HIGHTHORN SURFACE MINE

GEOTECHNICAL ASSESSMENT REPORT

May 2015

<table>
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<tr>
<th>Prepared by</th>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
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<tr>
<td></td>
<td>David Blythe</td>
<td></td>
<td>28&lt;sup&gt;th&lt;/sup&gt; May 2015</td>
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Issue Status: Final
Purpose: For Client’s information

Prepared by:

DAB Geotechnics Ltd.,
Ellington, MORPETH,
Northumberland
Tel. No. 07711 168524
E-mail dblythe735822@btinternet.co.uk
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EXECUTIVE SUMMARY AND HSE NOTIFICATION

A geotechnical assessment of Highthorn Surface Mine has been carried out in compliance with the Quarries Regulations (1999). This executive summary may be used as a notification to the HSE in accordance with Regulations 37 and 45.

1. **Brief Description**

   H. J. Banks Mining Ltd. plans to develop Highthorn site and recover coal and fireclay reserves by shallow excavation. The development will entail the construction of topsoil, subsoil and overburden storage mounds and water treatment lagoons. The excavations will be extended to a maximum depth of about 71m below ground level.

2. **Location**

   The centre point of the Highthorn site is located about 2km south-east of Widdrington, 2km east of Widdrington Station and 2.5km north-north-west of Ellington in the County of Northumberland. The approximate Grid Reference for the centre point is 426865 594525 (1/50,000 Ordnance Survey Sheet No. 81, Alnwick & Morpeth).

3. **Geotechnical Specialist’s Conclusion**

   The excavation slopes; overburden mounds OBM1 and OBM2; subsoil mounds SSM1, SSM2, SSM3, SSM4, SSM5, SSM7 and SSM11; drift storage mound DRM1; topsoil mounds TSM4 and TSM5; and the backfill tip and loosewall slopes have been identified as, ‘significant hazards’. The stability of these features has been assessed and recommendations have been made with regard to their formation.

4. **Frequency of Geotechnical Assessments (Regulation 33(1d) and 34)**

   Upon commencement of site operations, the geotechnical assessment should be reviewed at quarterly intervals by the operator’s appointed geotechnical specialist or at shorter intervals, if necessary, as defined in Regulation 34.

Signed…. …C. Eng. Date........28th May 2015..........
1. **INTRODUCTION**

1.1 **General**

H. J. Banks Mining Ltd. (Banks) has identified shallow coal and fireclay reserves at its Highthorn site in Northumberland and intends to recover these by surface mining. DAB Geotechnics Ltd. has been appointed by Banks to prepare a geotechnical assessment in accordance with the Quarries Regulations (1999).

The following features have been identified as representing, ‘significant hazards’, during the design and planning stages of the site:

(i) the excavation slopes which will reach a maximum height of 71m;
(ii) the overburden storage mounds OBM1 and OBM2 due to their height and size;
(iii) topsoil screening mounds TSM4 and TSM5 due to their close proximity to the excavation slopes;
(iv) subsoil and drift material screening mounds SSM1, SSM3, SSM5, SSM7 and DRM1 due to their close proximity to the excavation slopes;
(v) subsoil screening mounds SSM2, SSM4 and SSM11 due to their size;
(vi) the backfill tip due to its size and the loosewall slopes due to their height.

A copy of the geotechnical appraisal is given in Appendix A.

Consideration has also been given to the presence of groundwater and mine gas. These issues are further discussed in two separate reports prepared by DAB Geotechnics Ltd. (2015a & b).

1.2 **Location**

The centre point of Highthorn site is located about 2km south-east of Widdrington, 2km east of Widdrington Station and 2.5km north-north-west of Ellington in the County of Northumberland (Figure 1). The approximate Grid Reference for the centre point is 426865 594525 (1/50,000 Ordnance Survey Sheet No. 81, Alnwick & Morpeth). An aerial photograph is presented as Figure 2.

The site is bounded to the west by the A1068, to the north-east by the C110 and on all other sides by agricultural land. Hemscoft Hill Farm is located in its eastern part, whilst the former Highthorn Farm lies immediately to the south.
2. **TOPOGRAPHY AND LAND USE HISTORY**

2.1 **Topography**

The proposed site is located on the Northumberland coastal plain. Ground levels range from just over 26m above Ordnance Datum (AOD) along the western boundary of the site to 2m AOD on the north-eastern perimeter. Surface gradients reach a maximum of about 1v in 13h (4.4°) and are generally directed towards the east.

2.2 **Land Use History**

Early editions of the 1/2500 scale OS maps indicate that the land has been in agricultural use for some considerable time. However, there is also a long history of surface and underground coal mining in the area. Backfilled excavations are present in the northern and north-eastern parts of the site. Exploratory drilling has confirmed that the fill comprises overburden and there are no records of any materials having been imported. Abandoned mine workings are located in the south and west and although these have given rise to surface subsidence, there are no colliery spoil tips or mine openings within the site perimeter. It is therefore unlikely that there is any contamination. None has been encountered during extended ground investigations.
3. **GEOLOGY**

3.1 **Published Information**

The geology of the site has been determined by reference to a number of plans and documents:

- 1/50,000 Scale Geological Sheet No. 9. Rothbury. Drift Edition (1977);
- 1/63,360 Scale Geological Sheet No. 9. Rothbury. Solid Edition (1966);
- 1/50,000 Scale Geological Sheet No. 9 Rothbury. Bedrock and Superficial Deposits (2009);
- 1/10,560 scale Geological Maps, Sheet Nos. NZ29NE and SE;
- 1/10,000 scale Geological Maps, Sheet Nos. NZ29NE and SE; and
- ‘Geology of the Rothbury District’ (Lawrence et al., 2011).

The Rothbury maps were originally surveyed in 1895 and again in the early 1920’s, but the BGS has since undertaken a complete revision and the results were published in 2009. This entailed detailed fieldwork and the collation of borehole data, coal seam outcrop and fault locations provided by British Coal, the Coal Authority and other parties. Some of the field slips for the area of interest have been examined with the Survey’s permission. Reference has also been made to a number of archive boreholes held by the BGS.

3.2 **Site Investigations**

The extended site was previously investigated by the National Coal Board and British Coal when approximately 1,700 boreholes were drilled to a maximum depth of 288m below ground level (bgl), though typically not greater than 160m. Many of these boreholes were partly or fully cored from rockhead and logged using geophysical tools. A number of piezometers were also installed. Since that time, Banks have drilled forty-nine boreholes to a maximum depth of 122m bgl, six of which have been instrumented for groundwater monitoring purposes (nos. PZ1 to PZ6). The borehole data have been used to determine the geological structure, the coal reserves, the thickness and nature of the overburden and the lateral and vertical extent of the proposed excavations.

A geotechnical site investigation was carried out by Allied Exploration & Geotechnics Ltd. in January 2015 to examine the nature and properties of the superficial deposits. This comprised a total of 15 boreholes on 13 locations, together with a programme of soil laboratory testing. The borehole logs and test results are presented in, ‘Proposed Highthorn Surface Mine Ground Investigation – Factual Report’ (Contract 4007), a copy of which is provided in Appendix B. Reference has also been made to the results of an earlier ground investigation for a proposed nuclear power station. This was centred largely on the northern part of the site, although some boreholes were drilled offshore. The location of all the geotechnical boreholes and trial pits is shown in Figure 3.
The following plans and documents have been prepared or provided by Banks:

1/2500 scale Topographic Plan;
1/15,000 scale Composite Working Method Plan (Dwg. No. HJB/BA795/PA06);
1/15,000 scale Phasing Plans (Dwg. Nos. HJB/BA795/PA07 to PA11);
1/15,000 scale Restoration Strategy Plan (Dwg. No. HJB/BA795/PA13);
1/2500 scale Drift Thickness Plan;
1/2500 scale Rockhead Contours Plan;
1/2500 scale Seam Contour Plan for the Ashington (4D00) seam;
1/2500 scale Seam Contour Plan for the High Main or Diamond (E000) seam;
1/2500 scale Seam Contour Plan for Top Main (F200) seam;
1/2500 scale Seam Contour Plan for Bottom Yard (G100) seam;
1/2500 scale Abandoned Mine Plans for Ellington and Linton Collieries;
1/2500 scale Abandoned Mine Plan for Ferneybeds Colliery; and
1/2500 scale Abandonment Plans for Druridge, Radar South and Wallis Opencast Sites.

