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Orion Homes Ltd
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BY EMAIL

Our Ref: ORH/25/MHjcl6

07th March 2025

Dear Ian

195 Leeds Road Heckmondwike
Ground Gas Risk Assessment

In accordance with our commission and following issue of the ARP Geotechnical Ltd (ARP) Combined Stage 1/Stage 2 Geo-environmental Report (ref: ORH/25r1, dated 18th November 2024), we have now completed all six of the gas monitoring visits at the above site. A full set of gas monitoring results is appended and summarised below.

Background

During the site investigation undertaken in (October 2024), three gas monitoring wells were installed in boreholes WS1, WS5 and WS6 (see location plan enclosed). Subsequent ground gas and water monitoring was undertaken by ARP Geotechnical Ltd. The wells were installed to depths of between 2.0m and 2.5m, depth, with the top 0.5m (WS1) to 1m (WS5 & WS6) fitted with plain pipe and bentonite seal, and the bottom 1m to 2m with slotted pipe and gravel surround. All three wells were fitted with a lockable flush cover, bung and gas tap.

Monitoring Results

The ground gas investigation was undertaken in accordance with BS 8576: 2013 "Guidance on investigations for ground gas - Permanent gases and Volatile Organic Compounds (VOCs)". Ground gas risk assessment was carried out in accordance with BS 8485: 2015 + A1: 2019 "Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings".

The monitoring visits were carried out to record the levels of methane (CH_4), carbon dioxide (CO_2), oxygen (O_2), groundwater level, and borehole gas flow rate in litres/hour (l/hr) within the wells. Six visits were made over a 14-week period. The visits were made between 30th October 2024 and 04th February 2025. On the days of the visits, atmospheric pressures ranged between 1007mb and 1,037mb.

Readings for WS5 and WS6 had to be discarded due to groundwater levels being found to be above the response zone once the bung was removed and the borehole water level measured. This only occurred twice in WS5 and once in WS6. It is noted that WS5 and WS6 had to be bailed out prior to gas sampling on three occasions each owing to being either flooded or groundwater being found above the response zone.

The monitoring showed maximum concentrations, of CH_4 and CO_2, of 0.0%, and 2.8%, respectively, along with oxygen levels of a minimum of 14.1% (all results measured in percentage by volume). There was no detectable borehole flow rate (the detection limit of 0.1l/hr is assumed where no flow was detected).

Risk Assessment

The British Standard, BS 8485: 2015 + A1: 2019, utilises the concept of borehole hazardous gas flow rates (Q_{hg}), in litres/hour (l/hr), which are obtained by multiplying flow rate by concentrations in the air stream of the particular gas being considered for each borehole. The Q_{hg} is used to derive a gas screening value (GSV), which is defined as the "flow rate of a specific hazardous gas representative of a site or zone, derived from assessment of borehole concentration and flow rate measurements and taking account of all other influencing factors, in accordance with a conceptual site model".

The table below allows the selection of the 'Characteristic Gas Situation' (CS) based on GSVs, using a numbering system of 1 to 6, where 1 equates to a very low hazard potential and 6 equates to a very high hazard potential.

A table showing the Characteristic Gas Situations is provided below:-

Characteristic Gas Situation (CS)	Hazard Potential	Gas Screening Value - l/hr - (GSV)	Additional Factors
1	Very Low	<0.07	Typically <1% CH_4 and <5% CO_2, otherwise consider an increased Characteristic Gas Regime
2	Low	>0.07 to <0.7	Typical Measured Flow Rate <70 l/hr, otherwise consider an increase to CS 3
3	Moderate	>0.7 to <3.5	
4	Moderate to high	>3.5 to <15	
5	High	>15 to <70	
6	Very High	>70	

Based on Table 2 of BS 8485: 2015 + A1: 2019

A summary of the results obtained from the ground gas monitoring investigation, together with the Q_{hg} for carbon dioxide and methane, is presented in the table on the following page:-

Borehole Ref.	Max Recorded Steady Flow (l/hr)	Max. CO_2 (% v/v)	Max CH_4 (% v/v)	Max BH Qhg (CO_2)	Max BH Qhg (CH_4)
WS1	0.1	1.9	0.0	0.002	0.000
WS5	0.1	0.8	0.0	0.001	0.000
WS6	0.1	2.8	0.0	0.003	0.000

Worst-credible Qhg (l/hr) *	0.003	0.000
Worst-possible Qhg (l/hr) +	0.003	0.000

* Based on maximum recorded concentration and maximum flow rate applicable to any individual borehole.

+ Based on maximum recorded concentration and maximum flow rate across the whole site (any borehole)

The maximum recorded concentration of CH_4 and CO_2 is 0.0% v/v and 2.8% v/v, respectively. The worst credible gas regime identified on the site (based on the maximum recorded flow rate and concentration detected together within an individual borehole) is a Q_{hg} of 0.000 l/hr for CH_4 and 0.003 l/hr for CO_2. This equates to a Characteristic Situation of CS1, for CO_2 & CH_4.

