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Dear Phil,

LAND OFF NORTH ROAD, PONCIAU: MINING INVESTIGATION

Introduction

Freedom Land Developments Ltd (FHD) proposes to develop a site off North Road in Ponciau, with some seventeen conventional two storey houses.

Cross sections supplied of the proposed development show that on the western site boundary it is proposed to lower the ground levels slightly, while to the south of the access track it is proposed to raise the ground levels by around 1.20m.

Studio 83 is the architects for the scheme and GroundSolve Ltd (GL) have been appointed by FHD to carry out a mining site investigation, although mine entrances have been excluded from this commission.

This letter report presents the findings of the site investigation along with previous investigations on site and adjacent to the site. A limited mining desk study has also been undertaken from material held in GL archives and from material supplied by the client, Reference 1.

Recommendations are given for the development foundations to address the risk from mining.

Geology

The geology of the site has been studied on recent and historic 1:10,000/1:10,560 geology plans. In addition, the 1:50,000 scale plan, Sheet 121, and the Wrexham Applied Mapping Study and the geological memoirs have been researched, References 2 and 3.

The 1:10,000 geology plan shows the site to be underlain by glacial till overlying the Productive Coal Measures of the Bettisfield Formation, which is of Carboniferous age. These rocks comprise a cyclical sequence of fireclays, coal seams, mudstones and sandstones. Coal seams of the Fireclay group, comprising the Stone, Half Yard and Firedamp Coal seams are the uppermost seams recorded near the site.

These seams were worked in an opencast pit some 120m west of the site. The estimated angle of dip being about 5° to the south east. It was anticipated from the opencast records that the shallowest of these seams would be at a depth of around 20m beneath the western site boundary. The location of the open casting and a summary of the geology are shown on Figure 1.

There is also a further coal seam, the Red Coal some 0.70m thick lying approximately 12m above the Fireclay Group. The absence of a recorded outcrop and the thinness of the seam suggest it has not been worked in this area, Reference 1. This corresponds to experience elsewhere, where the Red Coal seam has a very low reputation for being worked. Reference 2 in the section on economic value of the coal seam does not even discuss this seam, it is therefore considered highly unlikely to have been worked.

A section of the Fireclay sequence in the geology memoirs from the Depth Pits revealed the following sequence:

<u>Seam</u>	<u>Thickness (m)</u>	<u>Separation (m)</u>
Upper Yard	0.74	16.46
Red Seam	0.38	13.1
Stone Coal	0.72	none
Fireclay A	0.3	none
Half Yard	0.46	none
Fireclay B	1.07	none
Firedamp Coal	0.48	3.04
Thin coals		
Fireclay C	1.07	none
Fireclay D	0.87	7.62
Fireclay E	1.22	10
Nant Coal	1.82	

The Ty Gwyn Fault is shown crossing the southern section of the site trending in an east to west direction with its downthrow to the south. To the south of the fault the Main Coal seam outcrops immediately west of the site and is anticipated to be at shallow depth beneath part of the site. The Main Coal comprises two leaves of 1.80m and 0.70m thickness and is anticipated to be around 8m depth beneath this section of the site. The

anticipated position of the fault at surface is shown on Figure 1 derived from mine plan information and the geology plans. The Lower Bench Coal (Brassey), which is 1.60m thick, lies some 6m beneath the Main Coal. An opencast operation on this seam is shown to the west of the outcrop of the Main Coal seam, see Figure 1.

Mining Report

A mining report for the site was presented in Reference 1, the main conclusions are summarised below, and the report is presented in full in Appendix A:

- The site is in the likely influence from workings in 4 seams of coal at shallow to 80m depth, last worked in 1878,
- Two mine entrances are shown on the site, with a third within 10m of the site.

Mine Plans

Several mine plans for the site were available in GL archives, and show the only recorded workings beneath the site, as follows:

875/7	Half Yard/Queen seam, abandoned in 1877,
NW 1441/1	Ruabon Yard Seam,
NW 1442	Wall and Bench Seam,
NW 1443	Nant Seam.

In addition, the plan for a nearby opencast called Ty-Gwyn, Reference NW 38 was obtained.

The mine plans confirmed the presence of a major fault trending in an east to west direction crossing the southern section of the site. The position of which is shown on Figure 1.

Mine plan NW 38 shows several old opencasts to the west of the site. The closest some 100m west of the site was on the Top Brassey Seam (Lower Bench) which appears to be to the south of the fault.

To the north of the fault the closest opencast (140m) shows the Nant and New Top seam being worked, with the New Top seam considered to be the Stone Coal within the Fireclay Group, which is above the Nant. The Nant seam is shown as being 2'9" (0.85m) thick and at a depth of around 30m to the west of the site. Therefore the Nant Seam should be at sufficient depth beneath the site.

