Options Appraisal

Table 4.1 Remedial Options Appraisal – Underground and Above Storage Tank Areas

Contaminant Source	Former underground storage tanks (suspected to have been concrete filled based on anecdotal evidence) located in the northwest and central north of the site, and above ground storage tanks on the western edge of the building.
Pollutant Linkage	Direct contact, ingestion, and inhalation of dust. Vapour inhalation. Leaching and migration via groundwater. Lateral and vertical migration of mobile contaminants.
Excavation with Disposal	Wholesale removal of tanks (if present), concrete cradles, any grossly impacted surrounding Made Ground soils. Pollutant linkage is broken, and site works can commence quickly. Given the localised nature this is considered commercially and practically viable. May include vacuum tanker removal of any associated grossly impacted groundwater and/or free-phase product (if encountered).
Capping including Membrane / Break layer	Would address direct contact, ingestion, and inhalation of dust pathways for human health but potential source for vapour risks and risks to controlled waters environment would remain. Also, would present ongoing hardspots / obstructions in the ground. Therefore would not achieve the technical objectives.
On site re-use	Excavation and on-site retention of non-impacted fill materials within the cradle (if chemical testing and assessment proves they are suitable for re-use), and concrete associated with the cradles as geotechnical materials for any proposed areas of fill under a Materials Management Plan or U1 Exemption / WRAP Protocol (for any inert aggregates) is potentially viable and environmentally sustainable to reduce volume going to landfill. Grossly impacted materials would; however, have to be removed in order to remove primary source of contamination.
Stabilisation / solidification	This is unlikely to be commercially, technically, or practicably viable when compared to other viable techniques and hardspots associated with the structures and stabilisation / solidification would remain.

Justification	It is considered that a combination of viable techniques above could be implemented to effectively break the pathways: a. Removal of UST, associated infrastructure and any surrounding visual/olfactory impacted soils. b. Verification testing of excavations c. Capping of the layer via hardstanding/footprint or a 600mm clean cover system within soft landscaped areas d. Implementation of ground gas protection measures commensurate with a CS-2 scenario with upgraded vapour resistant membrane Implementation of this combined approach provides confidence that the pollutant linkage will be adequately broken. Potential for impacted materials to be re-used under an MMP so long as the works are verified in accordance with this remediation strategy.

Table 4.2 Remedial Options Appraisal – Widespread PAH and TPH impacts

Contaminant Source	Measured concentrations of aromatic EC21 to EC35 and benzene, and a localised 'hot spot' of elevated dibenzo(ah)anthracene within Made Ground across the site.
Pollutant Linkage	Dermal contact, ingestion, and inhalation of PAHs/TPHs on site.
Excavation with Disposal	Wholesale removal of Made Ground. Pollutant linkage is broken, and site works can commence quickly. This is unlikely to be commercially or practically viable and not as sustainable as some other options as a significant volume of impacted materials would need to be landfilled.
Capping including Membrane / Break layer	Could be readily implemented at the site and would only be required in the soft landscaped areas as proposed hardstanding and building footprints would act as a capping layer elsewhere. Economic, practicable, feasible and commonly used and well understood approach to break dermal contact, ingestion and dust inhalation pathways.
On site re-use	Excavation and on-site retention of impacted soils as geotechnical material may be viable areas of fill under a Materials Management Plan in accordance with the CL:AIRE DoWCoP. Impacted materials remain on site which is a sustainable solution but would have to be used in conjunction with other techniques. Materials would need to be suitably re-engineered and emplaced beneath hardstanding and / or buildings and preferentially not beneath soft landscaped areas. May be used in conjunction with a capping solution in the event that some materials are emplaced beneath soft landscaped areas.
Stabilisation / solidification	This is unlikely to be commercially or practicably viable when compared to other viable techniques across the entire site.
Justification	It is considered that the following viable techniques above could be implemented to effectively break the pathways: a) Capping of the layer via hardstanding/footprint or a 600mm clean cover system within soft landscaped areas Implementation of this approach provides confidence that the pollutant linkage will be adequately broken. Potential for impacted materials to be re-used under an MMP so long as the works are verified in accordance with this remediation strategy.

On the basis of the above table, the following techniques are considered the Best Practicable Techniques (BPT) in accordance with LCRM:

For the underground storage tanks and any associated infrastructure

On the basis of the above it is proposed that excavation and removal of the underground storage tanks, associated tank cradles and other infrastructure (relict pipework etc) and any surrounding grossly impacted soils are excavated and removed from site. The works would also allow for the use of a vacuum tanker to remove any grossly impacted groundwater and/or free phase hydrocarbons observed after / during such removal works. Doing this would remove the primary remaining potential source of contamination in site, and facilitate further observations of the immediate surrounding soils / groundwater. In addition, it is proposed that should any materials arise (including concrete crush and cradle infill materials) that are demonstrably chemically suitable for re-use that such materials may be considered for sustainable re-use on Site via an MMP in accordance with CL:AIRE Definition of Waste Code of Practice and/or a U1 Exemption / WRAP Protocol for Inert Aggregates.

For the site wide other non-volatile PAHs and localised heavy-end aromatic TPH present a risk to residential end-users in proposed soft landscaping areas

It is proposed that a 600mm clean cover system for the soft landscaping areas will be sufficient to break the direct contact, dust inhalation and ingestion pathways associated with these determinands. The remaining areas of building footprint and external hardstanding will be sufficient to act as a physical barrier and effectively form a barrier between the end-users and the impacted Made Ground such that the clean cover system will only be required in those areas where Made Ground would otherwise remain at the surface (i.e. soft landscaping areas).

In addition to the above, and given the historic land uses and prevailing site and wider area ground conditions, Tier Environmental have also considered the potential for previously unidentified localised grossly impacted soils and groundwater, including the potential for free phase product. Whilst the ground investigation works conducted to date are regarded as comprehensive, Tier Environmental wishes to demonstrate that due consideration has been given at an early stage on possible remedial solutions in the event that local grossly impacted soils or groundwater are identified on site. On this basis, this report has also included for the following remediation measures that will be implemented to achieve betterment if, in the view of the supervising and suitably qualified geoenvironmental consultant, there is visual / olfactory evidence of grossly impacted soils and/or groundwater during earthworks / construction:

- Localised excavation and off-site disposal of grossly contaminated soils (if encountered); and,
- Vacuum tanker pumping of grossly impacted groundwater / free phase product (if encountered) potentially combined with localised in situ chemical oxidation or addition of oxidising agents;

The Tier Environmental Ground Investigation Report for this site is regarded as being sufficiently comprehensive to characterise the site and has previously identified contaminants of concern at the site that present a potential risk via the direct contact, dust inhalation, vapour inhalation and ingestion pathways. As remedial measures have been proposed within this report to address these potentially active pollutant linkages, it is considered that any localised, previously unidentified, gross contamination remedial measures will be conducted and need to demonstrate local betterment of the ground conditions has occurred within the Remediation Verification Report. As such, no remediation targets are proposed at this stage **for any previously unidentified contamination**; however, sufficient lines of evidence will need to be presented to demonstrate that 'betterment' has occurred which will be a function of localised soil and groundwater sampling before and after any such remedial measures are implemented (i.e. to demonstrate a reduction in soil or groundwater concentrations or evidence of removal of free phase product, if encountered). Further lines of evidence may be provided via comparison of the results to appropriate screening criteria (e.g. LQM / CIEH S4ULs (2015) protective of human health risks or Water Quality Standards protective of the controlled waters environment); however, it is not proposed that these should be used remediation criteria in this context.

5. REMEDIATION STRATEGY

5.1. Introduction

Tier Environmental considers that a combined remedial approach will be required to address the following potential contaminants of concern:

- presence of USTs/ASTs and associated infrastructure, in additional to any possible unrecorded hydrocarbon contamination present a risk to residential end-users in proposed soft landscaping areas and via potential vapour inhalation;
- site wide non-volatile soil concentrations of PAHs and heavy-end aromatic TPH present a risk to residential end-users in proposed soft landscaping areas;
- ground gas Characteristic Situation 2 – Low Risk scenario
- use of barrier pipe for water supply

In addition, due consideration has been made within this remediation strategy for previously unidentified and localised visual / olfactory evidence of gross contamination.

5.2. Anticipated Remedial Works

Based upon the findings of the Ground Investigation and the above Remedial Options Appraisal the following remediation strategy has been devised in order to make the site safe and suitable for redevelopment, as proposed:

- Removal and verification of USTs, and any previously unidentified areas of contamination, where required. This may include any soils or groundwater grossly impacted by hydrocarbons in the vicinity of the ASTs/USTs. Such measures to achieve this have been identified as one or more of the following:
    - Direct removal of UST/ASTs and associated infrastructure
    - Localised excavation and off-site disposal of grossly contaminated soils (if encountered);
    - Vacuum tanker pumping of grossly impacted groundwater / free phase product (if encountered) to significantly reduce the primary source mass potentially combined with Localised in situ chemical oxidation or addition of oxidising agents;
    - Verification soil chemical analysis (as required);
    - Lines of evidence approach to demonstrate local betterment of ground conditions and consideration of other remedial measures being implemented to break and residual pathways identified
- Removal, crushing and screening of any oversized material and obstructions in the ground
- Bulk earthworks to achieve the proposed development levels, including with fill materials compacted in accordance with a recognised specification, such as Specification for Highways Works Series 600. Re-use of site won materials to be conducted in via a Materials Management Plan in accordance with the Definition of Waste Code of Practice;
- Backfill of resultant excavations with suitable material;
- Installation of ground gas protection measures in accordance with BS8485: 2015 +A1:2019 and CIRIA C735;
- Installation of a volatile/hydrocarbon resistant membrane under proposed buildings in accordance with and CIRIA C748;
- Laboratory chemical testing and risk assessment of all imported materials; and,
- Installation of a minimum 600mm clean cover system underlain by a geotextile membrane in soft landscaped areas to act as a growing medium and physical barrier between impacted Made Ground soils and the end-users.

The above integrated strategy is designed to:

- Mitigate risks to human health via direct contact, ingestion and dust inhalation pathways;
- Mitigate risks to human health from indoor vapour inhalation pathways;
- Mitigate risks to human health from hazardous ground gases;
- Provide flexibility in the event that localised unexpected gross contamination is identified beneath the site.

5.3. Underground Storage Tanks / Cradle and Associated Infrastructure Removal

Uplift and Disposal of Underground Storage Tanks

Before any residual impacted soil removal can take place, it will be necessary to excavated and expose the anticipated concrete tank cradles associated with the USTs. In the event that metal tanks *are* encountered, it shall be determined if these tanks are solid filled (as anecdotal evidence suggests), foam or water filled and any residual product within the tank shall be removed as far as is practically possible, this is known as "bottoming". In addition, it may also be then necessary to treat the base of the tank with a proprietary emulsifier or hydrocarbon adsorbent to ensure, so far as is practicable, that all residual hydrocarbons are removed. Possible locations of remedial areas are indicated in drawing TE1010-TE-00-XX-DR-GE-001-V01.

Where a tank / tank cradle is being excavated and there is a danger that the surrounding soils may have been contaminated either by leakage from the tank or by spillage, the following precautions shall be taken:

i. Danger notices shall be displayed.
ii. No smoking or naked lights shall be allowed near the vicinity.

In all the above operations, care shall be taken to ensure that no hydrocarbons or hydrocarbon contaminated water is allowed to enter any drainage system. In order to prevent the potential for cross contamination with existing soils on site, it is recommended that some form of protective membrane is emplaced across any areas where the tanks, or any associated materials are to be placed, prior to their removal from site.

Due to the presence of loose Made Ground and natural soils, excavations are likely to be unstable, especially during the removal of the concrete cradles. Manned entry into unshored excavations should not be permitted and reference to CIRIA 97 Trenching Practice should be made to establish suitable means of support or battering of excavation sides during their removal.

If a tank is to be lifted by chains or wire ropes, they shall be protected from direct contact with the tank to prevent risk from spark generation. Natural fibre ropes may be preferable for small tanks. A tank shall not be lifted by placing chains or ropes around the manhole neck, as it is possible to rip the neck from the tank.

In preparation for transportation, the following precautionary work shall be carried out in the event that metal tanks are encountered and to be removed:

1. All pipework connected to the tank shall, as far as is reasonably practicable, be removed.
2. All openings to the tank shall be sealed.
3. Any holes in the tank caused by corrosion or damage during exhumation shall, so far as is reasonably practicable, be sealed.
4. The appropriate orange coloured (warning) panels as required by Schedule 10 to The Carriage of Dangerous Goods by Road Regulations 1996 shall be displayed.

5. The tank shall be securely attached to the carrying vehicle, following the precautions noted for chains or wire ropes as above.
6. Where there are holes or obvious areas of weakness in the tank, the tank shall be positioned on the carrying vehicle in such a way that the hole/areas of weakness are positioned above the level of any liquid or sludge remaining in the tank.
7. The transportation of a disused petroleum tank from the site by road is covered by the Carriage of Dangerous Goods by Road Regulations 1996, (Schedule 2 (4)).
8. The Contractor shall ensure that the recipient of the tank is made aware of the tank's previous use, the toxic hazard within the tank and the need to take adequate precautions against fires and explosions when handling and disposing of it.

Excavation and Removal of Tank Containment

If encountered, concrete cradles should be broken out and removed from site, if shown to be impacted by hydrocarbons, or crushed and stockpiled for future re-use and/or removed from Site by a suitably licenced contractor. Decommissioning paperwork for any metal tanks (if present) will need to be included in the site verification report.

Within the immediate vicinity of the known concrete cradles, samples of the Made Ground and / or natural strata shall be taken to determine the extent, if any, of potential speciated petroleum hydrocarbons (TPH). The results obtained shall be compared against the remedial target levels which have been derived in the following sections of this report.

Areas of highly/grossly contaminated material shall be determined by visual / olfactory observations. If any areas of odorous, 'oily' or brightly coloured materials or liquids are encountered, the Supervising Engineer (SE) if not in attendance, shall be notified immediately.

Any disposal of grossly contaminated materials shall take place by the direct placement onto a bunded Visqueen layer whilst chemical analysis is undertaken. This soil will also be covered in a layer of Visqueen to prevent leaching to the surrounding soils. Following WAC and soils analysis, the soil will be placed into a road haulage truck and subsequent disposed at a suitable landfill site. Alternatively, pre-existing data may be used alongside the assumption that the petroleum hydrocarbons are at hazardous levels and materials are then directly placed into a road haulage truck and subsequent disposed at a suitable landfill site. On site precautions will be required to prevent the spreading of contaminated soils around the site or to adjacent land.

The removal of sufficient soil will be validated by ensuring that remedial targets have been met for the contaminants and a suitable material should be used to backfill the excavations. The backfill materials will be analysed to confirm their suitability for use.

Remediation Criteria

The previous Tier Environmental GIR demonstrated that the site does not present a risk to controlled waters; however, it is considered that any grossly impacted hydrocarbon soils (**if** encountered and as observed by the Supervising Engineer) will be removed to provide further confidence that the last remaining potential source area has been effectively removed from the Site.

It is considered that remediation works will be necessary to remove the localised impacts associated with the USTs / UST tank cradles / associated infrastructure (including interceptors), at which point these and any impacted soils will be removed from Site, effectively removing the hydrocarbon source from the Site.

On this basis, it is proposed that LQM/CIEH (2015) S4ULs for speciated TPH CWG and BTEX are implemented as remediation criteria for comparison with soil samples obtained on a 5 m grid basis from the sides and base of the resultant tank / tank cradle excavation. This will ensure that residual TPH and BTEX do not present a potentially significant risk to human health for a commercial land use and will also be used as an indicator of any residual contamination that may present a risk to the controlled waters environment.

Independent Verification and Supervision of the Works

Verification of Impacted Soil Removal

In order to ensure verification of the removal of contaminated soils, if encountered, excavations will be carried out as follows:

- A visual inspection of the soil will be undertaken. The excavation will be progressed until no visual evidence of gross contamination remains or until excavation is **no longer practicable / safe** due to the proximity to adjoining structures / services / site boundary / off-site roads.
- Soil samples will be taken from the base and sides of the excavation, prior to infilling, on a 5m grid. Sample collection will be made by the use of the excavator bucket to 'scrape' the sample locations. The Site Engineer will not enter the excavation at any time. Base samples will be obtained in a 'W' shape pattern to provide confidence in the lateral and vertical verification of the resultant excavations;
- If, in the experience of the competent Site Engineer, it is thought that the sample is likely to be below remedial targets, the sample will be submitted for laboratory analysis;
- Should the results of laboratory analysis be greater than the remedial targets, then further assessment and/or potential remediation of the contamination will be necessary.

5.4. Clean Cover System

Installation

In order to remove the direct contact, dust inhalation and ingestion pollutant linkages, it is considered that the soft landscaped areas of the site should be covered with a 600mm deep clean cover system (typical make up would comprise 150mm Topsoil layer underlain by 450mm subsoil underlain by a Terram geotextile membrane **or** a full 600mm of topsoil underlain by a Terram geotextile membrane). It is considered that as the proposed development is for private residential land use purposes, that a 600mm clean cover system with a geotextile membrane will provide sufficient thickness for the exposure scenarios typical for these / this land uses / land use and the geotextile will provide a physical barrier in the unlikely event that any excavations are undertaken to this depth. Whilst the above system is preferable, the clean cover system may also comprise a minimum 300mm topsoil (or 150mm Topsoil and 150mm subsoil to make a total thickness of 300mm) underlain by a minimum 300mm hard dig layer constructed from 'clean' crush / stone.

It should be noted that the clean cover system should only be implemented in those areas for which shallow soils still lie at ground surface, i.e. soft landscaped areas as all other areas will be covered in hardstanding and/or buildings which will be sufficient to break the direct contact and dust inhalation pathways in these areas.

The source of the imported subsoil and Topsoil material (and crush materials if a hard dig layer system is to be implemented) should be inspected and tested **prior to being brought to site** on site to ensure its chemical suitability and absence of any deleterious materials such as glass, metal, roots, invasive weed species and the like.

Verification

In the absence of local guidance, Tier Environmental has taken into due consideration the requirements of the YALPAG (Yorkshire And Lincolnshire Pollution Advisory Group) guidance.

