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Our Ref: P8723\PEL\GAL

Date: 25th March 2019

Partner Construction Limited
18 Mallard Way
Derby
DE24 8GX

Waterloo Housing Group Limited
1700 Solihull Parkway
Birmingham Business Park
Solihull B37 7YD

Attention of Ms Katie Hollis

Dear Katie,

Re: Gas Addendum Letter for Crease Drove, Crowland

The gas monitoring programme at the above site is now complete. The assessment below supersedes the information in the Site Appraisal Report (P8723, January 2019) and should be submitted to the regulatory bodies for approval.

The Phase I desk study identified the following potential sources of ground gas:

- Potentially contaminated made ground
- Potentially contaminated infilled ground
- Organic rich natural strata

The ground investigation confirmed the presence of Peat in the south of the site, WS01, WS06 and WS07, to depths of between 1.0m and 2.8m begl, with a thin layer of material (0.15m to 0.25m thick) also possibly representative of the Peat, recorded below the topsoil in WS02 and WS03 to depths of 0.75m and 0.55m begl. The stratum was typically encountered as grey / brown occasionally slightly sandy occasionally slightly gravelly silty clay. Significant deposits of organic rich material, peat, were not present, though black staining was observed in WS01 between 1.7m and 2.8m and WS06 between 0.85m and 2.0m begl.

Evidence of contamination was observed in the Peat in the southwest corner of the site where strong hydrocarbon odours were recorded in WS06 from 0.85m to 1.5m begl, and slight hydrocarbon odours noted below 1.5m to the bottom of the stratum at 2.0m begl. Contamination was not observed in the Made Ground above this material or below it in the Abbey Sand and Gravel.

No further significant potential sources of ground gas or volatile vapours were identified during the ground investigation.

As the proposed end use has been classified as high sensitivity residential with gardens, five 35mm diameter gas/groundwater monitoring standpipes have been installed across the site in the window sample boreholes WS01 to WS04, and WS06 and targeted at the natural strata (low generation potential). Locations WS01, WS03 and WS06 target the areas likely to contain Peat, with WS02 positioned close to the anticipated boundary of the Peat and the Abbey Sand and Gravel.

On the basis of the confirmed sources of ground gas and proposed end use gas monitoring has been carried out over a 3 month period from the 19th December 2018 to 25th February 2019, to assess the risk posed to the end users from potentially harmful ground gases, with volatile vapours recorded on three of these occasions.

The post fieldwork monitoring has been designed to identify and assess the groundwater and gas regimes below the site. The results are enclosed for reference and are summarised below:

Well ID (No. of Readings)	Response Zone / Strata (m)	Methane (%v/v)	CO2 (%v/v)	Oxygen (%v/v)	Gas Flow (l/h)	Groundwater Level (m begl)	PID (ppm)
WS01	0.5-3.0 Peat	ND	0.70 – 2.30	17.50 – 19.40	ND	0.87 – 1.10	0.0 - 0.6
WS02	0.6-1.7 Abbey Sand & Gravel	ND	3.90 – 6.90	14.70 – 16.9	ND	0.75 – 0.93	0.0 - 0.3
WS03	1.0-3.0 Abbey Sand & Gravel	ND	0.30 – 1.40	18.90 – 20.00	ND	0.49 – 0.68	0.0 - 0.3
WS04	0.5-1.5 Abbey Sand & Gravel	ND	0.00 – 0.30	19.40 – 20.10	ND	0.00 – 0.39	0.0 - 0.0
WS06	1.0-2.0 Peat	ND	0.00 – 0.70	19.60 – 19.80	ND	0.75 – 1.10	0.0 - 0.3

NS = Natural Strata, ND = Not detected, Atmospheric Pressure 1001mb to 1044mb.

It should be noted that high groundwater levels were regularly recorded across the site, with several locations being completely saturated on one or more occasion, which may have impacted the higher readings.

Ground Gas Risk Assessment

The primary guidance document to determine if gas protection measures are required is BS8485:2015. This uses hazardous gas flow rates (Q_{hg}), which are gas concentrations multiplied by borehole flow rates, to derive a Gas Screening Value (GSV) for the site. The gas regime is then determined based on the GSV and other limiting factors including gas concentrations and flow rates.

Methane concentrations and flow rates above the monitor's lower limit of detection were not detected during the monitoring period. Therefore, in the following assessment the monitors lower limit of detection for methane (0.1% v/v) and flow rate (0.1l/hr) have been used.

