
Proposed Residential Development, Glan Gors, Wrexham.

Environmental Verification Plan

Prepared For:
Pennaf Housing Group and Wrexham County Borough Council

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CONTENTS

1.0 Introduction

2.0 Report Objectives

3.0 Summary of Ground Remediation Strategy

3.1 Summary of ground conditions

3.2 Summary of groundwater

3.3 Summary of contamination source

3.4 Ground contamination

3.4.1 Remediation options appraisal

3.4.2 Capping strategy

3.4.3 Capping validation

4.0 Summary of Ground Gas Strategy

4.1 Summary of ground gas monitoring

4.2 Summary of gas mitigation

4.3 Gas mitigation design parameters

4.4 Selected gas mitigation options

4.5 Summary of workmanship, testing and independent validation of proprietary gas membrane.

4.5.1 Workmanship.

4.5.2 Independent testing and validation

5.0 Details of who carried out works.

5.1 Main contractor

5.2 Remediation contractor

5.3 Groundworks (capping)

5.4 Final capping level checks

5.5 Gas membrane installers

5.6 Gas membrane verification report

5.7 Gas monitoring

6.0 Amendments to Remediation Strategy and Implementation Plan

7.0 Site Wide Verification Report

7.1 Phase 1 Ground Contamination - proof and evidence

- 7.1.1 Pre-placement testing of sub-soil for site-won capping materials
- 7.1.2 Inspection of sub-soil capping material and indicator barrier
- 7.1.3 Sub-soil placement levels
- 7.1.4 Post-placement testing of site-won capping materials
- 7.1.5 Disposal of unsuitable materials off-site
- 7.1.6 CBR testing of capped site
- 7.1.7 Import of granular construction materials

7.2 Phase 2 Ground Contamination – proof and evidence

- 7.2.1 Pre-placement testing of top-soil
- 7.2.2 Inspection of top-soil material
- 7.2.3 Top-soil placement levels
- 7.2.4 Post-placement testing of top-soil

7.3 Ground Gas Mitigation – proof and evidence

- 7.3.1 Remediation phase gas monitoring
- 7.3.2 Gas protection measures inspection
- 7.3.2 Gas installation integrity report
- 7.3.3 Post construction gas monitoring

8.0 Conclusion

Appendices

Appendix A Site Location, Layout and Remediation Drawings

Appendix B Bore Hole and Trial Pit Locations

Appendix C Schedule of Remediation Activities, Supporting Results and Evidence

Appendix D Record Information, Results and Evidence

Appendix E Certification

Appendix F Residual Risk Assessment and Future Risk Mitigation

1.0 INTRODUCTION

HLN Engineering Ltd (HLN, formerly known as Bay Associates) have been instructed by Pennaf Housing Group to develop the Remediation Strategy, Implementation Plan and Verification reports for the proposed redevelopment of land known as Glan Gors, off Anthony Eden drive, Wrexham. The site location and layout is shown in Appendix A.

The development proposal comprises 8No flats and 15No low rise residential units with gardens, adoptable highway and footway access and associated landscaping.

This report is part of a staged assessment of the site, set out below are the preceding investigations and reports/responses which have informed this staged assessment to date

Prior to the proposed development, the following studies were undertaken by Wrexham County Borough Council as part of a Stage 2 Contamination Assessment Report, undertaken over land to the north of the study area which was a former landfill know as Bala Road Landfill. These reports included:

- *Former Landfill Sites Stage 2 Contamination Assessment – Bala Road – commissioned by Wrexham County Borough Council. Oct 2007. Smith Grant LLP. Report R786-R27(BalaS2)(Final Rev1)*
- *Former Landfill Sites Stage 2 Contamination Assessment – Bala Road – commissioned by Wrexham County Borough Council. Oct 2007. Smith Grant LLP. Report R786-R54(BalaS2 Add)*
- *Former Landfill Sites Stage 2 Contamination Assessment – Review and Update of Previous B20(c) Investigation Works Under Part IIA Bala Road – commissioned by Wrexham County Borough Council. Oct 2012. Smith Grant LLP. Report R1661-R10(V2)*

The investigations of the Bala Road landfill were undertaken as part of a Part 2A assessment into former landfills. These reports provided useful information on the potential study site characteristics, which formed part of the Bala Road Landfill. The reports also informed the following site specific desk study and intrusive investigation works and reports, undertaken by E-geo Solutions Ltd, for the proposed residential development at Glan Gors.

- *Stage 1 Desk Study and Preliminary Ground Contamination Risk Assessment - Land at Glan Gors, Anthony Eden Drive, Wrexham, LL13 8TH – Commissioned by Bay Associates Nov 2012 E-geo Solutions Ltd Report E0500S1.P1.R1*
- *Intrusive Geotechnical and Geo Environmental Ground investigation - land at Glan Gors, Anthony Eden Drive. – Commissioned by Bay Associates August 2013 E-geo Solutions Ltd Report E0500.S1.P2.R1.V5*

Following the completion of the intrusive and interpretive investigations HLN developed, in consultation with Wrexham's contaminated land team, the following documents:

- *Proposed Residential Development, Glan Gors, Wrexham.*
*Detailed **Remediation Strategy***
On behalf of Pennaf Housing Group and Wrexham County Borough Council
December 2013
*Report Number: **6503/SR/Rem***

This report sets out the detailed Remediation Strategy (in accordance with CLR 11), which justifies the remediation/mitigation options chosen, indicates the scientific and technical bases of the chosen remediation type as well as indication of site management, site phasing and required licenses.

- *Proposed Residential Development, Glan Gors, Wrexham.*
*Environmental **Implementation Plan - Stage 1** – Ground Contamination*
On Behalf of Pennaf Housing Group and Wrexham County Borough Council
March, 2014
*Report Number: **6503/SR/Imp1***

This report sets out the Implementation Plan for the ground contamination remediation strategy and confirms a clear set activities for the site.

- *Proposed Residential Development, Glan Gors, Wrexham.*
*Environmental **Implementation Plan - Stage 2** – Ground Gas Mitigation*
On behalf of Pennaf Housing Group and Wrexham County Borough Council
April, 2014
*Report Number: **6503/SR/Imp2***

This report sets out the Implementation Plan for the ground gas remediation strategy and confirms a clear set activities for the site.