However, the New Top seam is 3' thick (0.91m) and at a depth of around 10m, see Figure 1. The plan shows that workings were encountered in this seam and these are likely to be at a depth of 20m on the western site boundary.

The mine plan shows the New Top seam having three separate leaves as follows:

- New Top 1.98' thick (0.60m),
- New Middle 0.872' thick (0.26m),

- New Bottom 1.254' thick (0.38m).

The above open cast mines were backfilled by 1951.

The other mine plans showed workings in the deeper seams all by total extraction techniques.

Previous Investigations

Ty Berllan

The house known as Ty Berllan immediately south of the site, see Figure 1 was drilled and grouted by Nkc Geotech in April 2004. It encountered 1.60m of glacial till overlying sandstone, with the Main Coal seam encountered at depths between 6.5 and 8.80m, giving a rock cover of 4.90m to the top of the seam. The underlying Brassey Coal was encountered at 15.2m and was 1.10m thick and 6.4m below the Main Coal. Gas testing during the investigation failed to reveal any mine gas

Immediate North of Inglenewke

At the same time as this investigation a site investigation was carried out on the southern site boundary for a new house adjacent to Inglenewke, see Figure 1.

This revealed the depth to the Main Coal seam to be between 4.6 and 7.1m, with the seam being around 2.50m thick. The thinner upper leaf was also proved, along with the underlying Brassey Seam. Extensive workings were encountered in the Main Coal seam and it was subsequently decided to grout the mine workings. No gas was encountered in any of the boreholes or grout holes.

This Site 2007

Four machine dug trial pits were excavated on site in 2007 by GL for a client who was considering purchasing the site.

The positions of the trial pits are presented on Figure 1 and the logs presented in Appendix B.

This Investigation

Four boreholes were drilled by rotary drilling techniques on the 4th March 2009 to a maximum depth of 30m. The drilling was carried out by PileTec Ltd and supervised on a full time basis by a Chartered Geologist from GL.

The positions of the boreholes were limited due to the presence of wet boggy ground at the eastern section of the site and also services adjacent to the access road.

The locations of the boreholes are shown on Figure 1 and the logs presented in Appendix C. Permission to drill was obtained from the Coal Authority a copy of which is attached in Appendix D.

Ground conditions

Made ground was only encountered in TP2 in the eastern side of Area A and comprised 0.60m of mudstone gravel, which was considered to be colliery spoil. The remaining trial pits proved the underlying glacial till to be a firm to stiff, becoming very stiff with depth, grey mottled brown, silty, sandy clay, with a little gravel and occasional cobble and boulder.

The bedrock beneath the till was encountered at depths between 2.3 and 3.3m and was weathered at surface to a stiff, grey, silty clay, with mudstone gravel, with depth grading into a weak grey thinly bedded mudstone.

The underlying bedrock was proved to be mainly mudstones with associated coals. Backfilled/collapsed workings were encountered in BH 2 and BH 3. BH 4 was drilled solely to accurately determine the location of the fault following the drilling on the adjacent site.

The boreholes are summarised in the table below:

BH	Superficial Thickness (m)	Depth to Stone Seam (m)	Rock Cover (m)	Depth to Workings (m)	Rock Cover (m)	Comments
1	2.20	20.80	18.60			
2	2.10			17.5	15.4	
3	2.10			16.3	14.1	
4	1.6					Drilled in Fault

Cross sections showing the ground conditions beneath the site are presented on Figure 2.

The sequence was best proved in BH 3, where the Red Coal seam was encountered at a depth of 6.50m, although it was not proved in any of the other boreholes. Workings were then encountered at a depth of 16.30m, with a coal at the base overlying a fireclay and then another coal, which is considered to be the Firedamp seam, with the base of the Half Yard proved above.

To the north of the fault the dip direction was confirmed by the boreholes to be towards the south east with a dip amount of 7.5°.

Discussion and Recommendations

Geology

The site can be divided into two distinct areas, A and B, with Area A to the north of the Ty Gwyn Fault and Area B to the south of the fault, see Figure 1.

In Area A, which includes most of the proposed development, the Fireclay Group has been found to have been worked at depth of 16.3 to 17.5m, giving a minimum rock cover of 14.1m. However, the total extraction of the coals and associated fireclays could be up to 3m between the Stone and Firedamp coal seams.

The Ty Gwyn fault has a recorded southerly downthrow of 32m, which places the Main Coal seam at shallow depth beneath Area B. The conjectural outcrop position of the Main Coal seam as taken from the geology plans are presented on Figure 1. This shows two separate outcrop positions, one some 100m to the west of the site and one some 40m east of the site. In between the two outcrop positions the geology plan records the position of a north to south trending fault, with its downthrow to the west, which has caused the Main Coal seam to be repeated, see Figure 1.

