

Crayfern Homes Ltd.

F.A.O. Kevin Wawman

Via email only: Kevin@crayfernhomes.co.uk

Our ref: 17403/SGRA

April 2019

Dear Kevin

RE: Land North of Mayflower Way, Angmering, Littlehampton, West Sussex BN16 4AY – Soil Gas Monitoring

Crayfern Homes commissioned Soils Limited to undertake a Soil Gas Risk Assessment at the above-named site.

This letter report must be read in conjunction with the following documents:

- Phase I Desk Study (Soils Limited report ref.:17028/DS, dated November 2016);
- Compiled Ground Investigation Report (Soils Limited report ref.: 17403/CGIR, dated February 2019).

Introduction

The Preliminary Investigation Report undertaken on the site identified a low risk of soil gas associated with the presence of an adjacent infilled pond. In addition, a thickness of Made Ground was identified on the development site during the intrusive site investigations.

Given the findings of the investigations to date, a soil gas risk assessment at the site was commissioned. Three soil gas monitoring wells (WS1 – WS3) were installed on site during an intrusive site investigation undertaken in November 2015 to depths of between 4.00m and 5.00m below ground level (bgl). The locations were selected to provide best possible coverage of the site where access was available at the time of investigation. Following the initial site works, monitoring of the wells was undertaken on a total of ten (10 No) occasions periodically between 30th November 2015 and 13th March 2019, with an additional two dedicated groundwater level readings undertaken.

This letter report documents the findings of the soil gas and groundwater level monitoring and makes recommendations for gas protection measures, where required.

General

The site had an approximate area of 0.85ha and was located at Land North of Mayflower Way, Angmering, Littlehampton, BN16 4AY at O.S Land Ranger Grid Reference of TQ072033.

The site at the time of investigation comprised open land used for the storage of building materials and equipment and stockpiles of aggregate and crushed building material. The site was level and slightly undulating. Mature vegetation was noted at the site boundaries, with mature trees lining the southern boundary. The site was bound by a nursery to the north, commercial and industrial land to the east, agricultural and residential to the south and recreational land to the west.

The site location plan as been appended as Figure 1.

Site Works

Three trial hole locations (WS1 – WS3) were fitted with combined soil gas and groundwater level monitoring standpipes during intrusive site investigation undertaken in November 2015. The monitoring well installations comprised 25mm ID HPDE pipework with a response zone set at 1.00m to 4.00m bgl for WS1 and 1.00m to 5.00m bgl for WS2 and WS3, comprising slotted pipe with non-calcareous gravel pack surround with a bentonite seal above. The headworks comprised a single gas tap within a metal stopcock cover set in concrete.

A plan detailing the trial hole locations has been appended in Figure 2.

Ground Conditions

A summary of the ground conditions encountered at the test hole locations during the site works are presented in Table 1.

Made Ground (MG) River Terrace Deposits (RTD)

Table 1. Ground Conditions

Strata	Epoch	Depth Encountered (m bgl)		Typical Thickness (m)	Typical Description
		Top	Bottom		
MG	Anthropocene	0.00	0.30 – 1.50 ¹	0.70	Black, brown and grey slightly sandy gravelly SILT/CLAY. Gravel was fragments of flint brick, concrete, glass and ash.
RTD	Quaternary	0.30 – 1.50 ¹	1.40 ² /5.00 ²	Not proven ³	Cohesive: Orangish brown slightly fine sandy silty CLAY. over Granular: Light brown gravelly clayey SAND and sandy clayey GRAVEL. Gravel was fine to medium angular clasts of flint.

Note: ¹ Depth inferred from dynamic probe. ² Final depth of trial hole. ³ Base of strata not encountered

Soil Gas and Groundwater Monitoring Records

A total of twelve monitoring visits were undertaken periodically between the 30th November 2015 and 13th March 2019, ten of which obtained soil gas readings from each of the three monitoring wells installed onsite (WS1 – WS3). These included targeting periods of low and falling pressure where possible.

The results of the monitoring are provided within Table 2.

