



GEO-ENVIRONMENTAL CONSULTING

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LAND AT BENMORE ROAD, BLACKLEY

Remediation Method Statement



Prepared for:

The Casey Group

Report Ref: BEK-23104-2 (Rev A)

October 2023



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Project Quality Assurance Information Sheet

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Report Title	Remediation Method Statement
Report Status	Final
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Date	October 2023
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REVISION STATUS / HISTORY

Rev	Date	Issue / Comment	Prepared	Checked
A	Oct 2023	Minor Mods	A Hope	M Buckley

GENERAL REPORT LIMITATIONS

BEK Enviro Limited (BEK) has prepared this report for the sole use of the client, showing reasonable skill and care, for the intended purposes as stated in the agreement under which this work was completed. The report may not be relied upon by any other party without the express agreement of the client and BEK. No other warranty, expressed or implied, is made as to the professional advice included in this report.

Where any data supplied by the client or from other sources have been used, it has been assumed that the information is correct. No responsibility can be accepted by BEK for inaccuracies in the data supplied by any other party. The conclusions and recommendations in this report are based on the assumption that all relevant information has been supplied by those bodies from whom it was requested.

No part of this report may be copied or duplicated without the express permission of BEK and the party for whom it was prepared. Where field investigations have been carried out, these have been restricted to a level of detail required to achieve the stated objectives of the work.

Unless explicitly agreed otherwise, in writing, this report has been prepared under BEK's limited standard Terms and Conditions as included within our proposal to the Client.

The report needs to be considered in the light of the BEK proposal and associated limitations of scope. The report needs to be read in full and isolated sections cannot be used without full reference to other elements of the report and any previous works referenced within the report.

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1. INTRODUCTION

1.1 Appointment

- 1.1 BEK Enviro (BEK) has been commissioned by The Casey Group Ltd to prepare a method statement for the remediation works to support the proposed residential development located at Benmore Road, Blackley, Manchester (hereafter referred to as 'the site').

1.2 Project Overview

- 1.1 The site is located to the east of Benmore Road approximately 5.7 km north-east of Manchester city centre and 6 km west of Oldham town centre. The site is currently comprised of a vacant grassed area.
- 1.2 Development proposals for the site are for the construction of 20 residential dwellings with associated private garden areas, access and parking. An extract of the proposed development is shown below:



Figure 1: Proposed Development Plan



1.3 Limitations

- 1.3.1 This report has been prepared to provide a summary of the remediation works required and the methodology for the validation of these works. The validation is important to confirm that the required works have been carried out in accordance with the approved remediation scheme and there are no future risks to end users of the site or the environment.
- 1.3.2 The site has been subject to previous site investigation and contamination assessment by BEK and by Curtins Consulting Ltd (see Section 2 below). These reports provide the basis for the remediation works required.
- 1.3.3 This report has been prepared in accordance with our understanding of current best practice. However, new information or legislation, or changes to best practice may necessitate revision of the report after the date of its issue.
- 1.3.4 BEK has prepared this report for the sole use and reliance of The Casey Group Ltd in accordance with our standard Conditions & Limitations. This report may not be used or relied upon by any unauthorised third party without the explicit written agreement from BEK.

2. PREVIOUS SITE INVESTIGATIONS

2.1 Previous Reports

2.1.1 The site has been subjected to detailed contamination assessment to identify potential significant risks associated with contamination with respect to the redevelopment of the site for industrial use. The assessment is detailed in the following reports:

- Curtins Consulting Limited – ‘Phase 2 Geo-Environmental and Geotechnical Report for Former Whitemoss Community Resource Centre Project 500 Sites’ Report Ref: 077873-CUR-00-XX-RP-GE-041-P01, dated November 2022.
- BEK – ‘Site Investigation & Ground Assessment’ Report Ref: BEK-23104-1, dated September 2023.

2.1.2 The above reports should be read in conjunction with this report. The Site Investigations form the basis for the remediation works required at the site.

2.2 Curtins Consulting Limited (November 2022)

2.2.1 The Curtins Consulting Phase II Ground Investigation was undertaken on the 10th August 2022 and comprised the drilling of 5 window sample boreholes to a maximum depth of 5.45 m below ground level.

2.2.2 Five soil samples (4 x made ground, 1 x natural strata) were obtained and tested for a wide range of chemical testing. In addition, geotechnical testing of the soils was undertaken including 4 x atterberg tests, 2 x particle size distribution tests and 6 x water soluble sulphate and pH tests in order to inform foundation design.

2.2.3 The ground conditions encountered during the Curtins Consulting Site Investigation are summarised in the table below:

Stratum	Depth to top of strata bgl (m AOD)	Thickness (m)		Description
		Min	Max	
Made Ground	0	0.3	0.9	<p>Surface cover of grass over made ground: loose dark brown slightly gravelly sand with abundant rootlets. Gravel is angular to subangular, fine to coarse of mudstone, brick and concrete</p> <p><u>Overlying</u></p> <p>Made Ground: Loose light grey gravelly sand. Gravel is subangular to subrounded fine to coarse of mudstone</p> <p><u>Or</u></p> <p>Made Ground: Loose dark brown slightly clayey gravelly sand with rare cobbles. Gravel is angular to subrounded fine to coarse of brick, concrete and mudstone. Cobbles are angular to subangular of brick and concrete</p>
Glacial Till	0.3 – 0.9	4.1 ¹	4.70 ¹	<p>Soft to firm sandy clay, Sand is fine to medium.</p> <p><u>Interbedded with:</u></p> <p>Brown slightly clayey fine to medium sand</p>

1 - Base of strata not encountered

Table 1: Summary of Ground Conditions (Curtins Consulting Report)

- 2.2.4 Groundwater was encountered at a depth of 4 m below ground level within Borehole No WS03 within the Glacial Till (granular). Furthermore, groundwater likely representing perched water within granular layers in the generally cohesive Glacial Till, was recorded during gas monitoring visits as shown in the below table:

Borehole	Strata	Response Zone m bgl (m AOD)	Depth to water m bgl (m AOD)					
			24/8/22	01/09/22	21/09/22	28/09/22	14/10/22	28/10/22
WS01	Glacial Till	1 – 3 (100 – 98)	3.82 (97.03)	3.97 (97.03)	3.96 (97.04)	3.97 (97.03)	3.97 (97.03)	3.97 (97.03)
WS02	Glacial Till	1 – 4 (99.5 – 96.5)	3.13 (97.37)	3.20 (97.30)	3.32 (97.18)	3.35 (97.15)	1.83 (96.67)	1.34 (99.16)
WS03	Glacial Till	1 – 3 (99.9 – 97.9)	3.88 (97.02)	DRY	DRY	DRY	DRY	DRY

Table 2: Monitoring well Response Zones (Curtins Consulting Report)

- 2.2.5 No obstructions or visual or olfactory contamination was observed during the Curtins intrusive site investigation works.