Table 5.1 Clean Cover Verification Requirements

Objective	It will be necessary to ensure that the development of the site does not cause an increased risk to receptors. All clean cover materials imported to the site will be tested to determine its suitability for use on the site in the residential front and rear garden areas
Testing frequency	Imported materials will need to be tested **before they are imported to site** at a rate of 1 No. sample per 50m^3 for Topsoil (with a minimum of 3 No. samples), 1 No. per 150m^3 for subsoil (with a minimum of 3 No. samples) and 1 No. per 150^3 for any crush used to form a hard dig layer.
Testing Suite	• Metals; • Speciated PAH; • Speciated TPH; • Total phenol; • pH; • Asbestos
Screening Criteria	The purpose of the testing is to verify the quality of any materials imported to the site and to determine the contaminant concentrations of materials. The samples will be compared with appropriate LQM / CIEH 2015 S4UL values protective of a residential with homegrown produce land use to confirm suitability for re-use.
On-site Verification Requirements	In addition to the chemical testing, the depth of clean cover will also be verified. Hand dug pits will be excavated on a 25m grid within landscaped areas to ensure that a minimum combined thickness of 600mm subsoil and Topsoil underlain by Terram geotextile (or 300mm topsoil/subsoil and 300mm hard dig layer) has been achieved. In the event that some or all of the soft landscaped areas have a clean cover system incorporating a hard dig layer, it may not be possible to advance through some hand pits through the full thickness of the hard dig layer due to density of the layer. It is considered; however, in these instances such refusals would be sufficient to demonstrate that the fundamental objective of the clean cover system has been achieved. Hand dug pits will be photographed and photographs will be submitted as part of the verification.

5.5. Site Turnover and Obstruction Removal

Given the potential for buried infrastructure associated with the historic land use as a filling station, it is proposed that the site is turned over to a depth specified by the earthworks contractor determined by the nature and extent of anticipated obstructions. Any USTs and associated pipework will be removed in accordance with this Remediation Strategy. Such features will be surveyed in as required and assessments will be made throughout by the supervising engineer as to whether any features represent potential vertical preferential pathways if removed or altered. If there is any risk of creation of preferential pathways the Local Authority Environmental Health Officer / Contaminated Land Officer or equivalent and National Resources Wales will be informed and proposals discussed and agreed to mitigate or adequately reduce any identified risks. Any materials (soils and concrete / brick etc) to be re-used on site should be done so under an appropriate end-of-waste protocol such as a U1 Exemption / WRAP Protocol or Materials Management Plan in accordance with the CL:AIRE Definition of Waste Code of Practice.

5.6. Contingency for any Unknowns or Previously Unidentified Localised Contamination

Whilst the ground investigation works conducted to date are regarded as, Tier Environmental wishes to demonstrate that due consideration has been given at an early stage on possible remedial solutions in the event that local grossly impacted soils or groundwater are identified on site.

Should any suspicious material be encountered during the redevelopment works, works shall be ceased within this part of the site and the area should then be investigated further by a suitably qualified geo-environmental engineer and sampled as necessary. The Contaminated Land Officer (or equivalent) at the Local Authority should also be notified immediately. Samples (if deemed necessary) will be forwarded to a UKAS/MCERTS accredited laboratory for a suite of analytical testing deemed appropriate based upon an appraisal of the material identified.

Once the results of the analysis are known and have been interpreted, the final required remedial action (if any) and remedial targets (as appropriate) will be determined and approved with the relevant regulatory authorities.

5.7. Water Supply Pipe Risk Assessment

Given the potential for contamination across site, a water pipe risk assessment has been completed. The assessment uses a risk assessment pro-forma published by the UK Water Industry Research (UKWIR) and is designed for use by developers, self-lay organisations, water companies and consultants when planning, designing and constructing water mains and/or services in brownfield sites. In the absence of a pro-forma produced by the local water provider, understood to be Welsh Water, the UKWIR guidance has been used.

Based on measured concentrations of hydrocarbons encountered during the investigation, barrier pipe will be required for the site. The completed risk assessment in included in Appendix H. It should be noted that this assessment has assumed 'Type A' barrier pipe will be selected.

5.8. Environmental Monitoring and Mitigation

Introduction

In order to mitigate the environmental impacts of the works on nearby surrounding land users, a programme of measures will be implemented during the remediation works.

Dust Mitigation

Appropriate measures shall be implemented at all times during the remediation works, to minimise dust emissions. Soils will be dampened down, as necessary, and activity will be minimised in extremely windy conditions to prevent dust nuisance. An adequate supply of water shall be maintained on site at all times to allow for dust suppression activities to be carried out at short notice.

When dusty material is being loaded onto trucks, extra care will be taken to ensure that the drop height is minimised. Trucks will be suitably covered when leaving the site with contaminated material to prevent dust migration.

The amount of disturbed surfaces left exposed for significant time periods will be minimised. Stockpiles of fine or loose materials should be tamped down or covered, if necessary, to reduce the production of dust. Traffic both entering and working on the site shall obey a maximum speed limit of 10 mph.

Noise

The requirements of BS 5228:1997 "Noise and Vibration Control on Construction Sites" shall be adhered to at all times. All machinery shall be fitted with effective silencers and shall be serviced at regular intervals. No plant shall be operated with engine covers raised.

Run-off into Drains

All potential drainage on site and any discharge points will be identified, including land drains, foul sewers, surface water drains and any combined drains. These will be marked, as appropriate, for easy identification.

Works will be minimised during periods of heavy rainfall to reduce the likelihood of contaminated run-off. Temporary containment and cover measures or tamping down of stockpiles to reduce run-off shall be used where necessary.

5.9. Waste Soils – Basic Characterisation and WAC

Any materials that require removal from the site will be exported from the site to the appropriate landfill and shall be hauled by a registered waste carrier in accordance with Duty of Care Regulations, 1991 and the Hazardous Waste Regulations, 2005.

There will be requirement for the waste producer to provide appropriate Waste Acceptance Criteria (WAC) testing of the soils for disposal to ensure that the soils are appropriately classified and that the landfill is licensed to receive such soils.

5.10. Verification Report

The SE should ensure that the requirements of the strategy are complied with. On satisfactory completion of all remedial works, a verification report should be produced. This report will comprise all relevant site records and act as certification that the remedial preparation works have been carried out in accordance with this remediation strategy.

The Verification Report shall include the following:

- A description of the works undertaken in accordance with the Remediation Strategy described above;
- Records of the works;
- Progress photographs;
- Photographs of the ground gas and vapour protection measures and details of the installed membrane;
- Waste Transfer Notes;
- Chemical verification test results.

6. GROUND GAS / VAPOUR MEMBRANE VERIFICATION PLAN

6.1. Ground Gas Risk Assessment and Mitigation Measures Summary

Ground gas monitoring was performed on 6 No. occasions on 8th June 2017 and 15th August 2017. A conservative Gas Screening Value (GSV) has been calculated assuming a maximum flow rate of 27.4l/hr and a maximum carbon dioxide concentration of 10.0% v/v. This has produced a GSV of 2.74l/hr, which places the site in a Characteristic Situation 3 - Moderate Risk Scenario in accordance with CIRIA C665. This assessment was based on flow rates that are elevated due to groundwater pumping. Based on the next highest flow rate of 0.1 l/hr, a GSV of 0.01 l/hr has been calculated which would place the site within a CS-1, very low risk scenario for which no gas protection measures would be required. However, due consideration of the conceptual site model including historic land use as a filling station, and potential for unrecorded contamination associated with USTs, and taking into consideration concentrations of carbon dioxide in excess of 'typical' thresholds in CIRIA C665 guidance, it is therefore considered that the site should be categorised as CS-2 (Low Risk), for which basic ground gas protection measures *are* required. The results of the human health risk assessment determined that the membrane should be upgraded to a volatile resistant membrane due to the historic land use as a filling station and potential for unrecorded contamination across site.

CIRIA C665 provides two separate methods to 'characterise' a site that firstly requires the assessor to distinguish between two fundamental development 'situations':

- **Situation A** - Any development other than Situation B (e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc) for which the **Modified Wilson and Card 'Characteristic Situation' classification system** is applied; and,
- **Situation B** - Low rise building with minimum ventilated under floor void (min 150mm) for which the **NHBC Traffic light classification system** is applied.

In this instance, as the site is due to be developed as low rise residential housing without basements, it should be regarded as a 'Situation B' scenario for the purposes of the ground gas risk assessment. The considerations outlined above suggest the site is placed in an Amber 1 scenario. It should be noted that support for the NHBC Traffic light classification system will be withdrawn by 1st July 2025, and new guidance is already in place under the NHBC Foundation NF94 publication 'Hazardous ground gas – an essential guide for housebuilders', released May 2023. The level of required ground gas protection measures for an Amber 1 scenario are comparable to those of a CS-2 scenario, however a points-based system will be followed in line with BS8485: 2015+A1:2019 to determine specific protection measures.

The proposed building footprint is considered by Tier Environmental to fall within a Type A category as defined by BS8485: 2015+A1:2019. Guidance document BS8485:2015+A1:2019 describes a Type A building as:

"Type A building: private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises."

As a result, gas protection measures with a minimum gas protection score of 3.5 would be required for a Characteristic Situation 2 – Low Risk scenario for the Type A building development.

It is proposed that the ground gas mitigation measures shall comprise:

- A gas resistant membrane conforming to guidance document BS8485:2015+A1:2019, Table 7 – 2.0 points
- Precast suspended segmental subfloor (i.e beam and block) – 0 points
- Good performance passive subfloor dispersal layer – 1.5 points

Notes: * In order for 1.5 points to be achieved, the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in.

It is understood proposed floor slab options are currently a ground bearing slab or block and beam construction. Based on the above measures, a block and beam floor does not contribute to the overall point score. A point score of 3.5 could therefore be achieved by means of a passive subfloor dispersal layer and a gas resistant membrane for 2 points. To comply with BS8485: 2015+A1:2019, a good performance dispersal layer should comprise one of the following:

- a minimum clear void space of 100mm which should avoid enclosed areas under the slab and allow for air flow between block and beam sections;
- a cuspated geocomposite with minimum thickness of 25 mm. (reduced point score to 1 if >15m building width)

in each case, for small to medium width buildings (up to 15 m wide), the minimum area of side ventilation should be 1 500 mm^2/m run of wall on at least two opposite sides, and, where there are multiple internal obstructions to air flow (caused by beams), there should be four or five times the area of the side vents provided in the internal obstructions

In order to fully qualify for the 2 points for the gas membrane in each instance, the membrane will be verified by Tier Environmental in accordance with CIRIA C735.

In addition to the above, the selected membrane will also need to be suitable to act as a vapour membrane tested against CIRIC C748 'challenge chemicals' in order to demonstrate protection against potential volatile hydrocarbon contamination associated with historic underground fuel tanks. An example of this would be the Visqueen Ultimate HC Block; however, an equivalent alternative membrane may be used so long as the above criteria are met.

6.2. Verification

General

An informed and risk-based approach has been taken as part of the verification plan, which has been produced to determine the following:

1. Decide which stakeholders are deemed suitable to undertake the necessary verification procedures;
2. How many site inspections should be undertaken; and,
3. The need for, and scope of, any integrity testing.

This risk-based system has taken into account the various factors that have influenced the scope of verification activities (including the possibility of integrity testing), which have included:

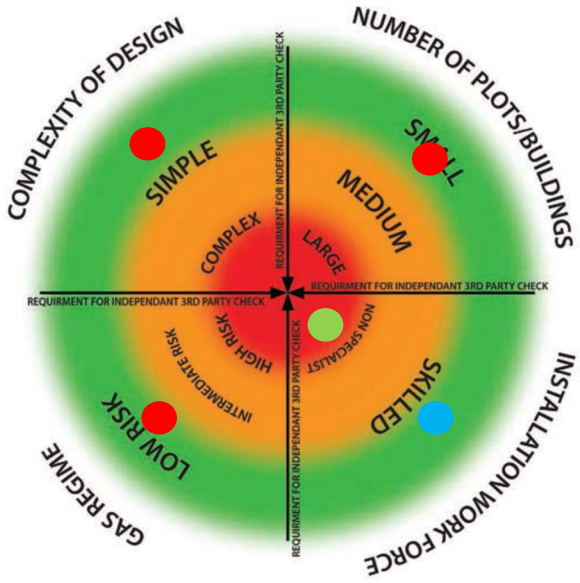
- Site-specific gas and vapour regime;
- Number of buildings to be inspected and the period over which this will take place;
- Complexity of the design and installation; and,

- Qualifications and experience of the workforce.

Figure 6.1 has been modified from CIRIA C735, with the red dots showing the relative placement of the site.

As the specific installation contractors and their skill level is not known at this time, two scenarios are considered, skilled and non-skilled. As such two dots have been placed on the Figure below to highlight this.

Figure 6.1 Analysis of the variables which have influenced the scope of the verification plan for this site.



Site and installation details

Skilled installation contractor

Non-skilled installation contractor

Independence and Competence

In respect to the level of competence required in general ground remediation, it is good practice to ensure that conflicts of interest in verification should be avoided. A contractor or gas / vapour membrane supplier certifying their own work or product is considered to be a conflict of interest and is therefore not good practice. If verification is carried out by the same company (or related company) that carried out the installation then the process, the results and report should be audited by an independent consultant.

It is not currently known who the installers of ground gas / vapour membranes will be. On this basis, two scenarios are considered, both for skilled and non-skilled installation workforce; this should be re-assessed upon appointment of the installers.

The verification will be undertaken by Tier Environmental.

The Inspection Regime

The gas / vapour membrane installation should be subject to a visual verification inspection to establish the adequacy of the ground preparation and, subsequently, possible damage to the installed ground gas / vapour membrane. The inspection visits should fall generally in line with the following:

1. The verifier should be a suitably qualified engineer with sufficient training and experience. The verifier will have minimum 2 No. years' experience and have completed in-house ground gas verification training.
2. The contractor should determine whether an area to be covered in a ground gas / vapour membrane is ready for inspection by initiating contact with verifier;
3. The verifier would then inspect all areas of interest with the site manager or groundworks supervisor;
4. The inspection will cover:
    - The ground prepared for the ground gas / vapour membrane which should be clean and free from stones etc;
    - The installation of the membrane to an acceptable standard, and;
    - The membrane itself.
5. The verifier should also inspect the ground gas / vapour membrane itself over the whole floor area, paying particular attention to laps, edges and the sealing of service entries and penetrations such as vent pipes;
6. The visual inspection should be recorded on the gas / vapour Protection Verification Pro Forma, as presented in Appendix J of this report;
7. Any discrepancies with the installation method recommended by the ground gas / vapour membrane supplier should be highlighted. These may include small or large holes and rips, tears and punctures, absence of tape (double sided or single sided tape) on the lapped areas, loose or unstuck tape, inadequate corner details, and unbounded seams such as loose edges and 'fish mouths' in the ground gas / vapour membrane;
8. Tapes used to join ground gas / vapour membranes should be inspected to make sure they are compatible with the ground gas / vapour membrane being joined and are as specified by the ground gas / vapour membrane supplier or specifier; non-proprietary ground gas / vapour resistant tape should never be used to seal a ground gas / vapour membrane. Where welded joints are used, the verifier should ensure they are correctly tested;
9. Repairs should be instructed and observed on the same day as the site visit or inspected at a later date. This will be documented on the gas / vapour Protection Verification Pro Forma for that visit. The frequency and intensity of inspections should increase to reflect any lower level of competence of the workers installing the gas protection system;
10. As the membrane may be located below floor construction, inspections should take place after the installation of the membrane and also before placement of the floor construction. The concrete / screed should then be poured as soon as possible after the ground gas / vapour membrane has been signed off, in order to ensure that follow-on trades do not damage a gas / vapour membrane that has been signed off; and,
11. All follow-on trades should be made aware of the presence and purpose of the ground gas / vapour membrane, and who they should contact if they believe their actions have had the potential to compromise it.

The final verification report will include photographs as supporting evidence. A pro forma should be completed for each inspection visit. All pro formas should be retained for inclusion within the final verification report in order to demonstrate the involvement of the verifier throughout the process and provide evidence of the appropriate installation of the gas protection measures. An example pro forma which highlights all aspects to inspect is provided in Appendix J of this report.

Inspection Timing and Frequency

There is currently no absolute guidance relating to the number and frequency of visits; however, for the purposes of this verification plan, reference has been made to Table A1 within Annex 1 of CIRIA C735. Whilst at this stage it is not possible to give specific dates for inspection visits, the following rules should be adhered to when attending site to make the required visual inspection (relative to the site specific risks shown in Figure 6.1).

- If skilled (defined by CIRIA C735 as holding NVQ Level 2 qualification in gas protection installation). installers are used, verifier to conduct a thorough verification (visual) inspection of the membrane and installation prior to between 25 and 50 per cent of concrete pours with inspections undertaken just prior to a concrete pour event; or,
- If non skilled (general builder/groundworker) installers are used, verifier to conduct a thorough verification (visual) inspection of the membrane and installation prior to all concrete pours with inspections undertaken just prior to a concrete pour event;
- Inspection will be predominantly visual but may include the mechanical point stress test (this involves running a blunt instrument (e.g. a screwdriver) along the edge of the seam to identify any unbounded seams); and,
- The installer to supply sign off sheets (verification evidence) including photographs to the verifier.

After all inspections are completed it is advised that the membranes are protected using insulation and/or other adequate measures to prevent any damage before the concrete pour. It is also advised that signs are displayed around the site advising all site users of the presence of the ground gas / vapour membrane and noting measures to avoid damage to the membrane.

Integrity Testing

Consideration has been made to the use of integrity testing as part of the verification of the gas protection measures. In determining the requirement for integrity testing, reference has also been made to the diagram in Figure 6.1 and Table A1 of Annex 1 of CIRIA C735:

- The site is Low Risk with respect to ground gases (Characteristic Situation 2 – Low Risk in accordance with CIRIA C665); and,
- The membrane is being inspected by a qualified geoenvironmental engineer

As such integrity testing is not currently recommended in this verification plan. It should be noted; however, that this is dependent upon the results of the initial verification visits. If, following these initial visits, it is deemed by the verifier that the installation is of a questionable standard, the use of integrity testing may be added to this verification plan. The results of any integrity testing must therefore be included in any final verification report.