Using the default methane concentration of 0.1%v/v and the default flow rate of l/hr a Q_{hg} of 0.0001/hr has been calculated for methane.

Using the maximum recorded steady state carbon dioxide concentration of 6.9%v/v and the default flow rate of 0.1l/hr a Q_{hg} of 0.0069l/hr has been calculated for carbon dioxide in the Abbey Sand and Gravel and using the maximum recorded steady state carbon dioxide concentration of 2.9%v/v and the default flow rate of 0.1l/hr a Q_{hg} of 0.0029l/hr has been calculated for carbon dioxide in the Peat.

On this basis the GSV for the site is determined as 0.0069l/hr.

Although the GSV is less than 0.07l/hr and the maximum recorded concentration of methane is less than 1%v/v, the maximum recorded concentration of carbon dioxide is in excess of 5%v/v and as such, further consideration has been given to the most appropriate Characteristic Situation.

At this stage it is considered that as the carbon dioxide results were recorded above 5% on three of the six visits that the site should be assessed as CS2 and therefore gas protection measures will be required.

As hydrocarbon odours were noted during site works in the Peat in WS06 all the monitoring wells were tested for the presence of volatile organic carbon (VOC) vapours using a Photo-Ionisation Detector (PID). The PID recorded very low levels of VOC's between the limit of detection for the apparatus and 0.6ppm. Further the results of the laboratory analysis on soil and water samples from WS06 recorded aliphatic and aromatic carbon groups EC5-EC6, EC>6-EC8 and EC>8-EC10 to be below the limit of detection for the analysis.

Therefore VOC vapour protection is not considered necessary for this site.

The site is not in an area where radon protective measures are required.

Once this assessment has been agreed with the appropriate regulators, a Gas Protection Measures Design and Verification Plan will be required (in line with CIRIA C735); however, at this stage, allowance should be made for the use of beam and block floors and a proprietary gas resistant membrane (which meets the requirements of BS8584:2015 such as Monarflex Reflex Super) installed to an appropriate standard by a qualified contractor with independent validation and integrity testing.

However if build times allow, as the Peat stratum has been shown to be of low organic content and is nearly entirely submerged and likely to be generating relatively insignificant quantities of ground gas, consideration could be given to continuing the gas monitoring in the summer when groundwater levels are lower to better understand the gas regime, which could result in the characteristic situation being downgraded to CS1.

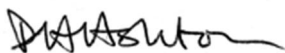
Groundwater

The monitoring program has confirmed the general presence of shallow groundwater beneath the site. Groundwater was encountered at depths of between 0.35m and 1.90m begl and as standing water during return monitoring, measured at minimum depths of between ground level (WS04) and 1.10m begl (WS01 and WS06).

An allowance for dewatering and the use of dig and pour techniques is recommended to mitigate excavation instability and groundwater ingress. Excavations should not be left open as they will suffer from water ingress, overbreak and additional concrete usage.

We trust this is suitable for your current requirements, should you require any further information or would like any clarification of the points raised please do not hesitate to contact us.

Yours sincerely,
for GRM Development Solutions Ltd



Enc:
P8723 Gas Monitoring Location Plan
P8723 Gas Monitoring Results



DO NOT SCALE

NOTES:

— Approximate Site Boundary

⊕ Window Sample Location with monitoring well

GRM
Development Solutions
geoenvironmental - civil - structural

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CLIENT:

Partner Construction Ltd

PROJECT:

Crease Drove, Crowland

TITLE:

Gas and Groundwater Monitoring Plan

SCALE@SIZE :	ISSUE:
NTS	FINAL
DESIGN/DRAWN by :	DATE:
LB	January, 2019
PROJECT No:	DRAWING No:
P8723	4



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction
 Date: 20/12/2018
 Weather: Raining
 Atmospheric Pressure (mb): 1001
 Pressure Trend: Rising
 Equipment: Gas Data GFM430
 Operator: Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	2.10	2.10	18.20	18.20	0.00	0.00	Not Recorded	
WS02	0.60	1.60	NS	0.00	0.00	3.90	3.90	15.60	15.60	0.00	0.00	Not Recorded	
WS03	1.00	3.00	NS	0.00	0.00	0.90	0.90	19.40	19.40	0.00	0.00	Not Recorded	
WS04	0.50	1.50	NS	0.00	0.00	0.30	0.30	19.80	19.80	0.00	0.00	Not Recorded	
WS06	1.00	2.00	NS	0.00	0.00	0.30	0.30	19.70	19.70	0.00	0.00	Not Recorded	

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
1.09	2.94
0.75	1.65
0.50	3.20
0.39	1.43
0.93	2.09

Comments: All holes bailed.