Consequently, Area B will be affected by shallow coal workings in the Main and Brassey coal seams. The presence of the fault suggests that the proposed unit in the eastern section of Area B will not be underlain by the Main Coal seam, although workings in The Brassey seam would also be anticipated at shallow depth. However, the presence of the Main and Brassey seams beneath Ty Berllan suggest that this fault is either mis plotted or has a very small downthrow. The units in the western section of Area B will almost certainly be underlain by workings in the Main seam based on the drilling and grouting records from the adjacent site.

Shallow Mine workings

The site investigation confirmed that Area A had been undermined in the Stone Coal and Fireclay Group at depths of 16.3 to 17.5m.

In addition, Area B was proved to be underlain by shallow workings in the Main and Brassey seams.

Workings in these seams are unrecorded and would therefore been carried out at a very early date.

There are two types of mining, partial and total extraction. Methods of partial extraction are nearly all variations of, “Pillar and Stall” techniques, with pillars of coal being left to support the roof of the mine. Extraction ratios of between 30 to 75% were typical, depending on geological conditions and depths. However, it was common practice to work pillars on withdrawal from the mine, so higher extraction ratios may have been possible.

Total extraction is achieved by longwall working and also by various pillar and stall techniques, where the pillars were removed in a second phase of mining, normally on retreat from the mine.

It is important to know the method of mining employed, as total extraction methods normally result in total collapse of the workings, with the exception of the main roadways. While partial abstraction techniques leave voids in the mine, which can become unstable and migrate to surface. These take the form of “crownholes” at surface, which are generally circular and can be several metres in diameter.

No detailed mine plans showing the method of working have survived, consequently, due to the age of the mining it must be assumed that the workings were by pillar and stall and

voids would have been left. This has certainly been confirmed by the drilling and grouting contract on the adjacent site and several of the opencast plans, which are discussed below.

No detailed research into mining subsidence in North Wales has been undertaken. However, extensive research has been carried out in South Wales, where similar pillar and stall mining has taken place. This research revealed:

- Almost all incidents are “crownholes” in form, delayed general subsidence is very rare,
- About 75% of subsidence incidents are caused by the collapse of mine entrances or workings close to outcrop,
- Mine entrances present the greatest risk and account for over 50% of recorded incidents,
- The recorded rate of occurrence is very low.

The remaining subsidence incidents were analysed for their migration ratio (H/T), where H is the thickness of rock above the workings and T is the typical seam/void thickness, taken here as 2m, the height of a typical roadway. Of these 75% of the incidents had an H/T ratio of less than 2 (4m rock cover), with 90% of incidents having an H/T ratio of less than 6 (12m rock cover). The majority of the remaining incidents were related to special events, probably relating to collapses on main roadways, which would have continually been cleared by miners leading to bigger residual voidage.

There is also strong evidence from data gathered from grouting contracts, opencast sites and site investigations that migration of voids above workings generally extends to a limited height above the original void. Records of over 10,000 drill and grout boreholes were collected, in almost every case, the record of broken ground, workings or voids, occurred at or immediately above the anticipated elevation of the worked horizon.

From the above it can be concluded that the majority of residual voids have already collapsed to a stable profile. Otherwise voids would be encountered at a wide range of depths as they progress to the surface.

To assess the risk from shallow abandoned mining the following risk based approach is followed, where risk (R) may be defined as:-

$$R = F \times C$$

Where F is the frequency of an undesirable event and C is the consequences of it happening.

The assessment of risk due to mining subsidence is a twofold process, involving first the assessment of probability of a subsidence event happening, i.e. the subsidence potential; secondly the consequences resulting from that event. For a crown hole to occur, the following must coincide at any one point:

- There must be a potential for mining (PM),
- There must be workings under the site (PW),
- A void must remain in the workings (PV),
- The void must be unstable and able to migrate to surface (PI),
- The thickness of rock overburden must be insufficient to choke the collapse feature before hitting rock head (PR),
- The thickness of drift must be insufficient to prevent the void reaching the surface (PD).

PW Workings Exist

In Area A the site investigation failed to reveal any voids; although backfilled/collapsed workings were encountered. In addition, the opencast plan shows the pattern of workings to the east of the site were largely by total extraction, although several large pillars were recorded.

In Area B the drilling adjacent to the site proved pillar and stall workings in the Main and Brassey Coal seams and the opencast workings in the Brassey Coal seam were clearly pillar and stall.

Therefore workings have been proved beneath both areas of the site.

PV Voids remain in Workings

While no definite voids were encountered in the boreholes in Area A, it is considered extremely likely that roadways exist beneath the site. The roadways were typically the only well constructed part of the workings, as they provided access to the mine. The thickness of the seam would ensure that any residual voidage left by workings or roadways would be around 2 to 3m.