Non-Conformances

Non-conformances to this verification plan will be recorded and noted to the contractors. Works will be then undertaken to rectify any non-conformance either under the supervision of Tier Environmental Ltd or a subsequent inspection will be undertaken post remedial works to verify that the non-conformance has been adequately rectified. An assessment will be made, depending on the scale, nature and extent of the non-conformance as to whether the Contaminated Land Officer shall be notified including agreement of any measures to be taken to rectify the situation.

7. REGULATORY APPROVALS

The conclusions and recommendations presented above are considered reasonable based on the findings of the site investigations. However, these cannot be guaranteed to gain regulatory approval and, therefore, the report should be passed to the appropriate regulatory authorities and/or other organisations for their comment and approval.

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9. GLOSSARY OF TERMS

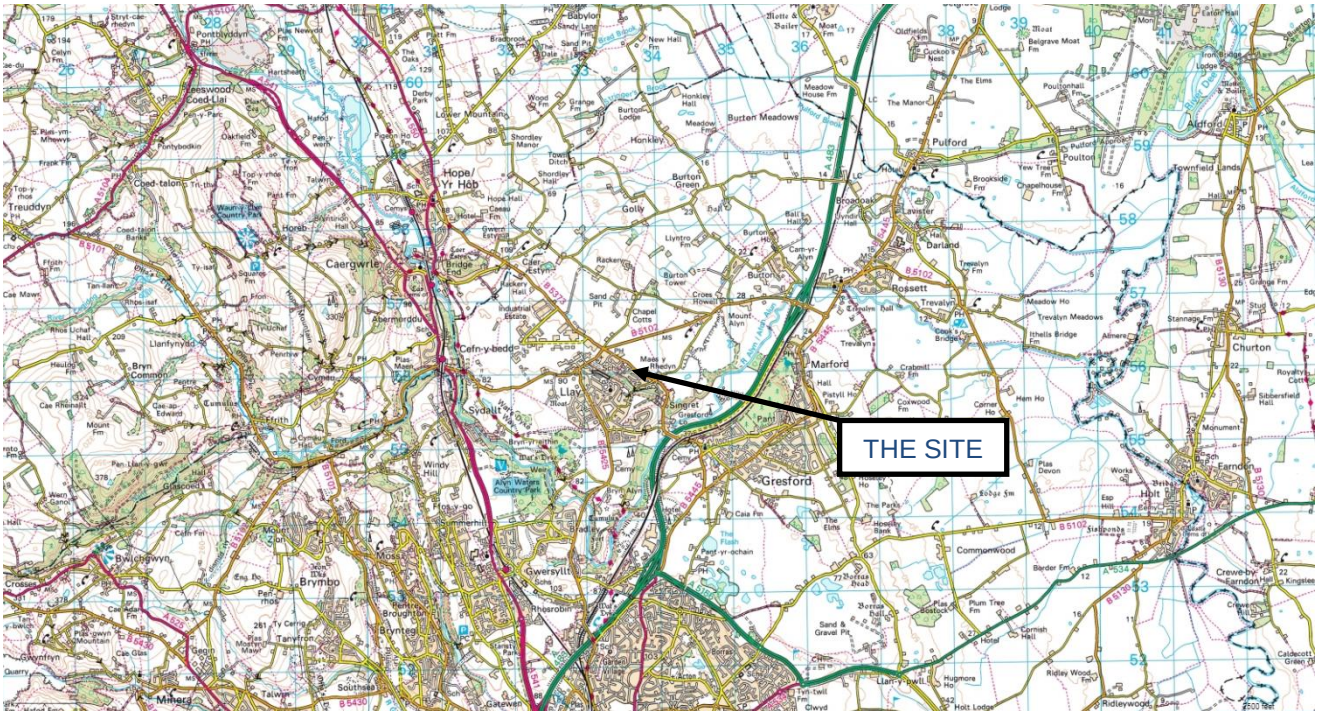
ACEC	Aggressive Chemical Environment for Concrete (classification)
aOD	Above Ordnance Datum
bgl	Below ground level
BGS	British Geological Survey
BRE	Building Research Establishment
CBR	California Bearing Ratio (test)
COMAH	Control of Major Accident Hazards (regulations)
Designated location	Site (and the ecosystem on that site) protected under national of international legislation. A potential ecological receptor to be considered as part of the assessment of land contamination. Example designated locations include SSSIs (q.v.), SACs (q.v.), national nature reserves, Ramsar sites and bird special protection areas.
DQA	Data Quality Assessment
DQO	Data Quality Objective
DQRA	Detailed Quantitative Risk Assessment
DWS	Drinking Water Standard
EQS	Environmental Quality Standard
GAC	Generic Assessment Criterion
GQA	General Quality Assessment (Environment Agency)
GSV	Gas Screening Value
HCV	Health Criteria Value
IPPC	Integrated Pollution Prevention and Control (regulations)
K_{ow}	Octanol-water partition coefficient
LEL	Lower Explosive Limit
LL	Liquid Limit
LoD	Limit of Detection (analytical)
LoQ	Limit of Quantification (analytical)
Mean Value Test	Statistical test (described in the CIEH Guidance) to estimate the mean value of a normally distributed population of data at a given level of confidence. Normally for contaminated land assessment, the 95th percentile (referred to as the 95%UCL or US95) is applied as a reasonable but conservative estimate of the mean concentration for comparison with the relevant assessment criteria.
Maximum Value Test	Statistical test (described in the CIEH Guidance) to identify whether an elevated concentration within a normally distributed data set forms part of the underlying population from which it has been sampled or whether it is an outlier (such as a localised area of contamination) that merits further consideration.
MC	Moisture Content
NGR	National Grid Reference
NIHHS	Notification of Installations Handling Hazardous Substances (regulations)
OS	Ordnance Survey
PI	Plasticity Index
PID	Photoionisation Detector
PL	Plastic Limit
ppm	Parts per million
ppmv	Parts per million by volume
QA	Quality Assurance
QC	Quality Control
SAC	Special Area of Conservation
SOM	Soil Organic Matter

SPT	Standard Penetration Test
SPZ	Source Protection Zone (see Appendix E)
SSAC	Site-Specific Assessment Criterion
SSSI	Site of Special Scientific Interest
SVOC	Semi-Volatile Organic Compound
TEF	Toxicity Equivalent Factor
TPH	Total Petroleum Hydrocarbons
TWA	Time Weighted Average
US95	95th percentile estimate of the true mean value of a data population (also known as 95%UCL).
VOC	Volatile Organic Compound

APPENDIX A - DRAWINGS

Contract Number	**TE1010**
Contract	Llay, Wrexham
Client	Tier Consult Ltd

Site Location Plan



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Scale	**NTS**		
Drawn by	OH	**Approved**	SL
Drawing Number	**TE1010/GIR/1**		

DO NOT SCALE

WS - Window Sample Location

REV	DATE	BY	DESCRIPTION	CHK	APD

DRAWING STATUS: DRAFT

Tier Consult Ltd.
Richmond House
Sandpiper Court
Chester Business Pa
Chester
CH4 9QZ
Telephone:
01244 684900
Fax:
01244 684901
Mobile:
07966 687066
Email:
info@tieruk.com

CLIENT: Tier Consult Ltd

ARCHITECT:

PROJECT: Llay
Wrexham

TITLE: Window Sample Location Plan

SCALE @ SIZE:	CHECKED:	APPROVED:
NTS	???	???
CAD FILE:	DESIGN/DRAWN:	DATE:
TE1010.GIR.WSLP	RH	May '17
PROJECT No:	DRAWING No:	REV:
TE1010	TE1010/GIR/WSLP	0

DO NOT SCALE

NOTES

5X5 AREA OF POSSIBLE TANK EXCAVATION

SUSEPCTED UST/AST

REV	DATE	BY	DESCRIPTION	CHK	APD
P1	03/12/2024	CS	ISSUED FOR INFORMATION	SM	SM

DRAWING STATUS: INFORMATION

Tier Environmental Ltd.
Unit 5 Office Village
Sandpiper Court
Chester Business Park
Chester | CH4 9QZ

t: 01925 818 388

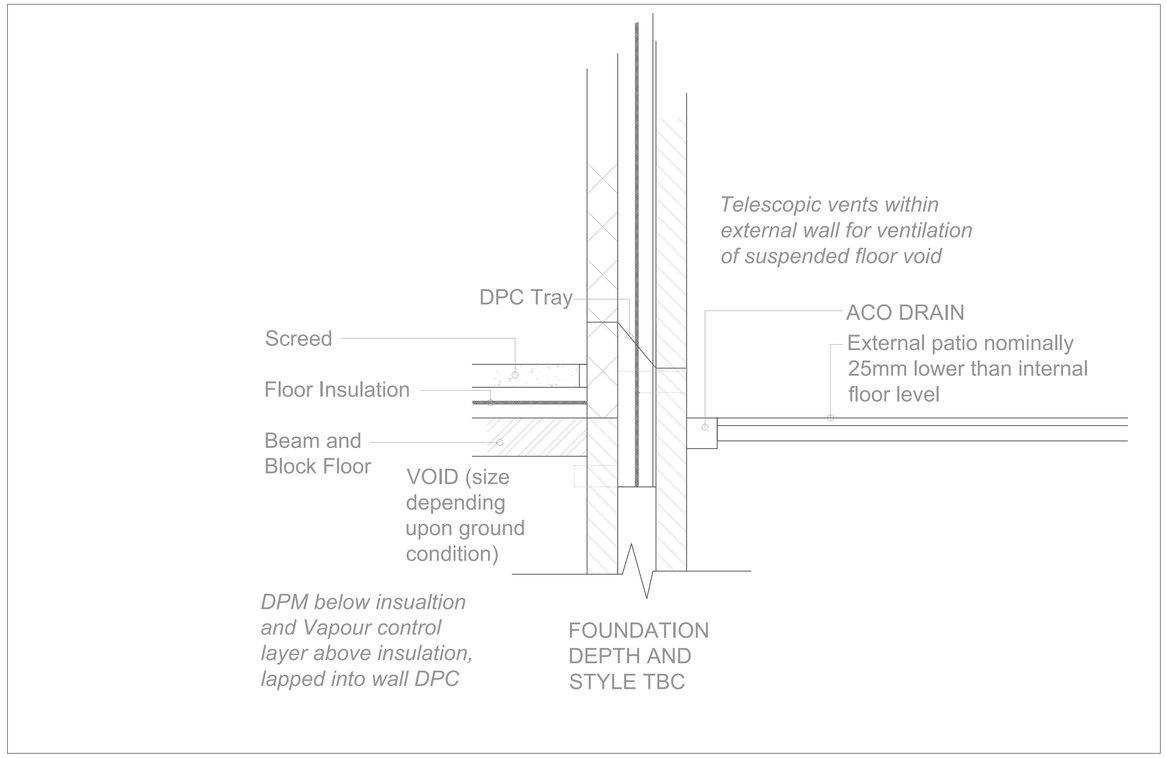
CLIENT: TIER CONSULT

PROJECT: LLAY, WREXHAM

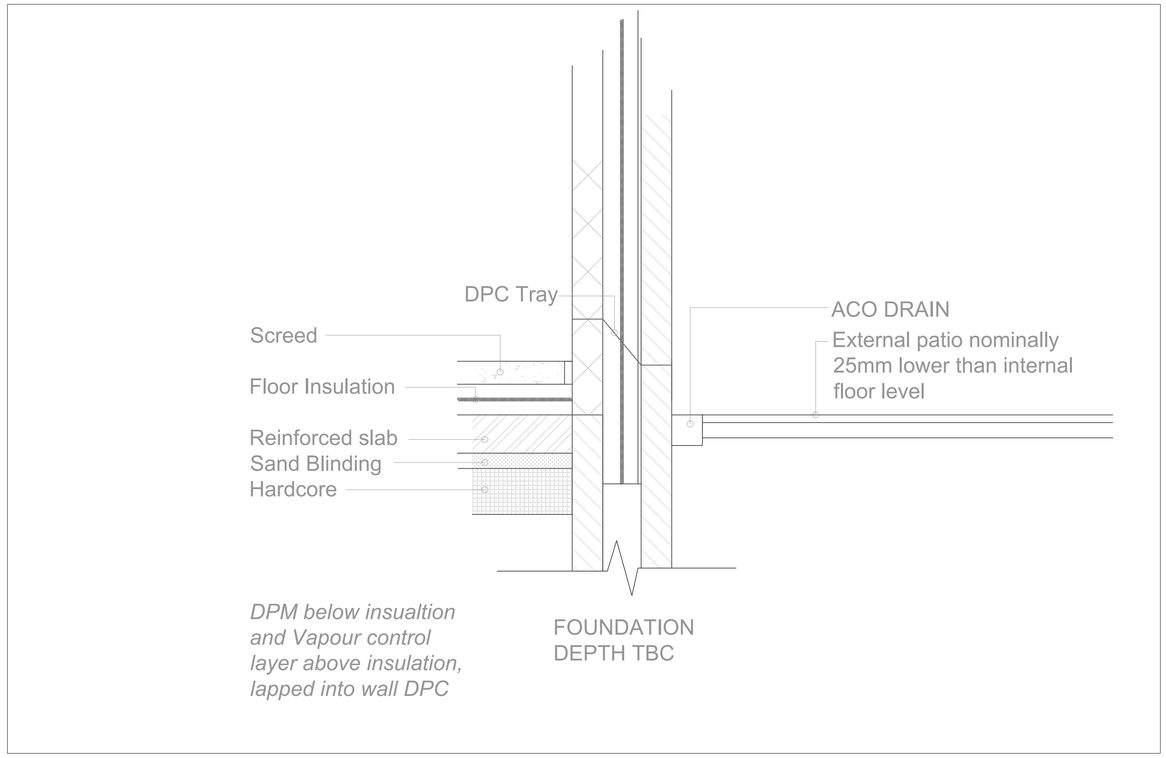
TITLE: POSSIBLE UNDER/ABOVE GROUND STORAGE TANK REMEDIATION LOCATIONS

SCALE @ SIZE:	CHECKED:	APPROVED:
NTS	SM	SM
CAD FILE:	DESIGN/DRAWN:	DATE:
–	CS	03/12/2024

PROJECT No:	DRAWING No:	REV:
TE1010	TE1010-TE-00-XX-DR-GE-001-V01	P1



INDICATIVE SECTION SUSPENDED BAM AND BLOCK FLOOR OPTION



INDICATIVE SECTION GROUND BEARING SLAB OPTION

STRUCTURAL ENGINEERS SITE INVESTIGATION AND DESIGN REQUIRED TO CONFIRM FOUNDATION AND SLAB BUILD UP

SCOTT ARCHITECTURE LTD
Tel: 07973117032
E-Mail:
info@scottarchitecture.co.uk
68 High Street, Tarporley,
Cheshire, CW6 0AT

CLIENT: Mr R. Whitney (Roof Plus)

PROJECT:
22008- Woodville Garage, 14 Gresford Road, Llay, LL12 0NW

DRAWING TITLE:
Draft slab build up options

Scale: 1:10@A1

JOB No. 22008

DRAWING No.22008-PL-800

STATUS: PLANNING

REVISION	DATE
0	04.12.24

GENERAL NOTES

This drawing is the copyright of Scott Architecture Ltd. All dimensions and levels are to be checked on site. Do not scale. All errors and omissions to be reported to the architectural designer prior to commencement. This drawing must be read in conjunction with the relevant specification clauses. This drawing must not be used on site unless issued for construction. This drawing must not be used for purposes other than that for which it is provided. It is supplied without liability for any errors or omissions. All drawings subject to statutory authority approval.

CDM REGULATIONS

The contractor is responsible for informing the client, and for carrying out all measures necessary to ensure compliance with any relevant health and safety legislation, in particular the construction design and management 'CDM' regulations. Any discrepancies in the drawings should be reported to the architectural designer for decision.

STRUCTURAL INFORMATION

for all structural information refer to structural engineers drawings and details. drawings to be read in conjunction with all other specialist drawings all dimensions to be checked on site before works and fabrication of components commence.all discrepancies to be reported to the architectural designer at the first opportunity.

MATERIALS

All materials and components must be suitable for their intended purpose and location and must be manufactured and installed in accordance with all relevant british standards and codes of practice. Any reference to an approved document in this specification relates to the relevant approved document of the building regulations. All work generally to be carried out in accordance with the building regulations and the satisfaction of the approved building control inspectorate.

All Dimensions and Levels to be checked on site

Impact on neigbouring property Right of Light advised to be assessed before commencement of proposed work

Community Infrastructure Levy Forms to be completed and confirmation received from council prior to commencement that all required information has been received. If these forms are not completed prior to commencement then the Levy will become due and no relief will be possible.

APPENDIX B - PREVIOUS SITE INVESTIGATION REPORT (AVAILABLE AS A SEPARATE DOCUMENT)

APPENDIX C - DEFINITIONS OF TERMS USED IN QUALITATIVE AND QUANTITATIVE RISK ASSESSMENTS

CIRIA C552 Terminology

For the qualitative and quantitative assessment of risks posed by potential pollutant linkages have been undertaken using the risk matrix adapted from CIRIA C552 and outlined in the table below.

	Category	Definition
Potential severity	Severe	Acute (short term) risk to human health, Major pollution of sensitive controlled waters, ecosystems or habitat. Catastrophic damage to buildings or property or crops.
	Medium	Chronic (Medium / long term) risk to human health Pollution of sensitive controlled waters, ecosystems or species, Significant damage to crops, buildings or structures
	Mild	Easily preventable permanent health effects on humans. Pollution of non-sensitive controlled waters. Minor damage to buildings or structures.
	Minor	Easily preventable non-permanent health effects on humans, or no effects. Minor, low level and localised contamination of on-site soil. Easily repairable damage to buildings or structures.
Probability of risk	High Likelihood	Pollutant linkage may be present, and the risk is almost certain to occur , or there is evidence of harm already occurring.
	Likely	Pollutant linkage may be present, and it is probable that the risk will occur over the long term.
	Low Likelihood	Pollutant linkages may be present and there is a possibility of the risk occurring, although there is no certainty that it will do so.
	Unlikely	Pollutant linkage may be present but the circumstances under which harm would occur are improbable.