It is also a requirement of the British Standard to check the very worst-case combination of the highest flow and highest detected concentrations, of any borehole, with values not necessarily from the same borehole. If the worst-case conditions indicate a higher hazard could reasonably exist, then this should be adopted as the GSV, unless further monitoring or other justification is provided for it not to be used. In this case, the worst-possible Q_{hg} is 0.000 l/hr for methane and 0.003 l/hr for carbon dioxide. This equates to a Characteristic Situation of CS1, for CO_2 & CH_4.

Coal Mine Gas Risk Assessment

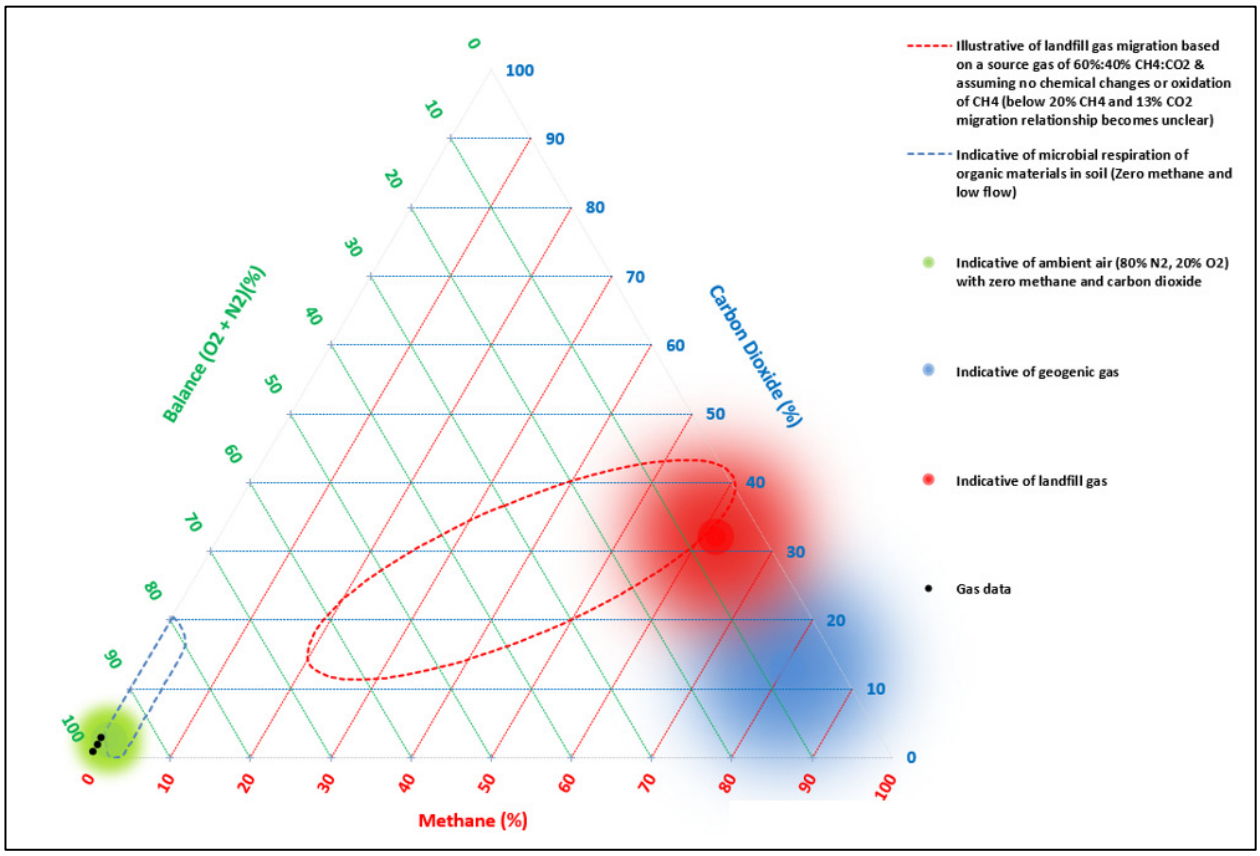
The Characteristic Situation is an empirical approach which was developed based on data from monitoring wells installed in soil-based sources. Coal mine gas emissions involve flow through open voids and fractured rock which the method was not intended to be applied to. As such, GSV's are to be used with extreme caution and should not be used in isolation. A decision support tool for coal mine gas risk assessment is provided in Figure 13.1 of the CL:AIRE Good Practice for Risk Assessment for Coal Mine Gas Emissions dated October 2021. Using this support tool, a multiple lines of evidence approach must be undertaken and is presented below.

<u>Oxygen depletion</u>

Carbon dioxide and depleted oxygen are commonly recorded in monitoring wells installed in either unworked strata with no credible pathway to workings, or in superficial deposits. This is caused by carbon cycling processes such as biological oxidation. The concentration can vary with temperature, soil moisture, nutrient availability and oxygen supply. Depleted oxygen (of 14.1%) was recorded on one occasion in WS6, and was associated with an elevated carbon dioxide concentration of 2.8%.

Ternary Plot

Where carbon dioxide from mine workings is of concern, methane may not be present. Carbon dioxide is produced in unworked Coal Measures and superficial strata by aerobic microbial respiration or the oxidation of organic material in soils. The monitoring undertaken on site has not recorded any concentration of methane. No flow has been recorded. The worst-case monitoring data has been plotted on the Ternary Plot below and indicates a possible microbial respiration source (zero methane and low flow).