Table 2. Soil Gas Results

Date	Trial Hole	CH ₄ (%)	CO ₂ (%)	O ₂ (%)	H ₂ S (ppm)	CO (ppm)	LEL (%)	aP (mb)	Flow (l/h)	Dp	H ₂ O (m bgl)	Base of Hole (m)	VOC (ppm)	CS ¹
30/11/2015	ATM	0.0	0.1	20.3	0.0	0.0	0.0	1016	-	-	-	-	0.0	-
	WS1	0.0	4.0	16.7	0.0	0.0	0.0	-	0.0	0.0	DRY	4.00	0.0	I
	WS2	0.0	2.3	18.3	0.0	0.0	0.0	-	0.0	0.0	DRY	5.20	0.0	I
	WS3	0.0	4.6	15.5	0.0	0.0	0.0	-	0.0	0.0	DRY	5.00	0.0	I
07/12/2015	ATM	-	-	-	-	-	-	1016	-	-	-	-	-	-
	WS1	0.0	6.2	12.5	0.0	0.0	0.0	-	0.0	0.0	3.84	4.15	0.0	I
	WS2	0.0	2.4	17.5	0.0	0.0	0.0	-	0.8	2.0	DRY	5.00	0.0	I
	WS3	0.0	6.3	11.6	0.0	0.0	0	-	1.2	2.0	DRY	5.00	0.0	2
08/01/2016	ATM	0.0	0.2	19.7	0.0	0.0	0.0	1016	-	-	-	-	0.0	-
	WS1	0.0	0.2	19.7	0.0	0.0	0.0	-	0.4	0.0	3.85	4.00	0.0	I
	WS2	0.0	0.2	20.1	0.0	0.0	0.0	-	0.4	0.0	DRY	5.20	0.0	I
	WS3	0.0	0.2	20.1	0.0	0.0	0.0	-	0.3	0.0	DRY	5.00	0.0	I
12/02/2016	ATM	0.0	0.2	20.3	0.0	0.0	0.0	987	-	-	-	-	-	-
	WS1	0.0	7.2	11.2	0.0	0.0	0.0	-	0.0	0.0	DRY	4.00	-	I
	WS2	0.0	0.6	20.2	0.0	0.0	0.0	-	0.0	0.0	DRY	5.20	-	I
	WS3	0.0	1.6	18.3	0.0	0.0	0.0	-	0.0	0.0	DRY	5.15	-	I
14/03/2016	ATM	0.0	0.0	21.6	0.0	0.0	0.0	1035	-	-	-	-	0.0	-
	WS1	0.0	7.9	9.9	0.0	0.0	0.0	-	0.0	0.0	DRY	4.10	0.0	I
	WS2	0.0	0.0	21.4	0.0	0.0	0.0	-	0.0	0.0	DRY	5.25	0.0	I
	WS3	0.0	2.6	16.3	0.0	0.0	0.0	-	0.0	0.0	DRY	5.20	0.0	I
12/04/2016	ATM	0.0	0.0	21.3	0.0	0.0	0.0	1009	-	-	-	-	0.0	-
	WS1	0.0	4.1	15.0	0.0	0.0	0.0	-	0.0	0.0	DRY	4.10	0.0	I
	WS2	0.0	0.0	20.9	0.0	0.0	0.0	-	0.0	0.0	DRY	5.10	0.0	I
	WS3	0.0	4.5	13.9	0.0	0.0	0.0	-	0.0	0.0	DRY	5.00	0.0	I
11/01/2018	ATM	-	-	-	-	-	-	-	-	-	-	-	-	-
	WS1	-	-	-	-	-	-	-	-	-	DRY	4.04	-	-
	WS2	-	-	-	-	-	-	-	-	-	DRY	5.24	-	-
	WS3	-	-	-	-	-	-	-	-	-	DRY	5.17	-	-
07/02/2018	ATM	0.0	0.0	20.2	0.0	0.0	0.0	1021	-	-	-	-	0.0	-
	WS1	0.0	8.3	12.0	0.0	0.0	0.0	-	1.5	7.0	DRY	4.07	0.0	2
	WS2	0.0	0.0	20.3	0.0	0.0	0.0	-	1.3	6.0	DRY	5.20	0.0	I
	WS3	0.0	5.2	15.0	0.0	0.0	0.0	-	1.3	6.0	DRY	5.15	0.0	I
06/03/2018	ATM	0.0	0.0	20.6	0.0	0.0	0.0	989	-	-	-	-	0.0	-
	WS1	0.0	6.9	14.6	0.0	0.0	0.0	-	0.0	0.0	DRY	4.04	0.3	I
	WS2	0.0	3.6	16.3	0.0	0.0	0.0	-	0.0	0.0	DRY	5.24	0.3	I
	WS3	0.0	6.0	14.1	0.0	0.0	0.0	-	0.1	0.0	DRY	5.17	0.3	I
16/04/2018	ATM	-	-	-	-	-	-	-	-	-	-	-	-	-
	WS1	-	-	-	-	-	-	-	-	-	DRY	4.04	-	-
	WS2	-	-	-	-	-	-	-	-	-	DRY	5.24	-	-
	WS3	-	-	-	-	-	-	-	-	-	DRY	5.17	-	-
25/02/2019	ATM	0.0	0.0	21.3	0.0	0.0	0.0	1037	-	-	-	-	0.0	-
	WS1	0.0	8.2	12.2	0.0	0.0	0.0	-	0.0	0.0	DRY	4.00	0.0	I
	WS2	0.0	0.7	20.7	0.0	0.0	0.0	-	0.0	0.0	DRY	5.15	0.0	I
	WS3	0.0	5.6	14.3	0.0	0.0	0.0	-	0.0	0.0	DRY	5.05	0.0	I
13/03/2019	ATM	0.0	0.0	21.9	0.0	0.0	0.0	1010	-	-	-	-	0.0	-
	WS1	0.0	8.7	10.4	0.0	0.0	0.0	-	0.0	0.0	DRY	4.00	0.0	I
	WS2	0.0	0.0	21.1	0.0	0.0	0.0	-	0.0	0.0	DRY	5.15	0.0	I
	WS3	0.0	5.6	15.2	0.0	0.0	0.0	-	0.0	0.0	DRY	4.90	0.0	I
Maximum		0.0	8.7	21.4	0.0	0.0	0.0	1037	1.5	7.0	3.84	-	0.3	-
Minimum		0.0	0.0	9.9	0.0	0.0	0.0	987	0.0	0.0	DRY	-	0.0	-