		Potential Severity			
		Severe	**Medium**	**Mild**	**Minor**
Probability of risk	**High Likelihood**	Very high risk	High risk	Moderate risk	Moderate / low risk
	Likely	High risk	Moderate risk	Moderate / low risk	Low risk
	Low Likelihood	Moderate risk	Moderate / low risk	Low risk	Very low risk
	Unlikely	Moderate / low risk	Low risk	very low risk	Very low risk

APPENDIX D - HUMAN HEALTH ASSESSEMENT CRITERIA

HUMAN HEALTH ASSESSMENT CRITERIA

Context

Contaminated Land is defined under law through Part IIA of the Environmental Protection Act 1990, implemented through Section 57 of the Environment Act 1995 and associated guidance ("Part IIA"). These specify that a "suitable for use" approach is to be applied in the assessment of potentially contaminated land, implemented through a phased programme of site investigation and risk assessment appropriate to the site under consideration.

The assessment of potential risks posed by contaminated land is based upon the assessment of plausible contaminant source - pathway - receptor linkages ("pollutant linkages") for the current and/or proposed future use of the site. The process for the assessment of contaminated land adopted in this report is in line with guidance issued by the Environment Agency Land contamination risk management (LCRM) - GOV.UK (www.gov.uk)

Land contamination can harm:

- human health
- drinking water supplies, groundwater and surface water
- soils
- ecosystems including wildlife, animals and wetlands
- property

It can also affect the current and future land use. Dealing with land contamination helps make the environment clean and safe. Through regeneration it can:

- enhance the health and wellbeing of all
- add to the economic, ecological and amenity value of the area

Use land contamination risk management (LCRM) to:

- identify and assess if there is an unacceptable risk
- assess what remediation options are suitable to manage the risk
- plan and carry out remediation
- verify that remediation has worked

You can use LCRM in a range of regulatory and management contexts. For example, voluntary remediation, planning, assessing liabilities or under the Part 2A contaminated land regime. The Environment Agency expects you to follow LCRM if you are managing the risks from land contamination.

We support the use of the National Quality Mark Scheme (NQMS). You can use it for any type of land contamination report.

Using the NQMS:

- will make sure all legislative requirements and necessary standards related to managing land contamination are met
- can provide increased confidence by submitting reports of the quality we expect
- can result in cost and time savings by 'getting it right first time'

LCRM is made up of 4 guides.

1. LCRM: Before you start.
2. LCRM: Risk assessment.
3. LCRM: Options appraisal.
4. LCRM: Remediation and verification.

We use a staged risk based approach. There are 3 stages, and each stage is broken down into tiers or steps.

Stage 1: Risk assessment

You will use a tiered approach to risk assessment. The 3 tiers are:

1. Preliminary risk assessment.
2. Generic quantitative risk assessment.
3. Detailed quantitative risk assessment.

Stage 1 includes information for intrusive site investigations.

Stage 2: Options appraisal

There are 3 steps to follow.

1. Identify feasible remediation options.
2. Do a detailed evaluation of options.
3. Select the final remediation option.

Stage 3: Remediation and verification

There are 4 steps to follow.

1. Develop a remediation strategy.
2. Remediate.
3. Produce a verification report.
4. Do long term monitoring and maintenance, if required

You must always start with a preliminary risk assessment.

The risk assessment stage is an iterative process. You can do the 3 tiers in order or progress from a preliminary risk assessment to a detailed quantitative risk assessment. As part of a generic or detailed quantitative risk assessment you will need to collect detailed information about the site. This is usually through an intrusive site investigation.

Depending on the level of risk or regulatory requirements, you can proceed from a preliminary risk assessment to the options appraisal stage. If you proceed direct to the options appraisal stage, you still need to collect the detailed site investigation information required by the generic and detailed quantitative risk assessments. This is to confirm that your approach is viable and acceptable.

Following the risk assessment stage, if you conclude that the risks are acceptable, with agreement from the relevant regulator, you can end the process.

If there are unacceptable risks, then remediation or mitigation is required. Follow stages 2 and 3 in order.

In stage 2 options appraisal, you will:

- look at the most feasible options
- produce a shortlist of options
- use evaluation criteria to assess them
- select which ones are the most suitable to take forward to stage 3

In stage 3 remediation and verification, you will produce a remediation strategy, do the remediation and then produce a verification report.

You will decide at the options appraisal stage if long term monitoring and maintenance is the remediation option. You may need to do post-remediation monitoring for further verification.

The risk assessment and subsequent investigation, remediation and verification must address all potential sources of pollutants that may be present on the site (the “hazards”), all receptors that may be harmed by these (e.g., human health, controlled waters, ecological receptors) and the pathways by which the contamination may be transported from the contaminant source(s) to the receptor(s). This is defined within the conceptual model for the site, which represents the characteristics of the site in a form that shows the possible pollutant linkages. As further information becomes available (for example, through site investigation), so the conceptual model will be refined.

Remedial action can be specified at any phase within this assessment process to break the identified pollutant linkage in determining whether or not to undertake further assessment or to undertake remediation, the potential cost-savings arising from a more thorough assessment of the pollutant linkages and more tightly defined remedial strategy must be considered against the direct costs involved in the work and the time that this will take to execute and gain regulatory approval.

A different approach to the statistical appraisal of data is required depending on whether the assessment is being undertaken to assess land as Contaminated Land in accordance with the regulations or whether the assessment is to assess whether the site is suitable for new development in accordance with the Planning regime. The statistical approach to assessment is discussed further in CL:AIRE:2020 “Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration”.

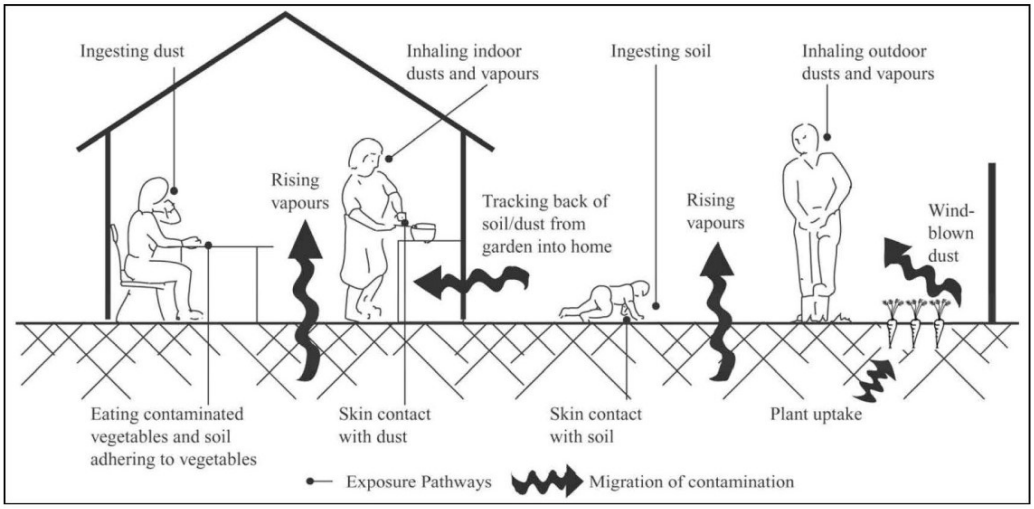
Some form of Detailed Quantitative Risk Assessment (DQRA) will be essential for those cases where appropriate GAC values cannot be established for the contaminant linkages under consideration.

Generic Assessment Criteria for Human Health Risk Assessment

In March 2002, the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency (EA) published the Contaminated Land Exposure Assessment (CLEA) Model and a series of related reports and guidance. These were designed to provide a scientifically based framework for the assessment of chronic risks to human health from contaminated land. The initial documents (CLR7 – 10) were withdrawn and replaced with revised guidance issued by the Environment Agency including:

- "Using Soil Guideline Values"; EA,2009; Land contamination: using soil guideline values (SGVs) - GOV.UK (www.gov.uk)
- "Human Health toxicology assessment of contaminants in soil" EA;, 2009; https://www.gov.uk/government/publications/human-health-toxicological-assessment-of-contaminants-in-soil
- "Update technical background to the CLEA model" 2009; https://www.gov.uk/government/publications/updated-technical-background-to-the-clea-model
- CLEA Software (Version1.05) Handbook 2015; https://www.gov.uk/government/publications/contaminated-land-exposure-assessment-clea-tool
- Compilation of Data for priority Organic Contaminants for Derivation of Soil Guideline Values; Science Report SC050021/SR7, 2008; and,
- "Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration". CL:AIRE:2020 https://www.claire.co.uk/component/phocadownload/category/9-other-cl-aire-documents?download=745:2020-stats-guidance

The CLEA model and associated guidance was developed to calculate an estimated tolerable daily intake (TDI) of contaminants for site users given a set of 'typical' human health exposure pathways which are detailed in "SR3: Updated technical background to the CLEA model"



(Science Report SC050021/SR3, EA, 2009) and reproduced below.

Ingestion

- Outdoor soil;
- Indoor dust;
- Home grown produce;
- Soil attached to home grown produce.

Dermal Contact

- Outdoor soil;
- Indoor dust.

Inhalation

- Outdoor dust;
- Indoor dust;
- Outdoor vapour;
- Indoor vapour.

It should be noted that the CLEA model does not include an exhaustive list of potential exposure pathways, e.g. certain compounds can pass through plastic water pipes into drinking water supply.

The potential significance of each of the exposure pathways is dependent upon the type of land use and the nature of the contaminant being considered. The CLEA model considers principal 'default' land use scenarios and makes a series of assumptions with regards to building type (where applicable), identification of the critical human receptor group, exposure frequency and duration. The definitions of the principal land use types given in SR3 (EA, 2009) are:

Residential land use;

- A typical residential property consisting of a two-storey terraced house built on a ground-bearing slab of 0.15m thickness with a private garden consisting of lawn, flowerbeds, and a small fruit and vegetable patch. The occupants are assumed to be parents with young children, who make regular use of the garden. The critical receptor is a 0 – 6-year-old female.
- Active exposure pathways are ingestion of outdoor soil, ingestion of indoor dust, ingestion of home grown produce and soil adhering to home grown produce; direct dermal contact with outdoor soil and indoor dust; inhalation of outdoor dust and vapour and indoor dust and vapour

Allotments

- A plot of open space commonly made available by the Local Authority to tenants to grow fruit and vegetables for their own consumption. There are usually several plots to a site and the overall site area may cover more than one hectare. The tenants are assumed to be the parents or grandparents and that young children make occasional accompanied visits to the plots. The critical receptor is a 0 – 6-year-old female and there is no building present on site.
- Active exposure pathways are ingestion of outdoor soil, ingestion of home grown produce and soil adhering to home grown produce; direct dermal contact with outdoor soil; inhalation of outdoor vapour.

Commercial and industrial land use.

- A typical commercial or light industrial property consisting of a three-story office building (pre-1970) with a ground bearing floor slab at which employees spend most time indoors and are involved in office based or related light physical work. The critical receptor is a working female adult aged 16 – 65 years.
- Active exposure pathway is ingestion of outdoor soil, ingestion of indoor dust; direct dermal contact with outdoor soil and indoor dust; inhalation of outdoor dust and vapour and inhalation of indoor dust and vapour.

Soil Guideline Values

Based on the assumption of each land use type, the EA and DEFRA developed and published Soil Guideline Value (SGV) using the CLEA model for a number of principal contaminants and 'default' end-use scenarios of residential, allotments and commercial/industrial use. The primary purpose of the SGVs is as trigger value for the tolerable daily intake (TDI), below which it can be assumed that the soil does not pose an unacceptable risk to the identified receptor. Where soils contamination is present above this level further assessment may be required. SGVs were developed for the following contaminants:

- Heavy metals and other inorganic compounds: arsenic, cadmium, chromium, cyanide, lead (now withdrawn), mercury, nickel and selenium.
- Benzene, ethylbenzene, toluene and xylenes.
- Phenol.
- Dioxins and dioxin-like polychlorinated biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs) – 11 substances

LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment

In addition, in 2009 CIEH through LQM and EIC published generic assessment criteria (GACs) for 82 substances including metals, petroleum hydrocarbons, PAHs and explosive substances for a variety of soil types and the three 'default' land uses – (residential, allotments and commercial end-uses) as described in SR3 (EA, 2009). These have been superseded as described below.

Category 4 Screening Values

In 2013 "SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination" (CL:AIRE 2013) was issued which detailed findings of a research project undertaken by CL:AIRE to set out the framework by which potential Category 4 Screening Levels (pC4SL) may be derived for 6 contaminants of concern, Arsenic, Benzene, Benzo(a)pyrene, Cadmium, Chromium VI and Lead.

This was supplemented in 2014 by "SP1010: Development of Category 4 Screening Levels for the Assessment of Land Affected by Contamination – Policy Companion Document" (DEFRA, 2014). SP1010 proposed several updated toxicology information relating to contaminant behaviour updated assumptions relating to the modelling of human exposure to soil contaminants, derivation of separate C4SLs for residential with the consumption of home grown produce, residential without the consumption of home grown produce, and two new land uses: public open spaces near residential housing (POS resi) and public parks (POS park).

Public Open Space: Residential

- For public open space in close proximity to residential housing and the central green area around which houses are located, as on many housing estates from the 1930s to 1970s. It is also applicable for smaller areas commonly incorporated in newer developments as informal grassed areas or more formal landscaped areas with a mixture of open space and covered soil with planting. It is considered to be a generally grassed area up to 0.5ha with up to 50% bare soil. The land use is an important resource

for children and the area is near the homes. The critical receptor is a female child age >3 - <9 years old (CLEA age class 4 – 9) as younger children are unlikely to play outdoors unsupervised.

- Active exposure pathways are ingestion of outdoor soil, ingestion of indoor dust; direct dermal contact with outdoor soil and indoor soil derived dust; inhalation of outdoor and indoor dust and inhalation of outdoor vapour.

Public Open Space: Park

- A public park is defined as an area of open space provided for recreational use and usually owned and maintained by the Local Authority. It is anticipated the park could be used for a wide range of activities, including the following:
    - Family visits and picnics;
    - Children's play area;
    - Sporting activities such as football on an informal basis (i.e. not a dedicated sports pitch); and
    - Dog walking.
- The park is modelled as an area >0.5 ha of predominantly grasses open space with no more than 25% of exposed soil.
- The critical receptor is a female child with CLEA age classes 1 – 6.
- Active exposure pathways are: ingestion of outdoor soil; direct dermal contact with outdoor soil; inhalation of outdoor dust and inhalation of outdoor vapour.

Furthermore, the C4SLs are based on a different toxicological benchmark, the 'low level of toxicological concern' (LLTC). This difference in approach was adopted because the C4SLs were primarily intended for use under Part2A of the EPA 1990 to quickly screen out Category 4 sites where there is "*no risk or that the level of risk posed is low*". SGVs and LQM GACs are based on the more conservative 'minimal or tolerable level of risk' as defined in SR2 (EA, 2009) and were derived for assessment of contamination for the Planning process.

LQM/CIEH Suitable 4 Use Levels (S4ULs)

The publication of the C4SLs resulted in considerable and inconclusive debate about the applicability of the lower level of protection of the C4SL, which are underlain by the LLTC, outside of the Part 2A context for which they were derived. In 2014 LQM/CIEH presented a Suitable 4 Use Levels (S4ULs), which incorporate the updated assumption exposure derived for the production of the C4SLs but within the context of deriving screening criteria above which further assessment of the risks or remedial action may be needed. The S4ULs replace the 82 substances, species and fractions and congeners contained in the previous LQM/CIEH GACs issued in 2009. Additionally, following changes and new land uses proposed in the C4SL research project, S4ULs have also been derived for the majority of substances for which the EA derived SGVs in 2009 with the exception of lead (see below).

Lead

The C4SL for lead provides a technically robust and conservative assessment tool using significantly updated toxicological modelling than the withdrawn SGV and derived in line with current science of lead toxicology.

EIC/AGS/CL:AIRE Soil Generic Assessment Criteria (2010)

In some instances, EIC/AGC/CL:AIRE GACs for certain VOC / SVOC potential contaminants of concern have been used *in lieu* of available LQM / CIEH S4UL values.