Ground Contamination Assessment (extracted from the Curtins Phase 2 Geo-Environmental and Geotechnical Report for Fromer Whitemoss Community Resource Centre)

- 2.2.6 Four soil samples from the made ground and one from the natural strata were compared against adopted Residential with homegrown generic assessment criteria (GACs).
- 2.2.7 Two exceedances of Mercury were identified within the made ground at the site (WS01 0.75 m and WS02 0.4 m). However, none of the samples tested proved positive for the presence of asbestos.
- 2.2.8 The preliminary design of buried concrete according to Table C2 of BRE Special Digest 1:2005 should be in accordance with Class DS-1 (AC-2z) conditions assuming mobile groundwater.

Gas Risk Assessment (extracted from the Curtins Phase 2 Geo-Environmental and Geotechnical Report for Fromer Whitemoss Community Resource Centre)

- 2.2.9 Three boreholes were installed with monitoring wells during the Curtins Site Investigation with six rounds of gas monitoring undertaken between 24th August 2022 and 28th October 2022.
- 2.2.10 The results of the gas monitoring programme undertaken by Curtins concluded that the borehole Q_{hg} value for carbon dioxide has been taken as the gas screening value for the site, which is consistent with a Characteristic Situation 2 (CS-2) gas regime, where gas protection measures are required.

Conclusions (extracted from the Curtins Phase 2 Geo-Environmental and Geotechnical Report for Fromer Whitemoss Community Resource Centre)

- 2.2.11 A moderate/low risk has been identified to site end-users from soil and dust inhalation, direct contact and ingestion of shallow site soils due to the mercury exceedances recorded. A suitable thickness of clean and inert capping should be installed in all private gardens and areas of soft landscaping, detailed in a Remediation Strategy.
- 2.2.12 The conclusions of the Curtins Phase 2 report highlight that no gas protection measures will be required for the proposed residential development, however this contradicts the previous sections of the report and is understood to be an error. As such it is understood that gas protection measures in accordance with Characteristic Situation 2 (CS2) are required.

- 2.2.13 Due to the presence of extremely soft clay in Borehole No WS04 to at least 3 m below ground level, additional supplementary investigation is recommended in this area to delineate the extent of the soft ground, as ground improvement or piling is likely to be required.

BEK Comments

- 2.2.14 BEK considers the Curtins Consulting Report to generally conform with current guidance on the assessment of potential risks associated with contamination. However, it is noted that the assessment criteria used for mercury in the Curtins Report is 1 mg/kg which relates to elemental mercury. BEK considers that the testing undertaken was mercury (total) therefore the assessment criteria used is incorrect. The re-assessment of the results for mercury (total) rather than mercury (elemental) indicates that there are no exceedances above the assessment criteria and therefore there are no elevated contaminants of concern at the site.
- 2.2.15 Furthermore, it is noted that the conclusions of the report indicate that gas protection measures are not required, but BEK considers that this has been included as an error and gas protection measures in accordance with Characteristic situation 2 are required at the site in accordance with section 6.0 of the Curtins Report.
- 2.2.16 BEK concurs with the Curtins recommendation that a suitable thickness of clean and inert capping should be installed due to the presence of inherently variable made ground across the site and a Remediation Method Statement should be produced. Furthermore, Curtins recommended that additional supplementary investigation should be undertaken in the vicinity of Borehole WS04 to delineate the extent of the soft ground. As such further site investigation has been undertaken by BEK in August 2023 as detailed with the sections below.

2.3 BEK Enviro (August 2023)

- 2.3.1 Additional supplementary ground investigation was undertaken by BEK during August 2023 to further assess the made ground encountered within the vicinity of Borehole WS04 in the Curtins Phase 2 report.
- 2.3.2 The site investigation works comprised the following:
- 11 machine excavated trial pits were excavated to a maximum depth of 3.2 m below ground level. The ground conditions were recorded by an engineer from BEK and in-situ testing (shear vane) was carried out where ground conditions permitted.
 - 3 cable percussive boreholes were drilled using a cable percussive rig to a maximum depth of 20.45 m. The ground conditions were recorded by an engineer from BEK and in-situ testing (SPTs) were carried out at each location.

- Samples were recovered for chemical and geotechnical testing.

Made Ground

- 2.3.3 BEK identified made ground within all exploratory locations to depths varying from 0.25 m to 2.1 m. The most frequently encountered made ground subtype comprised 'grass onto slightly clayey, gravelly sand with rootlets and broken/whole brick' which was encountered at the surface of all trial pit locations to a maximum depth of 1.0 m.
- 2.3.4 Further made ground was present throughout the site and generally comprised gravels and reworked clays which often contained broken/whole brick. Contamination encountered within the made ground was limited to an organic odour encountered within sandy clay in Trial Pit TP11 between 0.3 m and 1.8 m depth.

Natural Strata

- 2.3.5 Superficial strata was encountered within all exploratory locations to depths varying from 0.25 m to within excess of 20 m and generally comprised firm to soft silty sandy clay with pockets of wet fine to medium sand.
- 2.3.6 Soft brownish/black amorphous peat was identified within Cable Percussive Borehole CP1 between 2.1 m and 2.9 m depth, whilst sands and/or gravels were identified within all Cable Percussive Boreholes at depths varying from 5.2 m to within excess of 20 m. Bedrock was not encountered during the site investigation.

Groundwater

- 2.3.7 Groundwater was encountered within several exploratory locations at depths ranging between 0.35 m (Trial Pit TP8) to 3.0 m (Cable Percussive Borehole CP1).

Contamination Assessment

- 2.3.8 The chemical test results were compared to relevant generic assessment criteria to identify potential contaminants of concern. Based on the contamination assessment herein and with respect to the redevelopment of the site for residential use with gardens, no contaminants of concern were identified at the site. Moreover, risks to controlled waters are considered to be negligible.
- 2.3.9 Potential risk to service pipes are considered to be low but advice should be sought from the water supply provider. Risks to concrete are noted to be low and a concrete classification of DS-1 AC-2z is considered to be suitable.



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- 2.3.10 BEK did not undertake any further gas monitoring as the gas risk assessment undertaken by Curtins Consulting as part of the Phase 2 Geo-Environmental and Geotechnical Report was considered sufficient to classify a gas regime for the site.
- 2.3.11 The site is classified as Characteristic Situation 2 (CS2) gas regime and as such, specific mitigation measures to protect against the risks from ground gas are required for all new builds at the site. The installation and validation of gas mitigation measures should be carried out in accordance with a Gas Verification Plan.