2.0 REPORT OBJECTIVE

The objective of this verification plan report is to collate and present all the relevant records, results and evidence relating to the ground contamination and ground gas remediation works as set out in the remediation strategy and implementation plan, in order to demonstrate compliance with the previously approved plans.

The ultimate objective is to enable the Local Authority to discharge all the planning conditions relating to ground contamination and remediation.

3.0 SUMMARY OF REMEDIATION STRATEGY

To ensure that this report is able to be assessed as a stand-alone document, a summary of ground conditions and the proposed remediation strategy is presented below in Sections 3.1 to 3.3. The test results, evidence of completion and relevant records required to verify compliance with the approved strategy is presented in Section 7 and onwards.

3.1 Summary of Ground Conditions

The general stratigraphic sequence at the site (surface down) is:

- Black Topsoil.
- Made Ground – dark brown very silty fine to coarse sand and gravel with some to much plastic sheet, bags, glass bottles and gravel, cloth, metal wire, ash gravel, and cobbles of sandstone.
- Silt – dark and light grey slightly sandy clayey SILT.
- Peat – dark brown to black silty slightly clayey PEAT (in parts).
- Alluvium – brown slightly sandy clayey SILT and medium brown very silty fine SAND.
- Glacial Till – dark brown sandy silty CLAY with much fine to coarse gravel and some cobbles

The strata and depths encountered during the investigation were:

Stratum	Description	Depth to base m range (average)
Topsoil	Dark brown silty sandy topsoil	0.10
Made Ground	Loose dark brown very silty fine to coarse sand and gravel with some to much plastic sheet, bags, glass bottles and gravel, cloth, metal wire, ash gravel, and cobbles of sandstone	1.10 – 1.70 (1.50) (2.70m at BD3)
Silt	Very soft to soft dark and light grey slightly sandy clayey SILT	1.90 -2.10 (2.00)
Peat	Very soft dark brown to black silty slightly clayey PEAT (in parts)	1.70 – 3.00 (2.50) (BD1S, BS2, BH 1only)
Alluvium	Soft brown slightly sandy clayey SILT and loose to medium dense medium brown very silty fine SAND with silt partings	8.90 – 10.2 (9.40)
Glacial Till	Stiff dark brown sandy silty CLAY with some to much fine to coarse gravel and some cobbles	17m +

3.2 Summary of Groundwater

Groundwater was encountered in the trial pits and boreholes at the depths shown on the table below:

TP/BH No.	Water encountered	Comment	TP/BH No.	Water encountered	Comment
TP1	0.80	Rapid inflow	BD3S	1.70	Damp
TP2	1.00	Rapid inflow	BH 1	3.00	Medium inflow rising to 1.60 (20 min)
TP3	1.10	Rapid inflow	BH 2	5.50	Slow inflow rising to 3.60 (20 min)
TP4	0.90	Moderate inflow	BH 3	4.00	Slow inflow rising to 3.80 (20 min)
BD1S	1.20	Slight seepage			
BD2S	1.90	Slight seepage			
BS2	2.00	Damp			

Perched groundwater was encountered in the made ground in trial pits at depths of 0.80m to 1.10m, and in the shallow boreholes at depths of 1.20m to 1.90m. Subsequent monitoring in the shallow boreholes indicated the perched water standing at depths of 0.98m to 1.36m.

Shallow groundwater in the alluvial deposits was encountered at depths of 3.00m in BH 1 (rising to 1.60m in 20 minutes), 5.50m in BH 2 (rising to 3.60m in 20 minutes) and 4.00m in BH 3 (rising to 3.80m in 20 minutes)

Monitoring of the installations was undertaken during gas monitoring and water sampling with water levels shown in table below:

TP/BH No.	Water encountered	Comment	TP/BH No.	Water encountered	Comment
TP1	0.80	Rapid inflow	BD3S	1.70	Damp
TP2	1.00	Rapid inflow	BH 1	3.00	Medium inflow rising to 1.60 (20 min)
TP3	1.10	Rapid inflow	BH 2	5.50	Slow inflow rising to 3.60 (20 min)
TP4	0.90	Moderate inflow	BH 3	4.00	Slow inflow rising to 3.80 (20 min)
BD1S	1.20	Slight seepage			
BD2S	1.90	Slight seepage			
BS2	2.00	Damp			

3.3 Summary of Contamination Source

The results of the investigations, analysis of ground samples and waters and monitoring for ground gasses have identified the following:

- Very isolated occurrence of very slightly elevated concentrations of arsenic and lead in the made ground (BD2S – 0.70m).
- Isolated occurrence of elevated concentrations of petroleum hydrocarbons within the made ground (BS1 – 0.4m, BS3 – 1.70m, BD3S, BD3S – 0.90m)
- Very isolated occurrence of asbestos fibres (amosite) but with no detectable mass (TPSS2 and TPSS4)
- Slightly elevated concentrations of benzo (a)pyrene across the site
- Elevated concentrations of calcium, manganese and PAH in the perched water in the made ground
- Elevated concentrations of arsenic, calcium, manganese, potassium, ammoniacal nitrogen and PAH in the shallow groundwater in the alluvial deposits below the site
- Occasional elevated concentrations of methane across the site
- Elevated concentrations of carbon dioxide in the majority of locations across the site with depleted oxygen concentrations

The investigation involved sampling at discrete locations although the type of made ground encountered across the site was similar at all sampling locations. The screening analysis was based on a typical suite of tests, based on the initial conceptual model and to fall within an available budget. However it is possible that other substances may be present or that elevated concentrations of chemical parameters and gasses may be encountered between sampling locations.

3.4 Ground Contamination

To ensure that this report is able to be assessed as a stand-alone document, the following summary of the remediation for ground contamination is presented below in section 3.4.1 to 3.4.3. The test results, evidence of completion and relevant records required to verify compliance with the approved strategy is presented in Section 7 and onwards.

3.4.1 Remediation Options Appraisal

A remediation option appraisal within the detailed remediation strategy concluded that due to the nature of material in the made ground Civil Engineering methods of remediation would be the most appropriate.

Civil Engineering techniques remain the most widely used remedial method of brown field re-development although they are often not the most cost effective. The pressures of the development programme are often the drivers for employing a civil engineering remedial technique as the treatment timescales are significantly reduced.