While the drilling and grouting on the adjacent site to the south of the fault proved the workings to be largely backfilled, several large voids were encountered, with associated large grout takes.

PI Voids become unstable

The evidence from BH 3 suggests that some minor migration of void space has occurred. However, there is a potential worked height of 3m, which given a rock cover of 14m gives an H/T ratio of 4.6, which is low.

However, in Area B the drilling on the adjacent site revealed the rock cover to be very low, minimum 1, with some evidence of migration and the work at Ty Berllan recorded the presence of a crown hole.

PR Rock cover insufficient to prevent migration of rock

The investigation has indicated a minimum rock cover of 14m in Area A. Given a starting void height of around 3m, this would give an H/T ratio of 4.6. Consequently, the risk in Area A from upward migration of mine workings is considered to be low. In Area B the

top of the workings cover is virtually at rock head in places and the risk is considered to be very high.

PD Drift cover insufficient to prevent migration to surface

The site investigation has revealed that there is around 2m of superficial cover above the site and will not have an ameliorating affect on limiting void migration.

As can be seen from the above assessment the risk to the surface from crownhole collapse in Area A is low, although it cannot be completely discounted. While in Area B the risk must be considered to be high.

This must then be compared to the consequences and an appropriate remedial measure installed. Should a crownhole occur from shallow mine workings, it is likely that due to the shallow nature of the workings that any collapse would be a small feature by the time it reached surface, which would probably result in a small circular depression several metres wide and several metres deep.

The consequences then have to be considered for buildings and areas of open space. For buildings the consequences in terms of potential loss of life and financial implications should a building collapse are quite high. While in open space around the house the risk is lower, with the only likely consequences being bodily injury.

To address the low level of risk in Area A it is recommended that the houses be founded on raft foundations designed to span potential collapses of 3m and cantilever 1.5m at its edges to protect the building from any potential collapse.

This is confirmed using the methodology recommended in Reference 4, where Subsidence Potential (Sp) is defined as the probability of subsidence occurring at a site during its design life, as follows:

$$Sp = Pa \times Ld \times As/Ai$$

Where Ld = Design life,

Pa = annual probability of subsidence at any point,

As = Site area,

Ai = area affected by incident

Pa can be envisaged as $Pa = Df \times Vf$,

Where Df is a depth factor and Vf a voidage factor.

The depth factor (Df) represents the decreasing likelihood of a collapse reaching surface as the rock cover increases. The voidage factor represents the percentage of void remaining open and the likelihood of such voids becoming long term stable features, which never result in surface subsidence.

Using the values given in Reference 4 results in an R value of 0.8 with the resulting recommendations being to, “incorporate special measures to ensure buildings remain safe in the unlikely event of subsidence”, e.g. raft foundations

The edge of the rafts should extend a minimum of 750mm beneath final ground levels to protect the edge of the raft from frost heave. They should also extend into the underlying glacial till of at least firm to stiff consistency. However, it is understood that it is intended to raise the ground levels by around 1.20m in the eastern section of Area A. Therefore the above foundation solution would be suitable in the controlled earthworks.

In Area B, it is recommended that the units be drilled and grouted. It is only considered necessary to grout the Main Coal seam with a raft designed as above to address the risk from subsidence of mine workings in the Brassey seam. It is also recommended that due to the shallow depth to the mine workings that any garages are also grouted.

Drilling and grouting would involve drilling a perimeter curtain to the workings starting at the deepest point, i.e. down dip, where boreholes would typically be drilled at 3m centres and injected with a thick grout/gravel mix to form a perimeter to the subsequent infill grouting. The workings would then be grouted from a series of boreholes drilled on a 3m grid between the perimeter curtain and the outcrop position.

Access Roads

If it is intended to have the access roads adopted it will be necessary to provide some form of protection to the roads in Area B only. This should comprise provision of a reinforced sub grade using reinforcing geotextiles.

We trust the above report is satisfactory, should you have any queries please call Mike Scott on 01244 661361.

Yours Sincerely

M.J.Scott

Cc Tony Smith (Smith Grant)
 Paul Whale (Studio 83)
 Kim Barnes (REDES)

REFERENCES

1. Residential Development Land off North Road, Ponciau, Wrexham, Phase I Contamination Assessment, Smith Grant, December 08
2. Applied geological mapping in the Wrexham area: geology and land use planning: Technical Report WA/91/4,
3. The Geology of the Country around Wrexham, Memoirs of the Geological Survey, 1928,
4. An analysis of Drill and Grout Records from the South Wales Coalfield, Grouting in the round, Conf Proc, Statham I and Scott M

FIGURES

APPENDIX A

Coal Authority Report

APPENDIX B

Trial Pit Logs
(Previous Investigation)

APPENDIX C

Borehole Logs (This Investigation)

APPENDIX D

Coal Authority Permission