Notes

L.E.L. Lower Explosive Limit (100% L.E.L. = 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction
 Date: 02/01/2019
 Weather: Cloudy
 Atmospheric Pressure (mb): 1044
 Pressure Trend: Falling
 Equipment: Gas Data GFM430
 Operator: Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	2.30	2.30	17.50	17.50	0.00	0.00	Not Recorded	
WS02	0.60	1.60	NS	0.00	0.00	5.80	5.80	15.00	15.00	0.00	0.00	Not Recorded	
WS03	1.00	3.00	NS	0.00	0.00	1.40	1.40	18.90	18.90	0.00	0.00	Not Recorded	
WS04	0.50	1.50	NS	0.00	0.00	0.30	0.30	19.40	19.40	0.00	0.00	Not Recorded	
WS06	1.00	2.00	NS	0.00	0.00	0.60	0.60	19.60	19.60	0.00	0.00	Not Recorded	

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
1.03	2.91
0.85	1.63
0.58	3.15
0.00	1.41
0.95	1.92

Comments: All holes bailed.

Notes

L.E.L. Lower Explosive Limit (100% L.E.L. = 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction
 Date: 17/01/2019
 Weather: Ice
 Atmospheric Pressure (mb): 1003
 Pressure Trend: Rising
 Equipment: Gas Data LMSXi, Ion Science Tiger Pro Photo-ionising detector (PID)
 Operator: Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	0.70	0.70	19.40	19.40	0.00	0.00	0.60	0.60
WS02	0.60	1.60	NS	0.00	0.00	6.90	6.90	15.50	15.50	0.00	0.00	0.20	0.20
WS03	1.00	3.00	NS	0.00	0.00	1.30	1.30	19.20	19.20	0.00	0.00	0.00	0.00
WS04	0.50	1.50	NS	0.00	0.00	0.00	0.00	20.00	20.00	0.00	0.00	0.00	0.00
WS06	1.00	2.00	NS	0.00	0.00	0.00	0.00	19.80	19.80	0.00	0.00	0.30	0.30

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
1.10	2.90
0.89	1.63
0.68	3.20
0.30	1.43
1.10	1.90

Comments: None.

Notes

L.E.L. Lower Explosive Limit (100% L.E.L. = 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction
 Date: 28/01/2019
 Weather: Ice
 Atmospheric Pressure (mb): 1006
 Pressure Trend: Steady
 Equipment: Gas Data GFM430, Ion Science Tiger Pro Photo-ionising detector (PID)
 Operator: Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	2.90	2.90	18.30	18.30	0.00	0.00	0.30	0.30
WS02	0.60	1.60	NS	0.00	0.00	0.90	0.90	15.10	15.10	0.00	0.00	0.30	0.30
WS03	1.00	3.00	NS	0.00	0.00	0.70	0.70	19.60	19.60	0.00	0.00	0.30	0.30
WS04	0.50	1.50	NS	0.00	0.00	0.00	0.00	19.90	19.90	0.00	0.00	0.00	0.00
WS06	1.00	2.00	NS	0.00	0.00	0.00	0.00	19.80	19.80	0.00	0.00	0.30	0.30

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
1.10	2.91
0.93	1.65
0.67	3.12
0.33	1.39
1.10	1.91

Comments: None.

Notes

L.E.L. Lower Explosive Limit (100% L.E.L. = 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name:	Crease Drove Crowland Peterborough
Project Number:	P8723
Client:	Partner Construction
Date:	12/02/2019
Weather:	Sunny
Atmospheric Pressure (mb):	1031
Pressure Trend:	Steady
Equipment:	Gas Data GFM430, Ion Science Tiger Pro Photo-ionising detector (PID)
Operator:	Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	2.60	2.60	18.30	18.30	0.00	0.00	0.00	0.00
WS02	0.60	1.60	NS	0.00	0.00	4.50	4.50	16.90	16.90	0.00	0.00	0.00	0.00
WS03	1.00	3.00	NS	0.00	0.00	0.30	0.30	20.00	20.00	0.00	0.00	0.00	0.00
WS04	0.50	1.50	NS	0.00	0.00	0.00	0.00	20.10	20.10	0.00	0.00	0.00	0.00
WS06	1.00	2.00	NS	0.00	0.00	0.70	0.70	19.60	19.60	0.00	0.00	0.00	0.00

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
0.87	2.89
0.75	1.63
0.49	3.17
0.00	1.40
0.75	1.91

Comments All holes bailed.