Note: Zero reading = below the equipment detection limit. ¹ Characteristic Situation CO₂/CH₄ (BS8485 & C665).

The highest concentration of carbon dioxide (CO₂) was recorded at 8.7% v/v in WS1 on 13th March 2019. Elevated CO₂ levels (>5% v/v) were typically recorded within WS1 and WS3.

The lowest concentration of oxygen (O₂) was recorded at 9.9% v/v within WS1 on 14th March 2016.

No concentrations of methane, either total or LEL, (CH₄), carbon monoxide (CO) or hydrogen sulphide (H₂S) were recorded above instrument detection limit.

The maximum positive gas flow was recorded at 1.5l/h in WS1 on 7th February 2018. Gas flow was recorded below instrument detection limit on the majority of monitoring visits.

Concentrations of Volatile Organic Compounds (VOCs) within the monitoring wells were measured using a Photo-Ionisation Detector (PID). Results recorded a reading above instrument detection level on one monitoring occasion, recording a concentration of 0.3ppm within all monitoring wells on 6th March 2016, which is not considered to be significant and may have been the result of a localised source of cross contamination or instrumental error.

Groundwater

A total of twelve groundwater monitoring rounds were undertaken periodically between 30th November 2015 and 13th March 2019. The data recorded a groundwater level within WS1 at a depth of 3.84m bgl on 7th December 2015 and 3.85m bgl on 8th January 2016. All wells were recorded to be dry on all remaining monitoring rounds.

Data Quality

A review was made of the quality of the available data for the site, which can be viewed in Table 3. CIRIA 665 (2007) and BS 8485:2015 stress the need for risk assessments to be based on good quality data and give guidance as to best practice in this respect.