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Metals/metalloids																			
Arsenic	37			40			43			640			79			170			LQM (2014)
Beryllium	1.7			1.7			35			12			2.2			63			LQM (2014)
Boron	290			11000			45			240000			21000			46000			LQM (2014)
Cadmium	11			85			1.9			190			120			532			LQM (2014)
Chromium III	910			910			18000			8600			1500			33000			LQM (2014)
Chromium VI	6			6			1.8			33			7.7			220			LQM (2014)
Copper	2400			7100			520			68000			12000			44000			LQM (2014)
Lead	200			310			80			2330			630			1300			C4SL
Mercury (elemental)	1.2			1.2			21			58 (25.8)			16			30 (25.8)			LQM (2014)
Mercury (Inorganic)	40			56			19			1100			120			240			LQM (2014)
Methylmercury	11			15			6			320			40			68			LQM (2014)
Nickel	180			180			230			980			230			3400			LQM (2014)
Selenium	250			430			88			12000			1100			1800			LQM (2014)
Vanadium	410			1200			91			9000			2000			5000			LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Zinc	3700			40000			620			730000			81000			170000			LQM (2014)
Other																			
Total Sulphate	2,400			2,400			2,400			2,400			2,400			2,400			BRE (2005)
Water Soluble Sulphate (g/l)	0.5			0.5			0.5			0.5			0.5			0.5			BRE (2005)
PAHs																			
Acenaphthene	210	510	1100	3000 (57)	4700(141)	6000 (336)	34	85	200	84000 (57)	97000 (141)	100000	15000	15000	15000	29000	30000	30000	LQM (2014)
Acenaphthylene	170	420	920	2900 (86.1)	4600 (212)	6000 (506)	28	69	160	8300 (86.1)	97000 (212)	100000	15000	15000	15000	29000	30000	30000	LQM (2014)
Anthracene	2400	5400	11000	31000 (1.17)	35000	37000	380	950	2200	520000	540000	540000	74000	74000	74000	150000	150000	150000	LQM (2014)
Benzo(a)anthracene	7.2	11	13	11	14	15	2.9	6.5	13	170	170	180	29	29	29	49	56	62	LQM (2014)
Benzo(a)pyrene	2.2	2.7	3	3.2	3.2	3.2	0.97	2	3.5	35	35	36	5.7	5.7	5.7	11	12	13	LQM (2014)
Benzo(b)fluoranthene	2.6	3.3	3.7	3.9	4	4	0.99	2.1	3.9	44	44	45	7.1	7.1	7.1	13	15	16	LQM (2014)
Benzo(g,h,i)perylene	320	340	350	360	360	360	290	470	640	3900	4000	4000	640	640	640	1400	1500	1600	LQM (2014)
Benzo(k)fluoranthene	77	93	100	110	110	110	37	75	130	1200	1200	1200	190	190	190	370	410	440	LQM (2014)
Chrysene	15	22	27	30	31	32	4.1	9.4	19	350	350	350	57	57	57	93	110	120	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Dibenz(a,h)anthracene	0.24	0.28	0.3	0.31	0.32	0.32	0.14	0.27	0.61	3.5	3.6	3.6	0.57	0.57	0.58	1.1	1.3	1.4	LQM (2014)
Fluoranthene	280	560	890	1500	1600	1600	52	130	290	23000	23000	23000	3100	3100	3100	63	6300	6400	LQM (2014)
Fluorene	170	400	860	2800 (30.9)	3800 (76.5)	4500 (183)	27	67	160	63000 (30.9)	68000	71000	9900	9900	9900	20000	20000	20000	LQM (2014)
Indeno(1,2,3-cd)pyrene	27	36	41	45	46	46	9.5	21	39	500	510	510	82	82	82	150	170	180	LQM (2014)
Naphthalene	2.3	5.6	13	2.3	5.6	13	4.1	10	24	190 (76.4)	460 (183)	1100 (432)	4900	4900	4900	1200 (76.4)	1900 (183)	3000	LQM (2014)
Phenanthrene	95	220	440	1300 (36)	1500	1500	15	38	90	22000	22000	23000	3100	3100	3100	6200	6200	6300	LQM (2014)
Pyrene	620	1200	2000	3700	3800	3800	110	270	620	54000	54000	54000	7400	7400	7400	15000	15000	15000	LQM (2014)
Coal Tar (BaP as surrogate marker)	0.79	0.98	1.1	1.2	1.2	1.2	0.32	0.67	1.2	15	15	15	2.2	2.2	2.2	4.4	4.7	4.8	LQM (2014)
BTEX and TPH																			
Benzene	0.087	0.17	0.37	0.38	0.7	1.4	0.017	0.034	0.075	27	47	90	72	72	73	90	100	110	LQM (2014)
Toluene	130	290	660	880 vap (869)	1900	3900	22	51	120	56000 vap (869)	110000 vap (1920)	180000 vap (4360)	56000	56000	56000	87000 vap (869)	95000 vap (1920)	100000 vap (4360)	LQM (2014)
Ethylbenzene	47	110	260	83	190	440	16	39	91	5700 vap (518)	13000 vap (1220)	27000 vap (2840)	24000	24000	25000	17000 vap (518)	22000 vap (1220)	27000 vap (2840)	LQM (2014)
Xylene - o	60	140	330	88	210	480	28	67	160	6600 (478)	15000 (1120)	33000 (2620)	41000	42000	43000	17000 (478)	24000 (1120)	33000 (2620)	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Xylene - m	59	140	320	82	190	450	31	74	170	6200 (625)	14000 (1470)	31000 (3460)	41000	42000	43000	17000 (625)	24000 (1470)	32000 (3460)	LQM (2014)
Xylene - p	56	130	310	79	180	430	29	69	160	5900 (576)	14000 (1350)	30000 (3170)	41000	42000	43000	17000 (576)	23000 (1350)	31000 (3170)	LQM (2014)
Aliphatic EC 5-6	42	78	160	42	78	160	730	1700	3900	3200 (304)	5900 (558)	12000 (1150)	570000 (304)	590000	600000	95000 (304)	130000 (558)	180000 (1150)	LQM (2014)
Aliphatic EC >6-8	100	230	530	100	230	530	2300	5600	13000	7800 (144)	17000 (322)	40000 (736)	600000	610000	620000	150000 (144)	220000 (322)	320000 (736)	LQM (2014)
Aliphatic EC >8-10	27	65	150	27	65	150	320	770	1700	2000 (78)	4800 (190)	11000 (451)	13000	13000	13000	14000 (78)	18000 (190)	21000 (451)	LQM (2014)
Aliphatic EC >10-12	130 (48)	330 (118)	760 (283)	130 (48)	330 (118)	760 (283)	2200	4400	7300	9700 (48)	23000 (118)	47000 (283)	13000	13000	13000	21000 (48)	23000 (118)	24000(283)	LQM (2014)
Aliphatic EC >12-16	1100 (24)	2400 (59)	4300 (142)	1100 (24)	2400 (59)	4300 (142)	11000	13000	13000	59000 (24)	82000 (59)	90000 (142)	13000	13000	13000	25000 (24)	25000 (59)	26000 (142)	LQM (2014)
Aliphatic EC >16-35	65000 (8.48)	92000 (21)	110000	65000 (8.48)	92000 (21)	110000	260000	270000	270000	1600000	1700000	1800000	250000	250000	250000	450000	480000	490000	LQM (2014)
Aliphatic EC >35-44	65000 (8.48)	92000 (21)	110000	65000 (8.48)	92000 (21)	110000	260000	270000	270000	1600000	1700000	1800000	250000	250000	250000	450000	480000	490000	LQM (2014)
Aromatic EC 5-7	70	140	300	370	690	1400	13	27	57	26000 (1220)	46000 (2260)	86000 (4710)	56000	56000	56000	76000 (1220)	84000 (2260)	92000 (4710)	LQM (2014)
Aromatic EC >7-8	130	290	660	860	1800	3900	22	51	120	56000 (869)	110000 (1920)	180000 (4360)	56000	56000	56000	87000 (869)	95000 (1920)	100000 (4360)	LQM (2014)
Aromatic EC >8-10	34	83	190	47	110	270	8.6	21	51	3500 (613)	8100 (1500)	17000 (3580)	5000	5000	5000	7200 (613)	8500 (1500)	9300 (3580)	LQM (2014)
Aromatic EC >10-12	74	180	380	250	590	1200	13	31	74	16000 (364)	28000 (899)	34000 (2150)	5000	5000	5000	9200 (364)	9700 (899)	10000	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Aromatic EC >12-16	140	330	660	1800	2300 (419)	2500	23	27	130	36000 (169)	37000	38000	5100	5100	5000	10000	10000	10000	LQM (2014)
Aromatic EC >16-21	260	540	930	1900	1900	1900	46	110	260	28000	28000	28000	3800	3800	3800	7600	7700	7800	LQM (2014)
Aromatic EC >21-35	1100	1500	1700	1900	1900	1900	370	820	1600	28000	28000	28000	3800	3800	3800	7800	7800	7900	LQM (2014)
Aromatic EC >35-44	1100	1500	1700	1900	1900	1900	370	820	1600	28000	28000	28000	3800	3800	3800	7800	7800	7900	LQM (2014)
Aromatic EC >44-75	1600	1800	1900	1900	1900	1900	1200	2100	3000	28000	28000	28000	3800	3800	3800	7800	7800	7900	LQM (2014)
VOCs																			
1,2-dichloroethane (1,2-DCA)	0.0071	0.011	0.019	0.0092	0.013	0.023	0.0046	0.0083	0.016	0.67	0.97	1.7	29	29	29	21	24	28	LQM (2014)
1,1,1-trichloroethane	8.8	18	39	9	18	40	48	110	240	660	1300	3000	140000	140000	140000	57000 (1425)	76000 (2915)	100000 (6392)	LQM (2014)
1,1,2,2,tetrachloroethane	1.6	3.4	7.5	3.9	8	17	0.41	0.89	2	270	550	1100	1400	1400	1400	1800	2100	2300	LQM (2014)
tetrachloroethene	0.18	0.39	0.9	0.18	0.4	0.92	0.65	1.5	3.6	19	45	95	1400	1400	1400	810 (424)	1100 (951)	1500	LQM (2014)
tetrachloromethane (Carbon tetrachloride)	0.026	0.056	0.13	0.026	0.056	0.13	0.45	1	2.4	2.9	6.3	14	890	920	950	190	270	400	LQM (2014)
Trichloroethene	0.016	0.034	0.075	0.017	0.036	0.08	0.041	0.091	0.21	1.2	2.6	5.7	120	120	120	70	91	120	LQM (2014)
Trichloromethane (chloroform)	0.91	1.7	3.4	1.2	2.1	4.2	0.42	0.83	1.7	99	170	350	2500	2500	2500	2600	2800	3100	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Chloroethene (Vinyl chloride)	0.00064	0.00087	0.0014	0.00077	0.001	0.0015	0.00055	0.001	0.0018	0.059	0.077	0.12	3.5	3.5	3.5	4.8	5	5.4	LQM (2014)
2,4,6 Trinitrotoluene (TNT)	1.6	3.7	8.1	65	66	66	0.24	0.58	1.4	1000	1000	1000	130	130	130	260	270	270	LQM (2014)
RDX	120	250	540	13000	13000	13000	17	38	85	210000	210000	210000	26000	26000	27000	49000 (18.7)	51000	53000	LQM (2014)
HMX	5.7	13	26	6700	6700	6700	0.86	1.9	3.9	110000	110000	110000	13000	13000	13000	23000 (0.35)	23000 (0.39)	24000 (0.48)	LQM (2014)
Aldrin	5.7	6.6	7.1	7.3	7.4	7.5	3.2	6.1	9.6	170	170	170	18	18	18	30	31	31	LQM (2014)
Dieldrin	0.97	2	3.5	7	7.3	7.4	0.17	0.41	0.96	170	170	170	18	18	18	30	30	31	LQM (2014)
Atrazine	3.3	7.6	17.4	610	620	620	0.5	1.2	2.7	9300	9400	9400	1200	1200	1200	2300	2400	2400	LQM (2014)
Dichlovos	0.032	0.066	0.014	6.4	6.5	6.6	0.0049	0.01	0.022	140	140	140	16	16	16	26	26	27	LQM (2014)
Alpha-Endosulfan	7.4	18	41	160 (0.003)	280 (0.007)	410 (0.016)	1.2	2.9	6.8	5600 (0.003)	7400 (0.007)	8400 (0.016)	1200	1200	1200	2400	2400	2500	LQM (2014)
alpha-Hexachlorocyclohexane	0.23	0.55	1.2	6.9	9.2	11	0.035	0.087	0.21	170	180	180	24	24	24	47	48	48	LQM (2014)
beta-hexachlorocyclohexanes	0.085	0.2	0.46	3.7	3.8	3.8	0.013	0.032	0.077	65	65	65	8.1	8.1	8.1	15	15	16	LQM (2014)
gamma-hexachlorocyclohexanes	0.06	0.14	0.33	2.9	3.3	3.5	0.0092	0.023	0.054	67	69	70	8.2	8.2	8.2	14	15	15	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Chlorobenzene	0.46	1	2.4	0.46	1	2.4	5.9	14	32	56	130	290	11000	13000	14000	1300 (675)	2000 (1520)	2900	LQM (2014)
1,2-Dichlorobenzene	23	55	130	24	57	130	94	230	540	2000 (571)	4800 (1370)	11000 (3240)	90000	95000	98000	24000 (571)	36000 (1370)	51000 (3240)	LQM (2014)
1,3-Dichlorobenzene	0.4	1	2.3	0.44	1.1	2.5	0.25	0.6	1.5	30	73	170	300	300	300	390	440	470	LQM (2014)
1,4-Dichlorobenzene	61	150	350	61	150	350	15	37	88	4400 (224)	10000 (540)	25000 (1280)	17000	17000	17000	36000 (224)	36000 (540)	36000 (1280)	LQM (2014)
VOCs Continued																			
1,2,3-Trichlorobenzene	1.5	3.6	8.6	1.5	3.7	8.8	4.7	12	28	102	250	590	1800	1800	1800	770 (134)	1100 (330)	1600 (789)	LQM (2014)
1,2,4-Trichlorobenzene	2.6	6.4	15	2.6	6.4	15	55	140	320	220	530	1300	15000	17000	19000	1700 (318)	2600 (786)	4000 (1880)	LQM (2014)
1,3,5-Trichlorobenzene	0.33	0.81	1.9	0.33	0.81	1.9	4.7	12	28	23	55	130	1700	1700	1800	380 (36.7)	580 (90.8)	860 (217)	LQM (2014)
1,2,3,4-Tetrachlorobenzene	15	36	78	24	56	120	4.4	11	26	1700 (122)	3080 (304)	4400 (728)	830	830	830	1500 (122)	1600	1600	LQM (2014)
1,2,3,5-Tetrachlorobenzene	0.66	1.6	3.7	0.75	1.9	4.3	0.38	0.9	2.2	49 (39.4)	120 (98.1)	240 (235)	78	79	79	110 (39)	120	130	LQM (2014)
1,2,4,5-Tetrachlorobenzene	0.33	0.77	1.6	0.73	1.7	3.5	0.06	0.16	0.37	42 (19.7)	72 (49.1)	96	13	13	13	25	26	26	LQM (2014)
Pentachlorobenzene	5.8	12	22	19	30	38	1.2	3.1	7	640 (43)	770 (107)	830	100	100	100	190	190	190	LQM (2014)

Parameter	Residential with homegrown produce			Residential without homegrown produce			Allotment			Commercial / Industrial			Public Open Space near Residential			Public Open Space - Park			Source
	(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			(mg/kg, unless otherwise stated)			
SOM	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	**1%**	**2.50%**	**6%**	
Hexachlorobenzene	1.8 (0.2)	3.3 (0.5)	4.9	4.1 (0.2)	5.7 (0.5)	6.7 (1.2)	0.47	1.1	2.5	110 (0.2)	120	120	16	16	16	30	30	30	LQM (2014)
Phenol	280	550	1100	750	1300	2300	66	140	280	760 dir (31000)	1500 dir (35000)	3200 dir (37000)	760 dir (31000)	1500 dir (35000)	3200 dir (37000)	760 dir (31000)	1500 dir (35000)	3200 dir (37000)	LQM (2014)
Chlorophenols (excluding pentachlorophenol)	0.87 (g)	2	4.5	94	150	210	0.13 (g)	0.3	0.7	3500	4000	4300	620	620	620	1100	1100	1100	LQM (2014)
Pentachlorophenol	0.22	0.52	1.2	27 (16.4)	29	31	0.03	0.08	0.19	400	400	400	60	60	60	110	120	120	LQM (2014)
Carbon Disulphide	0.14	0.29	0.62	0.14	0.29	0.62	4.8	10	23	11	22	47	11000	11000	12000	1300	1900	2700	LQM (2014)
Hexachlorobutadiene	0.29	0.7	1.6	0.32	0.78	1.8	0.25	0.61	1.4	31	66	120	25	25	25	48	50	51	LQM (2014)

(g) derived based on 2,3,4,6-tetrachlorophenol; dir - based on a threshold protective of direct skin contact with phenol (guideline in brackets based on health effects following long term exposure provided for illustration only); (vap) calculated for vapour phase only. SOM – Soil Organic Matter; (4.5) solubility.

APPENDIX E - CONTROLLED WATERS RISK ASSESSMENT

CURRENT GUIDANCE FOR CONTROLLED WATERS RISK ASSESSMENT

Regulatory Context

Government policy is based upon a "suitable for use approach," which is relevant to both the current use of land and also to any proposed future use. When considering the current use of land, Part IIA of the Environment Protection Act 1990 (EPA 1990) provides the regulatory regime, which was introduced by Section 57 of the Environment Act 1995, which came into force in England on 1 April 2000. The main objective of introducing the Part IIA regime is to provide an improved system for the identification and remediation of land where contamination is causing unacceptable risks to human health, controlled waters or the wider environment given the current use and circumstances of the land. Part IIA provides a statutory definition of contaminated land under Section 78A(2) 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."*

Part IIA provides a statutory definition of the pollution of controlled waters under Section 78A(9) as:

> *"the entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter"*

Controlled Waters are defined Section 104 of the Water Resources Act 1991. In summary, the comprise relevant territorial waters which extend seaward for three miles from the low-tide limit from which the territorial sea adjacent to England and Wales is measured.

The Environment Agency has powers under Part 7 of The Water Resources Act (1991) to take action to prevent or remedy the pollution of controlled waters, including circumstances where the pollution arises from contamination in the land. This is reinforced in The Contaminated Land (England) (Amendment) Regulations 2012 and Contaminated Land Statutory Guidance (DEFRA, 2012) which came into force in early April 2012.

Part IIA introduces the concept of a contaminant linkage; where for potential harm to exist there must be a connection between the source of the hazard and the receptor via a pathway. Risk assessment in contaminated land is therefore directed towards identifying the contaminants, pathways and receptors that can provide contaminant linkages. This is known as the contaminant-pathway-receptor link (CPR or contaminant linkage).

Part IIA places contaminated land responsibility as a part of the planning and redevelopment process, rather than Local Authority or Environment Agency directly, except in cases of very high pollution risk or where harm is occurring. In the planning process, guidance is provided by National Planning Policy Framework (NPPF) of March 2012. The NPPF requires that a site which has been developed shall not be capable of being determined "contaminated land" under Part IIA. Therefore, appropriate risk-based investigation is required to identify the contaminant linkages that can then be assessed, and then mitigated using methods that can be agreed with the planners.

Source Protection Zones

Source Protection Zones (SPZs) are defined by the Environment Agency (for England and Wales), SEPA (Scotland) and the Environment and Heritage Service (Northern Ireland) for groundwater sources such as wells, boreholes and springs that are used for public drinking water supply. The zones show the risk of contamination from activities that might cause groundwater pollution in the area. The size and shape of a zone depends upon subsurface conditions, how the groundwater is removed, and other environmental factors.

SPZs are classified into four categories:

- **Zone 1 (Inner protection zone).** Any pollution that can travel to the abstraction point within 50 days from any point within the zone is classified as being inside Zone 1. This applies at and below the groundwater table. This zone also has a minimum 50 m protection radius around the abstraction point. These criteria are designed to protect against the transmission of toxic chemicals and water-borne disease.
- **Zone 2 (Outer protection zone).** The outer zone covers pollution that takes up to 400 days to travel to the abstraction point, or 25% of the total catchment area, whichever area is the largest. This travel time is the minimum period over which the Environment Agency considers that pollutants need to be diluted, reduced in strength or delayed by the time they reach the abstraction point.
- **Zone 3 (Total catchment).** This is the total area needed to support removal of water from the abstraction point, and to support any discharge from this.
- **Zone of special interest.** This may occasionally be defined as a special case. This is usually where local conditions mean that industrial sites and other potential sources of contamination could affect the groundwater source, even though they are outside the normal catchment area.