3. REMEDIATION STRATEGY

3.0.1 Following recommendations from the Curtins Consulting Phase 2 Ground Investigation Report and the BEK Site Investigation Report, the following specific remediation and mitigation measures need to be carried out:

3.1 Contamination

Made Ground

3.1.1 To mitigate the potential risks to human health associated with wide spread variable made ground, the following works will need to be undertaken:

- (i) All private garden areas – the made ground will be removed to a maximum depth of 400 mm within each garden area. The finished garden level will be achieved by the placement of a minimum of 400 mm of clean suitable soil (250 mm subsoil and 150 mm topsoil) atop a geotextile membrane to prevent soil mixing.
- (ii) Soils used in the capping system will need to be tested and assessed to ensure suitability of use. Materials can be sourced from other developments and commercial companies.

3.2 Ground Gas Precautions

3.2.1 On the basis of the assessment of the potential risks from ground gas, mitigation measures which adhere to Characteristic Situation 2 of CIRIA C665 will be required in all new build permanent structures on site.

3.2.2 Section 4 and 5 of this report herein include a Gas Verification Plan for the site which provides details of the specific mitigation measures required at the site to ensure the proposed gas measures comply with the points system presented within BS8485:2015+A1:2019 for the appropriate building type. The gas mitigation measures should be validated in accordance with CIRIA C735.

3.3 Imported Material

3.3.1 There may be a requirement to import suitable topsoil/subsoil for use in the landscaped/garden areas of the development.

3.3.2 The suitability of the sub/topsoil and any other material imported to the site should be independently validated.

3.3.3 The details pertaining to the independent validation of material to be imported to the site are outlined within Section 4 of this report.

3.4 Off-Site Disposal

- 3.4.1 The chemical testing regime for off-site disposal may be different to the chemical testing required to assess the suitability of the soils for retention on site and the risks to human health. Therefore, additional assessment may be required to classify the soils for off-site disposal with testing criteria to assess whether the soil is hazardous, non-hazardous or inert waste.
- 3.4.2 However, existing laboratory test certificate will help inform the process. Any additional testing should also be used in the classification of the waste soils for off-site disposal.
- 3.4.3 The receiving landfill may require additional specialist laboratory testing to further characterise the material proposed for disposal against Waste Acceptance Criteria (WAC). We would recommend early consultation between the Contractor and the receiving landfill to determine any specific laboratory testing requirements.
- 3.4.4 Individuals/companies removing soils from the site are bound by a Duty of Care and as such this should only be undertaken by an authorised person. All waste movements should be accompanied by a waste transfer note.

3.5 Dewatering

- 3.5.1 Based on site investigation works it was determined that groundwater levels are variable and not representative of laterally continuous perched water. The water encountered is likely to be associated with pockets of perched water within more permeable layers of the superficial strata.
- 3.5.2 However, if water entering any of the excavations is visually or olfactory affected by contamination then consideration should be made for dewatering. Any impacted water should be carefully pumped from the excavation directly into a tanker for off-site disposal. Water will be pumped from the near surface of the water and (as much as practicable) away from the sides of the excavation to avoid pumping up soils.
- 3.5.3 All pumping activities will be carefully monitored by BEK to watch for drawing in contaminated water from elsewhere on the site. Pumping will continue until visual/olfactory evidence of contamination has reduced/gone or as is considered reasonably practicable.

3.6 Construction Workers

- 3.6.1 It is recommended that construction personnel involved with direct contact with the soils at the site use appropriate PPE equipment (i.e. boots, gloves and overalls).

3.6.2 In addition, hygiene facilities should be made available in accordance with general health and safety guidelines. The successful remediation/site works contractor should undertake a suitable Risk Assessment to confirm the appropriate level of PPE.

3.6.3 A copy of all reports relating to the site should be included in the site Health & Safety File and site workers should be made fully aware of the site's setting.

3.7 Concrete Mix Design

3.7.1 It is recommended that a concrete classification of sulphate class DS-1 and Aggressive Chemical Environment for Concrete (ACEC) class of Ac-1 is suitable for the site.

3.7.2 Confirmation that the correct concrete mix has been used on site is outside the BEK validation remit.

3.8 Unforeseen Circumstances

3.8.1 Any areas of previously unidentified potentially contaminated soils encountered during site construction works must be brought to the attention of BEK, to ensure that the recommendations herein apply. Any potentially contaminated soils should be left in-situ and subjected to further assessment, to potentially include further chemical testing and risk assessment.

3.9 Utilities

3.9.1 Prior to redevelopment of the site, BEK recommends that a copy of this report and the previous reports relating to the site are supplied to utility companies, and that their recommendations relating to appropriate supply pipes are adhered to.

3.10 Re-use of Waste Soils on Site

3.10.1 The re-use of waste soils generated at the site should be covered through environmental permit exemptions (if applicable) and/or through the preparation of a Material Management Plan as part of compliance with the Definition of Waste: Code of Practice (DoW:CoP).

3.11 Communication

3.11.1 We would recommend that regular communication is maintained between BEK and the Site Manager throughout the development works.

3.12 Statutory Consultation

- 3.12.1 We would recommend that a copy of this Remediation Method Statement is issued to the local authority for review/comment and approval prior to the commencement of re-development works on site.
- 3.12.2 The insurer may also require written approval of the remediation proposals from the regulators in order to satisfy their Land Quality Conditions.

3.13 Pre-Start Meeting

- 3.13.1 It is recommended that a meeting is held between the relevant parties on site, prior to commencement of validation works.

3.14 Closure

- 3.14.1 Following satisfactory completion of remediation works, BEK will produce a Validation/Completion Report to demonstrate compliance with this Remediation Method Statement.

4. DESIGN OF GROUND GAS PROTECTION MEASURES

4.1 General

4.1.1 In accordance with Table 4 of BS8485 (2015) + A1 (2019), the proposed properties are assumed to represent **Type A** buildings. In order to protect against the CS2 ground gas risks identified, a gas protection score of **3.5 points** must be achieved.

4.1.2 A combination of two or more of the following protection measures should be used to achieve the Gas Protection Score:

- Structural barrier (floor slab)
- Ventilation measures
- Gas resistant membrane

Site Specific Assessment of Foundation Design - Gas Protection Score Assessment

4.1.3 The proposed construction elements to achieve the required points of 3.5 points are given below:

- Beam and block floor construction is to be utilised. This achieves **0 points**.
- A ground gas resistant membrane is recommended. This achieves **2 points**.
- A clear void passive venting layer with 'very good' performance is recommended. This achieves **2.5 points**.

4.2 Floor Slab

4.2.1 This floor type contains many construction joints and discontinuities and can be affected by cracking. As such, it offers little resistance to the passage of ground gas and has high permeability.