Table 3. Review of Data Quality

Data Type	Current Situation	UK Practice
Geological and hydro-geological conditions	With regard to soil gas risk assessment the data from Preliminary Investigation and logged trial holes was good.	CIRIA 665, Wilson and Card (2007) and BS 8485:2015 recommend that geology and hydrogeology be fully understood.
Monitoring period	The gas monitoring has been undertaken on a total of ten occasions. Monitoring has been undertaken over a range weather conditions including low and high atmospheric pressures.	CIRIA 665 recommends approximately 3-month monitoring over a range of weather conditions.
Gas data sets	Borehole flow velocity has been measured on each monitoring occasion.	Borehole flow velocity and borehole gas volume required to define characteristic gas saturation. Modified Wilson and Card, Table 8.5 of CIRIA 665 (2007)/Table 2 of BS 8485:2015.

Data quality was characterised as satisfactory, covering a range of atmospheric pressure trends. Geological and hydrogeological conditions have been investigated and fully understood.

Risk Assessment

Based on the documentation presented in the “BS 8485:2015, Code of practice for the characterisation and remediation from soil gas in affected developments” the hazardous gas flow rate (Q_{hg}) was calculated using Equation 1:

$$Q_{hg} = (C_{hg}/100) * q$$

Equation 1

Where:

C_{hg} is the measured hazardous gas concentration (in percentage volume-by-volume).

q is the flow rate in litres per hour of combined gases found by direct measurement.

The Q_{hg} for carbon dioxide was calculated using Equation 2a.

$$Q_{hg} \text{ (l/hr)} = \text{gas concentration} * \text{borehole flow rate (l/hr)}$$

Equation 2a

$$= 8.7/100 * 1.5 = 0.1305 \text{ l/h}$$

The maximum carbon dioxide concentration recorded was taken as the gas concentration and 1.5l/hr was taken for the borehole flow rate.

Based on a *Site Characteristic hazardous gas flow rate* (Q_{hg}) of 0.1305 l/hr, the site fell into a **Characteristic Gas Situation 2 (CS2)**, for which special precautions are required as given in BS 8485:2015 (refer to Figure 5).

However, whilst the worst-case calculation (Equation 2a) results in a CS2 level of gas protection recommendation, it is interesting to note that overall only two readings (both recorded during high pressures from different locations WS1 and WS3) resulted in a similar conclusion. These results could technically therefore be considered outliers and possible artefacts not representative of the actual underlying gas regime across the site as a whole. The remainder and majority of results calculated in Table 2 indicated values within the CS1 situation, where no precautions would be required.

However, even if the above was accepted as reason for acceptance of a lower protection level, the guidance recommends that consideration be given to raising levels of protection from CS1 to CS2 if there are consistent levels of carbon dioxide in excess of 5%. The high proportion of carbon dioxide >5% results recorded during the monitoring to date, their consistency and their lack of obvious variability with pressure and local water level appears to indicate that this is the case at this site. On this basis a precautionary CS2 is therefore recommended.

Conclusion

A total of twelve groundwater monitoring rounds and ten soil gas monitoring rounds were undertaken between the period of 30th November 2015 and 13th March 2019 to assess the risk posed to the site from the sources of soil gas identified in the initial conceptual model.

Groundwater was recorded in two occasions within WS1 on consecutive visits undertaken on 7th December 2015 and 8th January 2016 at depths between 3.84m and 3.85m bgl. All wells were recorded to be dry on all remaining monitoring rounds.

A review of the soil gas monitoring undertaken on the site to date has shown the site's soil gas regime to be technically representative of CS2 under current guidance, due to the generated worst case calculation, consideration of the site model and of the overall underlying levels of carbon dioxide recorded over differing conditions, using a data set rated as satisfactory to good.

The soil gas monitoring has therefore indicated that gas protection measures are likely to be required for the site.

Should you have any further questions please do not hesitate to contact the undersigned.

Yours sincerely



Tim Rudkin BSc. (Hons.), MSc., FGS.
Graduate Geo-Environmental Engineer



For and on behalf of Soils Limited

Enc.