Reference has also been made to the 1/10,560 scale Old Workings Plans, extracts of which are provided in Appendix C.

3.3 Geologic Succession

3.3.1 Superficial Deposits

3.3.1.1 Alluvium

A very thin deposit of alluvium (i.e. interbedded clay, silt, sand and gravel) is present along the course of Hemscott Burn which flows through the south-eastern part of the site.

3.3.1.2 Made Ground

Areas of backfilled opencast workings are present in the northern and north-eastern parts of the site and beyond its perimeter towards the north-west (Section 2.5.1). The deposits comprise a heterogeneous mixture of partly remoulded, soft to firm, silty sandy, gravelly clay and silt to boulder sized, angular to subangular fragments of mudstone, siltstone, sandstone and seatearth. The materials were loose tipped, but will have undergone significant self-weight compaction since their placement. They range in thickness from 6 to 58m.

3.3.1.3 Glacial Deposits

The BGS 1/50,000 scale Geological Maps record that apart from the areas affected by historic surface mining, Hithorn site is covered by Devensian glacial till or, ‘boulder clay’.
The 1/2500 scale Drift Thickness Plan provides a more definitive picture of the conditions on the site because it is based on exploratory drilling. The plan shows that the deposits measure between 7.50 and 28.25m and that they generally thicken towards the north and south-east due to the presence of infilled glacial or en-glacial channels. The borehole logs provided in AEG’s Factual Report confirm that the deposits predominantly comprise a succession of firm to stiff and very stiff clays (glacial till).

3.3.1.4 Rockhead Surface

The glacially weathered rockhead surface is generally inclined towards the south and east in the western part of the site, whilst a more complex pattern is present in the east. The gradients range from about 1v in 57h (1.0°) to 1v in 8h (7.1°). The surface has been modified by historic surface mining in the northern part of the site. Details are shown on the Rockhead Contours Plan.

3.3.2 Bedrock Strata

The excavations will extend from above the Ashington (4D00) coal seam to the base of the Bottom Yard (G100). Details are presented on the Generalized Vertical Section (Figure 4). The strata form part of the Pennine Middle Coal Measures of Upper Carboniferous age. They comprise interbedded silty mudstones, siltstones, sandstones, seatearths and coal seams. None of the strata is exposed on the site.

3.4 Geological Structure

The geological structure at Highthorn site is dominated by the Grange Moor Fault (Figure 5). This is one of the major WSW-ENE faults that traverse the coalfield and is accompanied by a number of subparallel structures. These variously extend across the northern part of the proposed excavation area and downthrow to the south by up to about 45m. The downthrown strata dip towards the east, south-east and north-east at between 1v in 56h (1.0°) and 1v in 12h (4.8°).

Surveys carried out at a number of historic surface mines in the Highthorn area and core samples from the site have shown that there are at least two major, subvertical joint sets. These are probably aligned WSW-ENE and NNW-SSE (i.e. parallel and at right angles to the trend of the Grange Moor Fault). Added to this, many of the strata have been fractured by mining subsidence.

3.5 Mining History

3.5.1 Surface Mining

Copies of the abandonment plans for the former Druridge, Radar South and Wallis surface mines have been obtained from the Coal Authority and a summary of the recorded details is given in Table 1. The location of the backfilled excavations is shown on the 1/10,560 scale Old Workings Plans, extracts of which are presented in Appendix C.
Druridge (OE/COMP/02/173)  
Coaling from 17th September 1951 to 20th January 1954.  
Coal recovered from the Top Yard Top Leaf or Top Ulgham (G230), Top Yard (G210) and Bottom Yard (G120/G110).

Radar South (OE/COMP/02/190)  
Coaling from September 1954 to March 1956.  
Coal recovered from Top Yard Top Leaf or Top Ulgham (G230), Top Yard (G210), Bottom Yard (G120/G110), Top Bensham (H200), Bottom Bensham (H100), Little Wonder (J300/J200), Top of Radar (J100), New of Radar (K200), Main of Broomhill (K100).

Wallis (OE/COMP/02/190)  
Coaling from July 1951 to March 1954.  

<table>
<thead>
<tr>
<th>Site Name, Drawing Ref. No. and Coaling Dates</th>
<th>Notes</th>
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<tr>
<td>Druridge (OE/COMP/02/173) Coaling from 17th September 1951 to 20th January 1954.</td>
<td>Coal recovered from the Top Yard Top Leaf or Top Ulgham (G230), Top Yard (G210) and Bottom Yard (G120/G110).</td>
</tr>
<tr>
<td>Radar South (OE/COMP/02/190) Coaling from September 1954 to March 1956.</td>
<td>Coal recovered from Top Yard Top Leaf or Top Ulgham (G230), Top Yard (G210), Bottom Yard (G120/G110), Top Bensham (H200), Bottom Bensham (H100), Little Wonder (J300/J200), Top of Radar (J100), New of Radar (K200), Main of Broomhill (K100).</td>
</tr>
<tr>
<td>Wallis (OE/COMP/02/190) Coaling from July 1951 to March 1954.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Summary of Details Shown on Surface Mine Abandonment Plans

Site investigations have confirmed that the backfill is largely confined within the areas shown on the abandonment plans, though some has been spread during the course of their restoration.

3.5.2 Underground Mining

Records show that there are abandoned underground workings in the Ashington (4D00), High Main or Diamond (E000), Top Main (F200), Yard (G210/G120), Bottom Yard (G120/G110) and Little Wonder (J300/J200) seams within the site boundary. The workings extend from the former Linton, Ellington and Ferneybeds Collieries (Figure 5, Appendix C). The proposed excavations have been designed to avoid the more intensely worked areas and will not extend to the Little Wonder (J300/J200) seam. There are no recorded mine openings (i.e. shafts and drifts) on the site and there do not appear to be any uncharted mine workings.

3.6 Engineering Properties

3.6.1 Superficial Deposits

A programme of laboratory soil testing has been undertaken as part of AEG’s ground investigations at Hithorn site. These tests were carried out in accordance with BS1377 (1990) and details are provided in the Ground Investigation Report (Appendix B). A summary of the consolidated, undrained (‘effective stress’) test results is provided in Table 2. Reference has also been made to the test results from the National Coal Board’s offshore drilling and the permitted Ferneybeds surface mine site which lies immediately to the southwest (Tables 3 and 4). The test results have been used to carry out the slope stability calculations detailed in Appendices D and E.

