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BY Email

Dear Mr T Ralph,

**Ground Gas Addendum Report
Barton and Redman**

Further to our report 12-757-r2-rev 1 (February 2019) please find below the complete gas and groundwater monitoring results and ground gas risk assessment.

Ground Gas Monitoring

Subsequent to the fieldwork, five ground gas monitoring surveys were undertaken between 28th August 2018 and the 3rd September 2018.

Concentrations of methane (CH₄), carbon dioxide (CO₂) and oxygen (O₂) were measured using a calibrated infra-red gas analyser with gas flow rates measured using an integrated flow meter.

Groundwater monitoring was also undertaken using an electronic dip meter to record the depth to groundwater and note the presence of any visible suspended solid or separate phase chemical compounds, if present.

Gas measurements were recorded for a minimum of sixty seconds at each location, at which point the maximum concentration of CH₄ and CO₂ together with the lowest concentration of O₂ were recorded. The results of the ground gas monitoring are presented overleaf in Table 1.0.



Table 1.0 Gas Monitoring Results

WELL	DATE	CH ₄ INITIAL %V/V	CH ₄ STEADY %V/V	CH ₄ GSV l/hr	CO ₂ INITIAL %V/V	CO ₂ STEADY %V/V	CO ₂ GSV l/hr	O ₂ %V/V	ATMOS(mB)	ATMOS. DYNAMIC	FLOW (l/hr)	RESPONSE ZONE / STRATUM (mbgl)	DEPTH TO BASE (mbgl)	DEPTH TO WATER (mbgl)
WS102	10/10/18	0.1	0.1	0.00052	2.4	2.4	0.01248	17.0	1007	Falling	0.52	1.0-4.5	4.22	0.64
	17/10/18	0.1	0.1	0.00026	1.9	1.9	0.00494	18.4	1009	Rising	0.26		4.21	0.70
	01/11/18	0.1	0.1	0.00026	1.1	1.1	0.00286	18.8	1006	Rising	0.26		4.22	0.71
	6/11/2018	0.1	0.1	0.00026	0.7	0.7	0.00182	19.3	999	Falling	0.26		4.22	0.68
WS103	10/10/18	0.1	0.1	0.00378	1.9	1.9	0.07182	13.2	1007	Falling	3.78	1.0-2.0	1.9	0.42
	17/10/18	0.1	0.1	0.0024	1.4	1.4	0.0336	14.5	1009	Rising	2.40		1.9	0.53
	01/11/18	0.1	0.1	0.00141	1.7	1.7	0.02397	13.9	999	Rising	1.41		1.89	0.45
	6/11/2018	0.1	0.1	0.00052	2.0	2.0	0.0104	14.5	988	Falling	0.52		1.87	0.42
WS104	10/10/18	0.1	0.1	0.00324	4.5	4.5	0.1458	11.6	1007	Falling	3.24	1.0-4.0	4.1	1.40
	17/10/18	0.1	0.1	0.0019	4.1	4.1	0.0779	12.4	1009	Rising	1.90		4.1	1.51
	01/11/18	0.1	0.1	0.00196	5.9	5.9	0.11564	9.4	999	Rising	1.96		4.1	1.69
	6/11/2018	0.1	0.1	0.00154	9.6	9.6	0.14784	2.7	988	Falling	1.54		4.1	1.75
WS105	10/10/18	0.1	0.1	0.0001	0.1	0.1	0.0001	17.2	1007	Falling	0.10	1.0-4.0	3.84	2.44
	17/10/18	0.1	0.1	0.00013	0.2	0.2	0.00026	17.1	1009	Rising	0.13		3.84	2.52
	01/11/18	0.1	0.1	0.00087	0.3	0.3	0.00261	17.8	999	Rising	0.87		3.84	1.99
	6/11/2018	0.1	0.1	0.00144	0.4	0.4	0.00576	18.3	988	Falling	1.44		3.84	1.97
WS106	10/10/18	0.1	0.1	0.0001	1.0	1.0	0.001	13.5	1007	Falling	0.10	1.0-1.5	1.67	Dry
	17/10/18	0.1	0.1	0.00026	0.7	0.7	0.00182	14.3	1009	Rising	0.26		1.68	Dry
	01/11/18	0.1	0.1	0.00052	0.8	0.8	0.00416	18.1	999	Rising	0.52		1.67	Dry
	6/11/2018	0.1	0.1	0.00013	0.6	0.6	0.00078	19.3	988	Falling	0.13		1.65	Dry

Ground Gas Risk Assessment Methodology

The potential impact on the development from ground gases has been assessed with reference to standards and guidelines published in CIRIA Report 665 (*Assessing risks posed by hazardous ground gases to buildings*, 2007). However, it is recommended that the full ground gas assessment and recommended protection measures are agreed with the local authority prior to their adoption on-site. Furthermore, all protection measures adopted should be validated by a suitably qualified engineer.