4.2.2 Based on Table 6 of BS8485:2015+A1:2019, this will achieve a gas protection score of 0 points.

4.3 Ventilation Measures

4.3.1 For the proposed development, it is intended to include a minimum 150 mm deep ventilated sub-floor void with ventilation provided via air vents around the perimeter of each property. The number of vents is to be confirmed but will meet or exceed the BS8485:2015+A1:2019 requirements of 1,500 mm²/m run of wall on at least two opposite sides. This should be sufficient to provide very good performance.

4.3.2 Where there are multiple internal obstructions to air flow (caused by beams) there should be at least four (to five) times the area of the side vents provided to the internal obstruction.

4.3.3 Based on Table 6 of BS8485:2015+A1:2019, this will achieve gas protection score of 2.5 points.

4.4 Gas Resistant Membrane

4.4.1 A low permeability methane and carbon dioxide resistant membrane (also protective against ingress of radon) which meets all of the requirements of Table 7 of BS8485:2015+A1:2019 will achieve a score of 2 points. This membrane should:

- Be made from virgin polymer and have a methane transmission rate of less than 40.0ml/day/m²/atm (average);
- Be chemically resistant to degradation by other contaminants that may be present;
- Be sufficiently impervious, both in the sheet material and in the sealing of sheets and sealing around sheet penetrations, to prevent any significant passage of methane and/or carbon dioxide through the membrane;
- Be sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions;
- Be sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); and to withstand in-service stresses (e.g. settlement if placed below a floor slab);
- Be capable, after installation, of providing a complete barrier to the entry of the relevant gas; and
- Be verified in accordance with CIRIA C735

4.4.2 The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. If a membrane is installed that does not meet all the criteria above then the score is zero.

5. INSTALLATION OF GROUND GAS PROTECTION MEASURES

5.1 General Comments

- 5.1.1 In concurrence with the NHBC guidance 'Hazardous Ground Gas - an essential for housebuilders – April 2023', BEK has advised the client that the welded solution is the preferred method for sealing gas membranes at critical junctions including laps and joints. The client has opted for a taped solution.

5.2 Components of the Membrane System

- 5.2.1 The manufacturer of the membrane and its associated components has yet to be confirmed by the client. The installed membrane and its associated components will need to meet the requirements of BS8485:2015+A1:2019.

- 5.2.2 BEK recommends two membranes which are considered suitable for use as a gas barrier and these are:

- Juta GP1 (Juta)
- Visqueen Ultra Gas Barrier

- 5.2.3 All membrane installation must be undertaken to the manufacturer's specification.

- 5.2.4 Installation accessories will also be necessary (the exact components will depend on the installation method and the exact design of the building). Components utilised to install the gas membrane system include but are not limited to:

- Jointing tape (double sided, gas resistant tape)
- Pre-formed top hats
- Pre-formed Corners and Stop Ends
- Jubilee clips
- Gas Resistant Self Adhesive Membrane (and primers if this is sealed directly to masonry, metal or concrete)
- Gas Resistant Damp Proof Course (strongly preferred in areas where internal and external walls are to be constructed)
- Liquid Gas Membrane

- 5.2.5 All products utilised in the gas membrane system will need to be pre-approved by BEK. Any additional products utilised will need to be re-reviewed to confirm they meet the requirements of BS8485:2015+A1:2019.

5.3 Ventilation Measures

Sub-Floor Void

- 5.3.1 The beam and block system should incorporate a void depth of a minimum 150 mm free from debris and obstructions.

Air Bricks

- 5.3.2 The number of vents will meet or exceed the BS8485:2015+A1:2019 requirements of 1,500 mm²/m run of wall on at least two opposite sides. A typical air brick provides (6,000mm² vent area).

- 5.3.3 Regardless of ground gas protection requirements, the NHBC advise for protection against moisture is that void ventilation should be provided to whichever gives the greater opening area of either (i) 1500mm² per metre run of external wall or (ii) 500 mm² per m² of floor area. Therefore, minimum NHBC requirements are likely to be appropriately protective in terms of ground gases for low rise housing. It is outside the BEK remit to confirm whether the NHBC standards/building regulations are met with regards to protection against moisture.

- 5.3.4 BEK will validate that the number of vents will meet or exceed the BS8485:2015+A1:2019 requirements of 1,500 mm²/m run of wall on at least two opposite sides.

Internal Sleeper Walls

- 5.3.5 Where there are multiple internal obstructions to air flow caused by beams and sleeper walls, cross vents will need to be installed. These need to provide a minimum of 6,000 mm²/m.

- 5.3.6 The simplest approach is to use short sections of 100 mm diameter PVC drainage pipe through the sleeper wall or construct it with gaps in the blockwork.