Groundwater Vulnerability Assessments

From 1 April 2010 The Environment Agency Groundwater Protection Policy began to use aquifer designations which are consistent with the Water Framework Directive. These designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems.

The aquifer designation data is based on geological mapping provided by the British Geological Survey. It is updated regularly to reflect their ongoing programme of improvements to these maps. The maps are split into two different type of aquifer designation:

- Superficial (Drift) - permeable unconsolidated (loose) deposits. For example, sands and gravels.
- Bedrock -solid permeable formations e.g. sandstone, chalk, and limestone.

The maps display the following aquifer designations:

Table 1. Aquifer Classification ("Geological Classification").

Classification	Definition
Principal Aquifers (Highly Permeable)	These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.
Secondary A Aquifers	Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.
Secondary B Aquifers	Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.
Secondary Undifferentiated Aquifers	This has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.
Unproductive Strata	These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Environment Agency Guidance

The Environment Agency's stance on groundwater resources is:

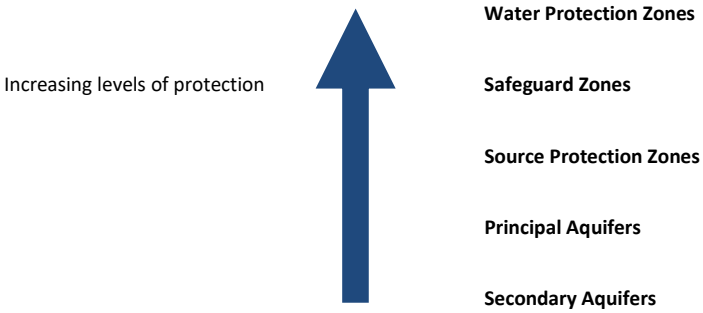
> *"to protect and manage groundwater resources for present and future generations in ways that are appropriate for the risks we identify"* (Groundwater Protection: Policy and Practice GP3, 2012).

At present, the legislation and guidance pertaining to the protection of controlled waters in the UK is complex; however, the core objectives seek to enforce the position given above.

In 1992, the National Rivers Authority published their Policy and Practice for the Protection of Groundwater (PPPG), this document introduced areas of focus for developments such as Source Protection Zones (SPZs) and Groundwater Vulnerability Maps. The Policy was revised in 1998, since which there have been substantial changes in legislation, driven by key European Directives relating to groundwater include the Groundwater Directive (80/68/EEC) and the Water Framework Directive (2000/60/EC). Aspects of these directives are controlled by primary UK legislation such as the Water Resources Act 1991 as amended by the Water Act 2003. Gaps in the 1998 PPPG that emerged as the result of further legislative changes were addressed in the Environment Agency Policy document Groundwater Protection: Policy and Practice (GP3), Version 1 of November 2012. The three main parts of GP3 were:

- Groundwater principals;
- Position statements and legislation; and
- Technical information.

The Environment Agency has a tiered risk based approach to drinking water protection as summarised below:



Controlled Waters Risk Assessment

A number of tools are available (as detailed in GP3) in order for a developer of a potentially contaminated site to fulfil their obligations under the legislation. A site assessment would be required in order to identify any potential risks to controlled waters and to derive suitable clean up criteria, if required, to ensure the protection of controlled waters.

There are three main stages to any risk assessment of controlled waters:

1. Risk Screening (devise Conceptual Site Model, making reference to groundwater vulnerability maps, site setting, controlled waters context etc)
2. Generic Risk Assessment (EA Remedial Targets Methodology Tier 1 / Comparison of groundwater data with relevant standards)
3. Detailed Quantitative Risk Assessment (Consideration of aquifer properties and site specific parameters, EA Remedial Targets Methodology Tiers 2 & 3)

Risk Screening

Here, the Conceptual Site Model (CSM) is a critical tool to assessing any potentially contaminated site. The information from a robust CSM can be used to establish any pathways or receptors that do not require further assessment at an early stage. For example, it may be possible to confirm the absence of a particular sensitive controlled water receptor (such as a surface water feature) within the vicinity of the site thereby breaking the associated source-pathway-receptor pollutant linkage. Information from subsequent tiers of risk assessment, such as following intrusive investigations, are used to update the CSM accordingly.

Generic Risk Assessment - England and Wales

When undertaking the Generic Hydrogeological Risk Assessment (EA Remedial Targets Methodology Tier 1), comparison of chemical analytical results is made with those screening criteria.

In accordance with Part 2A of the Environmental Protection Act 1990, Tier Environmental has made regard to all of the Water Quality Standards (WQS) that are relevant to the specific site and a judgment has been made against the most stringent of those relevant standards:

- EQS Directive 2008/105/EC
- Priority Substances Directive 2013/39/EU
- Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015
- UK Drinking Water Standards (UK DWS)
- World Health Organisation (WHO Guidelines) for Drinking Water Quality
- Council Directive 98/83/EC on the quality of water intended for human consumption (Drinking water directive)

In some instances, the laboratory method detection limit is greater than the appropriate EQS/UKDWS value. In these instances, only measured concentrations in excess of the laboratory method detection limit have been considered likely to potentially represent a possible significant risk to controlled waters.

Please note that there is no quantitative criterion for total petroleum hydrocarbons (TPH), or speciated TPH fractions. Historically, standards provided for petroleum hydrocarbons ranges from 10µg/l (Private Water Supply Regulations 1991, removed from the 2009 regulations) to 50µg/l-1000µg/l (Surface Waters (Abstraction for Drinking Water) Regulations 1989) which related to the degree of treatment of water prior to use as drinking water. Over time, the legislative standards have been rescinded and no alternative standard provided, although the Environment Agency planned to release speciated TPH criteria (Fretwell et al., 2009).

In order to assess whether there is a potentially unacceptable risk of pollution of controlled waters, the results of the groundwater chemical analysis for TPH and BTEX were evaluated against Water Quality Standards (WQS) appropriate to the conceptual model for the site:

Table 2. Summary of Selected TPH and BTEX Water Quality Standards Selected for Tier 1 Screening

Determinand	Units	WQS Selected	Source of WQS
Aliphatics >C5-C6	µg/l	15000	Table 5.4 of CL:AIRE 2017#
Aliphatics >C6-C8	µg/l	15000	Table 5.4 of CL:AIRE 2017#
Aliphatics >C8-C10	µg/l	300	Table 5.4 of CL:AIRE 2017#
Aliphatics >C10-C12	µg/l	300	Table 5.4 of CL:AIRE 2017#
Aliphatics >C12-C16	µg/l	300	Table 5.4 of CL:AIRE 2017#
Aliphatics >C16-C21	µg/l	-	Table 5.4 of CL:AIRE 2017#
Aliphatics >C21-C35	µg/l	-	Table 5.4 of CL:AIRE 2017#
Aromatics >C5-EC7	µg/l	10	Table 5.4 of CL:AIRE 2017#
Aromatics >EC7-EC8	µg/l	700	Table 5.4 of CL:AIRE 2017#
Aromatics >EC8-EC10	µg/l	300	Table 5.4 of CL:AIRE 2017#
Aromatics >EC10-EC12	µg/l	100	Table 5.4 of CL:AIRE 2017#

Aromatics >EC12-EC16	µg/l	100	Table 5.4 of CL:AIRE 2017#
Aromatics >EC16-EC21	µg/l	90	Table 5.4 of CL:AIRE 2017#
Aromatics >EC21-EC35	µg/l	90	Table 5.4 of CL:AIRE 2017#
Benzene	µg/l	10	Priority Substance Water Framework Directive 2015 and Table 5.3 of CL:AIRE 2017#
Toluene	µg/l	74	Table 1 Water Framework Directive 2015 and Table 5.3 of CL:AIRE 2017#
Ethylbenzene	µg/l	20	R&D Technical Report P2-115/TR4, 2002
Total xylenes	µg/l	30	DoE (1997c) Hedgecott S. and Lewis S, An update on proposed environmental quality standards for xylenes in water, final report to the Department of the Environment. Report No. DoE 4273/1. Medmenham: WRc; and; Table 5.3 of CL:AIRE 2017#

Notes - # = CL:AIRE document 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies' (ISBN 978-1-905046-31-7, dated 2017),

Table 5.3 was referenced in the first instance from the CL:AIRE document 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies' (ISBN 978-1-905046-31-7, dated 2017), the to select appropriate Freshwater EQS values for benzene, toluene and total xylenes. The selected value for Ethylbenzene was derived from the proposed EQS value of 20µg/l from the Environment Agency R&D Technical Report P2-115/TR4, 2002. This represents a more conservative value than the 300µg/l value in Table 5.3.

With respect to speciated TPH CWG fractions, Table 5.3 states and refers the reader to 'See Table 5.4'. On this basis, Tier Environmental selected the World Health Organization (WHO) guide values for TPHCWG fractions in drinking water that are presented in Table 5.4 which may be considered appropriately protective of the controlled waters environment based on the conceptual site model.

Generic Risk Assessment is generally undertaken via comparison of reported leachate and/or groundwater concentrations against selected assessment criteria for the potential contaminants of concern identified for the site from a preliminary desk based assessment.

The selected Generic Assessment Criteria (GAC) derived from a Water Quality Standard (WQS) for any specific substance may not necessarily be a simple number and can often be found to be expressed as:

- Annual mean concentration;
- Maximum allowable concentration;
- 95th percentile concentration for *n* samples;
- Total concentration;
- Dissolved concentration (applicable to filtered samples)

The values may sometimes be expressed for individual substances (e.g. arsenic or for groups of substances e.g. total xylenes or sums of certain PAHs).

Environmental Quality Standards (EQS) have been used where available for Priority Substances and Priority Hazardous Substances set at a European level:

- Priority Substances Directive 2013/39/EU;
- Amending 2008/105 and 2000/118/EC

In addition, EQS values derived for Specific Pollutants have been used as presented in The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

For assessing risks to potable water abstraction supplies, UK Drinking Water Standards presented in the Water Supply (Water Quality) Regulations 2000 (SI/2000/3184) (as amended) have been applied.

In selecting a GAC for a particular site, Tier Environmental considers the following factors:

- Current use/function of the groundwater (e.g. drinking water, irrigation water, industrial use, base-flow to rivers and streams);
- Plausible, proposed or planned future uses of the water and nearby waters;
- Sensitivity of the critical receptor (e.g. human health, aquatic life); and,
- Requirements to trigger action under the legal context

In accordance with Part 2A:

> *"in deciding whether pollution of controlled waters is occurring, the assessor will have regard to all of the water quality standards that are relevant to the specific site and make a judgment against the most stringent of those relevant standards"*

Should the Level 1 or 2 assessments indicate threshold levels to be exceeded, then there are three alternative ways in which to proceed:

- To devise suitable remedial solutions;
- To carry out more investigation, sampling, and analysis;
- To conduct a site-specific Detailed Quantitative Risk Assessment (DQRA) to whether or not the soil materials are suitable for their site-specific intended use or to devise a site-specific clean-up level.

Detailed Quantitative Risk Assessment (DQRA)

The decision to carry out a DQRA will be informed by the initial qualitative and generic assessment. The scope of any such assessment will be accurately defined by the outcomes of the former two stages. The robust CSM will be sufficiently refined by this stage that only certain contaminants of concern, certain pathways and certain receptors will require further assessment.

Additional site specific data is normally required for this stage of assessment, as explained above, more processes that are capable of affecting contaminant concentrations are considered (such as dilution and attenuation).

Remediation criteria derived will therefore be specific to each site and will be based on a detailed assessment of the potential impact at the identified receptor or compliance point. A greater level of confidence can be placed on the predicted impact on the compliance point following a DQRA.

Hazardous and Non Hazardous Substances

The Groundwater (England and Wales) Regulations 2009 control the disposal to the hydrogeological environment of potentially polluting substances which are divided into Hazardous Substances and Non-hazardous Contaminants (this roughly approximates to the former List 1 and List 2 substances).

Hazardous Substances are the most damaging and toxic and must be prevented from directly or indirectly entering the groundwater environment. Hazardous Substances include mineral oils and hydrocarbons, pesticides, biocides, herbicides, solvents and some metals. Discharge of Hazardous Substances to Controlled Waters must be prevented.

Non-hazardous Pollutants are any contaminants other than Hazardous Substances. Non-hazardous Pollutants are potentially toxic but are less harmful than Hazardous Substances, but their direct discharge to groundwater is generally not permitted and any indirect discharge to groundwater must be limited and be controlled by technical precautions in order to prevent pollution. Non-hazardous Pollutants include ammonia and nitrites, many metals and fluorides.

APPENDIX F - CHEMICAL TEST SAMPLING

Samples were selected by a representative of Tier Environmental during the site investigation works in accordance with the sampling approach described elsewhere in this report.

Samples for chemical analysis

All samples for chemical analysis were placed into clean new containers as summarised in Table 1. Unless explicitly stated elsewhere in this report, no preservatives were used to eliminate the risk that preservatives cause contaminant dissolution or analytical interference. Containers for VOC analysis were fully filled to exclude headspace.

Soil samples were dispensed as soon as possible after collection using reusable stainless steel spatulas, trowels, or similar implements.

Ground water samples were collected from boreholes using single-use Teflon bailers or dedicated Waterra tubing with foot valves, except as otherwise noted within this report. Caution was taken to avoid excessive agitation during collection

New disposable gloves were used by the engineer for the collection of each sample.

Reusable equipment was washed down with distilled or deionised water between samples, except where tarry or similarly sticky materials were present. In such cases specific cleaning procedures were adopted as specifically described elsewhere in this report.

All sub-samples taken for chemical analysis were placed into refrigerators or cool boxes containing frozen ice packs immediately after aliquoting. All samples were transferred in cool boxes containing frozen ice packs to the relevant UKAS/MCERTS accredited laboratory as soon as possible. Recommended maximum holding times before analysis are summarised in Table 1.

Table 1. Sample containers and holding times.

Analysis	**Container/special requirements**	**Max. holding time at 4°C before analysis**
Soil and sediment samples		
VOCs	30-60 g brown or green glass jar with VOC-resistant cap and inert cap liner. Must be fully filled.	14 days
TPHCWG	30-60 g brown or green glass jar with VOC-resistant cap and inert cap liner **PLUS** 250-500 g brown or green glass jar with unwaxed cap liner.[1] The former must be fully filled.	14 days
All other organics	250-500 g brown or green glass jar with unwaxed cap liner.	7 days
Inorganics	Air-tight 0.5-2.0 kg plastic container (250-500 g brown or green glass jar may also be used).	14 days[2]
Water samples		
VOCs	40-50 ml glass vial with VOC resistant screw cap and inert liner. Must be fully filled.	14 days
TPHCWG	40-50 ml glass vial with VOC resistant screw cap and inert liner **PLUS** 500-1000 ml brown or green glass bottle with screw cap and unwaxed liner.[1] The former must be fully filled, the latter should be filled if possible.	14 days
All other organics	500-1000 ml brown or green glass bottle with screw cap. Fill if possible.	7 days
Inorganics	500-1000 ml translucent or opaque screw cap plastic *or* brown or green glass bottles. Fill if possible.	14 days[3]

1 The smaller vessel is used for analysis of the volatile components within the TPH mixture and the larger one is for the non-volatile components.

2 14 days is set as a reasonable limit for all routine analyses of soil for those inorganic components vulnerable to chemical and/or biological breakdown. Samples for sulphate analysis are vulnerable to biological sulphate-reduction but can be held for up to 28 days. For total metals, a holding period of up to 6 months is acceptable.

3 14 days applies for all routine analyses of most inorganic components that may be vulnerable to chemical and/or biological reactions. In the specific cases of sulphide, nitrite, nitrate and phosphate analyses, storage time must not exceed 48 hours. For total metals, a holding time of up to 6 months is acceptable.

Tier Environmental standard analytical suites

The analyses included with Tier Environmental's standard analytical suites for soil, soil leachate and water samples are presented in Table 2. Other individual analyses were specified as described within this report.

Table 2. Tier Environmental Standard Analytical Suites.

Parameter	**Sample type**					
	Soil		**Leachate[1]**		**Water**	
		LoD[2] (mg/kg or as stated)		**LoD (µg/l or as stated)**		**LoD (µg/l or as stated)**
Metals and metalloids						
Arsenic	✓	1	✓	10	✓	10
Cadmium	✓	1	✓	5	✓	5
Chromium	✓	1	✓	5	✓	5
Mercury	✓	1	✓	1	✓	1
Lead	✓	1	✓	4	✓	4
Selenium	✓	2	✓	10	✓	10
Copper	✓	1	✓	1	✓	1
Nickel	✓	1	✓	50	✓	50
Zinc	✓	1	✓	8	✓	8
Other inorganics						
Ammonia (as NH_4-N)					✓	15
Total sulphate	✓	100			✓	50 mg/l
Water-soluble sulphate	✓	0.1 g/l				
Hardness (as $CaCO_3$)					✓	1 mg/l
Organics						
Monohydric phenol	✓	1	✓	0.5	✓	0.5
Speciated PAHs (USEPA 16)	✓	0.1	✓	0.01	✓	0.01
Total Organic Carbon	✓	0.1 wt%				
Others						
Electrical conductivity					✓	NA
pH	✓	NA	✓	NA	✓	NA

NA - Not applicable

1 Leachate preparation according to NRA (1994), 10:1 liquid to solid ratio.

2 The table presents the desired limit of detection for the analysis. Higher LoDs may be reported on analytical data sheets due to interference between analytes within specific samples or if the laboratory needed to dilute samples to achieve results within the calibrated range for that instrument.

Analytical QA procedures

Introduction

Quality Assurance (QA) is a system of review and audit that assesses the effectiveness of that product and assures the producer and user that defined standards of quality have been met. If we consider site investigation and chemical analysis, QA is the management system that ensures these measures are in place and working as intended.

QA within the laboratory form part of relevant certification programmes (such as UKAS and MCERTS) and, indeed, will be undertaken in some form by any reputable analyst, whether for a certified technique or not. Laboratory QA/QC is beyond the control of Tier Environmental and will not be considered further in this document, although the relevant laboratory documentation can be obtained upon request. QA must also form part of the design and execution of a site investigation.