Typically these methods are:

- Full excavation and disposal: This would result in full depth removal of contaminated ground across the site with disposal to suitable land fill. The resulting level change would require the import of suitable clean material to achieve accessible development levels.
- Capping Layers: Provision of suitable capping layers to remove the pathway with the contaminants with the soil. Capping layers can consist of hard forms such as building footprints, roads, footpaths and hard landscaping or soft landscaping of suitable composition and thickness.

3.4.2 Capping Strategy

The overall objective of the capping strategy is to break the exposure pathway between contaminants of concern and receptor in this case humans. Normal construction hard standings and building footprints will provide the majority of the barrier layers, with **garden areas receiving a minimum of 1000mm total of validated clean inert material with perimeter landscaping receiving 600mm total of validated clean inert material**. A minimum 200mm of validated topsoil is included within the total capping depths above.

Drawing 6503-122 – Capping plan in Appendix B sets out the proposed capping strategy for the site with capping form/type and make up identified in Table 1 below. Drawings 6503-8, 9 & 10 in Appendix B sets out the residential garden capping levels at both formation and finished level.

Residential garden capping will comprise

- 800mm of clean inert general fill, it is proposed to utilise a general fill material in accordance with Specification for highway works series 600 class 2C or 2D stony or silty cohesive. **This general fill material will be partially won on-site from underlying natural subsoil**, the use of existing ground means that the placement of capping layer should not impact significantly on existing gas regimes and pathways and will not create additional horizontal migration.
- **200mm of clean inert Multi-purpose Topsoil to BS 3882:2007.**

Ground to receive Engineering finishes will be placed to Formation level to achieve the design requirement of 5% CBR

Within soft landscaping areas an **orange geotextile separation/identification layer** will be provided on the formation level, to identify the limit of remediation, to inform future activities. This acts as the demarcation zone between the existing made ground and clean capping.

Within Residential garden areas the contractor was required to **validate formation and finished levels to ensure correct depth of capping**. Refer to table 2 below. The as-built levels are provided as part of this report.

Site Location	Capping strategy
Buildings and Footprint	Screed, insulation, Gas protection (See section 5.2) for details Beam and Block Flooring minimum 200mm Clear void.
Driveways and Parking Bays	40mm Thin Surface Course 60mm Dense Binder AC 225 Type 1 Sub base
Carriageway	40mm Thin Surface Course 60mm Dense Binder DBM50 100mm Dense Base DBM50 150 Type 1 Sub base
Footpaths	20mm Dense AC 6 Surface course 40mm Dense Binder AC 20 200 type 1 Sub base
Garden Paths	40mm Flagstones 40mm sand 100mm Type 1 sub base
Gardens	18 Number Residential Gardens 200mm Validated* Clean inert imported topsoil in accordance with BS 3882:2007 800mm validated clean inert imported Fill – Class 2C and 2D in accordance with the specification for highway works Series 600 table 6/1 Total depth to be validated* PAGeotechnical Bioliner Orange - OSA * Refer to section 3.3.3 below
Landscaping	200mm Validated* Clean inert imported topsoil in accordance with BS 3882:2007 400mm validated clean inert site won and imported Fill – Class 2C or 2D in accordance with the specification for highway works Series 600 table 6/1 Total Depth to be validated* * Refer to section 3.3.3 below

Table 1 – Capping Strategy

3.4.3 Capping Validation/Verification.

The following validation and verification details were set out within the remediation strategy.

	Capping Material	
	Topsoil	Subsoil
Type	Multi-purpose Topsoil to BS 3882:2007	Class 2C and 2D in accordance with the specification for highway works
Certification	BS 3882:2007 Declaration of analysis Analysis Certificate Sampling protocol	Series 600 table 6/1
Testing Regime	1 No per 100m3 per source	1 No per 200m3 per source
Chemical Composition	Suite 1 - pH, arsenic, cadmium, chromium (hexavalent and total), lead, copper, nickel, zinc, boron, mercury, selenium, sulphide, sulphur, sulphate, PAH, cyanide (total, free, complex), thiocyanate, phenol, and total petroleum hydrocarbons as a screen (FCC) and TPHCWG (Wrexham) Note where source is unknown samples to analyzed for PCB;s and Asbestos screen	Suite 1 - pH, arsenic, cadmium, chromium (hexavalent and total), lead, copper, nickel, zinc, boron, mercury, selenium, sulphide, sulphur, sulphate, PAH, cyanide (total, free, complex), thiocyanate, phenol, and total petroleum hydrocarbons as a screen (FCC) and TPHCWG (Wrexham) Note where source is unknown samples to analysed for PCB;s and Asbestos screen
Thickness	200mm	800mm
Depth Validation	5 No spot levels to be taken on top of subsoil. Locations to be garden corners and centre 1 No Finished Garden level to be taken in centre.	5 No spot levels to be taken at formation following placement of marking layer. Locations to be garden corners and centre

Table 12 - Validation and testing strategy for capping

3.4.4 Assessment Criteria Values and Remediation Targets

To demonstrate the site won excavated materials are chemically/environmentally suitable for reuse on the site (with reference to the assessments previously undertaken by e-Geo Solutions Ltd and Bay Associates Consulting Ltd) for placement beneath soft cover/hard surfaces, they were inspected for visual and olfactory evidence of any organic contamination. During the excavation works, samples of any Made Ground suspected to be contaminated from visual or olfactory evidence were taken and tested for Soil Organic Matter (SOM), Speciated PAH and TPHCWG banded Aliphatic/Aromatic split and validated against the values stated in Table 1 below, within this section.

Representative samples of site sourced subsoil for use in the clean cover layer were taken and tested for the suite of chemical determinands listed in Table 12 of Bay Associates Consulting Ltd's Remediation Strategy (Ref. No. 6305 – dated December, 2013, copy above in section 3.4.3). Imported (and any site sourced) topsoil for use in the clean cover layer was tested as detailed in Section 4.4 and Table 12 of the aforementioned detailed Remediation Strategy.

To demonstrate the excavated materials are geotechnically suitable for reuse beneath road footprints, plate load testing was undertaken to determine that minimum CBR values of 5% had been obtained at the sub-grade level. These tests were undertaken by an independent accredited laboratory at a minimum of 25m centres along the line of the proposed road(s).