Detailed q’-p analysis of British Coal’s site investigation data in Northumberland has provided shear strength parameters for the principal types of cohesive glacial material (Robertson, 1991). The results are summarized in Table 5 and are similar to those reported by Treter (1999), but are higher than those derived from all the Hithorn test results (Appendix D).
<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Depth (m bgl)</th>
<th>Sample Description</th>
<th>Final Moisture Content (%)</th>
<th>Final Bulk Density (Mg/m$^3$)</th>
<th>$c'$ (kN/m$^2$)</th>
<th>$\phi'$ (º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01</td>
<td>2.50</td>
<td>Firm and stiff brown mottled grey gravelly CLAY. Gravel is fine to coarse subangular to subrounded and includes sandstone and coal (Unit 1).</td>
<td>22.9</td>
<td>2.08</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>4.50</td>
<td></td>
<td>Firm and stiff brown mottled grey gravelly CLAY. Gravel is fine to coarse subangular to subrounded and includes sandstone and coal (Unit 1).</td>
<td>19</td>
<td>2.17</td>
<td>5</td>
<td>27</td>
</tr>
<tr>
<td>8.50</td>
<td></td>
<td>Firm brown laminated silty slightly gravelly CLAY local silty partings. Gravel is fine to medium angular to subrounded and includes sandstone (Unit 4).</td>
<td>14.2</td>
<td>2.21</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>10.00</td>
<td></td>
<td>Firm dark brown gravelly CLAY. Gravel is fine to medium angular to subrounded and includes sandstone and coal (Unit 2).</td>
<td>11.8</td>
<td>2.26</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>H04</td>
<td>1.50</td>
<td>Firm and stiff brown gravelly CLAY. Gravel is fine to medium angular to subrounded and includes sandstone and coal.</td>
<td>21.8</td>
<td>1.52</td>
<td>12</td>
<td>25.5</td>
</tr>
<tr>
<td>3.50</td>
<td></td>
<td>Firm and stiff brown gravelly CLAY. Gravel is fine to medium angular to subrounded and includes sandstone and coal.</td>
<td>21.1</td>
<td>2.07</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>5.50</td>
<td></td>
<td>Stiff and very stiff dark brown gravelly CLAY with low to medium cobbles. Gravel is fine to medium subangular to subrounded and includes sandstone and coal.</td>
<td>12.4</td>
<td>2.25</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>8.50</td>
<td></td>
<td>Stiff brown gravelly CLAY with low to medium cobbble content. Gravel is fine to medium subangular to subrounded and includes sandstone and coal.</td>
<td>11.4</td>
<td>2.31</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>11.50</td>
<td></td>
<td>Stiff brown gravelly CLAY with low to medium cobbble content. Gravel is fine to medium subangular to subrounded and includes sandstone and coal.</td>
<td>12.4</td>
<td>2.25</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>H05</td>
<td>1.00</td>
<td>Firm and stiff slightly sandy gravelly CLAY. Gravel is fine to coarse subangular to subrounded and includes sandstone and coal.</td>
<td>16.7</td>
<td>2.14</td>
<td>5</td>
<td>35</td>
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<tr>
<td>H08</td>
<td>1.50, 3.50 &amp; 5.50</td>
<td>Remoulded firm and stiff brown mottled grey and brown sandy gravelly CLAY with some sandy horizons. Sand is fine to medium. Gravel is fine to coarse angular to subrounded and includes sandstone and coal. Remoulded.</td>
<td>15.0</td>
<td>2.06</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>8.50, 11.50, 17.50 &amp; 19.50</td>
<td>Remoulded firm and stiff dark brown gravelly CLAY. Gravel is fine to coarse angular to subrounded and includes sandstone and coal. Remoulded.</td>
<td>11.0</td>
<td>2.16</td>
<td>9</td>
<td>26</td>
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</table>

**Table 2 Effective Stress Shear Strength Results taken from AEG’s Final Factual Report for Highthorn Site**
<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Depth (m bgl)</th>
<th>Sample Description</th>
<th>Final Moisture Content (%)</th>
<th>Final Bulk Density (Mg/m³)</th>
<th>(c') (kN/m²)</th>
<th>(\phi^') (º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H09</td>
<td>4.50</td>
<td>Firm and stiff laminated brown mottled grey slightly sandy gravelly CLAY. Gravel is fine to coarse angular to subangular and includes sandstone, mudstone and coal (Unit 4).</td>
<td>22.7</td>
<td>2.06</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>17.50</td>
<td>Stiff and very stiff brown faintly laminated silty CLAY with silt/fine sand lenses/interbeds.</td>
<td>18.5</td>
<td>2.05</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>Firm and stiff red brown mottled grey slightly sandy gravelly CLAY with some sand pockets. Gravel is fine to coarse angular to subrounded and includes sandstone and coal (Unit 1).</td>
<td>19.4</td>
<td>1.95</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>Soft brown sandy CLAY. Sand is fine to medium.</td>
<td>21.1</td>
<td>2.05</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>H11A</td>
<td>4.50</td>
<td>Firm and stiff dark brown gravelly CLAY. Gravel is angular to subangular and includes sandstone and coal.</td>
<td>18.5</td>
<td>2.14</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>6.50</td>
<td>Firm and stiff dark brown gravelly CLAY. Gravel is angular to subangular and includes sandstone and coal.</td>
<td>11.1</td>
<td>2.30</td>
<td>0</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td>9.50</td>
<td>Firm and stiff dark brown gravelly CLAY. Gravel is angular to subangular and includes sandstone and coal.</td>
<td>10.8</td>
<td>2.28</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>Firm and stiff brown gravelly CLAY. Gravel is fine to coarse subangular to subrounded and includes sandstone and coal.</td>
<td>21.3</td>
<td>2.07</td>
<td>11</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>Firm locally soft dark brown laminated slightly gravelly CLAY. Gravel is fine to medium angular to subangular and includes sandstone (Unit 4).</td>
<td>24.7</td>
<td>1.92</td>
<td>9</td>
<td>22.5</td>
</tr>
<tr>
<td>H13</td>
<td>3.50</td>
<td>Firm locally soft dark brown laminated slightly gravelly CLAY. Gravel is fine to medium angular to subangular and includes sandstone (Unit 4).</td>
<td>22.1</td>
<td>2.05</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>5.50</td>
<td>Firm dark grey gravelly CLAY. Gravel is fine to coarse angular to subrounded and including sandstone and coal.</td>
<td>Sample proved unsuitable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.00</td>
<td>Firm dark grey gravelly CLAY. Gravel is fine to coarse angular to subrounded and including sandstone and coal (Unit 2).</td>
<td>11.9</td>
<td>2.21</td>
<td>8</td>
<td>29</td>
</tr>
</tbody>
</table>

Table 2 cont’d. Effective Stress Shear Strength Results taken from AEG’s Final Factual Report for Hithorn Site
<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Depth (m bgl)</th>
<th>Sample Description</th>
<th>Final Moisture Content (%)</th>
<th>Final Bulk Density (Mg/m³)</th>
<th>$c'$ (kN/m²)</th>
<th>$\phi'$ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>601</td>
<td>6.50</td>
<td>Stiff brown slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>24</td>
<td>2.06</td>
<td>0</td>
<td>22.5</td>
</tr>
<tr>
<td>603</td>
<td>4.50</td>
<td>Firm to stiff dark grey brown slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>22</td>
<td>2.09</td>
<td>12</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>11.50</td>
<td>Stiff laminated dark grey brown slightly sandy slightly gravelly CLAY with sand on laminae (Unit 4).</td>
<td>27</td>
<td>2.00</td>
<td>12</td>
<td>19.5</td>
</tr>
<tr>
<td>604</td>
<td>4.00</td>
<td>Firm to stiff brown slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>23</td>
<td>2.06</td>
<td>4</td>
<td>27.5</td>
</tr>
<tr>
<td>605</td>
<td>6.50</td>
<td>Stiff brown slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>25</td>
<td>2.05</td>
<td>0</td>
<td>22.5</td>
</tr>
<tr>
<td>606</td>
<td>3.00</td>
<td>Firm to stiff grey brown sandy slightly gravelly CLAY (Unit 2).</td>
<td>24</td>
<td>2.06</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>5.00</td>
<td>Firm to stiff grey brown slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>24</td>
<td>2.02</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>9.50</td>
<td>Stiff brown poorly laminated slightly sandy slightly gravelly CLAY (Unit 2).</td>
<td>26</td>
<td>2.03</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>14.00</td>
<td>Very stiff grey brown sandy gravelly CLAY (Unit 3).</td>
<td>9</td>
<td>2.38</td>
<td>30</td>
<td>29.5</td>
</tr>
</tbody>
</table>