Figure 1. Site Location Plan

Figure 2. Trial Hole Location Plan

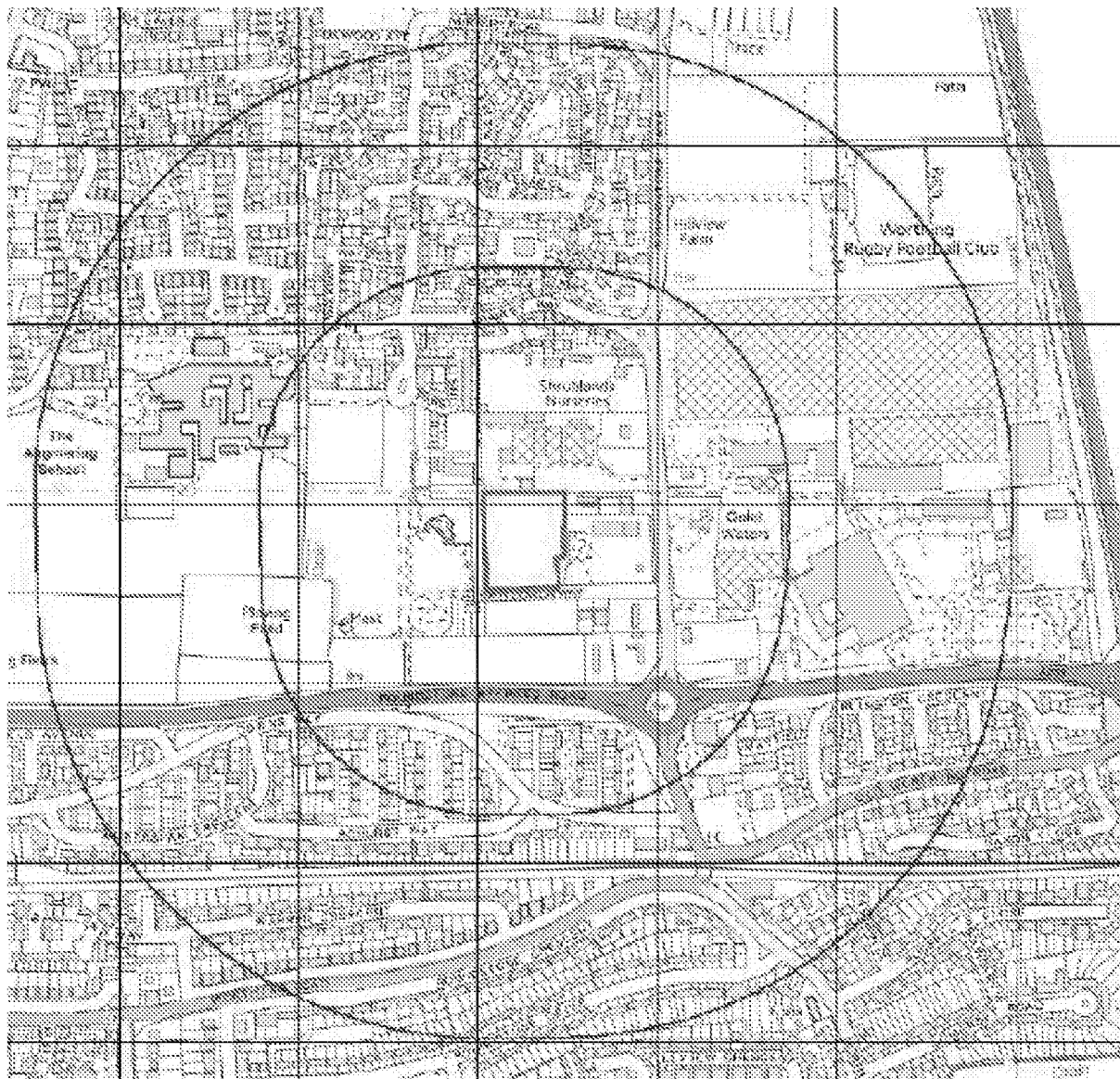


Figure 1 – Site Location Plan

Figure number	Title
1	Site Location Map
Project	Date
Land North of Mayflower Way, Angmering, BN16 4AY	April 2019
Client	Reference
Crayfern Homes	I7403/SGLR



Figure 2 – Trial Hole Location Plan

Figure number
2

Title
Trial hole location plan

Project
Land North of Mayflower Way, Angmering, BN16 4AY

Date
April 2019

Client
Crayfern Homes

Reference
I7403/SGLR