Mine Workings and Geological Fault

A Coal Mining Risk Assessment was undertaken by ARP Geotechnical Ltd (reference ORH/25/JRjcl1), dated 7th November 2024. The report concluded that potential coal workings beneath the site pose a risk to ground stability, and a rotary borehole investigation was recommended to be carried out. In accordance with our commission, the recommended investigation was carried out on 8th and 9th January 2025, and 14th and 17th February 2025 (reference ORH/25/JRjcl5 dated 21st February 2025).

Fifteen boreholes were drilled, using rotary open hole water flush techniques. Eight were drilled on 8th and 9th January 2025 (numbered RH1 to RH8) and seven were drilled on 14th and 17th February 2025 (numbered RH101 to RH107). The boreholes were taken to depths of between 4.8m and 32mbgl. The mapped geological fault in the southwest of the site was confirmed by comparison of the strata recorded in RH3 (east of the fault) and RH5 (west of the fault). Shallow groundwater is present on site; however due to the use of water flush whilst drilling, it was not possible to determine if the workings are flooded.

Coal mine workings were identified across the site and generally do not have sufficient rock cover. Stabilisation treatment by injection of grout into a grid of boreholes (drilling and grouting) will be required. A general 3m grid was recommended, continuing 3m beyond proposed building footprints, roads and an attenuation tank. In the area at/around RH1 in the northwest of the site, an initial 9m grid was recommended, closing to 3m where cover is found not to be sufficient.

Conclusions

Six rounds of gas monitoring have been undertaken on site. The maximum recorded concentration of CH_4 and CO_2 was 0.0% v/v and 2.8% v/v respectively. No flow was recorded. Atmospheric conditions at the time of the monitoring visits were generally high barometric pressure, with two visits undertaken during falling conditions. Depleted O_2 was recorded in one borehole, on one occasion, and corresponded to the elevated CO_2 concentration recorded.

The worst-case monitoring data has been plotted on the Ternary Plot below and indicates a possible microbial respiration source (zero methane and low flow).

Coal mine workings were identified across the site during intrusive rotary drilling and generally do not have sufficient rock cover. Stabilisation treatment, by injection of grout into a grid of boreholes, is required before development can progress. No evidence of open workings associated with the outcrop in the north of the site has been identified during site investigation. The mapped geological fault in the southwest of the site was confirmed to be present by comparison of the strata recorded in RH3 (east of the fault) and RH5 (west of the fault).

Given the above lines of evidence approach, there is considered to be a low risk of mine gas emissions across the majority of the site. Uncertainties exist regarding the potential for gas migration vertically through the geological fault in the southwest of the site and so in this area there is considered to be a moderate risk.

As a result, it is considered that gas protection measures (equivalent to CS2) are required, to mitigate the identified risks. These protection measures should be provided to properties within 20m of the fault. The protection should include a vented sub-floor void, and a gas membrane resistant to CO_2 and CH_4.

The specific design of the protection measures, and the verification required, is dependent on the detailed foundation design, the selection of products/suppliers, and who installs the protection. Once more of these factors are known, as a minimum following foundation design and design of the protection measures, a Statement on Gas Protection should be prepared. The document should provide information for the Client and other interested parties, such as the regulatory authorities, including detailed drawings of the gas protection, how the design has been arrived at, how the protection will be installed, and how the installation will be verified as satisfactory. The document should be agreed, prior to implementation, with the relevant Regulatory Authorities, usually the local Planning Authority and NHBC or other building control provider.

We trust the above is sufficient for your requirements. However, should you have any queries, or wish to discuss the matter further, please do not hesitate to contact us at your convenience.

Yours sincerely
for ARP GEOTECHNICAL LTD

Mike Harper
BSc (Hons) MSc CEnv MIEnvSc

Encs

0m 20m

Approximate Scale

- Trial Pit
- Window Sample Borehole
- Window Sample Borehole and Gas Well Installation

ARP GEOTECHNICAL LTD
CHARTERED CONSULTING ENGINEERS
Northwest House 5-6 Northwest Business Park Servia Hill Leeds LS6 2QH

Project	LAND AT 195 LEEDS ROAD HECKMONDWIKE
Client	ORION HOMES LTD
Title	SITE INVESTIGATION PLAN
Date	NOVEMBER 2024
Drawn	JP
Scale	AS SHOWN
Job No.	**ORH/25**

ARP GEOTECHNICAL BOREHOLE MONITORING RESULTS

JOB NO. ORH/25 **CLIENT:** Orion Homes Ltd

SITE: Leeds Road, Heckmondwike

BAROMETRIC PRESSURES

Monitor Date	Weather on Day	Pressure on Day (mb)*	Pressure on day before (mb)*	Pressure 2 days before (mb)*	Pressure 3 days before (mb)*	3 Day Trend*
30/10/2024	Sunny, cold	1028	1024	1017	1019	Rise
11/11/2024	Sunny, cold	1037	1025	1023	1025	Rise
17/12/2024	Overcast, mild	1019	1024	1021	1019	Stable
09/01/2025	Sunny, Cold	1007	1000	994	978	Rising
21/01/2025	Sunny, cold	1010	1015	1017	1027	Falling
04/02/2025	Overcast, cold	1012	1020	1019	1026	Falling