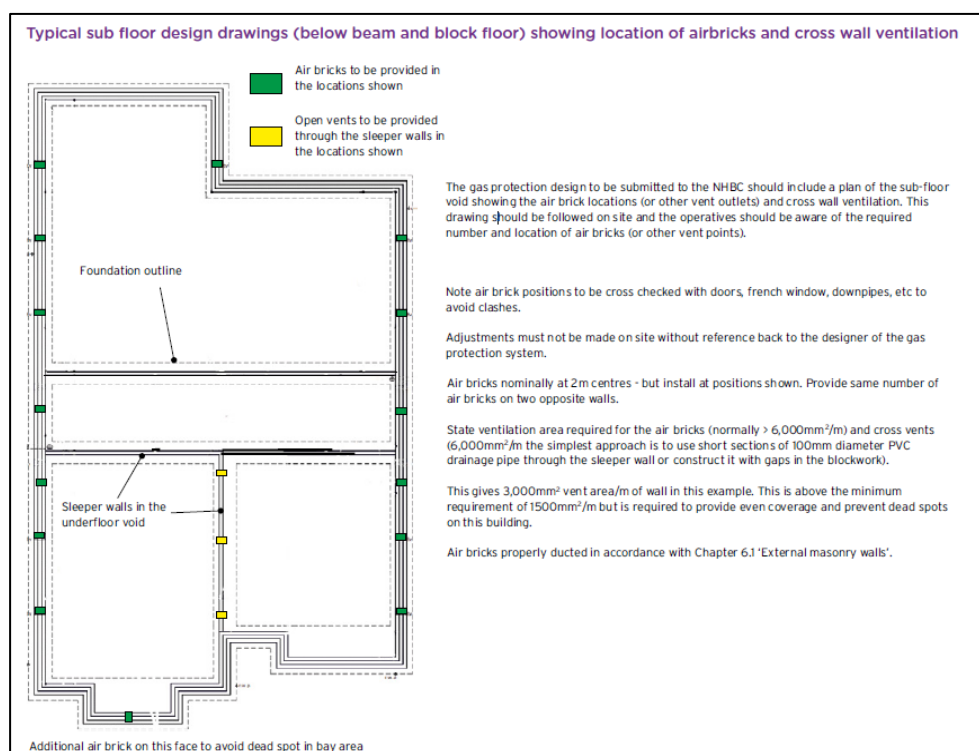


Figure 2: Example Drawing Showing Air Brick Locations

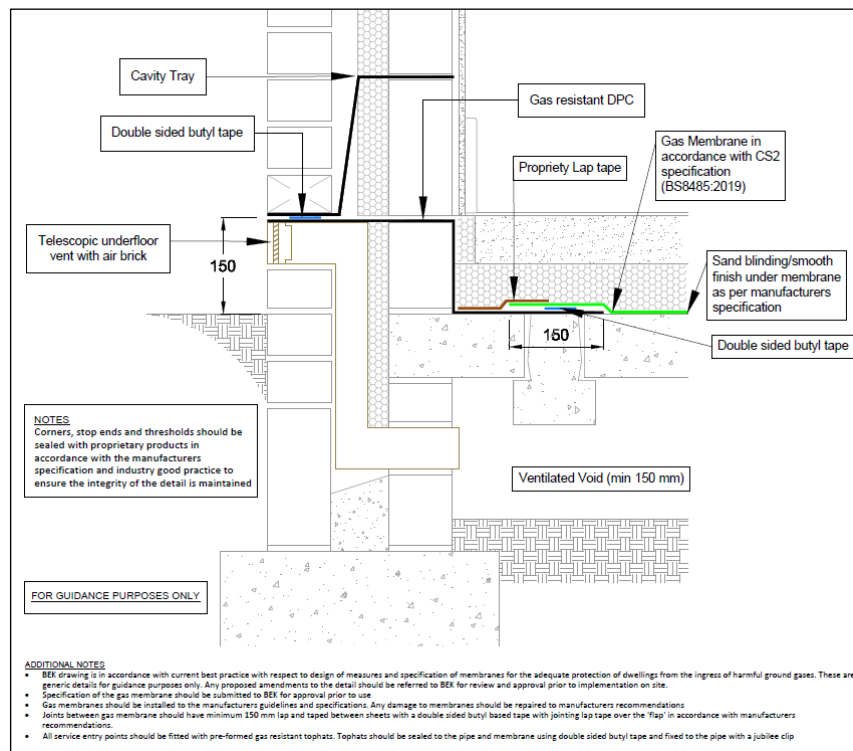
5.4 Ground Gas Membrane Installation - Outline Methodology

Preparation of the surface underlying the membrane

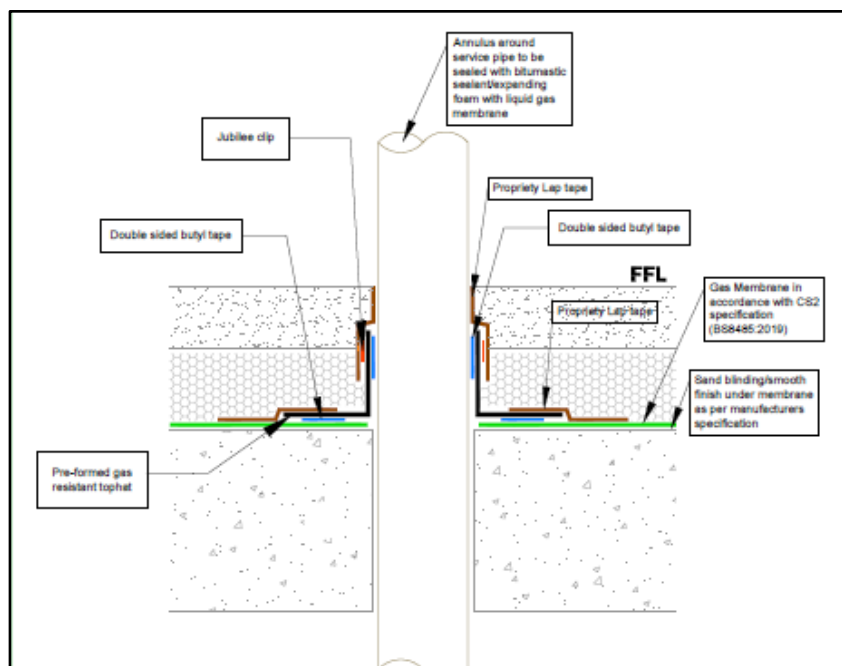
- 5.4.1 The surface underlying the membrane should have a smooth finish - free from voids, projections, and mortar deposits.
- 5.4.2 The gaps between the block and beams should be filled with a sand cement screed brushed into the joint. In many instances blocks are cut leaving gaps around pipe penetrations, these should be filled with expanding foam or sand and cement to ensure that the gas membrane is fully supported.
- 5.4.3 The beam and block floor should be prepared as per the manufacturer's specification (e.g. a sand blinding layer, protection fleece, or a smooth concrete float finish).

Laying of the Gas Membrane System

- 5.4.4 The membrane system shall be laid loosely extended across cavities and sealed around joints/service entries as per the manufacturers specification. This will typically require 150 mm membrane overlaps with proprietary double-sided tape within the joint and single sided proprietary tape over the top of the joint. A cross section showing the installation of membrane is illustrated in Figure 3.



5.4.5 Service penetrations shall be sealed with proprietary 'top hats' to the membrane and service pipe using proprietary products in accordance with the manufacturer's specification. Top hats should be sealed to the pipe and gas membrane utilising double sided jointing tape and fixed with a jubilee clip. A schematic showing the installation of a top hat as per the manufacturer's specification is shown in Figure 4.



- 5.4.6 Corners and non-standard service entries will be preferentially sealed utilising Gas Resistant Self Adhesive Membrane. Corners and block ends can also be sealed with pre-formed units.

Protection of the Gas Membrane System

- 5.4.7 BEK recommends that the gas membrane is protected through placement of the insulation and/or fleece protection above the membrane within one working day of a passed inspection (as per the manufacturers specification).

Sealing of Internal Annulus around Service Pipe

- 5.4.8 In terms of the internal annulus of the duct holding each of the service pipes and conduits (electric cables and water pipes in some areas etc.) this will be filled with expanding foam and liquid applied gas membrane. The detail for this is provided in Figure 5.