**Table 3 Effective Stress Shear Strength Results taken from the National Coal Board’s Offshore Boreholes**
<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Depth (m bgl)</th>
<th>Sample Description</th>
<th>Final Moisture Content (%)</th>
<th>Final Bulk Density (Mg/m³)</th>
<th>c' (kN/m²)</th>
<th>°</th>
</tr>
</thead>
<tbody>
<tr>
<td>GH01</td>
<td>5.50</td>
<td>Firm thinly laminated dark brown slightly sandy slightly gravelly CLAY. Gravel is fine to coarse angular cubic tabular rough and includes sandstone, limestone and coal. Clay of intermediate to high plasticity. (Unit 4)</td>
<td>23.3</td>
<td>2.07</td>
<td>9</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>9.50</td>
<td></td>
<td>18.4</td>
<td>2.27</td>
<td>6</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>13.50</td>
<td>Very stiff grey brown slightly sandy gravelly CLAY with medium cobble content. Gravel is fine to coarse angular cubic tabular rough and includes sandstone, limestone, coal and mudstone. Cobbles are angular cubic tabular rough and include mudstone and sandstone. Clay of low plasticity. (Unit 3)</td>
<td>10.7</td>
<td>2.26</td>
<td>0</td>
<td>28.0</td>
</tr>
<tr>
<td>GH02</td>
<td>1.50</td>
<td>Firm thinly laminated brown with grey veining slightly sandy CLAY of intermediate to high plasticity. Clay of intermediate plasticity. (Unit 4)</td>
<td>24.5</td>
<td>2.02</td>
<td>3</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>5.50</td>
<td>Firm thinly laminated brown with grey veining slightly sandy CLAY of intermediate to high plasticity. Clay of intermediate plasticity with some sand lenses. (Unit 4)</td>
<td>27.3</td>
<td>2.01</td>
<td>2</td>
<td>27.0</td>
</tr>
<tr>
<td></td>
<td>14.00</td>
<td>Very stiff dark grey slightly sandy gravelly CLAY of low plasticity with medium cobble content. Gravel is fine to coarse angular cubic rough and includes sandstone, limestone, mudstone and coal. Cobbles are subangular cubic rough and include sandstone. (Unit 3)</td>
<td>11.4</td>
<td>2.23</td>
<td>5</td>
<td>27.0</td>
</tr>
<tr>
<td>GH03</td>
<td>3.50</td>
<td>Stiff dark brown slightly sandy slightly gravelly CLAY. Gravel is fine to coarse angular cubic rough and includes sandstone, limestone, mudstone and coal. (Unit 2)</td>
<td>15.2</td>
<td>2.22</td>
<td>4</td>
<td>29.5</td>
</tr>
<tr>
<td></td>
<td>11.00</td>
<td>Very stiff dark grey sandy gravelly CLAY of low plasticity with medium cobble content. Gravel is fine to coarse subangular cubic tabular rough and includes sandstone, limestone, mudstone and coal. (Unit 3)</td>
<td>11.3</td>
<td>2.26</td>
<td>0</td>
<td>27.5</td>
</tr>
<tr>
<td>GH08</td>
<td>6.00</td>
<td>MADE GROUND. Stiff grey slightly sandy slightly gravelly clay with high cobble content. Gravel is fine to coarse angular cubic rough and includes mudstone and sandstone. Cobbles are angular cubic rough and include mudstone and sandstone. (Opencast Backfill).</td>
<td>16.7</td>
<td>2.10</td>
<td>6</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4 Effective Stress Shear Strength Results taken from AEG’s Final Factual Report for Ferneybeds Site

<table>
<thead>
<tr>
<th>Soil Description (Unit No.)</th>
<th>Undrained Shear Strength (cu) (kN/m²)</th>
<th>Effective Shear Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft to firm, occasionally stiff, mottled orange brown/grey, sandy silty CLAY with some to much fine to medium gravel. (Unit 1)</td>
<td>150 (30-375)</td>
<td>c' (kN/m²) 0°</td>
</tr>
<tr>
<td>Firm to stiff, brown to dark brown sandy silty CLAY with some fine to coarse gravel, occasional cobbles and boulders. (Unit 2)</td>
<td>180 (50-410)</td>
<td>2.6</td>
</tr>
<tr>
<td>Stiff to very stiff, grey, grey/brown or grey sandy silty CLAY with some to much fine to coarse gravel, occasional cobbles and boulders. (Unit 3)</td>
<td>200 (65-410)</td>
<td>0</td>
</tr>
<tr>
<td>Soft, firm or stiff, predominantly brown, laminated CLAY with occasional partings of sand and silt, occasional gravel. (Unit 4)</td>
<td>100 (50-360)</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5 Summary of Shear Strength Parameters Derived from the Analysis of British Coal’s Site Investigation Data (Robertson, 1991)
3.6.2 Bedrock Strata

3.6.2.1 Continuously Cored Boreholes

The following boreholes were continuously cored from rockhead and are located within or adjacent to the proposed excavation area as shown in Figure 3:

1161, 1252, 1494, 1903, 2006, 2216, 2259, 2280, 2320 and 2501.

Detailed logs have been prepared which include fracture index and rock quality designation (RQD) measurements. The RQD values generally reflect the intact strength of the various rock types and the effects of natural and mining induced fractures. By far the majority of the natural fractures are very steeply dipping.

3.6.2.2 Geophysical Logs

The majority of the boreholes drilled on Highthorn site were logged using a dual density, natural gamma tool. Greater resolution of the thinner coal seams and bands was achieved using a bed resolution density (BRD) tool. A number of more specialised logs were also obtained using neutron-neutron and sonic tools from which it is possible to derive some indication of rock strength.

3.6.2.3 Very Weak Mudstone/Soft Clay Horizons

Coal Measures strata are characterized by the presence of relatively thin (generally ≤ 25mm), very weak mudstone or soft clay horizons. These have been referred to as, ’clay mylonites’, and their presence can strongly influence the stability of excavated slopes, even where the dip is relatively low. Table 6 provides typical shear strength parameters as determined by Stimpson and Walton (1970), Salehy et al (1977) and Newcastle University’s rock mechanics laboratory.

<table>
<thead>
<tr>
<th>Peak Shear Strength</th>
<th>Residual Shear Strength</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>c’ = 11 - 12.4 kN/m²</td>
<td>c’ = 0 kN/m²</td>
<td>Stimpson and Walton (1970)</td>
</tr>
<tr>
<td>Φ’ = 16º</td>
<td>φ’ = 11 - 11.5º</td>
<td></td>
</tr>
<tr>
<td>–</td>
<td>c’ = 6 kN/m²</td>
<td>Salehy, Money and Dearman (1977)</td>
</tr>
<tr>
<td></td>
<td>φ’ = 9º</td>
<td></td>
</tr>
<tr>
<td>c’ = 1.5 – 25 kN/m²</td>
<td>c’ = 3 - 23 kN/m²</td>
<td>Newcastle University* (1993)</td>
</tr>
<tr>
<td>Φ’ = 17 - 18.9º</td>
<td>φ’ = 11.3 - 17.0º</td>
<td></td>
</tr>
</tbody>
</table>

* Unpublished data.