To confirm that no contaminated Made Ground was present within 1000mm of the proposed ground levels beneath garden and 600mm below POS/landscape areas, level surveys were to be undertaken to prove the final depth of capping material met the requirements of the remediation strategy. This ensured that a minimum 800mm/400mm of natural subsoil and 200mm of topsoil has been placed over any Made Ground present beneath gardens and the POS/landscape area. Beneath garden areas, a geo-textile (Bay Associates specified in Table 11 of the Remediation Strategy, "PA Geotechnical Bioline Orange") was placed to separate/demarcate the interface between the underlying Made Ground and the subsoil cover layer.

The assessment criteria used are as set out in the site investigation report for the development site by e-Geo ref. "E0500.S1.P2.R1.V5 Report".

The assessment of contamination undertaken during the works was a 'Tier 1 Generic Risk Assessment' which requires the comparison of contaminant concentrations to a set of generic Tier 1 Screening Values (GSV) risk based screening concentrations.

Contaminant concentrations below the GSVs are considered not to warrant further risk assessment. Concentrations of potential contaminants above the GSVs are considered further in relation to distribution and potential pollution linkages. It should be noted that exceeding the GSVs does not necessarily mean there is a risk and the site should be remediated.

GSVs for soil derived to be protective of human health are defined for standard end use situations in accordance with UK CLEA framework. The values chosen are dependent on the site use or proposed development. For assessment purposes the proposed use of the site has been taken as 'residential'. The GSVs selected to assess soils in relation to human health have been taken from CLEA soil guideline values (SGVs) published by the Environment Agency. For lead the values have been withdrawn and have not been replaced and therefore reference is made to the former SGV. Where SGVs are not available the values have been taken from the LQM/CIEH Generic Assessment Criteria (GACs). Total Petroleum Hydrocarbons (TPH) describes a broad range of organic compounds

derived from crude oil. The SGV for TPH has yet to be set and due to the huge number of individual hydrocarbon compounds, and fact that they are present as highly complex mixes makes substance specific risk assessment unfeasible. Therefore to assess the results other screening and guideline values have been used to determine the presence and magnitude of contamination and risk. The applicable GSVs for assessment of the analytical results are based on the following guideline criteria:

Ref	Guideline Criteria
1	(CLEA 2009) Soil Guideline Values (SGVs) for 'residential' end-use. (where available)
2	Tier 1 screening criteria for general soil contaminants not addressed by CLEA such as 2.1 - TPH Criteria Working Group Risk Based Screening Levels (RBSLs), 2.2 – LQM CIEH Generic Assessment Criteria – 2 nd Edition 2009
3	Water Regulations Advisory Scheme (WRAS) Guidance on the Selection of Materials for Water Supply Pipes to be laid in Contaminated Ground (2002) for TPH and PAHs.

The results of the screening against guideline criteria values are presented in the tables below. Where values exceed the relevant GSVs they are highlighted in the tables.

		Ref: 1 - SGV	Ref: 2,2,3			LQM 2.5%
Arsenic	mg/kg	32		Naphthalene	mg/kg	3.7
Cadmium	mg/kg	10		Acenaphthylene	mg/kg	400
Chromium	mg/kg	130		Acenaphthene	mg/kg	480
Copper	mg/kg		2330	Fluorene	mg/kg	380
Lead	mg/kg	450		Phenanthrene	mg/kg	200
Mercury	mg/kg	1		Anthracene	mg/kg	4900
Nickel	mg/kg	130		Fluoranthene	mg/kg	460
Selenium	mg/kg	350		Pyrene	mg/kg	1000
Total Sulphate	mg/kg		2400	Benzo(a)anthracene	mg/kg	4.7
Zinc	mg/kg		3750	Chrysene	mg/kg	8
SO4 (2:1)	mg/kg		1.2	Benzo(b/k)+(j)fluoranthene	mg/kg	6.5
Total Cyanide	mg/kg			Benzo(a)pyrene	mg/kg	0.94
Total Organic Carbon	mg/kg			Indeno(1,2,3-cd)pyrene	mg/kg	3.9
Organic Matter	mg/kg			Dibenz(a,h)anthracene	mg/kg	0.86
Sulphide	mg/kg			Benzo(g,h,i)perylene	mg/kg	46
pH			<5	Coronene	mg/kg	
Phenol	mg/kg			PAH 16 Total	mg/kg	
EPH >C10-C25	mg/kg			PAH 17 Total	mg/kg	
EPH >C25-C40	mg/kg			Benzo(b)fluoranthene	mg/kg	
EPH >C10-C40	mg/kg			Benzo(k)fluoranthene	mg/kg	
Mineral Oil (C8-C40)	mg/kg			PAH Surrogate % Recovery	%	

		Ref:	Ref:
		1 - SGV	2.2,3
MTBE	ug/kg		
Benzene	ug/kg	330	
Toluene	ug/kg	61+04	
Ethyl benzene	ug/kg	35+04	
m & p Xylene	ug/kg	16+04	
o Xylene	ug/kg	26+05	
GRO (>C6-C8)	ug/kg		
GRO (>C8-C10)	ug/kg		
GRO (>C6-C10)	ug/kg		
Aliphatics C5-C6	mg/kg		55
Aliphatics >C6-C8	mg/kg		160
Aliphatics >C8-C10	mg/kg		46
Aliphatics >C10-C12	mg/kg		230
Aliphatics >C12-C16	mg/kg		1700
Aliphatics >C16-C21	mg/kg		64000
Aliphatics >C21-C35	mg/kg		64000
Total Aliphatics C5-C35	mg/kg		
Aromatics C6-C7	mg/kg		130
Aromatics >C7-C8	mg/kg		270
Aromatics >EC8-EC10	mg/kg		65
Aromatics >EC10-EC12	mg/kg		160
Aromatics >EC12-EC16	mg/kg		310
Aromatics >EC16-EC21	mg/kg		480
Aromatics >EC21-EC35	mg/kg		1100
Total Aromatics C6-C35	mg/kg		
TPH (C5-C35)	mg/kg		

4.0 Summary of Ground Gas Strategy

To ensure that this report is able to be assessed as a stand-alone document, the following summary of the remediation for ground gas is presented below between Section 4.1 and 4.5. The test results, evidence of completion and relevant records required to verify compliance with the approved strategy is presented in Section 7 and onwards.