Two parameters often used to assess measurement quality objectives are bias and precision. Bias is a systematic deviation in the data. For example, a positive bias (concentrations higher than in reality) would be introduced if sampling bottles were a source of the analyte and this fact was unknown. Precision is the variation in the measurements around a central 'expected' value. This could be due both to real variability in the environmental medium being measured and random errors in the analytical process. Both precision and bias can be assessed by the use of appropriate blanks and replicates within the site investigation programme.

The objectives of the QA activities undertaken in this present site investigation were to recognise and quantify systematic bias within the analytical dataset and to obtain an indication of precision. In environmental samples, much of the observed variability is likely to result from heterogeneity in the sampled medium, particularly for soil and sediment samples.

Such QA practice within the sampling programme is required by current guidance (e.g., Environment Agency report P5-065/TR (2000); Environment Agency LFTGN02 (2002); BS 10175:2001).

Alternative QA procedures to the generic approach presented in this appendix may be specified for a project, provided case-specific justification is given.

QA checking procedure (data validation)

The responsible Engineer and Project Reviewer are required to undertake data validation and provide comment on data quality within the main body of the report(s) issued, when noteworthy matters arise. This QA checking should involve:

Confirming that data reported by the laboratory have achieved the standards specified by the certification scheme (MCERTS or UKAS). This will be indicated on the analytical certificates issued by the laboratory.

Checking that the limit of detection (LoD) and limit of quantification (LoQ) achieved by the laboratory for an individual analyte is appropriate for the purposes of the report. LoD and LoQ will vary dependent upon analyte concentrations, sample matrix properties and interference from co-contaminants.

A check that the reported range of concentrations are reasonable for the analyte. For example, the dissolved concentration of an analyte in a water sample should not exceed saturation. If it does, then this merits further consideration (e.g., was colloidal organic matter or other solid-phase material present or could there have been unobserved free-phase organic liquid?) and explicit comment. At its simplest, there may be a unit error.

Where analysis involves reporting of Tentatively Identified Compounds (TICs; normally by mass spectrometry), the reviewers should check that these might reasonably be expected at the site under consideration. The uncertainties in identification by MS mean that it is not uncommon that TICs are incorrectly assigned. In cases of doubt, the analytical laboratory can re-check the raw data and confirm.

A review of the analytical precision by comparing data obtained for duplicate samples. There is no absolute threshold - variability is entirely dependent upon the sample matrix and manner in which the contaminant has entered the sample. Variability that cannot reasonably be assigned to such factors (for example a very high apparent variability in data for sediment-free water samples) should be reviewed with the laboratory. Variability that is attributable to the sample matrix can nevertheless provide important pointers to improve understanding of contaminant transport pathways and the risks posed by pollutant linkages (e.g., soil heterogeneity, the association of contamination with particular soil fractions, the presence of residual NAPL within soil pores or the role of suspended sediments in contaminant transport).

Confirmation that no errors have been introduced by data transcription, unit conversion or corrections between preliminary and certificates issued by the laboratory. The reviewer should audit a proportion (typically 5-10%) of all data from the original (final) certificates of analysis through to the equivalent values in the report for those specific samples.

In is important to consult the analytical laboratory if apparent QA issues arise. Many apparent concerns can be adequately resolved on the basis of revisiting the raw analytical data or by obtaining a better understanding of the inherent limitations of the analysis for a particular matrix or sample type.

APPENDIX G – SITE SPECIFIC RADON REPORT (AVAILABLE AS SEPARATE REPORT)

APPENDIX H – WATER PIPE RISK ASSESSMENT

Contaminated Land Assessment Guidance

Protocols published by agreement between Water UK and the Home Builders Federation

Published by Water UK

January 2014

Introduction

In January 2011, UK Water Industry Research (UKWIR) published "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites" (Ref 10/WM/03/21; the 'UKWIR Guidance'). Its aim is to ensure that the correct materials are selected for water pipes and components to be used below ground in brownfield sites to protect the quality of drinking water whilst taking into account the service life of the water distribution system. It supersedes the Water Regulations Advisory Scheme (WRAS) Information and Guidance Note 9-04-03 "Laying Pipes in Contaminated Land" which has been withdrawn.

The UKWIR Guidance is for use by developers, self-lay organisations, water companies and consultants when planning, designing and constructing water mains and/or services in brownfield sites. It defines brownfield sites as "land or premises that have previously been used or developed. They may also be vacant or derelict. However, they are not necessarily contaminated." The UKWIR Guidance states that it does not apply to greenfield sites; however, we consider this supplementary guidance and the relevant sections of the UKWIR guidance as being equally suitable for application to those greenfield sites considered to be potentially affected by contamination. Where greenfield sites are not affected by contamination a preliminary risk assessment (see below) will suffice.

The UKWIR Guidance also states that there should be no departure from its provisions "*except where formally approved by the Water Company, such departure being technically justifiable or representing advances in knowledge or product development"*.

We have adopted the UKWIR Guidance in principle and produced this supplementary guidance which includes the Risk Assessment for Water Pipes (the 'RA').

This guidance does not cover operative safety, health exposure modelling or accidental pipe damage.

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Risk Assessment for Water Pipes in Land Potentially Affected by Contamination

Any application for new water supplies to a development (construction of new properties, or renovation or conversion of existing buildings) in land potentially affected by contamination shall include a completed RA.

As a minimum a desk study (preliminary risk assessment) shall be provided with the RA in accordance with the framework in Environment Agency publication “Model Procedures for the Management of Land Contamination” (ref: CLR11) that sets out whether the land through which the pipes are to be laid may be affected by contamination. The application of the source, pathway, receptor concept will be an integral part of any pipeline risk assessment. For each potential source (the contamination) and each potential receptor (the water pipe), consideration shall be given to whether a potential pathway between source and receptor exists, or may exist in the future, linking the two. There are normally only three pathways by which contamination may come into contact with water pipes. These are direct contact with the soil or backfill, an excessive vapour phase or a contaminated groundwater regime. If none of these conditions exist on site (adopting the source, pathway, receptor concept) then it is likely that extended and/or targeted soil testing will not be required and a simple risk assessment will suffice. For those sites where land may be affected by contamination appropriate testing shall be undertaken on the materials within which the pipes are to be laid, whether that be existing ground materials, remediated materials or imported capping materials. The testing requirements are as described in the following section.

The signatories of the Water Supply Application Form and the RA must ensure that all assessments of land condition have been carried out in accordance with applicable current standards and guidelines by or under the direction of a suitably qualified competent person.

The competent person to be a) a chartered member of an appropriate professional body (such as the Institution of Civil Engineers, the Geological Society of London or the Royal Institution of Chartered Surveyors) with relevant experience of investigating contaminated sites or b) a Specialist in Land Condition (SiLC) with appropriate geo-environmental experience.

Testing Requirements

The soil, rock and if appropriate groundwater tests that are required on all sites where the potential for organic contamination has been identified in the desk study and where water pipes are proposed to be laid must be accredited by United Kingdom Accreditation Service (UKAS) as a minimum and where commercially available the Environment Agency's Monitoring Certification Service (MCERTS). These accredited tests should be undertaken for:

Banded hydrocarbons EC5-EC10, EC10-EC16, EC16-EC40 (Total aliphatic and aromatic hydrocarbons for each banding may be summed). Aliphatic/aromatic fractionation and subsequent banding may be required should a more detailed site specific risk assessment be undertaken. The bandings have been amended to take into account readily available laboratory tests. The equivalent carbon number (EC) is used to assess petroleum hydrocarbon mixtures rather than the actual number of carbon atoms in the molecule in line with guidance issued by the Environment Agency (2005).

Volatile organic compounds (VOCs) (method by head space or purge & trap GCMS) with tentative identification of compounds greater than 20µg/kg. The method used should be capable of detecting a wide range of compounds listed in US EPA Method 8260C or similar. The method should include analysis of naphthalene.

BTEX (Benzene, toluene, ethyl benzene and xylenes) plus MTBE (Methyl-tertiary butyl ether) (by head space GCMS)

Semi-Volatile Organic Compounds (SVOCs) (method by GCMS) with tentative identification of compounds greater than 20µg/kg The method used should be capable of detecting the compounds listed in US EPA Method 8270D or similar. The total concentration of SVOCs excludes polycyclic aromatic hydrocarbons, ethers, nitrobenzene, ketones, aldehydes, phenols, cresols and chlorinated phenols. Phenols, cresols and chlorinated phenols which are detected by the SVOC analysis are given their own assessment criteria.

Table G1 and Table 3.1 of the UKWIR Guidance are not considered to be a definitive guide for assessing total concentrations. Table 1 in the RA below replaces Table 3.1 of the UKWIR Guidance.

Where previous site uses include the use, storage, treatment, disposal or manufacture of any of the following, appropriate testing for these substances will be required:

Ethers, nitrobenzene, ketones, aldehydes and amines. Note that the presence of amines on any site at the proposed pipe depth +/- 1.0m precludes the use of polyethylene. The methods of analysis and method of calculation of total concentrations of these compounds will need to be agreed with water company.

To comply with the testing requirements, the suites of tests that are required on all brownfield sites where wrapped steel, wrapped ductile iron or copper pipes are to be laid as minimum must include:

pH, Conductivity and redox potential

Sufficiency of Testing

Water pipes are normally laid at between 0.75 and 1.35m from finished ground level to crown of pipe. Samples taken and tested must represent both a) the soil in which the water pipes are to be laid and b) the soil down to at least 500mm below the underside of the proposed pipe. Where the proposed depth of the pipes is unknown at the time of application, soil samples representative of the ground condition between surface level and 1.5m below finished ground level shall be taken as a minimum. Where appropriate (see UKWIR Guidance) groundwater sampling and groundwater monitoring will also be necessary. Photo-ionisation detection (PID) monitoring along the proposed route of the pipeline may be employed, though this does not provide a definitive guide to the suitability of water pipe materials.

Where required a sufficient number of test results should be obtained from the material in which the pipes are to be laid. CLAIRE/CIEH 2008 "Guidance on comparing soil contamination data with a critical concentration" may be used, where appropriate, to justify the number of soil samples tested; however, this statistical model should not be used on heterogeneous materials or used to average test results from different types of materials.

Further guidance on representative sampling is contained within BS10175:2011 Code of Practice for the Investigation of Potentially Contaminated Sites, the Department of the Environment's Contaminated Land Research Report "Sampling strategies for contaminated land" prepared by The Centre for Research into the Built Environment, Nottingham Trent University (Ref: CLR 4; 1994) and the Environment Agency's "Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination" (ref: R&D Technical Report P5-066/TR; 2000).

Where remediation has been carried out on the site, the test results obtained from validation samples will be used in the assessment. Where a horizontal capping system has been or will be employed using materials spread across a site, sufficient samples will need to be taken to characterise the capping material used and the results presented. However, the sufficiency of sampling on the horizontal capping system, in which the pipeline will be placed, may be assessed on the basis of the source, quantity and type of materials used.

Detection Limits

Only positive concentrations, ie those above the limit of detection should be used in summation of VOC and SVOC (or other test groups of compounds ie phenols, cresols and chlorinated phenols). Laboratory methods shall provide a minimum limit of detection of 10µg/kg for each individual VOC or SVOC (or other test groups of compounds) quantitatively detected in accordance with the methods described above. For tentatively identified compounds (TICs), only those compounds with a concentration of 20µg/kg or greater shall be used in the summation of VOC and SVOC (or other test groups of compounds).

Protective Measures

Where polyethylene, ductile iron, steel or copper pipes are to be laid on a brownfield site or other land potentially affected by contamination (whether or not it has been remediated) and where the concentrations exceed the generic guideline values set out in Table 1 of the RA, the developer shall provide either:

a) a robust risk assessment to show how any contaminants will not significantly impact on proposed water supplies or buried assets over the lifetime of the assets; or
b) more suitable pipe materials; or
c) an engineering solution to protect the pipe work backed up by an adequate assessment of the risk.

Liquid free phase product (e.g. oil or free solvent layers) shall not remain in the ground or groundwater in the vicinity of water pipes, whether barrier pipe or any other pipe materials are used.

When designing pipe routes on land potentially affected by contamination, new preferential contamination pathways along the route of new water pipes shall not be created. Particular measures may be required to prevent the possible migration of contamination through pipe bedding and into controlled waters.

References

BS10175:2011 “Investigation of Potentially Contaminated Sites Code of Practice”

CLAIRE/CIEH “Guidance on comparing soil contamination data with a critical concentration” 2008

Department of the Environment Contaminated Land Research Report “Sampling strategies for contaminated land” prepared by The Centre for Research into the Built Environment, Nottingham Trent University (Ref: CLR 4) 1994

Environment Agency “Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination” (ref: R&D Technical Report P5-066/TR) 2000

Environment Agency “Model Procedures for the Management of Land Contamination” (ref: CLR11), 2004

Environment Agency P5-080/TR3 “The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils”, 2005

UK Water Industry Research (UKWIR) "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites" (Ref 10/WM/03/21)” January 2011

Water Regulations Advisory Scheme (WRAS) Information and Guidance Note 9-04-03 “Laying Pipes in Contaminated Land” 2002

The risk assessment for water pipes will help you choose appropriate materials for your development. We are happy to deal with a risk assessment for water pipes in advance of any formal application for a new water supply.

The Risk assessment (RA)

Section 1: Development Details	
Development Name *(if it has one)*	
Development Address	
OS Grid Reference *(mid point)*	
Developers Name	
Water company reference number	
Please provide details below of the current and historical use of the site and adjacent sites. *If your supporting information has details of the current and historical site use, please reference below the relevant sections of your report.*	

Section 2: Preliminary Risk Assessment	
Has your desk study and site walkover identified any land potentially affected by contamination?	☐ Yes ☐ No
If the site is potentially affected by contamination but you have not completed any intrusive site investigation please provide details below of the rationale behind the intended pipe selection. *If your supporting information has details of the rationale behind the intended pipe selection, please reference below the relevant sections of your report.*	
Section 3: Intrusive Site Investigation	
Have you completed any intrusive site investigation?	☐ Yes ☐ No
Date(s) when the site investigation(s) undertaken	
At what level has groundwater been encountered?	metres below ground level or ☐ Not encountered
Table 1 (Pipeline Selection Risk Assessment Summary (PSRAS)) below classifies testing required where the preliminary risk assessment has identified land potentially affected by contamination. Please provide details below of any test groups which have not been tested and the rationale for not testing. *If your supporting information has details of the rationale behind not testing any particular test groups, please reference below the relevant sections of your report.*	

If the intrusive site investigation has identified concentrations above the PE threshold (see PSRAS) and your intended pipe selection is PE please provide details below of the rationale behind the intended pipe selection. *If your supporting information has details of the rationale behind the intended pipe selection, please reference below the relevant sections of your report.*

Section 4: Site Remediation	
Please provide details below of any site remediation (which may include a change in site levels) already completed. *If your supporting information has details of the site remediation already completed, please reference below the relevant sections of your report.*	
Has the PSRAS (Table 1) been completed using appropriate data after remediation?	☐ Yes ☐ No ☐ N/A
Please provide details below of any proposed site remediation and an analysis of whether this will affect your intended pipe selection. *If your supporting information has details of any proposed site remediation and whether this will affect your*	

intended pipe selection, please reference below the relevant sections of your report.

Section 5: Final Use of Site	
Please provide details below of any chemicals (including fuel) to be stored on site and any other future contamination risks which may affect your intended pipe selection. *If your supporting information has details of potential contamination risks which may affect your intended pipe selection, please reference below the relevant sections of your report.*	
What water pipe materials are intended to be used on site?	☐ PE ☐ PE Barrier Pipe Type A ☐ PE Barrier Pipe Type B Other (please specify):

Section 6: Additional Information
Please use the section below to provide any additional details to support your intended pipe selection. *If your supporting information has additional information to support your intended pipe selection, please reference below the relevant sections of your report.*

Section 7: Risk Assessor	
Name and relevant qualifications of person directing the risk assessment for water pipes	
Name and address of risk assessor's company	
Date risk assessment performed	

Section 8: Declaration			
I confirm I have completed this form and provided supporting information in accordance with 'UKWIR Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites' and the water company's Supplementary Guidance. I also confirm that if any further site investigation is needed and carried out, I will be required to submit an additional Risk Assessment for Water Pipes with the relevant supporting information. I understand that failure to supply any of the required information may delay my application being processed.			
Name		Company	
Phone Number		Date	

Table 1 - Pipe Selection Risk Assessment Summary (PSRAS)

1) *Testing must be undertaken on the materials within which the pipes are to be laid, whether that be existing ground materials, remediated materials or imported capping materials. Please use the appropriate testing data to complete Table 1 below.*

2) *If more than one pipe selection is being made, for example, for pipes in different areas of a large site, a completed PSRAS is required for each selection.*

What materials have been tested to populate Table 1 below?	☐ Existing ground materials ☐ Remediated materials ☐ Imported capping materials

All concentrations in mg/kg

Test Group	**Testing Required?**	**PE threshold**	**Metal Pipes/ Barrier Pipe**	**Laboratory Detection Limit**	**Testing UKAS accredited Y/N**	**Maximum concentration at proposed pipeline depth** See Note [2]	**Maximum site concentration** See Note [3]	**Locations and depths where concentrations exceed proposed pipeline threshold**
Total VOCs	Where Preliminary Risk Assessment (PRA) has identified land potentially affected by contamination	0.5	Pass					
Total BTEX & MTBE		0.1	Pass					
Total SVOCs (excluding PAHs and those substances marked with an *)		2	Pass					
EC5-EC10 aliphatic and aromatic hydrocarbons		2	Pass					
EC10-EC16 aliphatic and aromatic hydrocarbons		10	Pass					
EC16-EC40 aliphatic and aromatic hydrocarbons		500	Pass					
Phenols* (from SVOC analysis)		2	Pass					
Cresols and chlorinated phenols* (from SVOC analysis)		2	Pass					
Ethers*	Only where identified	0.5	Pass					
Nitrobenzene*		0.5	Pass					
Ketones*		0.5	Pass					
Aldehydes*		0.5	Pass					
Amines		Fail	Pass					
Corrosive	Conductivity, Redox and pH	Pass	See Note [1]					

Note [1] Threshold: For wrapped steel, corrosive if pH<7 and conductivity > 400µS/cm. For wrapped ductile iron corrosive if pH<5, Eh not neutral and conductivity > 400µS/cm. For copper, corrosive if pH<5 or >8 and Eh positive.
Note [2] Water pipes are normally laid at 0.75-1.35m below finished ground level.
Note [3] Also state if liquid free product is present in soil or groundwater.