Table 6 Summary of Shear Strength Data for Very Weak Mudstone and Soft Clay Horizons

Similar test results for shear zones in sediments of vastly differing age have been reported by Hosseyni, Torii and Bromhead (2011). Their de-stabilizing effects were first reported following the New Cross railway cutting failure in 1841 (Gregory, 1844).
A lengthy programme of sampling and testing of very weak strata was carried out in northern England as part of a post-graduate research project at Newcastle University. Table 7 provides a summary of some of the test results. The accuracy of the testing cannot be guaranteed.

<table>
<thead>
<tr>
<th>SITE</th>
<th>HORIZON</th>
<th>Peak Strength</th>
<th>Residual Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$c'$ (kN/m$^2$)</td>
<td>$\phi'$ (°)</td>
</tr>
<tr>
<td>Highthorn Surface Mine – Geotechnical Assessment Report</td>
<td></td>
<td>$c_r'$ (kN/m$^2$)</td>
<td>$\phi_r'$ (°)</td>
</tr>
<tr>
<td>Chester House, Northumberland</td>
<td>Below Beaumont Rider (2M00)</td>
<td>25.0</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>Below Top Beaumont (N200)</td>
<td>3.5</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>Above Widdrington Bottom Yard Top Leaf (P102)</td>
<td>1.5</td>
<td>18.9</td>
</tr>
<tr>
<td>Chester House Extension, Northumberland</td>
<td>Below Brockwell (T000)</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Below Brockwell (T000)</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Above Top Bandy (S200)</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Herrington Colliery, Tyne &amp; Wear</td>
<td>Below Unnamed (A400)</td>
<td>18</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>Below Unnamed (A300)</td>
<td>6</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>Below Usworth Middle Leaf (B220)</td>
<td>-3</td>
<td>25.7</td>
</tr>
<tr>
<td></td>
<td>Below Usworth Bottom Leaf (B100)</td>
<td>12</td>
<td>24.7</td>
</tr>
<tr>
<td>Foxhouse South, Cumbria</td>
<td>Below Eighteen Inch (φ000)</td>
<td>-26</td>
<td>23.7</td>
</tr>
<tr>
<td></td>
<td>Above Top Half (1M00)</td>
<td>-8.2</td>
<td>22.6</td>
</tr>
<tr>
<td>Foxhouse Northwest, Cumbria</td>
<td>Above Upper Yard (1F00)</td>
<td>2.5</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>Above Upper Yard (1F00)</td>
<td>13.0</td>
<td>16.7</td>
</tr>
</tbody>
</table>

Notes. $c'$ and $\phi'$ represent (respectively) the cohesion and angle of friction corresponding to the maximum (peak) shear strength determined for a consolidated and undrained sample of weak clay in a shear box test. $c_r'$ and $\phi_r'$ represent the cohesion and angle of friction corresponding to the residual shear strength determined after repeated shearing of a consolidated and undrained sample. Values in parenthesis have been determined by assuming that the tangent to the non-linear failure envelope passes through the origin (i.e. $c'$ or $c_r'$ is zero).

**Table 7 Shear Strength Parameters for Very Weak Mudstone/Soft Clay Horizons(1977)**  
*(from unpublished Ph.D. thesis by D Jameson, Newcastle University)*

### 3.6.2.4 Joint Shear Strengths

Typical shear strength test results for natural joints in Coal Measures lithologies are provided in Table 8.
### Summary of Frictional Properties of Discontinuities in Coal Measures Strata (from Hassani, 1980)

<table>
<thead>
<tr>
<th>Rock Type (Carboniferous)</th>
<th>Location</th>
<th>Test Condition</th>
<th>No. of Tests</th>
<th>Apparent Cohesion ($c'$) (MN/m²)</th>
<th>Angle of Friction ($\phi'$) (°)</th>
<th>Range of Normal Stress (MN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine grained</td>
<td>East Midlands</td>
<td>Dry</td>
<td>42</td>
<td>0.091-0.370</td>
<td>36.7-37.4</td>
<td>0.2-9.5</td>
</tr>
<tr>
<td>Medium grained</td>
<td>East Midlands</td>
<td>Dry</td>
<td>8</td>
<td>0.218</td>
<td>34.7</td>
<td>0.5-3.0</td>
</tr>
<tr>
<td>Medium grained</td>
<td>East Midlands</td>
<td>Wet</td>
<td>16</td>
<td>0.658</td>
<td>32.4</td>
<td>0.3-8.0</td>
</tr>
<tr>
<td>Medium grained</td>
<td>North East</td>
<td>Dry</td>
<td>11</td>
<td>0.102</td>
<td>36.7</td>
<td>0.2-5.0</td>
</tr>
<tr>
<td>Coarse grained</td>
<td>North East</td>
<td>Dry</td>
<td>14</td>
<td>1.500</td>
<td>30.0</td>
<td>2.5-10.5</td>
</tr>
<tr>
<td>Coarse grained weathered</td>
<td>East Midlands</td>
<td>Dry</td>
<td>114</td>
<td>0.119</td>
<td>34.0</td>
<td>0.3-4.0</td>
</tr>
<tr>
<td>Medium grained weathered</td>
<td>East Midlands</td>
<td>Dry</td>
<td>70</td>
<td>0.456</td>
<td>28.3</td>
<td>0.2-12.0</td>
</tr>
<tr>
<td>Medium grained weathered</td>
<td>East Midlands</td>
<td>Wet</td>
<td>45</td>
<td>0.364</td>
<td>25.7</td>
<td>0.2-6.5</td>
</tr>
<tr>
<td>Siltstone</td>
<td>Scotland</td>
<td>Dry</td>
<td>29</td>
<td>0.083-0.796</td>
<td>19.8-49.0</td>
<td>0.5-2.6</td>
</tr>
<tr>
<td>Mudstone</td>
<td>Scotland</td>
<td>Dry</td>
<td>97</td>
<td>0.000-0.458</td>
<td>21.9-38.2</td>
<td>0.1-4.0</td>
</tr>
<tr>
<td></td>
<td>South Wales</td>
<td>Dry</td>
<td>36</td>
<td>0.000-0.071</td>
<td>23.1-24.1</td>
<td>0.2-2.0</td>
</tr>
<tr>
<td></td>
<td>East Midlands</td>
<td>Dry</td>
<td>14</td>
<td>0.042</td>
<td>23.8</td>
<td>0.03-0.9</td>
</tr>
<tr>
<td></td>
<td>East Midlands</td>
<td>Wet</td>
<td>11</td>
<td>0.355</td>
<td>14.8</td>
<td>0.05-1.6</td>
</tr>
</tbody>
</table>

1. Peak shear envelopes for every individual joint sample were evaluated by linear regression (Coulomb's Law). Generally, there was insufficient data to permit the determination of (non-linear) power law relationships.

2. The variation of apparent cohesion and angle of friction for each lithology is largely due to differing surface roughness and inherent strength. The shear strength of mudstone joints is lower than those for siltstone and sandstone because the surfaces are generally smoother.

3. Significant reduction in shear strength occurs when joint surfaces are wet, particularly in mudstones.

4. Comparison of test results for saw cut and natural rock surfaces indicates that the effect of roughness is relatively small.

**Additional Note.** These tests were carried out as part of a research programme at Nottingham University and as such their accuracy cannot be guaranteed.
4. HYDROLOGY AND HYDROGEOLOGY

4.1 Hydrology

4.1.1 Rainfall

The long term average annual rainfall for Highthorn site is about 667mm (NERC, 1999).