4.1 Summary of Ground Gas Monitoring (Investigation Stage)

During the site investigation works, gas monitoring standpipes were installed in all the shallow boreholes with the response zones within the depth of made ground where exchange of atmospheric and soil gasses occur.

Monitoring of the standpipes for methane (% volume), carbon dioxide (% volume), oxygen (% volume), and flow was undertaken with a GA2000 Serial number GA12439.

Initial gas monitoring was undertaken on six occasions over an 8 week period on 15/02/13, 27/02/13, 12/03/13, 20/03/13, 03/04/13, and 11/04/13. Additional monitoring was undertaken on a further six occasions between 01/05/13 and 31/07/13. This extended period of monitoring together with monitoring results from previous gas monitoring over a period which extended from 2007 to 2011 is considered an acceptable period of monitoring to characterize the site particularly with the consistency of the results obtained

Borehole Number	Installation (From ground level down)	Borehole Number	Installation (From ground level down)
BD1S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround	BD3S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround
BS1	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround	BS3	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround
BD2S	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround		
BS2	0.00-1.00m(bgl) plain with bentonite surround, 1.00-3.00m(bgl) slotted with 10mm gravel surround		

Table 3 - Gas Monitoring

Previous gas monitoring of installations at the site and adjacent Bala Road Landfill over a period from 2007 to 2011 had indicated consistent methane concentrations less than 1% but with carbon dioxide concentrations greater than 5% but with negligible flow. Based on the previous (by others) and current assessment of risk, the historic low gas concentrations recorded and the low gas generation potential of the materials placed within the site, guidance suggests that a minimum of six gas monitoring visits should be undertaken. This is the minimum normally acceptable to regulators however if site conditions or monitoring results differ from previous findings an extended period of monitoring will be considered.

Groundwater was encountered at shallow depth within the boreholes. The water inflows were generally at the base of the made ground or interface of made ground and underlying alluvial deposits allowing monitoring of gasses within the unsaturated zone of the made ground.

During the construction of the boreholes water inflow was either not noted or recorded as being very slow with the ground strata becoming damp or only seepages noted at depths of 1.20m to 1.90m (bgl). The absence of moderate or rapid inflows suggests that the strata are of relatively low permeability. However following completion of the monitoring installations standing water levels of 0.98m to 1.36m below ground level were recorded causing the lower portions of the response zones to be flooded.

The water inflows were generally at the base of the made ground or interface of made ground and underlying alluvial deposits which allowed monitoring of gasses within the unsaturated zone of the made ground, however with higher standing water levels the thickness of the unsaturated zone decreased. Although the thickness of the unsaturated zone in some of the boreholes was relatively small it is considered that with the number of boreholes across that site, the type of made ground and the presence of more silty made ground at depth that the gas monitoring results provide a representative indication of the gas regime.

Additional monitoring was undertaken on a further six occasions between 01/05/13 and 31/07/13 when the standing water level reduced which increased the thickness of the unsaturated zone. Bore Hole and Trial Pit locations can be seen in Appendix B.

4.2 Summary of Gas Mitigation

The investigation findings and the evaluation of risk for the proposed residential site and its proposed redevelopment with residential properties has identified sources of contamination which present some degree of risk. The risks are primarily associated with the presence of elevated concentrations of chemical parameters and the presence of hazardous ground gasses.

Due to the elevated concentrations of methane and carbon dioxide the site has been classed as 'amber 2 in accordance with NHBC Guidance on Methane and Carbon Dioxide Report Edition No.04 (March 2007) and CIRIA Publication C659 Assessing Risks Posed by Hazardous Ground Gases to Buildings. All structures and buildings will have to incorporate gas control and protection measures appropriate for the site characterisation category which requires high level gas protection measures, comprising a membrane and ventilated sub-floor void with a minimum of one complete volume change per 24 hours. Provision of venting should be in accordance with current accepted guidance and standards.

All risk control and mitigation measures undertaken at the site should be carefully controlled and checked in accordance with best quality control procedures. Gas protection and control measures in particular should be checked at each stage of installation in accordance with current guidance.

4.3 Gas Design Parameters

The maximum results obtained from the monitoring regime classify the site as Amber 2 in accordance with NHBC guidelines or gas characteristic 3 in accordance with CIRIA C665. These guidelines can be used to inform the design strategy for the form and occupancy type of building.

4.4 Selected Gas Mitigation Options

In determining the gas mitigation methods based on the guidelines provided by NHBC and CIRIA C665 reference is made to the following British standard

BS 8485:2007 'code of practice for the characterization and remediation from ground gas in affected developments.'

Following determination of the site specific gas situation Section 7 of BS8485:2007 sets out the recommended gas protection appropriate for the buildings. As there are a number of existing designs and component elements available in the market this provides a guide as to the relative performance of types of designs and systems available.

The proposed development at this site is one of managed housing however it is recognised that there may be fluidity in ownership during the development lifetime and for that reason the mitigation requirement will be based on that of non-managed private housing.

BS8485:2007 Table 2 advises that the required gas protection will need to achieve a score of 4.

From BS8485:2007 Table 3 sets the levels of protection required to achieve that score and based on the development foundation solution these comprise

- Passive subfloor venting to achieve very good performance
- Proprietary gas resistant membrane installed to reasonable levels of workmanship/in line with current good practice under CQA with integrity testing and independent validation

Construction make up for ALL plots will comprise the following (Selected Gas Protection measures to achieve a score of 4.5)

- Beam and Block flooring comprising:
65mmscreed laid on
Isolation layer laid on
125mm kingspan TF70 Urethane insulation laid on
PAGeotechnical Monarflex Reflex Super Proprietary gas protection system
All joints and penetrations lapped taped and sealed in accordance with manufacturer's recommendations. Refer to drawing 6503-0011 – Gas membrane details)
Cavity wall tray lapped taped and sealed to gas membrane
- 200mm clear void from underside of beam to ground.
- 225x75mm gridded airbricks and proprietary periscope vents around perimeter at 2m centres, cross vents to internal load bearing walls to be set at 2m centres. Note Minimum cross sectional area to be 3000mm² per opening in accordance with building regulations Part C 2004 edition (incorporating 2010 amendments) Section 4: walls cl 4.19.