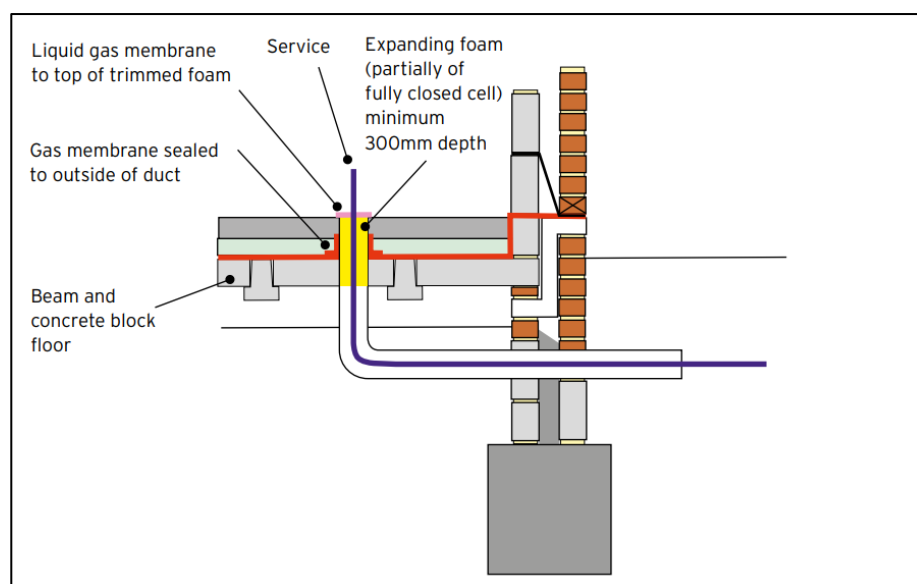


Figure 5: Sealing of the Internal Annulus of the Service Duct (extracted from NHBC – an essential guide for house builders – April 2023)

5.5 Installer of Ground Gas Measures

- 5.5.1 The exact construction company appointed to install the gas protection measures is unknown at the time of writing. The installers should be trained and experienced in the installation of ground gas resistant membranes.

5.5.2 BEK has recommended that in accordance with the NHBC 'Hazardous Ground Gas – an essential guide for housebuilders' the installation of the gas membrane system should be carried out by a specialist gas membrane installation company (specialist installer) with at least 50% of staff holding an NVQ level 2 (gas membrane installation) and/or TWI/CSWIP plastic welding accreditation with the remaining staff working towards one of those qualifications.

5.5.3 If non-specialist groundworkers are utilised to install the ground gas mitigation measures, BEK has recommends that the general contractor doing the installation should receive adequate training from the suppliers of materials and be suitably qualified to carry out the installation.

5.6 Verification

5.6.1 The installation of the membrane will be independently validated by an appointed environmental consultant from BEK. Michael Buckley (BSc (Hons) MSc MEnSci CEnv), owner and Managing Director at BEK Enviro Ltd has over 25 years' experience in the verification of ground gas mitigation measures. Michael Buckley is responsible for the appointment/training of suitably qualified staff to verify gas measures and the ultimate sign off of all verified gas mitigation measures.

5.6.2 All staff involved in the verification of ground gas mitigation measures are degree qualified and a number of employees at have attended the 'Verification of Gas Protection Systems Course' delivered by CL:AIRE. In house training has been delivered to all BEK employees involved the verification of ground gas mitigation measures.

6. GAS MEASURES VALIDATION PLAN

6.1 Supervision of Works

- 6.1.1 The verification as described herein follows the recommendations set out in CIRIA C735 'Good practice on the testing and verification of protection systems for buildings against hazardous ground gases'. The works will be verified in accordance with CIRIA 735 (2014) by an experienced, suitably qualified verifier.
- 6.1.2 The installation of the gas protection measures (ventilation system and gas membrane installation) will be checked and verified by the Engineer at key stages during the works.

6.2 Key Verification Responsibilities & Hold Points

- 6.2.1 Verification lines of evidence need to be collated at a number of hold points. Such lines of evidence are required to ensure that the gas mitigation measures have been installed in accordance with the methodology presented in the Gas Verification Plan report herein.
- 6.2.2 However, it will not always be possible (or practicable) for BEK to be present for every stage of the remediation works in every plot and therefore some degree of verification will need to be undertaken by the developer. However, this should only be done following communication with BEK to ensure that appropriate validation records are maintained.
- 6.2.3 In all cases, it will be the responsibility of the developer to ensure that the verifier is contacted to collate verification evidence/in house verification evidence is collated at the below mentioned hold points:

Verification Hold Points	Evidence Requirement and Party Responsible for collation of such evidence
Verify depth of sub-floor void	Verification Consultant &/or Developer (Developer can only provide these records when BEK is confident that appropriate evidence has been collated) - Provide location referenced example photos
Spacing of air bricks, inspection of underside of membrane placement and sealing of the gas membrane across the entire building footprint	Verification Consultant - is to conduct a thorough visual inspection of 100% of the membrane area prior to it being overlain by insulation and a concrete screed poured to ensure all joint/penetrations are sealed appropriately. BEK is also to verify that the air bricks have been installed at the locations specified in the design drawings.
Placement of the insulation and/or fleece protection above the membrane.	Developer - is to ensure that the membrane is insulated within 1 working day of the inspection passing on a given plot. This should be considered for periods of site closures (ie the Christmas break).
Watch brief following inspection of the membrane and prior to concrete pour to ensure gas membrane is not punctured/damaged by follow on trades	Developer - is to ensure that follow on trades are aware of the presence and purpose of the gas membrane, and who they should contact if they believe their actions have had the potential to compromise it. A watch brief should be maintained by the developer to ensure that the membrane is not damaged by follow on trades. BEK should be contacted if the developer has reason to believe the measures have been compromised.
Sealing of service ducts (prior to occupation)	Developer - is to provide confirmation that the internal annulus of any open portion of any service duct annulus has been sealed in accordance with the design drawings. Plot specific location referenced photos to be collated for all seals and to be provided to the local authority on request
Ground level checks at airbricks (prior to occupation).	Developer - is to inspect the placement of airbricks with reference to finished ground levels after completion of landscaping works to ensure these have not been obscured.

Table 3: Summary of Key Verification Hold Points and Lines of Evidence Required at Each Hold Point.

6.3 Visual Inspection & Integrity Testing

6.3.1 A visual inspection method is recommended to be carried out by BEK on every plot. This should be undertaken following laying of the beam and block floor and laying of gas membrane on top, but prior to laying of insulation and pouring of the screed.

6.3.2 Integrity testing is not required. However, pick testing may be carried out on site at the discretion of the BEK engineer.

6.4 Verifier Checklist

6.4.1 The BEK Enviro Ltd verifier or other suitably qualified verifier should:

- Confirm that the correct membrane has been used, including sealing/jointing tape and preformed components e.g. top hats, corners, self-adhesive gas membrane.
- Confirm that the underside of the membrane has been installed and prepared as per the manufacturer's specification with the underside of the membrane being free from voids, projections, and mortar deposits.
- Inspect the general condition of the membrane for punctures, rips and tears.
- Check that joints and laps have been sealed in accordance with manufacturers specification.
- Check that the membrane has been installed correctly across cavities, including correct jointing in these areas.
- Check that top hats have been correctly installed around service entries, including jubilee clips around the pipe and correct sealing arrangements to the membrane/pipe infrastructure as per the manufacturer's specification.
- Check that vents have been installed around the perimeter of the building in sufficient number and in the correct locations, including inspecting the condition i.e., not blocked or otherwise restricted.
- Check the presence of a passive ventilation system (clear >150mm void), including measuring that this is of a sufficient depth and the void has not been filled or otherwise compromised.
- Check that internal sleeper walls are also vented to provide adequate flow-through within the void so that none of the walls are blocking off unvented sections within the void.