4.1.2 Drainage

By far the majority of the site is drained by Hemscott Burn. This flows in a north-easterly direction across the south-eastern part of the site. Further details are provided in the Hydrological and Hydrogeological Assessment (DAB Geotechnics Ltd., 2015a).

The proposed development will require the temporary diversion and reinstatement of the burn. The restored channel should have sufficient capacity to cater for 1 in 100 year storm flows, taking into consideration the likely effects of climate change, and should be suitably lined to prevent infiltration where it extends across the backfilled excavations.

4.2 Hydrogeology

4.2.1 Glacial Deposits

The glacial deposits at Highthorn are under-drained because the groundwater in the underlying strata lies well below rockhead. There is little or no groundwater in the glacial clay because of its very low permeability and this was confirmed during the geotechnical site investigation (Appendix B). Some groundwater may be present where there are lenses or beds of silt, sand and gravel, but these are relatively uncommon at Highthorn site and are unlikely to contain large volumes of water.

4.2.2 Made Ground

Surface mine backfill will be exposed along a section of the northern highwall. Groundwater may well present towards the base of the deposit from which it is likely to flow. Inflows may also occur at higher levels where the water has been perched above less permeable layers of fill. However, the inflow rates are unlikely to be excessive because the material has been in place for some considerable time and there will have been significant self-weight compaction and consolidation. This will have reduced the permeability.

4.2.3 Bedrock Strata

Groundwater flow in undisturbed Coal Measures strata is almost exclusively controlled by natural joints and fractures. The permeability is relatively low and inflow rates can be adequately managed even where the strata have been disturbed by intense faulting (e.g. at Shotton site). However, the hydraulic properties are radically changed by the presence of old workings. The permeability may increase by orders of magnitude due to the following factors:
(i) the presence of open voids along which groundwater can flow quite freely;

(ii) brittle failure and the creation of a large number of fractures where the roof strata has failed and collapsed; and

(iii) the dilation of natural joints and the separation of bedding planes due to the collapse of the underlying strata.

Mine workings are present throughout the excavation area and these extend for some considerable distance to the south and east. The 1/10,560 scale Old Workings Plans (Appendix C) show the degree and extent of extraction in a number of coal seams. The workings are interconnected by shafts and cross-Measures drifts and consequently the effects of large scale pumping such as that previously undertaken at Ellington Colliery can extend over a very great distance.

4.2.4 Groundwater Monitoring Installations

A number of standpipes and piezometers have been installed at Hightorn site to assess the groundwater conditions. Many were subsequently removed or have become faulty, but a further six (nos. PZ1 to PZ6) have been constructed to target the seams that will now be excavated. Details of all the working installations are summarized in Table 9 and their locations are shown in Figure 6.

It is important that these installations are maintained for as long as possible, in particular nos. PZ1 and PZ6. They should be carefully monitored on a monthly basis during the operation of the site and for a period of 6 months after the excavations have been backfilled.
## Table 9 Summary of Fully Functional Standpipe and Piezometer Installations

<table>
<thead>
<tr>
<th>Bh. No. (Status)</th>
<th>Grid Reference</th>
<th>Ground Level (m AOD)</th>
<th>Depth of Tip (m bgl)</th>
<th>Standpipe Height (m)</th>
<th>Horizon of Tip</th>
<th>Type</th>
<th>Range of Recorded Water Levels</th>
<th>Date Installed</th>
<th>Last Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1346</td>
<td>427887 595363</td>
<td>103.89</td>
<td>51.80</td>
<td>0.50</td>
<td>1.80m above Top Bensham (H200) seam in sandstone.</td>
<td>P</td>
<td>6.30-23.22 -18.83 to -1.91</td>
<td>21/03/86</td>
<td>08/05/15</td>
</tr>
<tr>
<td>1497</td>
<td>427789 595096</td>
<td>103.92</td>
<td>57.90</td>
<td>0.44</td>
<td>3m above Top Yard Top Leaf (G230) in sandstone.</td>
<td>P</td>
<td>39.19-55.72 -51.36 to -34.83</td>
<td>18/04/86</td>
<td>08/05/15</td>
</tr>
<tr>
<td>1674</td>
<td>425747 595003</td>
<td>131.55</td>
<td>36.20</td>
<td>0.52</td>
<td>0.90m above base of opencast backfill.</td>
<td>S</td>
<td>19.55-26.24 5.83 to 12.52</td>
<td>25/02/84</td>
<td>08/05/15</td>
</tr>
<tr>
<td>1783</td>
<td>425746 595006</td>
<td>131.48</td>
<td>109.00</td>
<td>0.28</td>
<td>2.81m below base of Bottom of Broomhill (L200) seam in siltstone sequence.</td>
<td>P</td>
<td>28.60-40.57 -8.81 to 3.16</td>
<td>02/11/87</td>
<td>08/05/15</td>
</tr>
<tr>
<td>1784</td>
<td>425746 595009</td>
<td>131.51</td>
<td>79.00</td>
<td>0.30</td>
<td>2.06m above Little Wonder (J300/J200) seam in sandstone.</td>
<td>P</td>
<td>31.66-43.74 -11.93 to 0.15</td>
<td>04/11/87</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ1</td>
<td>427811 594423</td>
<td>6.81</td>
<td>37.50</td>
<td>0.28</td>
<td>Diamond (E000) seam.</td>
<td>P</td>
<td>33.31-33.78 -26.69 to -26.22</td>
<td>22/09/14</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ2</td>
<td>427811 594423</td>
<td>6.81</td>
<td>49.00</td>
<td>0.27</td>
<td>Top Main (F200) seam.</td>
<td>P</td>
<td>46.01-47.84 -40.76 to -38.93</td>
<td>22/09/14</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ3</td>
<td>427811 594423</td>
<td>6.81</td>
<td>65.50</td>
<td>0.28</td>
<td>Bottom Yard (G100) seam.</td>
<td>P</td>
<td>54.64-55.75 -48.66 to -47.55</td>
<td>22/09/14</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ4</td>
<td>427459 594042</td>
<td>13.00</td>
<td>68.00</td>
<td>0.20</td>
<td>Bottom Yard (G100) seam.</td>
<td>P</td>
<td>58.90-60.58 -48.61 to -46.93</td>
<td>4/11/14</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ5</td>
<td>427459 594042</td>
<td>13.00</td>
<td>38.00</td>
<td>0.18</td>
<td>Diamond (E000) seam.</td>
<td>P</td>
<td>41.54-42.06 -30.11 to -29.59</td>
<td>4/11/14</td>
<td>08/05/15</td>
</tr>
<tr>
<td>PZ6</td>
<td>427811 594423</td>
<td>6.81</td>
<td>46.85</td>
<td>0.23</td>
<td>Top Main (F200) seam.</td>
<td>P</td>
<td>50.23-53.36 -38.23 to -41.36</td>
<td>4/11/14</td>
<td>08/05/15</td>
</tr>
</tbody>
</table>

bcl – below collar level  S – Standpipe  P – Piezometer
4.2.5 **Groundwater Conditions at Highthorn Site**

A number of the monitoring installations record the rise in groundwater levels that has occurred since Ellington Colliery was closed and all pumping operations were stopped. This process was continuing at the time of compiling this report and some of the mine workings that lie within the excavation area have been flooded. These workings will have to be dewatered to allow the safe recovery of the remaining coal. **Table 10** provides a summary of the recorded water levels and those of the excavation.