Supporting calculations for passive venting requirements were included within the remediation strategy and implementation plan. These calculations confirm that using the worst case emission and flow rates and setting design concentration as 1% v/v Co₂ in the voids and vents and utilising a 0.3m/s wind speed, the venting requirements are significantly below that required as a minimum for building regulations and the passive venting provides very good performance.

4.5 Summary of workmanship testing and independent validation of proprietary gas membrane.

The approved strategy set out the minimum requirements regarding workmanship, testing and validation. The successful contractor was required to ensure and allow for the following **workmanship testing and independent validation:**

4.5.1 Workmanship.

Contractor is to ensure that the installer of the gas proprietary system is suitable qualified and experienced, installation technicians to be trained to and hold appropriate certification to NVQ level 2 qualification in gas protection installation. Prior to commencing work on site appropriate qualification certification is to be provided to the client team.

4.5.2 Independent Testing and Validation.

The contractor is to employ an independent environmental consultant to carry out integrity testing and certification. Consultant to carry out thorough visual inspection of the first 5 plots including vented void and sub grade and membrane before placement of insulation and screeds. All joints and penetrations corners etc to be air lanced to ASTM D 4437. On successful completion of the first 5 plots independent verification inspections should be carried out at a rate of 1 in 5. Resulting in testing and verification of 35% of the total of 23 plots.

Note the above statement taken from the remediation strategy was subsequently superseded to meet Wrexham's specific requirements that ALL plots are tested and validated.

The contractor is to supply plot sign off sheets (verification evidence) including photographs to independent consultant for all other plots.

The contractor is to provide a detailed installation plan, method statements and QA procedures for inclusion within the implementation and subsequent verification plan.

Upon completion of all gas protection works the contractor is to provide all verification and testing reports completed by the independent consultant to the client team for inclusion within the final site wide verification plan.

5.0 Details of who carried out works

5.1 Main contractor

*Keepmoat Regeneration (Bramall) Ltd,
The Lighthouse
14 Salford Quays
M50 3BF*

5.2 Remediation contractor

*ADM Regeneration Ltd
Warrington Lane
Lymm
WA13 0SA*

5.3 Groundworks

*M.Logan & Son Ltd
Bracken Lea House
479 Leigh Road
Westhoughton
Bolton
Lancashire
BL5 2JH*

5.4 Final sub-soil and top-soil level surveys

*Sub-soil levels by ADM Regeneration
Top-soil levels by M.Logan & Son Ltd*

5.5 Gas Membrane installers

*PAGeotechnical Ltd
Darwin House
Corby Gate Business Park
Corby
Northants.
NN17 5JG*

5.6 Gas membrane testing and verification report

*MEC Environmental Ltd
8 Parkes Way
Fernhurst Farm
Blackburn
BB2 4FH*

5.7 Ground gas Monitoring

*e-geo Solutions Ltd.
Oak House
Groes Lwyd
Abergele
Conwy
LL22 7SU*

5.8 Post-placement soil testing

e-geo Solutions Ltd.
Oak House
Groes Lwyd
Abergele
Conwy
LL22 7SU

5.9 Consulting Civil and Environmental Engineer

HLN Engineering
14 Cathedral Road
Cardiff
CF11 9LJ

6.0 Amendments to Remediation Strategy

The general principles of the approved remediation strategy and implementation plan have not been changed. However, the following amendments were made:

- The Contaminated Land Officer requested that all plots (not just a portion) should receive ground gas protection integrity testing and certification. This was subsequently completed and evidence/results are contained within this report.
- Agreement between HLN (Simon Reynolds) and ADM Regeneration in July 2014 that a sampling rate of 1 sample per 1500m³ for site won soils was acceptable. The testing was subsequently completed and the results are contained within this report.
- In July 2015 the Contaminated Land Officer requested post-placement sub-soil testing for alternative plots across the site. The testing was subsequently completed and the results are contained within this report.

7.0 Site Wide Verification Report

Following the approval of the remediation strategy and the completion of the works set out in the implementation plan, a body of evidence has been collected to demonstrate that the designed and planned works have been completed in accordance with the approved documents.

The information summarised and appended to this report has been obtained through various channels and from various parties, depending on the particular element of the works. This report is intended to collate the proof, evidence records and results that demonstrate compliance

7.1 Phase 1 Ground Contamination - proof and evidence

Record information, evidence of completion and testing is required for the following site activities listed below.

- 7.1.1 Pre-placement testing of sub-soil for site-won capping materials
- 7.1.2 Inspection of sub-soil capping material and indicator barrier
- 7.1.3 Sub-soil placement levels
- 7.1.4 Post-placement testing of site-won capping materials
- 7.1.5 Disposal of unsuitable materials off-site
- 7.1.6 CBR testing of capped site
- 7.1.7 Import of granular construction materials

Refer to the schedule titled “**SCHEDULE OF REMEDIATION ACTIVITIES, SUPPORTING RESULTS AND EVIDENCE**” contained in **Appendix C** for a breakdown of the activity, the reference of the supporting evidence, dates and compliance notes

Appendix D contains the **individual records of proof and evidence** that are referred to in the schedule in Appendix C.

- 7.1.1 Pre-placement testing of sub-soil for site-won capping materials. All test results from the site-won material stockpile show compliance.
- 7.1.2 Inspection of sub-soil capping material and indicator barrier. Completed by Keepmoat and HLN through this period
- 7.1.3 Sub-soil placement levels. As-laid (800mm and 400mm) capping levels provided and are compliant. Some minor (50mm) shortfalls in some areas required additional topsoil to be placed to make up the required total depth of capping
- 7.1.4 Post-placement testing of site-won capping materials. Test results from the site-won material stockpile show compliance.
- 7.1.5 Disposal of unsuitable materials off-site. Material removal records and tickets obtained and included in this report.
- 7.1.6 CBR testing of capped site. Testing completed and compliant with specification
- 7.1.7 Import of granular construction materials. Material import records and tickets obtained and included in this report.

In conclusion, all activities, materials and completed works are deemed to be compliant with the remediation strategy and implementation plan requirements.

7.2 Phase 2 Ground Contamination – proof and evidence

Record information, evidence of completion and testing is required for the following site activities listed below.