CIRIA C665, provide assessments for carbon dioxide and methane based upon Gas Screening Values (GSVs) utilising flow rates and concentrations. The site based GSVs for steady state methane and carbon dioxide are based upon the following equation:

$$GSV = \frac{\text{concentration (by vol)}}{100} \times \text{flowrate (1/hr)}$$

The GSVs within CIRIA C665 are based upon all buildings other than standard residential houses. The thresholds for GSVs based upon CIRIA guidance are provided within Table 2 (below)

Table 2 **Thresholds for Gas Screening Values (GSV) in accordance with CIRIA C665 Commercial End Use.**

CIRIA – NO SUB-FLOOR VOID	
CLASSIFICATION	GSV (METHANE AND CARBON DIOXIDE)
CS1	<0.07
CS2	<0.70
CS3	<3.5
CS4	<15
CS5	<70
CS6	>70

Sources of Ground Gas

The potential impact on the development from ground gases has been assessed with reference to standards and guidelines published in CIRIA Report 665 (*Assessing risks posed by hazardous ground gases to buildings*, 2007) and BS8485 (insert full title). It is recommended that the full ground gas assessment and recommended protection measures including structural detailing are agreed with the local authority and building control officer prior to their adoption on-site. Furthermore, all protection measures adopted should be validated by a suitably qualified engineer.

The Phase I report and subsequent Ground Investigation has identified the following potential sources of ground gas:

-  Made Ground deposits; and;
-  Landfill within 250m of the site

The ground conditions encountered are summarised below:

Made Ground

Made Ground was encountered within all exploratory locations, up to a maximum depth of 5.00m bgl (WS105).

The depth of Made Ground varies significantly between exploratory holes, however it is generally less than 2.50m thick. Made Ground typically comprises a layer of either asphalt or concrete overlying interbedded sands and gravel that in turn underlain by either a soft to firm dark coloured clay or a firm to stiff purple brown mottled grey gravelly clay.

The base of the Made Ground was not proven in many of the trial pits. This was in part due to the presence of underground services and obstructions within several of the exploratory locations.

Drift

Natural drift deposits were encountered within several exploratory locations and proven to a maximum depth of at least 13.00m bgl (CP101). Drift deposits predominantly comprise firm and stiff sandy gravelly clays.

Solid

Rockhead was not encountered in this investigation.

Groundwater

Groundwater levels were observed to fluctuate over the monitoring period with levels generally decreasing over the monitoring period. The greatest groundwater change occurred within WS105 where levels increased by 0.47m over the monitoring period. WS105 was set within a low permeability clay stratum and groundwater may be a result of surface water collecting in the well rather than a measure of true groundwater.

Gas Flow

During the monitoring a positive flow was noted within all of the monitoring wells. The measure of positive flow is considered to be the result of groundwater fluctuations and flooding of the well causing compression as opposed to gas generation as highest flows are recorded during periods of high groundwater levels.

Negative flows were not encountered during the monitoring period.

Gas Concentrations

No elevated concentrations of methane were recorded within any of the monitoring wells.

Carbon dioxide concentrations were recorded within all the monitoring wells at concentrations ranging from 0.2% v/v to 9.6% v/v (WS104). The maximum carbon dioxide were also associated within low oxygen concentrations and appear to be associated with Made Ground which were identified in WS104.

Gas Assessment

In accordance with the methodology outlined with the CIRIA publication C665, E3P have utilised the results of the ground gas monitoring surveys to calculate a tentative Gas Screening Value (GSV). The GSVs for the monitoring positions are summarised in Table 3.0

Table 3.0 Gas Risk Profile & Location

LOCATION	Max CO2	GSV	Max CH4	GSV	Classification
WS102	2.4	0.00494	0.1	0.00052	CS1
WS103	2.0	0.07182	0.1	0.00378	CS2
WS104	9.6	0.14784	0.1	0.00324	CS2
WS105	0.4	0.00576	0.1	0.00144	CS1
WS106	1.0	0.00416	0.1	0.00052	CS1

The GSV has been compared to the criteria outlined with CIRIA C665 to determine the level of risk to the proposed development and to ensure the appropriate remedial options are incorporated into any future building design in this area.