### Table 10 Recorded Groundwater Levels and Proposed Minimum Levels of Extraction

<table>
<thead>
<tr>
<th>Seam/Old Workings Horizon</th>
<th>Approximate Groundwater Level (m AOD)</th>
<th>Minimum Level of Excavation (m AOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashington (4D00)</td>
<td>NA</td>
<td>-25</td>
</tr>
<tr>
<td>Diamond (E000)</td>
<td>-27</td>
<td>-34</td>
</tr>
<tr>
<td>Top Main (F200)</td>
<td>-38</td>
<td>-40</td>
</tr>
<tr>
<td>Bottom Yard (G100)</td>
<td>-47</td>
<td>-63</td>
</tr>
</tbody>
</table>

NA – not available, but likely to be similar to that recorded in the underlying Diamond (E000) seam.

The Coal Authority is presently establishing a permanent pumping operation at the former Lynemouth Colliery. Use has been made of one of the old shafts and a submersible pump has been installed with the intention of controlling the water levels at around -34m AOD. This will prevent any uncontrolled discharges inland and protect important water supplies near Morpeth. Discussions have been held with the Authority with a view to lowering the groundwater levels so that the workings at Highthorn are dewatered. This will necessitate additional pumping and treatment capacity so that the water can be discharged into the sea in accordance with an Environment Agency permit. Further details are provided in the Hydrological and Hydrogeological Assessment (DAB Geotechnics Ltd., 2015a). If agreement is not reached with the Coal Authority or the required levels cannot be achieved at Lynemouth for technical reasons, the water will have to be pumped and treated on site.

Apart from the area of backfilled surface excavations, the strata to the north of the Grange Moor Fault remain unworked on Highthorn site and for some distance to the north. The groundwater in the bedrock lies at a higher level because the fault partly constrains the flow of water. The drawdown that was created by pumping at Ellington Colliery was much less pronounced, but recovery has again occurred since its closure. Borehole piezometer no. 1346 (**Table 9, Figure 6**) presently records a level of about -2m AOD. Seepage and inflow will therefore occur when the strata are exposed along the northern highwall, especially where they are fractured by faulting. However, they are unlikely to be significant as proved to be the case at the former Stobswood site and it is anticipated that the water can be managed using conventional sump pumping.
5. **ASSESSMENT OF EXCAVATED SLOPES AND TIPS**

5.1 **Method of Working**

Details of the proposed surface mine development are shown on the 1/15,000 scale Composite Working Method Plan (Dwg. No. HJB/BA795/PA06) and 1/15,000 scale Phasing Plans (Dwg. Nos. HJB/BA795/PA7 to PA11). The development will entail the removal and reinstatement of the upper reaches of Hemscott Burn which extends across the south-eastern part of the site.

Mining operations will commence with the stripping of soils in the excavation and overburden storage areas; the construction of water treatment lagoons; and the establishment of the site infrastructure. The topsoil will be deposited in discrete visual and acoustic screening mounds of not more than 6m in height (nos. TSM1 to TSM9), the majority of the material being deposited along the western and south-eastern perimeters of the site. Subsoil mounds will be constructed to the north-west, north-east and south of the excavation area (nos. SSM1 to SSM7 and SM11). These will reach a maximum height of 10m. Drift material will also be deposited at a maximum height of 11m to form a screening mound (no. DRM1) along the eastern perimeter. The outer slopes of the mounds will be constructed at not greater than 1v in 2h (26.6°).

A boxcut will be created in the northern part of the excavation area. The overburden will be placed in an adjacent storage mound (OBM1) which will reach a maximum height of 25m with outer slopes of not greater than 1v in 2h (26.6°). The excavations will progress in a southerly direction by developing a succession of WNW-ESE oriented cuts. The exhausted workings will be backfilled, but overburden will continue to be placed above ground, firstly in the northern storage mound, but then in a second one (OBM2) that will be constructed in the western part of the site. This will reach a maximum height of 27m and will again have outer slopes of not greater than 1v in 2h (26.6°). The final void will be formed in the southern part of the site and will be backfilled using the overburden stored above ground. The soils will be replaced and the watercourse re-instated as part of the restoration works. The excavations will extend up to 71m bgl.

5.2 **Topography and Surface Features**

The proposed working area (i.e. the excavations and tips) are relatively isolated, but attention is drawn to the close proximity of the A1068 road along the western perimeter. All services on the site will otherwise be diverted before the commencement of operations. There are a number of occupied dwellings on and around the site, but none is likely to be affected by the development, although environmental controls will have to be implemented with regard to noise levels and dust emissions. Such controls will form part of the environmental management system for the site.
5.3 **Storage Mounds (Tips)**

5.3.1 **Topsoil Mounds**

5.3.1.1 **General**

Topsoil will be deposited to form visual and acoustic screening mounds of not greater than 6m in height. The mounds will be founded on undisturbed glacial clay or till; although laminated clay may also be present in some areas.

5.3.1.2 **Slope Stability Analysis**

A number of slope stability calculations have been carried out using Bishop’s Simplified Janbu’s methods for circular and non-circular failure. These are the most likely potential failure mechanisms. The calculations are presented in Appendix D. The results indicate that adequate stability can be maintained if the outer slopes of the mounds are formed at not greater than 1v in 2h (26.6°). Minor unravelling of the outer slopes is possible, but this is unlikely to present a hazard to plant and personnel.

5.3.1.3 **Construction and Excavation**

The topsoil mounds should be constructed at the locations shown on the 1/15,000 scale Composite Working Method Plan (Dwg. No. HJB/BA795/PA06) on well drained ground that is inclined at less than 1v in 12h or 4.8°. The material should be end-tipped and then pushed up to the required height and shape using a dozer. Alternately, the material should be constructed in layers of not greater than 1m in thickness. (Adequate edge protection will be required where dumptrucks are required to access the top of the mound.) The side slopes should be graded using a dozer or backactor in accordance with the specifications shown on the plan and in any event at not greater than 1v in 2h (26.6°) as soon as the material is deposited. The backactor should have adequate reach to grade and shape up the side slopes and able to operate from a level platform on the top of the mound. A standoff of not less than 3m measured between the toes of the topsoil mounds and the site boundary will ensure that adjacent properties are fully protected. A minimum standoff of 5m should be provided from the crests of the surface excavations and any adjacent mounds unless they form part of the same visual and acoustic screen (e.g. Mounds TSM9 and SSM6). Provision should be made for the drainage of water between the mounds.

It should be possible to safely excavate the topsoil mounds in a single lift and within the maximum reach of a suitable hydraulic shovel working at ground level or a backactor operating from a stable platform on its upper surface.

5.3.2 **Subsoil Mounds**

5.3.2.1 **General**

The majority of the subsoil mounds will be constructed to a maximum height of 10m, but SSM1 and SSM8 will only reach 8m and SSM6 will be formed at 6m. The mound foundations will comprise undisturbed glacial till and possibly some laminated clay.
5.3.2.2 Slope Stability Calculations

The stability of the subsoil mounds has been assessed and further details are provided in Appendix D.

The analysis results indicate that adequate stability can be maintained provided that the outer slopes of the mounds are formed at the specified grades.

5.3.2.3 Construction and Excavation

The subsoil mounds should be constructed at the locations shown on the 1/15,000 scale Composite Working Method Plan (Dwg. No. HJB/BA795/PA06) on well drained ground that is inclined at less than 1v in 12h or 4.8º. The material should be block tipped and spread to form layers of not greater than 1 to 2m in thickness and thoroughly trafficked. The side slopes should be graded in accordance with the specifications shown on the plan and in any event at not greater than 1v in 2h (26.6º) as soon as the height of the deposited soil reaches 3m in height. This practice should be continued as the upper surface of each mound is raised.

Edge protection bunds of not less than 1.5m in height will be required along the upper perimeter of the mounds and these should be extended along the access ramps.