6.4.2 Any sections of the gas membrane displaying a flaw, failing a visual inspection or failing integrity testing (if required) should be repaired under the supervision of the verification consultant until rectifications are considered acceptable. The verification consultant should record the type and result of the repairs on the gas proforma (to be completed on a plot x plot basis).

6.4.3 If the verification consultant leaves the site without rectifications being made then the plot inspection will be failed subject to re-inspection at a later date.

6.4.4 Photographic evidence will be recorded during all inspections and a suitable record of the validation will be included within a validation report.

6.4.5 A gas measures proforma sheet will be completed detailing the inspection for each inspection visit. An example of the gas pro-forma to be used is presented in Appendix A.

7. SUPERVISION AND VALIDATION

7.1 Supervision of Works

7.1.1 The works will be supervised by BEK who will ensure the following verification procedures are adopted:

- (i) Liaison with the appointed groundwork/remediation contractor
- (ii) Inspection and supervision of the works
- (iii) Collection of samples and co-ordination of laboratory testing

7.1.2 The remediation areas will be checked and verified by the Engineer at key stages during the works, including:

- (i) Installation of the telescopic vents for the passive ventilation.
- (ii) Following placement and sealing the proprietary gas membrane

7.1.3 For a sustainable approach it is recommended that the excavated soils are retained on site. However, this may not be achievable due to the requirements in meeting finished site levels.

7.2 Validation of the Works

7.2.1 Validation testing is required to ensure the remediation works have been undertaken in accordance with the methodology presented herein.

7.3 Imported Material

7.3.1 It may be necessary to import additional soil for use in the landscape/garden areas. If possible, all imported soils should be sourced locally.

7.3.2 The methodology to validate the quality of any imported material for use in the gardens will depend on source of those materials. Materials from a known source, where independent risk assessment has been carried out would require no further testing, provided it has been sampled on an appropriate density and has been proven fit for purpose in accordance with residential criteria.

7.3.3 To confirm the suitability of the sub/topsoil it will be necessary to recover representative samples for chemical testing and assessment. We initially recommend that this consists of a minimum of 3 samples, however the sampling frequency may be varied at the discretion of the Engineer depending on the nature and variability of the soil.

- 7.3.4 The methodology to validate the quality of any imported material for use in the gardens will depend on source of those materials. Materials from a known source, where independent risk assessment has been carried out would require no further testing, provided it has been sampled on an appropriate density and has been proven fit for purpose in accordance with residential criteria.
- 7.3.5 Without any validatory information, all potentially suitable capping material will be thoroughly assessed at source prior to importation onto the site. The Engineer will obtain samples from the identified sources, at a rate of between 3 and 5 samples per source depending upon the volume of material available.
- 7.3.6 It will also be necessary to carry out routine inspection and sampling during the importation process in order to confirm the material is consistent with the source testing and assessment.
- 7.3.7 The visual inspection shall ensure that the soil is visually acceptable for use and does not contain any deleterious material (i.e. glass, plastic, brick, concrete etc.).
- 7.3.8 Imported topsoil and subsoil being brought to the site should be tested for contamination to ensure that they are suitable for residential end use. Testing of imported soils can be undertaken upon import within a stockpile, or preferably upon placement within rear gardens areas. Testing will vary based on the source of the material.
- 7.3.9 All soils from greenfield sources will be checked to confirm the greenfield status and confirmation will be provided in the Validation Report (ie red line site boundary, grid reference and other checks).
- 7.3.10 If soils are not greenfield then sampling frequencies should be agreed with the Local Planning Authority (LPA) prior to undertaking the work.
- 7.3.11 If other materials will be used, re-used or imported as a component of the cover system in the top 600 mm then they should be afforded the same sampling and analytical strategy as the soils in order to provide the confidence that they are suitable for use.
- 7.3.12 Imported topsoil and subsoil will be tested in accordance with Table 4 below.

Type	Number of Samples	Testing Schedule	Assessment Criteria
Please note that these guidelines apply to a typical residential development, and relaxation of the guidelines or more stringent requirements may apply dependent on local and site specific factors. Therefore, <u>all parameters need to be agreed with the Local Authority.</u>			
Virgin Quarried Material	1 or 2 depending on the type of stone utilised, to confirm the inert nature of the material.	Standard metals/metalloids (should include as a minimum As, Cd, Cr, CrVI, Cu, Hg, Ni, Pb, Se, Zn)	The assessment criteria need to be UK based, e.g. LQM S4ULs, Defra C4SLs or other similarly derived GACs.
Crushed Hardcore, Stone, Brick (excluding asphalt)	Minimum 1 per 500m ³	Standard metals/metalloids (as above), PAH (16 USEPA speciation), asbestos, total TPH. Any additional analysis dependant on the history of the donor site (e.g. phenol, total cyanide, BTEX, MTBE).	
Greenfield/ Manufactured Soils	Minimum 3 Dependent on source and receptor, between 1 per 50m ³ and 1 per 250m ³	Standard metals/metalloids (as above), PAH (16 USEPA speciation), asbestos, pH and soil organic matter (SOM) (or calculated from total organic carbon (TOC)).	
Brownfield/ Screened Soils	Minimum 6 Dependent on source and receptor, between 1 per 50m ³ and 1 per 100m ³	Standard metals/ metalloids (as above), PAH (16 USEPA speciation), TPH (CWG banded), asbestos, pH and SOM (or calculated from TOC). Any additional analysis dependant on the history of the donor site (e.g. phenol, total cyanide, BTEX, MTBE).	

Table 4: Summary of Soil Testing Frequency and Schedule (taken from YALPAG)

7.3.13 The sampling frequency may be varied at the discretion of the Engineer depending on the nature and variability of the imported material and its source (subject to Local Authority approval).

7.3.14 Following assessment of the source of material, it may be necessary to test for additional determinands. The assessment criteria for the determinands to be tested for are presented in Table 3.

7.4 Assessment Criteria

7.4.1 The following table provides a list of assessment criteria for assessing suitability of material to be used within the capping system.

- 7.4.2 The criteria have been sourced from the LQM/CIEH Suitable 4 Use Level (S4UL). In addition, the category 4 Screening Level (C4SL) for lead has been used and the Atkins ATRISKSIL screening level for cyanide has been used.