*Pressures at midday (EGNM) corrected to sea level.

https://www.timeanddate.com/weather/uk/leeds/historic

ARP GEOTECHNICAL BOREHOLE MONITORING RESULTS

JOB NO: ORH/25 **CLIENT:** Orion Homes Ltd

SITE: Leeds Road, Heckmondwike

BH: WS1

Date	BH Steady Flow Rate (l/hr)*	Peak CH_4 %	Qhg CH_4 (l/hr)	Peak CO_2 %	Qhg CO_2 (l/hr)	Min. O_2 %	Depth to G Water (m)	Comment
30/10/2024	0.1	0.0	0.000	1.3	0.001	18.7	1.93	
11/11/2024	0.1	0.0	0.000	1.9	0.002	17.0	2.00	
17/12/2024	0.1	0.0	0.000	1.2	0.001	19.0	2.10	
09/01/2025	0.1	0.0	0.000	1.8	0.002	18.3	1.80	
21/01/2025	0.1	0.0	0.000	1.0	0.001	18.8	1.75	
04/02/2025	0.1	0.0	0.000	0.4	0.000	19.3	1.91	

* Where no flow is detected, detection limit of 0.1l/hr should be inserted

Qhg = Hazardous gas flow rate, in accordance with BS8485:2007

ARP GEOTECHNICAL BOREHOLE MONITORING RESULTS

JOB NO: ORH/25 **CLIENT:** Orion Homes Ltd

SITE: Leeds Road, Heckmondwike

BH: WS5

Date	BH Steady Flow Rate (l/hr)*	Peak CH_4 %	Qhg CH_4 (l/hr)	Peak CO_2 %	Qhg CO_2 (l/hr)	Min. O_2 %	Depth to G Water (m)	Comment
30/10/2024	0.1	0.0	0.000	0.2	0.000	20.4	0.71	Water above response zone
11/11/2024	0.1	0.0	0.000	0.7	0.001	18.9	1.34	
17/12/2024	0.1	0.0	0.000	N/A	#VALUE!	N/A	0.50	Water above response zone
09/01/2025	0.1	0.0	0.000	0.8	0.001	19.0	1.20	Bailed out the day before
21/01/2025	0.1	0.0	0.000	0.3	0.000	19.3	1.15	Bailed out on the day
04/02/2025	0.1	0.0	0.000	0.2	0.000	19.5	1.20	Bailed out on the day

* Where no flow is detected, detection limit of 0.1l/hr should be inserted

Qhg = Hazardous gas flow rate, in accordance with BS8485:2007

ARP GEOTECHNICAL BOREHOLE MONITORING RESULTS

JOB NO: ORH/25 **CLIENT:** Orion Homes Ltd

SITE: Leeds Road, Heckmondwike

BH: WS6

Date	BH Steady Flow Rate (l/hr)*	Peak CH_4 %	Qhg CH_4 (l/hr)	Peak CO_2 %	Qhg CO_2 (l/hr)	Min. O_2 %	Depth to G Water (m)	Comment
30/10/2024	0.1	0.0	0.000	0.3	0.000	20.4	1.72	
11/11/2024	0.1	0.0	0.000	2.8	0.003	14.1	1.71	
17/12/2024	N/A	N/A	#VALUE!	N/A	#VALUE!	N/A	0.00	Well Flooded
09/01/2025	0.1	0.0	0.000	0.4	0.000	19.8	1.20	Bailed out the day before.
21/01/2025	0.1	0.0	0.000	0.2	0.000	19.0	1.20	Bailed out on the day
04/02/2025	0.1	0.0	0.000	0.3	0.000	19.4	1.20	Bailed out on the day