Ground gas monitoring has assessed the site as being CS2 and properties will require specialist protection measures as detailed below.

Commercial Building Gas Risk Mitigation

British Standard BS8485 A1 2019) provides two types of residential property that require assessment. These building types are:

-  **Type C building:** commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels).
-  **Type D building:** industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C).

Based on the ground gas risk assessment and the proposed Type D Building, it is envisaged that a point score of 1.5 will be required for affected properties, however the office area is categorised as a Type C building where 2.5 points must be achieved as summarised in Table 4.0 below

Table 4.0 BS8485 (2015) Points Required for Building Types

CHARACTERISTIC SITUATION	MINIMUM GAS PROTECTION SCORE (POINTS)			
	High Sensitivity		Low Sensitivity	
	Type A building	Type B building	Type C building	Type D building
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6.5	5.5	4.5	3.5
5	—	6.5	5.5	4.5
6	—	—	7.5	6.5

The proposed development has been categorised as a type D/ C building therefore 1.5 points is suitable for the majority of the building however 2.5 points is required for the office area by installation of a suitable combination of measures detailed in Table 5.0.(below).

Table 5.0 Summary of Ground Gas Mitigation Measures - BS8485 (2015)

GAS PROTECTION SCORES FOR THE STRUCTURAL BARRIER		SCORE ^A
a) Floor and substructure design		
Precast suspended segmental subfloor (i.e. beam and block).		0
Cast in situ ground bearing floor slab (with only nominal mesh reinforcement.		0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations.		1 or 1.5 ^B
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing.. ^C		2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing. ^C		2.5
A) The scores are conditional on breaches of floor slabs, etc., being effectively sealed. B) To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in (see A.2.2.2). C) The score is conditional on the waterproofing not being based on the use of a geosynthetic clay liner waterproofing product (see C.3, Note 4).		
PROTECTION ELEMENT SYSTEM	SCORE	COMMENTS
Gas protection scores for ventilation protection measures		
(a) Pressure relief pathway (usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building)	0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measures systems. If the layer has a low permeability and / or is not terminated in a venting trench (or similar), then the score is zero.
(b) Passive sub floor dispersal layer: Media used to provide the dispersal layer are:  Clear void  Polystyrene void former blanket  Geocomposite void former blanket  No-fines gravel layer with gas drains  No-fines gravel layer	Very good performance	The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing and type and the thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B of BS8485:2015. Passive ventilation should be designed to meet at least "good performance".
	Good performance	

PROTECTION ELEMENT SYSTEM	SCORE	COMMENTS
(c) Active dispersal layer, usually comprising fans with active abstraction (suction) from a sub floor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers.	1.5 to 2.5	This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure the continued maintenance of the system, including pumps and vents. Active ventilation should always be designed to meet at least "good performance".
(d) Active positive pressurization by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket.	1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park)	4	Assumes that the car park is vented to deal with car exhaust fumes, designed to <i>Buildings Regulations 2000, Approved Document F [9]</i> .
Gas protection score for the gas resistant membrane		
Gas resistant membrane meeting all of the following criteria:  Sufficiently impervious to the gases with a methane gas transmission rate <40.0 ml/day/m ² /atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method);  Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions;  Sufficiently strong to withstand in-service stresses (eg settlement if placed below a floor slab);  Sufficiently strong to withstand the installation process and following trades until covered (eg penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools etc);  Capable, after installation, of providing a complete barrier to the entry of the relevant gas; and,  Verified in accordance with CIRIA C735.	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. For example, a minimum 0.40mm thickness (equivalent to 370g/m ² for polyethylene) reinforced membrane (virgin polymer) meets the performance criteria opposite. If a membrane is installed that does not meet all the criteria opposite then the score is zero.
This table should be read in conjunction with the notes presented in BS8485 (2015)		

I trust the above is sufficient, however if you have any queries please do not hesitate to contact me.

Yours sincerely,
For and on behalf of E3P Ltd



Andrew Allcock
Geo-Environmental Consultant