Contaminant of Concern	Assessment Criteria (mg/kg)
Arsenic	37
Cadmium	11
Chromium (total)	910
Copper	2400
Lead	210
Mercury	40
Nickel	180
Selenium	250
Zinc	3700
Cyanide	41
Acenaphthene	210
Acenaphthylene	170
Anthracene	2400
Benzo(a)anthracene	7.2
Benzo(a)pyrene	5
Benzo(b)fluoranthene	2.6
Benzo(ghi)perylene	320
Benzo(k)fluoranthene	77
Chrysene	15
Dibenzo(ah)anthracene	0.24
Fluoranthene	280
Fluorene	170
Indeno(1,2,3-cd)pyrene	27
Naphthalene	2.3
Phenanthrene	95
Pyrene	620
Phenols	<0.001%

Table 5: Assessment Criteria for Imported Sub/Topsoil

7.5 Assessment of Chemical Test Results

- 7.5.1 BEK will be responsible for the assessment of all chemical test results to determine suitability of material to be used on site.
- 7.5.2 The assessment will be undertaken in accordance with current UK policy and guidelines and the method agreed with the local authority.
- 7.5.3 All chemical test results will be presented in the Validation Report.

7.6 Gas Measures

7.6.1 The following information should be included within a Verification Report to demonstrate the successful installation of ground gas protection on the site:

- Site details and objectives of verification
- A summary of the original site conditions and the ground gas regime.
- A description of the gas measures installed
- Details of the gas-resistant membrane manufacturer and type used (including sealing / jointing tape and pre-formed components e.g. top hats, corners). This shall include the manufacturer specification / datasheet.
- Installer and verifier and credentials of such organisations, i.e. level of competency of installer – NVQ Level 2 or general groundworker.
- Detailed description of any variations from the specification provided in this report, with explanation and justification of such deviations.
- As-built construction drawings (if available).
- A description of the verification approach – in this case visual inspection.
- Verification lines of evidence – including contractor records, proformas and photographic evidence.
- Details of all relevant communications held with regulatory bodies during implementation
- Verification conclusions, including any future gas monitoring or management requirements to manage residual hazards (anticipated none in this case due to passive approach)
- Any limitations to the measures installed/verified

7.7 Unexpected Areas of Ground Contamination

7.7.1 As stated previously within this report the site has been subject to previous site investigation and as such, indicative ground conditions are known.

7.7.2 However, if any area of suspect material is encountered during the development of the site (i.e. that do not conform to the anticipated ground conditions) appropriate action will be taken. This will initially include the cessation of work in the area of concern and information BEK, who will attend site and carry out further assessment.

7.7.3 As a minimum BEK will notify the Local Authority and prevent any additional work in the area pending further assessment which may include sampling, testing and risk assessment.



8. REPORTING

8.1 On completion of the remediation and mitigation works, BEK will prepare a Validation/Completion Report.

8.2 The Completion Report will describe the works undertaken in order to satisfactorily demonstrate that the works have been completed successfully and will include the following:

- A description of works undertaken
- Record of any unforeseen contamination encountered during the works
- Confirmation of the suitability of the gas membrane and confirmation of the installation of the gas mitigation measures
- Record of any material imported into the site for use in the residential gardens (if required)
- Validation samples recovered and tested
- Assessment of the chemical test results
- Photographs showing the remediation works being undertaken and completed

APPENDIX A

Gas Proforma Sheet

BEK Ground Gas Validation Inspection Record

Site:				Inspected by:	
Plot No:		Date:		Inspection Method:	

	Inspected Item	Y/N	Comments/Defects/Remedials requested	Photo? Y/N
1.1	External Wall Airbricks			
1.2	Sub-Floor Void/ Pressure Relief / Passive Venting			
1.3	Any internal sleeper walls – require appropriate ventilation			
1.4	External vent trenches/ducts			
2.1	Condition of subgrade and underside of membrane			
2.2	Gas Membrane type including associated components			
2.3	Gas Membrane Condition			
2.4	Lapping Design/Seals of Laps and Joints			
2.5	Perimeter Installation/Cavities and Corners			
2.6	Service Entries			
2.7	Are there any level changes/steels/abnormals?			
Additional Notes:				

BEK Ground Gas Validation Inspection Record

	Inspected Item	Comments/Defects/Remedials requested
1.1	External Wall Airbricks	Meet or exceed the BS8485:2015+A1:2019 requirements of 1,500 mm ² /m run of wall on at least two opposite sides. A typical air brick provides (6,000mm ² vent area). Check design
1.2	Sub-Floor Void/ Pressure Relief / Passive Venting	Check the presence of a vented void / pressure relief pathway, including measuring that this is of a sufficient depth and not been filled or otherwise compromised. Subfloor Void minimum 150 mm for residential properties with beam and block construction (unless otherwise specified by design drawing)
1.3	Any internal sleeper walls	Venting of sleeper walls to provide adequate flow-through within the void (6,000 mm ² /m for low rise residential). Ventilation holes (honeycomb brickwork/pipe crossings?) – size, spacing, location in accordance with design? Check that none of the walls are blocking off unvented sections within the void
1.4	External vent trenches/ducts	Located and constructed in accordance with design drawings? If open-topped gravel – gravel type/presence of fines? If pipe or other vent, check position and construction for functionality and absence of blockages. Ability of void former to withstand bearing of the superstructure?
2.1	Condition of subgrade and underside of membrane	Check that the subgrade does not contain rough/uneven surfaces, is appropriately clean and that there are no sharp object E.g. projections, and mortar deposits. Check protective sand blinding layer or geotextile (if specified) is present and meets design specification
2.2	Gas Membrane Type including associated components	Ensure that the correct membrane have been used including components eg sealing/jointing tape, self-adhesive gas membrane, pre-formed tophats, corners, damp proof course
2.3	Gas Membrane Condition	Inspect for rips/tears/punctures/stretching of membrane. Confirm that the membrane is free from dirt, evidence of heavy foot traffic and building materials. Specify and photograph any repairs carried out during inspection
2.4	Lapping Design/Seals of Laps and Joints	Minimum lap as per manufacturers specification of 150 mm. Are joints lapped and sealed in accordance with manufacturers requirements/specification? Check double sided tape is sufficiently stuck and that lap tape isn't lifting/no fish mouths
2.5	Perimeter Installation/Cavities and Corners	Check that membrane goes across the cavity or that membrane jointed correctly to corners, stop ends and threshold (preformed corners/SAGM). Cavity should be free from debris and water.
2.6	Service Entries	Weld sealed using SAM or Tophats need to be correctly installed with no gaps between tophat and membrane and no lifting of tape. Double sided tape should be used around tophat and service entry. Jubilee clips around the pipe and correct sealing arrangements to the membrane/pipe infrastructure as per the manufacturers specification
2.7	Are there any level changes/steels/abnormals?	Changes of level are complex and should be undertaken in accordance with a site specific 3D drawing of the gas membrane detail. Steels require primer with liquid gas membrane and/or self-adhesive membrane