* Where no flow is detected, detection limit of 0.1l/hr should be inserted

Qhg = Hazardous gas flow rate, in accordance with BS8485:2007

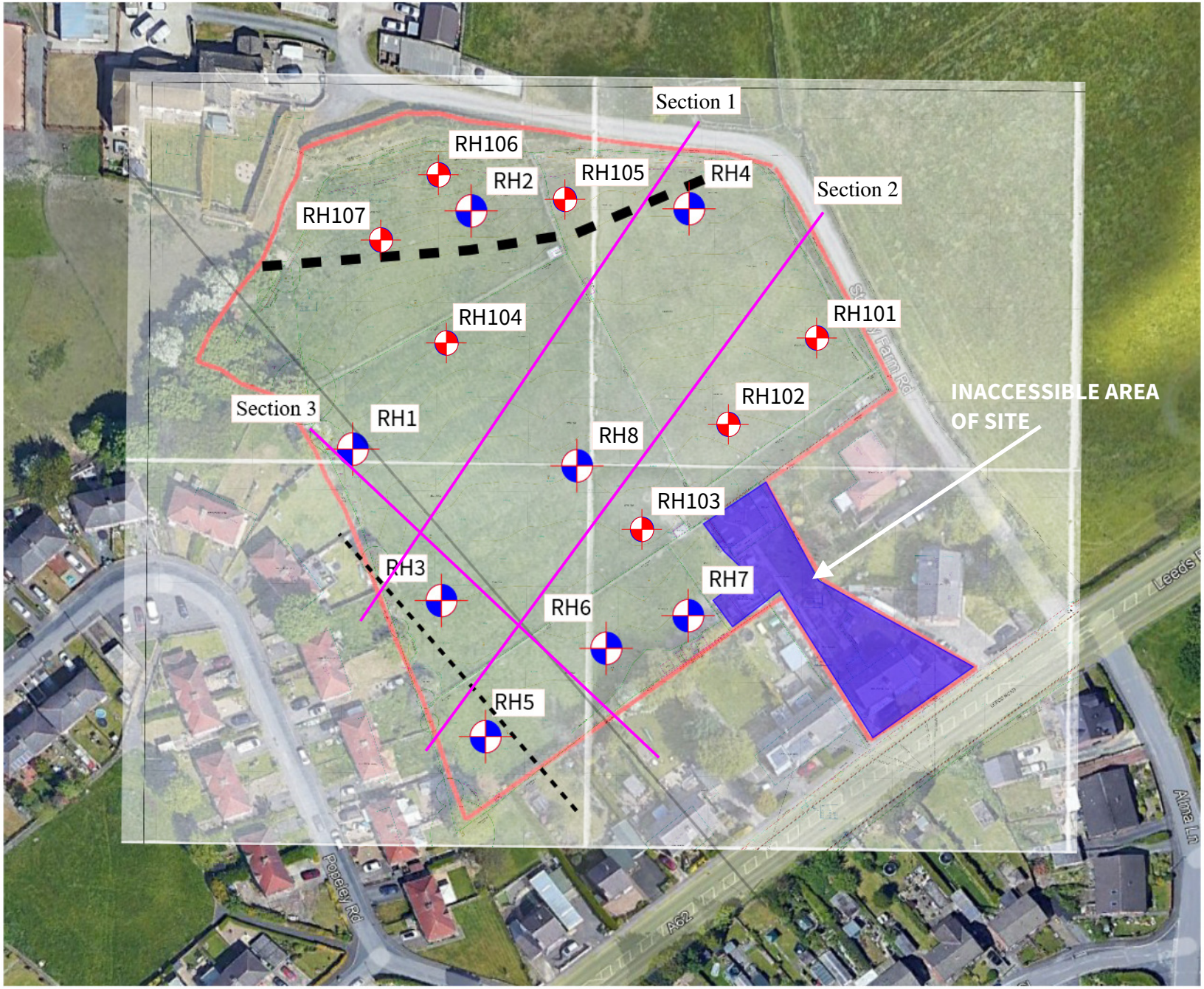
ORH/25 **COMBINED DETAILS OF ROTARY DRILLING CARRIED OUT IN JANUARY AND FEBRUARY 2025**

Flockton Thin is 1.5m thickness unless proved otherwise in a BH, and using average 2.15m depth to rock head (average from 16No. Trial pits and window sample BHs)

Borehole	ARP Ave Depth to Rock (m)	Depth (m) to base of 1st seam or wkgs	Probable Seam Identifed	Seam Thickness in this borehole (if coal found) (m)	Thickest solid seam found on site unless proved otherwise in this BH	Depth to original 1st seam roof (m)	Rock cover to original 1st seam roof (m)	Rock Cover Needed (m)	Cover to 1st seam adequate? (Y/N)	Depth (m) to base of 2nd seam or wkgs	Probable Seam Identifed	Seam Thickness in This BH (if coal found) (m)	Thickness from nearest borehole with solid coal, if solid seam not found in this BH	Depth to original 2nd seam roof (m)	Rock cover to original 2nd seam roof (m)	Rock Cover Needed (m)	Cover to 2nd seam adequate? (Y/N)
RH1	2.15	17.0 C	Flockton Thin	1.0	N/A	16.0	13.85	10.0	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH2	2.15	2.6 C	Flockton Thick	1.0	N/A	1.6	0.00	10.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH3	2.15	13.0 C	Flockton Thin	1.0	N/A	12.0	9.85	10.0	NO	27.5 W	1st Brown Metal	N/A	0.7	26.8	13.8	7.0	Yes
RH4	2.15	16.0 W	Flockton Thin	N/A	1.5	14.5	12.35	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH5	2.15	8.0 W	Not Known	N/A	1.4 *	6.6	4.45	14.0 *	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH6	2.15	14.0 W	Flockton Thin	N/A	1.5	12.5	10.35	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH7	2.15	13.5 W	Flockton Thin	N/A	1.5	12.0	9.85	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH8	2.15	14.0 C	Flockton Thin	1.0	N/A	13.0	10.85	10.0	Marginal #	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH101	2.15	13.5 C	Flockton Thin	1.5	N/A	12.0	9.85	15.0	NO	27.0 W	1st Brown Metal	N/A	0.7	26.3	12.8	7.0	Yes
RH102	2.15	13.0 W	Flockton Thin	N/A	1.5	11.5	9.35	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH103	2.15	13.8 W	Flockton Thin	N/A	1.5	12.3	10.15	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH104	2.15	15.0 W	Flockton Thin	N/A	1.5	13.5	11.35	15.0	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH105	2.15	2.0 C	Flockton Thick	1.0	N/A	1.0	0.00	10.0	NO (note at/nr surface	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH106	2.15	3.6 C	Flockton Thick	1.6	N/A	2.0	0.00	16.0	NO (note at/nr surface	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RH107	2.15	3.0 C	Flockton Thick	1.5	N/A	1.5	0.00	15.0	NO (note at/nr surface	16.8 W	Flockton Thin	N/A	1.5	15.3	12.3	15.0	NO