- 7.2.1 Pre-placement testing of top-soil
- 7.2.2 Inspection of top-soil material
- 7.2.3 Top-soil placement levels
- 7.2.4 Post-placement testing of top-soil

Refer to the schedule titled “**SCHEDULE OF REMEDIATION ACTIVITIES, SUPPORTING RESULTS AND EVIDENCE**” contained in **Appendix C** for a breakdown of the activity, the reference of the supporting evidence, dates and compliance notes.

Appendix D contains the **individual records of proof and evidence** that are referred to in the schedule in Appendix C.

- 7.2.1 Pre-placement testing of top-soil. At source chemical test results and specification show compliance
- 7.2.2 Inspection of top-soil material. Visual inspection record by HLN
- 7.2.3 Top-soil placement levels. As-laid topsoil levels provided and are compliant. Minor shortfalls in capping depths made up with additional topsoil depth (1000mm total cover in gardens, 600mm in other landscaped areas)
- 7.2.4 Post-placement testing of top-soil. Test results from the site-won material stockpile show compliance.

In conclusion, all activities, materials and completed works are deemed to be compliant with the remediation strategy and implementation plan requirements.

7.3 Ground Gas Mitigation –proof and evidence

Record information, evidence of completion and testing is required for the following site activities listed below.

- 7.3.1 Remediation phase gas monitoring
- 7.3.2 Gas protection measures inspection
- 7.3.2 Gas installation integrity report
- 7.3.3 Post construction gas monitoring

Record information, evidence of completion and testing is required for the following site activities. Refer to the schedule titled “**SCHEDULE OF REMEDIATION ACTIVITIES, SUPPORTING RESULTS AND EVIDENCE**” contained in **Appendix C** for a breakdown of the activity, the reference of the supporting evidence, dates and compliance notes.

Appendix D contains the **individual records of proof and evidence** that are referred to in the schedule in Appendix C.

- 7.3.1 Remediation phase gas monitoring
- 7.3.2 Gas protection measures inspection
- 7.3.2 Gas installation integrity report
- 7.3.3 Post construction gas monitoring. This will continue for 6 months following the completion of the construction works in August 2015

In conclusion, all activities, materials and completed works are deemed to be compliant with the remediation strategy and implementation plan requirements.

8.0 Conclusion

Ground Contamination

The requirements and objectives of the Remediation Strategy and the Implementation Plan in relation to ground contamination have been met.

The required depth of inert material has been placed in garden areas and public landscaped areas to protect future residents

Ground Gas Protection

The requirements and objectives of the Remediation Strategy and the Implementation Plan in relation to ground gas mitigation and protection have been met.

A robust gas protection system has been installed and independently validated, in line with relevant standards.

APPENDIX A: SITE LOCATION, LAYOUT AND REMEDIATION DRAWINGS

APPENDIX B: BORE HOLE AND TRIAL PIT LOCATIONS

APPENDIX C: SCHEDULE OF REMEDIATION ACTIVITIES, SUPPORTING RESULTS AND EVIDENCE

APPENDIX D: RECORD INFORMATION, RESULTS AND EVIDENCE

The following sub-sections contain the record information, results and evidence required to support the schedule on Appendix C

D1 Imported Material Records

Delivery records for granular construction materials brought into the site

D2 CBR Testing Results

Records of CBR testing at various locations and depths

D3 Soil and Waste Removal Records

Collection records for all soil and ground waste materials off-site

D4 Sub Soil (Capping)Test Results

Chemical test results for site-won sub-soils, used to cap the ground up from the remediated development formation level

D5 Level Surveys

Topographical level surveys of the development site during various stages of remediation to prove compliant environmental capping depths achieved

D6 Gas Monitoring

In-situ gas monitoring results

D7 Gas Protection Measures

Proof of gas protection measures installation

D8 Inspections

Visual inspection records

APPENDIX D – CONTENTS

D1 Imported Material Records

1. 14.05 - 10309_SITE TICKETS_6F2 ASH - material import
2. 14.06 - 10309_SITE TICKETS_6F2 MD - material import
3. 14.06 - 10309_SITE TICKETS Clean Stone - material import
4. 14.07 - 10309_SITE TICKETS_STONE DPW - material import
5. 5.05.15 - Ellesmere Report Top Soil Report - lab test results

D2 CBR Testing Results

1. 14.06.02 - 10309 008 CBR Locations Rev A - CBR site testing
2. 14.06.02 - 10309 008 CBR Locations-Sheet - CBR site testing
3. 14.07.02 - 10309_GEO_CBRs_140702 - CBR site testing
4. 14.07.02 - 10309_GEO_CBRs_140702 - CBR site testing
5. 14.07.24 - 10309_GEO_CBRs_140724 - CBR site testing
6. 14.07.28 - 10309_GEO_CBRs_140728 - CBR site testing
7. 14.07.30 - 10309_GEO_CBRs_140725 Report - CBR site testing

D3 Soil and Waste Removal Records

1. 14.07 - 10309_SITE TICKETS - waste disposal
2. 14.07 - 10309_SITE TICKETS_Oversize - soil disposal
3. 14.07 - 10309_SITE TICKETS_Soil Disposal - soil disposal

D4 Sub Soil Test Results (awaiting location plans for each)

1. 14.07.01 - 10309_CHEM_Peat_140616 - lab test results
2. 14.07.16 - 10309_CHEM_Subsoil C1 - lab test results
3. 14.07.24 - 10309_CHEM_Topsoil_140722 - lab test results
4. 14.07.25 - Sub-Soil Test Report 142694 C2 - lab test results
5. 15.07.22 - E0500.V.R1.160715 Placed Garden Area Soils Chem Analysis - lab test results

D5 Level Surveys

1. 14.07.10 - 10309 006 Natural Strata Survey Rev B- Isopachytes - level survey
2. 14.07.10 - 10309 006 Natural Strata Survey Rev B-Survey - level survey
3. 14.08.04 - 10309 007 Garden Remediation Depth Survey Rev B
4. 14.08.04 - 10309 007 Residential Gardens - Subsoil Level Survey Rev B - level survey
5. 14.08.08 - 10309 011 As-Built Survey - level survey
6. 15.07.29 - Total capping depth placed – plots 1 to 6
7. 15.07.29 - Total capping depth placed – plots 18 to 23
8. 15.07.27 - Finished top-soil levels – plots 18 to 23
9. 15.07.27 - Finished top-soil levels – plots 1 to 6
10. 04.08.15 – Total capping depths plot 23 front garden
11. 04.08.15 – Total capping depths – plots 12 to 17
12. 04.08.15 – Total capping depths – plots 7 to 8
13. 04.08.15 – Total capping depths – plots 9 to 11