APPENDIX I – ASSESSMENT CRITERIA APPLIED FOR GROUND GAS

Ground Gas Monitoring Methodology

Monitoring for the following is generally performed as part of ground gas assessment:

- Methane (CH_4): an odourless, flammable gas. Mixtures of methane with air containing between 5 and 15% v/v methane are explosive.
- Carbon dioxide (CO_2): an asphyxiant at elevated concentrations. Denser than air, it can accumulate in excavations, and within low points inside buildings
- Oxygen (O_2): important in the assessment of the potential formation of explosive mixtures with methane. Monitoring normally measures both methane and oxygen concentrations in ground gas to derive an indication of the risk of explosive mixture formation, expressed as a percentage of the Lower Explosive Limit (LEL). Low concentrations of oxygen in ground gas can also exacerbate the risk of CO_2 asphyxiation.
- Hydrogen sulphide (H_2S): odorous and toxic, capable of forming flammable mixtures with air.

In addition, depending on the Conceptual Site Model, monitoring may also include for measurements of Volatile Organic Compounds (VOCs); present as chemical contaminants of soil and sometimes also biologically produced in low concentrations.

Assessment of methane (CH_4) and carbon dioxide (CO_2)

Methane and carbon dioxide can arise from natural geological sources, mine workings, rotting organic matter (peat, landfilled materials, etc.) and/or contaminant biodegradation. Assessment of ground gas composition and flows is therefore an essential part of site assessment. The need to adequately address potential risks from ground gas on development sites is therefore required under the planning regime.

In order to appropriately assess the site risks, the Construction Industry Research and Information Association (CIRIA) and others have issued several guidance documents on landfill and ground gas that are intended to provide advice on how to investigate and deal with gas contaminated ground with respect to development. These are:

- Report 149: 'Protecting Development from Methane' (CIRIA, 1995a)
- Report 150: 'Methane Investigation Strategies' (CIRIA, 1995b)
- Report 151: 'Interpreting Measurement of Gas in the Ground' (CIRIA, 1995c)
- Report 152: 'Risk Assessment for Methane and Other Gases from the Ground' (CIRIA, 1995d)

More recent guidance has been published to update the documents detailed above to collaborate and promote industry 'good practice'. These are:

- CIRIA Report 665: 'Assessing risks posed by hazardous ground gases to buildings (CIRIA, 2008)
- NHBC: 'Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present' (NHBC, 2007)
- BS8485:201+A1:2019: Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (BSI Group, 2019)
- BS8576:2013: Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds (VOCs) (BSI Group, 2013)
- SoBRA Report Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater (Feb 2017)
- CL:AIRE Technical Bulletin TB17 Ground Gas Monitoring and 'Worst Case' Conditions (CL:AIRE Aug 2018)

The earlier CIRIA 149 approach is now considered to be too conservative. A more realistic measure of the risk posed by methane and CO2 in ground gas can be established by determining an appropriate Gas Screening Value (GSV), using the methods described in the NHBC and CIRIA 659 documents. These values are based upon earlier work undertaken by Wilson and Card (1999).

GSVs are calculated by multiplying the borehole flow rate (l/hr) by the percentage (% v/v) concentration in the gas stream of the specific component, i.e.:

GSV = (Concentration / 100) x Flow rate.

A risk-based methodology for deriving GSVs is defined for two situations (designated A and B), which are adequate for the great majority of site cases (as per CIRIA 665 Section 8.3):

- **Situation A**: Any development other than Situation B, e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc
- **Situation B**: Low rise building with minimum ventilated under floor void (min 150 mm)

Under Situation A, classification of the scope of protection required is determined from the site GSV, summarised in Table 1. For Situation B, GSVs derived are used in a 'Traffic Light' classification (summarised in Table 2) which determines the required level and scope of protection measures. Tables 1 and 2 are summaries only: the details provided in the body text, footnotes and appendices of the above-referenced documents should be read in conjunction with the results to determine the appropriate level of protection.

For conservatism, Tier Environmental **initially** uses the maximum concentration and gas flow rate of methane detected in any borehole during all of the monitoring visits in deriving recommendations on appropriate protection measures. This represents the worst-case risk of forming an explosive mixtures. For carbon dioxide, steady state concentrations and flow data are applied, as these determine the development of an asphyxiating mixture. All values are selected whether or not they occurred in the same borehole or during the same monitoring event.

Exceedances of the maximum concentrations used in a Tier 1 Gas Risk Assessment can be tolerated, when the conceptual site model indicates that it is safe to do so. However, appropriately derived GSV values must never be exceeded - where site-specific circumstances permit the derivation of alternative GSVs according to the defined conceptual model, then the appropriate GSV values should be applied.

Table 1. GSV Categories Defined for Situation A (Summarised from CIRIA Report 665).

Risk classification	GSV (CH4 or CO2; l/hr)	Additional factors	Characteristic Situation
Very low	<0.07	Typically methane <=1% and/or CO_2 <=5%, otherwise consider increase to Low Risk.	1
Low	<0.7	Typically borehole ground gas flow rate <=70 l/hr; otherwise consider increase to Moderate Risk.	2
Moderate	<3.5	---	3
Moderate to high	<15	QRA required to evaluate scope of remediation measures.	4
High	<70	---	5
Very high	>70	---	6

Table 2. GSV Categories Defined for Situation B (Summarised from NHBC, 2007).

Methane		CO_2		"Traffic light" classification
Typical max. conc. (% v/v)	GSV (l/hr)	Typical max. conc. (% v/v)	GSV (l/hr)	
				Green
1	0.13	5	0.78	
				Amber 1
5	0.63	10	1.60	
				Amber 2
20	1.60	30	3.10	
				Red

Assessment of hydrogen sulphide (H2S)

H2S is toxic and highly odorous ("rotten eggs") gas. It is often a minor component within mine gases, in ground gas within or overlying strata rich in pyrites or other sulphide-rich ores, and in most natural gas fields.

H2S can be generated biologically in significant concentrations by the decomposition by sulphate-reducing bacteria of natural or anthropogenic organic matter under oxygen-free conditions. Its potential generation will be greater in environments containing elevated sulphate concentrations (including sea water). H2S is therefore common within the gas arising from estuarine and marine sediments, pond sediment, stagnant water bodies, bogs and marshlands and landfilled waste, for example.

It must be noted that H2S normally occurs together with other potentially hazardous ground gases. The measures adopted for protection against these will prove equally protective against H2S.

There are no standards by which H2S concentrations in ground gas can be assessed directly. Therefore, the significance of measured H2S concentrations in ground gas must be evaluated on a case-by-case basis, taking into account the measured concentrations of other components and the specific conceptual site and exposure models. To assist in this process, the following standards and guidance may be applied.

General protection of land users

There are no UK air quality standards for general exposure to H2S. The World Health Organisation has derived ambient air quality standards (WHO, 2000) for this gas, which may be used to inform risk assessment and decision-making:

The 24 hour average exposure guideline value for ambient air: 0.15 mg/m3 (0.1 ppmv, approx.; this was derived by the application of a 100x safety factor to the LOAEL for long-term exposure).

This is significantly above the odour threshold, which is typically around 0.01 mg/m3. To avoid substantial nuisance odour complaints, WHO (2000) recommends that the 30 minute average H2S concentration in ambient air should not exceed: 0.007 mg/m3 (0.005 ppmv, approx.).

Occupational exposures

For occupational exposure, the HSE (2005) limits for H2S are applicable:

- 8 hour time weighted average occupational exposure limit: 5 ppmv (7 mg/m3).
- Short-term exposure limit (15 minute reference period): 10 ppmv (14 mg/m3).

VOC Data Collection, Sampling and Assessment

BS8576 Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).

Volatile organic compounds (VOCs) include, for example, halogenated hydrocarbons such as trichloroethene, non-halogenated hydrocarbons such as benzene, and organosulfur compounds such as thiols (mercapatans). They can occur as a component of ground gas originating from historically contaminated ground, spills and leaks from industry, commercial or residential properties (e.g. from pipelines, storage facilities, and at the point of use or dispensing), land-filled wastes and from naturally occurring sources.

The migration of VOCs in ground gas can be via three primary mechanisms:

- diffusive flow (movement of constituent along a concentration gradient);
- advective flow (movement of constituent due to motion of a transporting fluid);
- dispersion (transport resulting from local variations in fluid flow, e.g. due to friction effects in the matrix).

The choice of sampling and monitoring techniques should be based upon the conceptual model and be designed to achieve the objectives of the investigation, bearing in mind the requirements of any subsequent analytical procedures and the need to provide relevant data of sufficient quantity and quality. Consideration should also be given to the nature of ground under investigation, as well as the nature and distribution of contamination, the geology and the hydrogeology. Every effort should be made to avoid cross-contamination and at no point should underlying aquifers be put at risk.

Where the response zone extends below the water table, gas present in the groundwater will tend to produce an equilibrium concentration in the well headspace. This applies to both permanent gases and VOCs but can be particularly misleading in the latter case. Testing for dissolved gases in groundwater is useful to help interpret monitoring results in such a situation. Similarly, any VOCs in a floating non-aqueous hydrocarbon layer will produce an equilibrium concentration in the well headspace.

The monitoring period and frequency of monitoring for VOCs in ground gases should be developed on a site-specific basis from the conceptual site model and investigation data quality objectives.

Ground gas samples can be collected from the unsaturated zone adjacent to, or above, the known or suspected source of VOCs in ground gas through installation of a ground gas monitoring point in the unsaturated zone (see 10.2), and from a near-surface location beneath hardstanding or a floor or foundation slab through installation of a near- or sub-slab monitoring point (see 10.3). For monitoring of VOCs in ground gas the monitoring well should be installed into unsaturated ground to allow sampling for VOCs to take place. The borehole should not be progressed below the groundwater table or the surface of any floating non-aqueous layer. The borehole should be progressed to the target sampling depth within the unsaturated zone. Full details can be found in BS8576 Section 10.2 onwards.

Assessment of VOC concentrations have been made for limited number of VOCs by SoBRA with the Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater in Feb 2017.

The assessment of VOC concentrations is not covered by above-referenced reports. These data can be used to inform the human health risk assessment for site occupants but should not be relied upon to assess human health risk due to uncertainties in the ground gas flow regime, variability in the (generally low) contaminant concentrations measured and inaccuracies in the concentrations measured by PID instruments.

Data on the VOC concentration in ground gas can also help inform potential occupational exposure risks to construction and similar workers. For this purpose, the measured values can be compared to the relevant occupational exposure limit (OEL) for the contaminant(s) of concern, as given in HSE (2005). In cases of doubt as to the identity of the organic contaminants within the ground gas or when these are present as a complex mixture, then the 8 hour time-weighted average (TWA) exposure limit for benzene (1 ppmv) will be applied for screening purposes. This is a reasonably conservative approach since the OEL for benzene is lower than that for the great majority of organic contaminants commonly encountered in soil and groundwater at contaminated sites

APPENDIX J – GROUND GAS \ VAPOUR PROTECTION VERIFICATION PROFORMA

VISUAL INSPECTION OF GAS PROTECTION MEASURES

VISIT: 1 of X

Site name:	[Keywords]	Gas characteristic situation:	[Category]
Job number:	[Company]	Type of development and building:	[Company Address]
Date:		Building description:	[Manager]
Visit by:		Foundation type:	[Status]
Weather:		Gas protection type:	[Subject]

No.	Item	Comments
1	***Gas membrane***	
1.1	Condition of sub-grade and/or underside of gas membrane	
1.2	Gas membrane type	
1.3	Gas membrane condition	
1.4	Joining tape product	
1.5	Lapping design	
1.6	Laps, welds and joint seals	
1.7	Service entries seals	
1.8	Other features	
2	***Passive venting***	
2.1	Sub-floor void	
2.2	External wall airbricks	
2.3	Internal sleeper walls	
2.4	External vent trenches/ducts	
3	***Active venting***	
3.1	System details	
Additional notes:		

Photographs

No.	Description
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

APPENDIX K - COMPLYING WITH CONTROL OF ASBESTOS REGULATIONS 2012

Complying with Control of Asbestos Regulations (CAR): Risk Assessments, Licensing and Training

This appendix outlines CAR risk assessments and where they should be applied in relation to assessing and remediating brownfield sites. The information below details the different classifications of work with asbestos under CAR, summarises the legal requirements for asbestos awareness training for all involved in the investigation and management of asbestos containing soil (ACS), and details the potential requirements for suitable proficiency training relating specifically to ACS.

CAR RISK ASSESSMENTS

A CAR Risk Assessment is required for any work which may expose employees to asbestos. It is recommended that a precautionary approach is adopted if there is any doubt about risks associated with asbestos.

There are three main activities for potential asbestos exposure during work on brownfield sites:

- Site reconnaissance visits;
- Site investigation works; and
- Site remediation.

CAR risk assessments are needed at each stage but may be incorporated during the site investigation stage into the overarching health and safety risk assessments.

The CAR risk assessment must:

- Identify the type of asbestos to which employees are liable to be exposed, where possible, or assume it is present in different forms;
- Determine the type and extent of exposures to asbestos that may occur during the work
- Identify the steps to be taken to prevent exposure or reduce it to the lowest level reasonably practicable; and,
- Consider the effects of control measures that have been or will be taken.

The CAR risk assessment should include any information used to inform the risk assessment such as asbestos reports or desk study information. In the event that this information is not available, the assessor should be assumed that all forms of asbestos may be present on site.

For all investigation and remediation of ACSs, a detailed written work plan should he produced and followed as detailed on the HSE website and in the CAR.

The CAR risk assessments for specific investigations or remediation projects, will determine whether or not work is 'licensable work' (LW)**,** notifiable non-licensable work' (NNLW) or 'non-licensed work' (NLW). In addition, training requirements are also defined by the CAR risk assessment.

Some examples of control measures that apply during site reconnaissance, site investigation works, and site remediation are given below and should be applied depending on the asbestos risks identified for the site at each stage of investigation:

- Avoiding stirring up dust;
- Cleaning footwear after site works;
- Removing and bagging any overalls for disposal/laundering;
- Respirators and hygiene facilities for high risk sites;
- Segregated welfare units;
- Wetting ground
- Minimising soil disturbances;
- Implementation or retention of capping/break layers;
- Implementation of awareness training;
- Air monitoring;
- Managing stockpiles;
- Area segregation;
- Wheel washing
- Road washing/cleaning

It is important to note that during site reconnaissance visits, site investigation works and site remediation that asbestos should not be considered in isolation and control measures are likely to form part of a wider health and safety precautions.

Respiratory protective equipment (RPE)

RPE is the last line of defence and its requirement would be defined by the CAR risk assessment. HSE (2013b) advises that RPE should have an assigned protection factor of 20 or more for all work with asbestos. In certain instances, full face-piece, positive pressure respirators with a protection factor of 40 are necessary (to EN 12942:1998, TM3).

Suitable types of RPE for most ***short*** duration non-licensed asbestos work:

- Disposable respirator to standards EN149 (type FFP3) or EN1827 (type FMP3)
- Half mask respirator (to standard EN140) with P3 filter
- Semi-disposable respirator (to EN405) with P3 filter

These filters are not suitable for people with beards/stubble or for long or continuous use.

LICENSING

CAR defined certain types of activities involving asbestos as 'licensable work' (LW) or as 'notifiable non-licensable work' (NNLW). All other work would be 'non-licensable work' (NLW).

LW is defined as:

- work where exposure is not 'sporadic and low intensity'
- work where the risk assessment cannot demonstrate that the control limits (four hour and 10 minute limits) will not be exceeded
- work on asbestos coating
- work on AIB or insulation where risk assessment is either of first two points above or not of short duration (where short duration is defined for any work liable to disturb asbestos as taking less than two hours per week (including ancillary work) and no one person carries out that work for more than one hour').

NNLW includes work with:

- AIB or asbestos insulation of short duration that is not licensable
- fire-damaged asbestos cement or asbestos cement damaged so as to create significant dust and debris
- asbestos ropes, yarns, woven cloths in poor condition or handling cutting or breaking up the materials
- asbestos papers, felts and cardboard in poor condition, unencapsulated or not bound into another material.

Work with weathered asbestos cement, air monitoring and collecting samples of ACM in buildings would not normally be notifiable.

It is impossible to specify definitively what activities will and will not be licensable. This decision should be made as part of the CAR risk assessment. CAR is not primarily aimed at work with ACSs and there is little published information on airborne asbestos concentrations during work with ACSs. Nevertheless, CAR will require some remediation projects, and occasionally site investigations, to be LW. Investigations on other sites may involve NNLW. The decision as to whether work is LW or NNLW should be made during the CAR risk assessment by those in charge of the brownfield site investigations and remediation projects.

TRAINING REQUIREMENTS

Asbestos health and safety courses are offered by a number of providers in the UK. Training courses that include the problem of identifying ACMs in soil should be undertaken at regular intervals by those involved in the investigation, assessment and management of sites where ACs are known or suspected. It is the role of the employer to identify the level of training required for an employee based on their role, experience and duties. Reference to Regulation 10 of CAR should be referred to for more information on training requirements.

Recognising asbestos within soils is challenging due to the heterogeneity of such soils and the discolouration of asbestos by smeared soil. Specific training for ground workers should include understanding fibre release potential, potential control measures in the field, how to take representative ACSs safely, sample labelling and what analytical tests are available and when the y should be implemented.

Health and safety training required under CAR includes asbestos awareness, non-licensable work (including notifiable non-licensable work) and licensable work with asbestos.

In addition to health and safety training, some staff involved in the technical identification on site of ACMs, sampling and analysis may require technical proficiency training (competency training).

Training vs. Competence

HSE (2005) identifies that ‘training alone does not make people competent. Training must be consolidated by practical experience so that the person becomes confident, skilful and knowledgeable in practice on the job’. It is critical that ACS surveyors demonstrate competency with details of relevant field experience alongside training and examples of previous works/references.