Rock head is not comfortably on the acceptable side (less than 1m margin), therefore assume it needs grouting.

* Worst case from potential underlying seams W = Workings, C = Solid Coal



0m 20m

Approximate Scale

RH1 ROTARY BOREHOLE JANUARY 2025

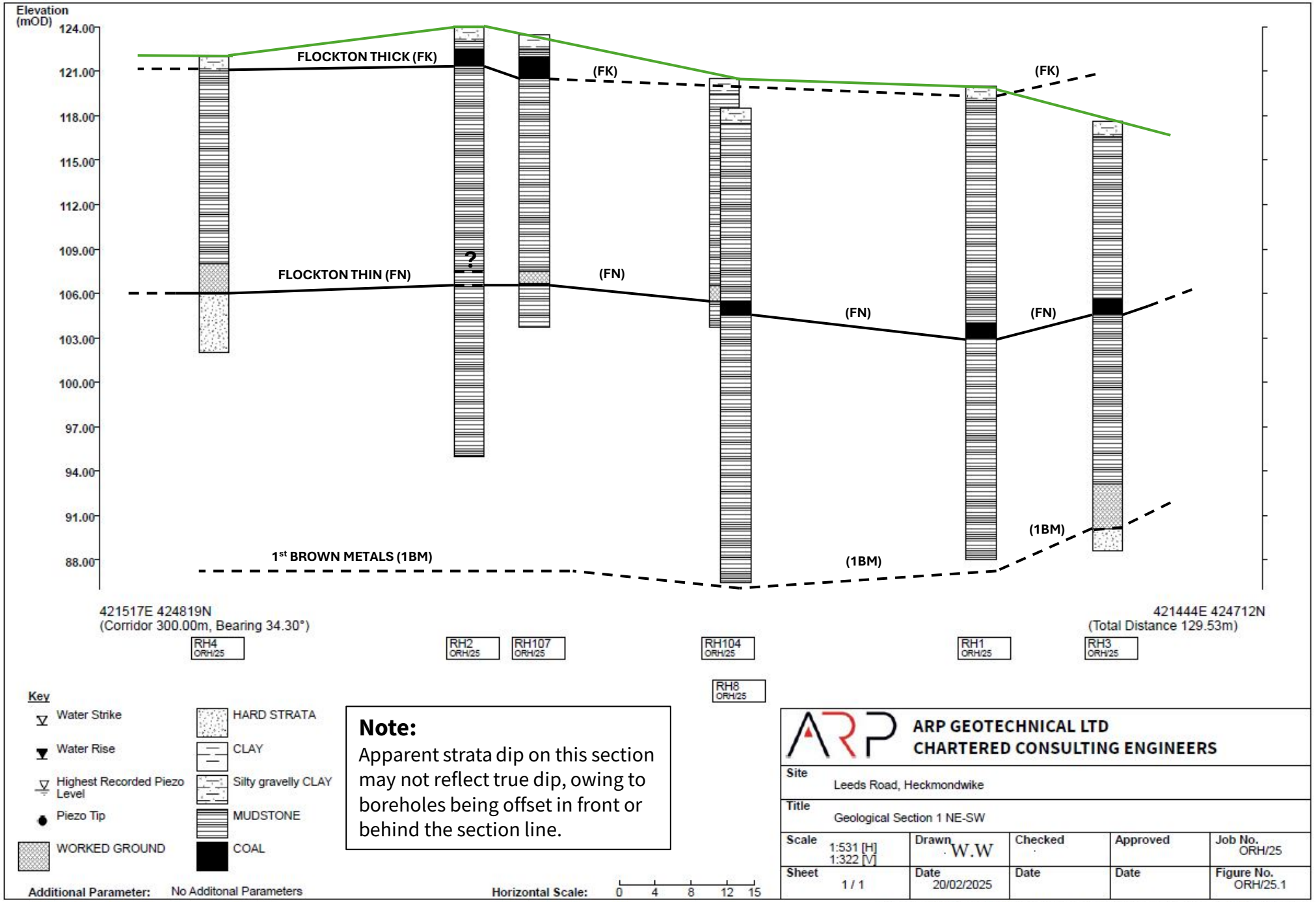
RH101 ROTARY BOREHOLE FEBRUARY 2025

CONJECTURED FAULT

CONJECTURED COAL SEAM OUTCROP

ARP GEOTECHNICAL LTD
CHARTERED CONSULTING ENGINEERS
Northwest House 5-6 Northwest Business Park Servia Hill Leeds LS6 2QH

Project	LAND AT 195 LEEDS ROAD HECKMONDWIKE
Client	ORION HOMES LTD
Title	ROTARY BOREHOLE LOCATION PLAN
Date	FEBRUARY 2025
Drawn	WW
Scale	AS SHOWN
Job No.	ORH/25



Note:
Apparent strata dip on this section may not reflect true dip, owing to boreholes being offset in front or behind the section line.