D6 Gas Monitoring

1. 15.07.13 - E0500.S3.R1.Remediation Phase Gas Monitoring Results - gas results

D7 Gas Protection Measures

1. 15.06.10 - Gas Validation Report Anthony Eden Drive Wrexham – report
2. Post construction gas monitoring

D8 Inspections

1. 15.07.15 - HLN Trial Pit Depth Check –phase 1 - visual inspection
2. TBC - Keepmoat Trial Pit Depth Check – phase 2 - visual inspection (awaiting photos)
3. 14.10.22 – HLN Gas installation inspection photos

D1 Imported Material Records

1. 14.05 - 10309_SITE TICKETS_6F2 ASH - material import
2. 14.06 - 10309_SITE TICKETS_6F2 MD - material import
3. 14.06 - 10309_SITE TICKETS_Clean Stone - material import
4. 14.07 - 10309_SITE TICKETS_STONE DPW - material import
5. 5.05.15 - Ellesmere Report Top Soil Report - lab test results

D2 CBR Testing Results

1. 14.06.02 - 10309 008 CBR Locations Rev A - CBR site testing
2. 14.06.02 - 10309 008 CBR Locations-Sheet - CBR site testing
3. 14.07.02 - 10309_GEO_CBRs_140702 - CBR site testing
4. 14.07.02 -10309_GEO_CBRs_140702 - CBR site testing
5. 14.07.24 -10309_GEO_CBRs_140724 - CBR site testing
6. 14.07.28 - 10309_GEO_CBRs_140728 - CBR site testing
7. 14.07.30 - 10309_GEO_CBRs_140725 Report - CBR site testing

D3 Soil and Waste Removal Records

1. 14.07 - 10309_SITE TICKETS - waste disposal
2. 14.07 - 10309_SITE TICKETS_Oversize - soil disposal
3. 14.07 - 10309_SITE TICKETS_Soil Disposal - soil disposal

D4 Sub Soil Test Results

1. 14.07.01 - 10309_CHEM_Peat_140616 - lab test results
2. 14.07.16 - 10309_CHEM_Subsoil C1 - lab test results
3. 14.07.24 -10309_CHEM_Topsoil_140722 - lab test results
4. 14.07.25 - Sub-Soil Test Report 142694 C2 - lab test results
5. 15.07.22 - E0500.V.R1.160715 Placed Garden Area Soils Chem Analysis - lab test results

D5 Level Surveys

1. 14.07.10 - 10309 006 Natural Strata Survey Rev B- Isopachytes - level survey
2. 14.07.10 - 10309 006 Natural Strata Survey Rev B-Survey - level survey
3. 14.08.04 - 10309 007 Garden Remediation Depth Survey Rev B
4. 14.08.04 - 10309 007 Residential Gardens - Subsoil Level Survey Rev B - level survey
5. 14.08.08 - 10309 011 As-Built Survey - level survey
6. 15.07.29 - Total capping depth placed – plots 1 to 6
7. 15.07.29 - Total capping depth placed – plots 18 to 23
8. 15.07.27 - Finished top-soil levels – plots 18 to 23
9. 15.07.27 - Finished top-soil levels – plots 1 to 6
10. 04.08.15 – Total capping depths plot 23 front garden
11. 04.08.15 – Total capping depths – plots 12 to 17
12. 04.08.15 – Total capping depths – plots 7 to 8
13. 04.08.15 – Total capping depths – plots 9 to 11

D6 Gas Monitoring

1. 15.07.13 - E0500.S3.R1.Remediation Phase Gas Monitoring Results - gas results

D7 Gas Protection Measures

1. 15.06.10 - Gas Validation Report Anthony Eden Drive Wrexham – report
2. Post construction gas monitoring

D8 Inspections

1. 15.07.15 - HLN Trial Pit Depth Check –phase 1 - visual inspection
2. TBC - Keepmoat Trial Pit Depth Check – phase 2 - visual inspection
3. Gas installation inspection photos by HLN

APPENDIX E – CERTIFICATION

Individual property certificates will be completed and signed to confirm that the requirements of the three environmental remediation reports have been completed. The certificates will be formally issued to the contractor and developer once local authority approval has been obtained. A draft sample is included below.

CERTIFICATE OF REMEDIATION [SUBJECT TO LOCAL AUTHORITY APPROVAL]

This is to certify the remediation of plots 1 to 23 at the redevelopment of land known as Glan Gors, off Anthony Eden drive, Wrexham

at Approximate grid reference: SJ351498

has been part carried out in accordance with the Remediation strategy agreed with Wrexham County Council, with specific reference to the following Documents completed on behalf of **Pennaf Housing Group and Wrexham County Borough Council**

Document reference **6503** Title: **Detailed Remediation Strategy
December 2013 Rev /**

Document reference **6503/SR/Imp1** Title: **Environmental Implementation Plan
Stage 1 – Ground Contamination
March 2014**

Document reference **6503/SR/Imp2** Title: **Environmental Implementation Plan
Stage 2 – Ground Gas Mitigation
April 2014**

Document reference **6503/RB/Ver1** Title: **Environmental Verification Plan
August 2015**

which were designed to afford protection from gaseous and/or other contaminants in, on or under the site to a standard appropriate for the proposed end use.

The proposed end use was: **Residential Gardens**

Signed this **Day/Date/ Month/Year**



.....
(Consulting Engineer supervising the works)

NAME: RICHARD BAKER
POSITION: ASSOCIATE DIRECTOR

COMPANY NAME AND ADDRESS:

**HLN Engineering
3rd Floor
14 Cathedral Road
Cardiff
CF11 9LJ**

APPENDIX F: RESIDUAL RISK ASSESSMENT AND FUTURE RISK MITIGATION

A copy of this risk assessment shall be included in the developer's tenant pack for hand-over to each individual tenant