Notes

L.E.L. Lower Explosive Limit (100% L.E.L.= 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction
 Date: 25/02/2019
 Weather: Sunny
 Atmospheric Pressure (mb): 1039
 Pressure Trend: Steady
 Equipment: Gas Data GFM430
 Operator: Tom Robson

Ground Gases													
				Methane %v/v		CO2 %v/v		Oxygen %v/v		Gas Flow l/h		PID Reading ppm	
ID	Top	Base	Strata	Peak	Steady	Peak	Steady	Low	Steady	Peak	Steady	Peak	Steady
WS01	0.50	3.00	NS	0.00	0.00	2.50	2.50	17.70	17.70	0.00	0.00	Not Recorded	
WS02	0.60	1.60	NS	0.00	0.00	5.40	5.40	14.70	14.70	0.00	0.00	Not Recorded	
WS03	1.00	3.00	NS	0.00	0.00	0.60	0.60	19.80	19.80	0.00	0.00	Not Recorded	
WS04	0.50	1.50	NS	0.00	0.00	0.00	0.00	20.00	20.00	0.00	0.00	Not Recorded	
WS06	1.00	2.00	NS	0.00	0.00	0.40	0.40	19.80	19.80	0.00	0.00	Not Recorded	

Ground Waters	
Depth to Groundwater mbegl	Total Well Depth mbegl
1.05	2.93
0.88	1.63
0.63	3.14
0.29	1.39
1.06	1.91

Comments

Notes

L.E.L. Lower Explosive Limit (100% L.E.L. = 5% Flammable Gas)
 N.D. Not Detected
 N.R. Not Recorded
 PID Photo-Ionising Detector
 % By volume

Highlighted cell for following conditions:
 a Methane =>1% v/v
 b Carbon Dioxide =>5% v/v
 MG Made Ground
 NS Natural Strata

Ground Material Key

NS Natural Strata



In-Situ Gas Monitoring Results

Project Name: Crease Drove Crowland Peterborough
 Project Number: P8723
 Client: Partner Construction

Pressure Range:	900mb-1044mb
Reading Below 1000mb:	1

Summary of Results for period: 20/12/2018 to 25/02/2019

Ground Gases													
				Methane (%v/v)		CO2 (%v/v)		Oxygen (%v/v)		Gas Flow (l/h)		PID Reading (ppm)	
ID	Top	Base	Strata	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
WS01 (6)	0.50	3.00	NS	0.00	0.00	0.70	2.90	17.50	19.40	0.00	0.00	0.00	0.60
WS02 (6)	0.60	1.60	NS	0.00	0.00	0.90	6.90	14.70	16.90	0.00	0.00	0.00	0.30
WS03 (6)	1.00	3.00	NS	0.00	0.00	0.30	1.40	18.90	20.00	0.00	0.00	0.00	0.30
WS04 (6)	0.50	1.50	NS	0.00	0.00	0.00	0.30	19.40	20.10	0.00	0.00	0.00	0.00
WS06 (6)	1.00	2.00	NS	0.00	0.00	0.00	0.70	19.60	19.80	0.00	0.00	0.00	0.30

Groundwater	
Depth to Groundwater (mbegl)	
Min	Max
0.87	1.10
0.75	0.93
0.49	0.68
0.00	0.39
0.75	1.10

BS8485:2015 Suggested Worse Case Site Classification:

Site Summary:

	GSV (l/h)	Max Values
Methane	0.0001	0.1
CO2	0.0069	6.9
Default Flow (l/h)	0.1	

Notes

L.E.L.	Lower Explosive Limit (100% L.E.L.= 5% Flammable Gas)	Highlighted cell for following conditions:
N.D.	Not Detected	a Methane =>1% v/v
N.R.	Not Recorded	b Carbon Dioxide =>5% v/v
PID	Photo-Ionising Detector	GSV Gas Screening Value:
%	By volume	Peak state values used for Methane
NS	Natural Strata	Steady state values used for Carbon Dioxide and Gas Flow