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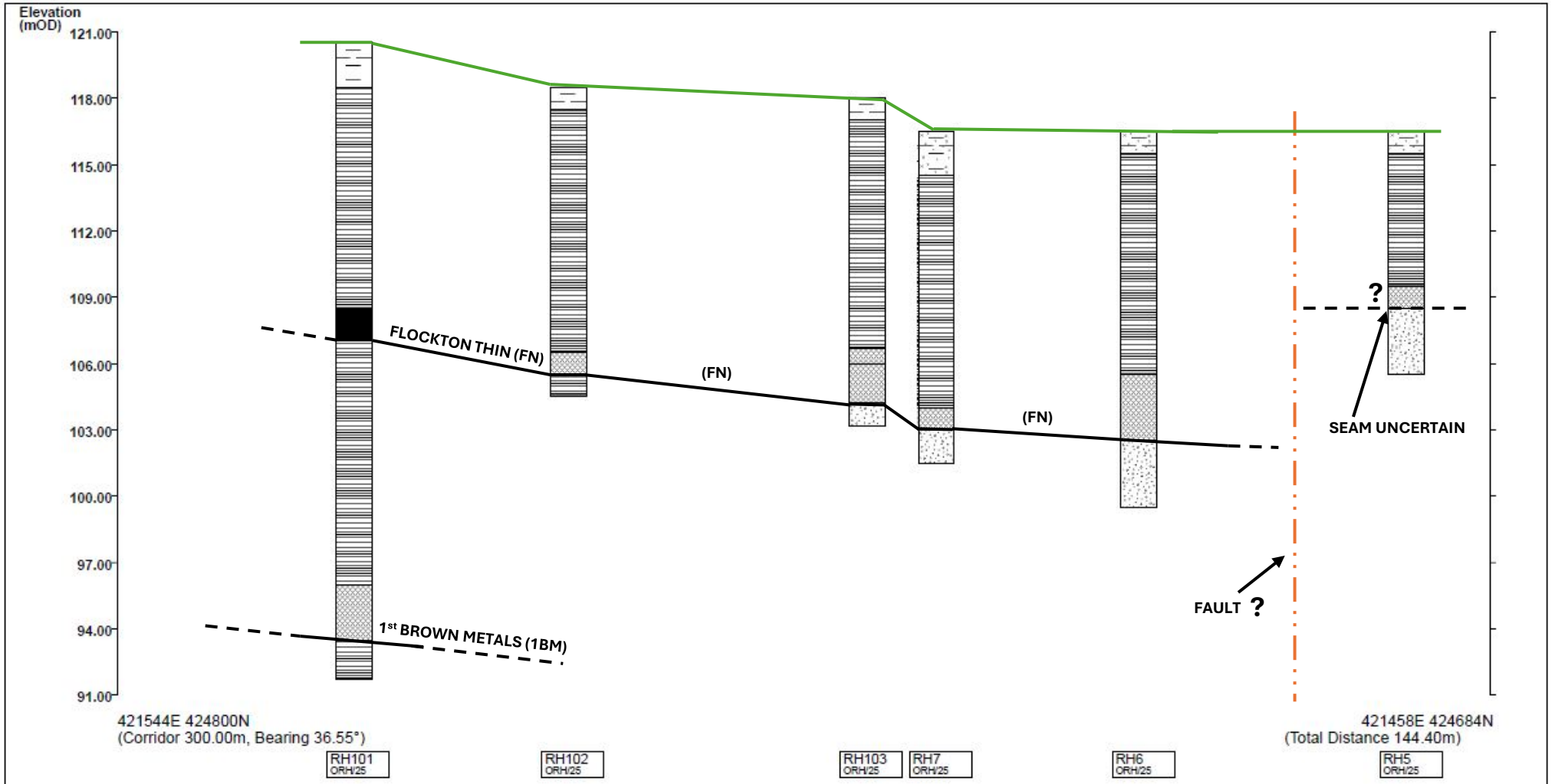
Site: Leeds Road, Heckmondwike				
Title: Geological Section 1 NE-SW				
Scale: 1:531 [H] 1:322 [V]	Drawn: W.W	Checked:	Approved:	Job No.: ORH/25
Sheet: 1 / 1	Date: 20/02/2025	Date	Date	Figure No.: ORH/25.1



Key

- Water Strike
- Water Rise
- Highest Recorded Piezo Level
- Piezo Tip
- WORKED GROUND
- HARD STRATA
- CLAY
- Silty gravelly CLAY
- MUDSTONE
- COAL

Additional Parameter: No Additonal Parameters

Horizontal Scale: 0 5 10 15 17

Note:
Apparent strata dip on this section may not reflect true dip, owing to boreholes being offset in front or behind the section line.

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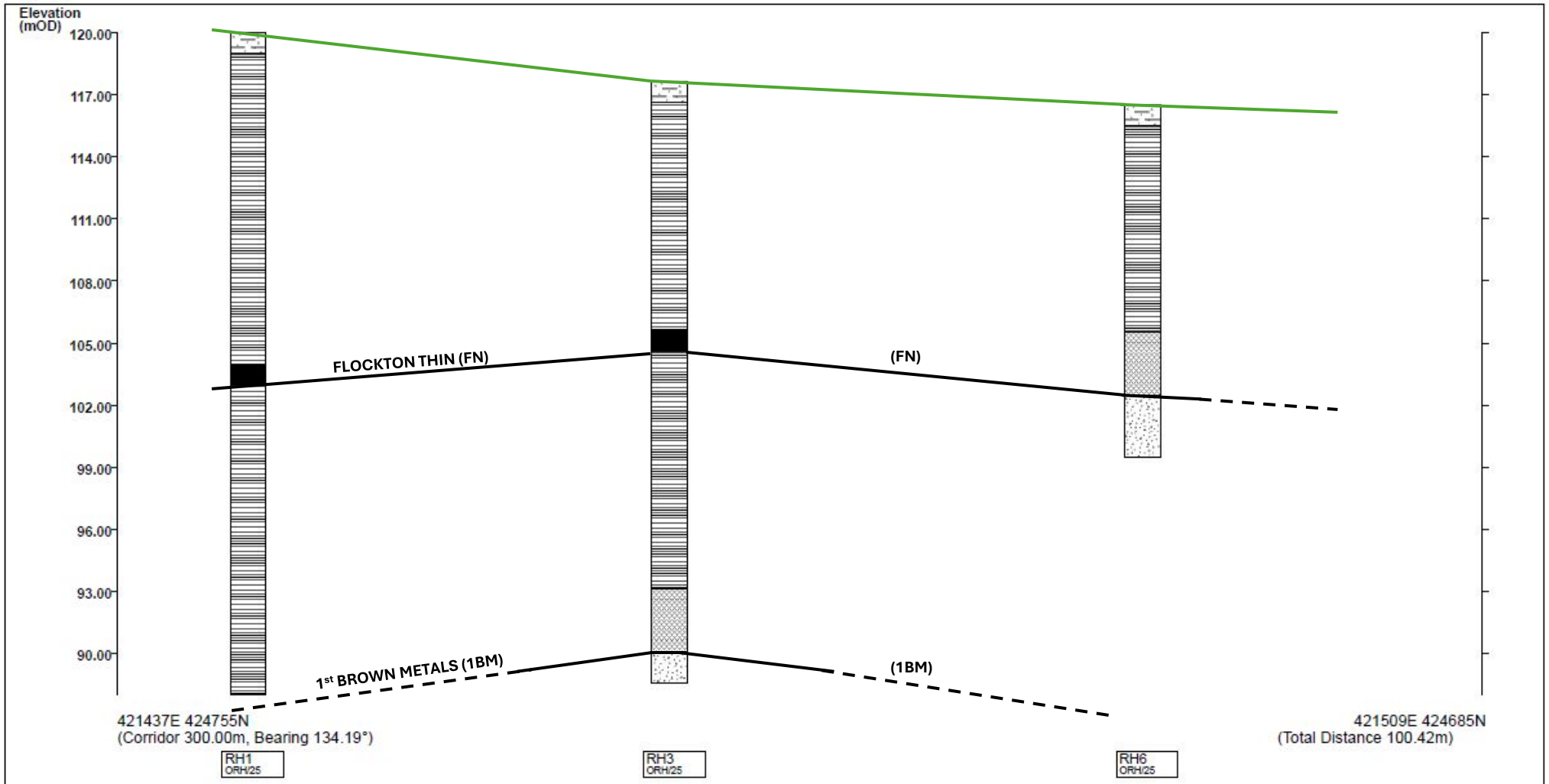
Site: Leeds Road, Heckmondwike				
Title: Geological Section 2 NE-SW				
Scale: 1:592 [H] 1:254 [V]	Drawn: W.W	Checked	Approved	Job No.: ORH/25
Sheet: 1 / 1	Date: 20/02/2025	Date	Date	Figure No.: ORH/25.1



Key

- Water Strike
- Water Rise
- Highest Recorded Piezo Level
- Piezo Tip
- WORKED GROUND
- HARD STRATA
- Silty gravelly CLAY
- MUDSTONE
- COAL

Note:
Apparent strata dip on this section may not reflect true dip, owing to boreholes being offset in front or behind the section line.

Additional Parameter: No Additonal Parameters

Horizontal Scale: 0 3 6 9 12

ARP GEOTECHNICAL LTD
CHARTERED CONSULTING ENGINEERS

Site: Leeds Road, Heckmondwike				
Title: Geological Section 3 NW-SE				
Scale: 1:413 [H] 1:271 [V]	Drawn: W.W	Checked	Approved	Job No.: ORH/25
Sheet: 1 / 1	Date: 20/02/2025	Date	Date	Figure No.: ORH/25.1