A standoff of not less than 3m measured from the toes of the subsoil mounds to the site boundary will ensure that adjacent properties are fully protected. A minimum standoff of 5m should be provided from the crests of the surface excavations and any adjacent mounds unless they form part of the same visual and acoustic screen (e.g. Mounds SSM6 and TSM9). Provision should be made for the drainage of water between the mounds.

The subsoil mounds should be excavated in one or two benches using hydraulic backactors or shovels, dependent on their maximum reach. The bench face heights should be maintained within that reach. Edge protection bunds of not less than 1.5m in height should be constructed along the access ramps and any elevated loading areas. Alternately, the material can be pushed down using a dozer and then excavated at the requisite safe height.

5.3.3 Overburden Mounds

5.3.3.1 General

Two overburden mounds, OBM1 and OBM2, will be constructed on the site to maximum heights of 25 and 27m respectively. Mound OBM1 will be partly founded on the backfilled excavations of the former Radar South opencast site (Figure 3). Elsewhere, the foundation will comprise glacial till. Laminated clay may also be present.
5.3.3.2 Slope Stability Calculations

The stability of the overburden mounds has been assessed using Bishop’s Simplified and Janbu’s methods for circular and non-circular failure. These are the most likely potential failure mechanisms. A range of parameters was considered to reflect the types of material that will be deposited as well as those of the various foundations. Worst case scenarios were considered. The analysis results are presented in Appendix D.

5.3.3.3 Construction and Excavation

The following recommendations are made with regard to the construction of the mounds.

(i) The mounds should be constructed at the locations shown on the 1/15,000 scale Composite Working Method Plan (Dwg. No. HJB/BA795/PA06).

(ii) The mounds should be formed on an evenly graded surface that is inclined at not greater than 1v in 12h (4.8º). Any soft ground should be excavated and replaced with more competent material. Measures should also be taken to ensure that the ground is properly drained.

(iii) A standoff of not less than 10m should be provided between the toes of the mounds and the site boundary to protect adjacent properties and 5m from any adjacent topsoil and subsoil mounds. Similarly, a standoff of not less than 20m should be provided from the crests of the adjacent surface excavations. Adequate drainage should be provided.

(iv) The overburden should be deposited in layers of 2-3m in thickness and thoroughly trafficked. Ideally, each layer should be spread across the full area of the mound foundation as its height is raised, but it is recognized that some parts will have to be developed first in order to create the necessary visual and acoustic screening.

(v) It is recommended that a bund of rockfill (or rock-rich fill material) should be formed along the lower perimeter of the two mounds, the height of which should be raised to about 8-10m. This bund should be at least 25m wide. Alternately, the outer slope should be graded at not greater than 1v in 2½h (21.8º). [The use of clayfill and the formation of a 1v in 2h (26.6º) slope profile could lead to instability. This will not affect adjacent properties if a standoff of 10m is applied.]

(vi) The outer slopes of the mounds should be graded in accordance with the specifications shown on the Composite Working Method Plan and not greater than 1v in 2h (26.6º) as soon as the deposited material reaches a height of 3m and this practice should be continued as the height of each mound is increased.

(vii) A significant proportion of the overburden will comprise clayfill because of the relatively thick superficial cover in the excavation area. It is therefore recommended that the material should only be deposited by block tipping, levelling and spreading in suitably bunded areas. Clay and rockfill should be inter-layered wherever possible. Suitable rockfill will be required to maintain the haul roads.
The edge protection bunds should be formed at a height equivalent to half the diameter of the maximum wheel size or 1.5m, whichever is greater, by end tipping the overburden not closer than 5m from the tip edge. Dumptrucks should reverse at right angles to the edge under the supervision of a dozer operator and keep the dozer on the driver’s side wherever practicable. The tip edge should be regularly examined during each working shift for signs of deterioration. If it becomes unstable, the affected area should be blocked off to prevent vehicle access and the Site Manager informed immediately.

The tipping areas should be of sufficient size to allow safe turning, reversing and tipping manoeuvres (taking into account the size and type of plant being used). Newly prepared tipping areas should be well graded, free of obstruction and standing water. Portable lighting should be used during hours of poor natural light.

Any saturated overburden or silt dredged from the water treatment lagoons should only be tipped in the upper parts of the mound, where at least partial drainage can be achieved prior to intermixing and spreading with more competent materials. It should not be deposited in large concentrations as this might give rise to instability.

The completed tip surface should be kept smoothly graded at all times in order to shed surface water towards its outer perimeter and reduce infiltration. The establishment of a vegetative cover will minimize surface erosion.

Every effort should be made to drain any areas of standing water that may form as a consequence of consolidation and settlement of the tip materials.

Comprehensive tipping rules should be drafted by the Site Manager.

5.4 Excavations in the Glacial Deposits

5.4.1 General

5.4.1.1 Long term (Highwall) Slopes

Experience has shown that the following slope profiles will provide adequate stability where it is required to form endwalls and highwalls in glacial and fluvio-glacial deposits:

<table>
<thead>
<tr>
<th>Height of Slope</th>
<th>Safe Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5m</td>
<td>1v in 1h (45°)</td>
</tr>
<tr>
<td>Greater than or equal to 5 and less than 12m</td>
<td>1v in 1½h (33.7°)</td>
</tr>
<tr>
<td>Greater than or equal to 12</td>
<td>1v in 2h (26.6°)</td>
</tr>
</tbody>
</table>
The operator is strongly advised to fully grade the slope profiles where they form part of the excavation highwalls, as this will improve their stability. Slacker gradients may have to be adopted if water-bearing, granular materials are encountered in the glacial deposits (i.e. interbedded silts, sands and gravels); although site investigations have shown that these are uncommon at Hithorn site. Further advice should be sought from the geotechnical specialist should the need arise. If fully drained or dry sand is exposed, this should be covered with clay or rockfill as wind erosion can lead to the instability of overlying material.

Public and private properties that lie adjacent to the site, such as the A1068 road and Hithorn Farm, will remain unaffected because of the isolated location of the excavation area. (The standoff from the A1068 is not less than 500m and will measure approximately 190 and 400m from Hithorn and Hemscott Hill Farms respectively.) However, particular attention should be paid to the crests of the slopes and the adjacent soil screening mounds. It is important that measures are taken to stabilize the excavated slopes in the glacial deposits should the need arise before the underlying excavations are formed; otherwise the integrity of the soil mounds could be compromised.

5.4.1.2 Short Term (Advance) Slopes

Experience has shown that steeper profiles of up to 1v in ½h (63.4º) can be formed in firm to stiff glacial clay where the slopes are relatively short lived (e.g. in the advance excavations). However, the deposits are commonly fissured and bench faces may suddenly collapse with little or no warning. The consequences of any such risk can be minimized by maintaining the face heights within the maximum reach of the excavating plant (typically 6 to 8m). Adequate safety benches of not less than 10m in width should be maintained where the material is being excavated in more than one lift. Additional room will be required to allow the safe movement of plant where haul roads are constructed (Section 6) or excavations are being undertaken. Dumptrucks should be parked at a safe distance and reversed into position during excavating and loading operations. Pedestrian access should be restricted. No vehicles should operate within 5m of the crest of an underlying bench face and edge protection of not less than 1.50m in height should be maintained at all times.

In the unlikely event that substantial thicknesses of silt, sand and gravel are encountered, it is unlikely that a stable excavation profile of 1v in ½h (63.4º) can be formed or maintained. Allowance must therefore be made for the creation of a loose slope inclined at its normal angle of repose (typically 1v in 1½h or 33.7º). Additional measures may have to be taken if such deposits prove to be water bearing. Deposits of dry sand and silt may have to be covered to protect them from wind erosion, as this could lead to the collapse of the overlying material.

5.4.2 Slope Stability Calculations

A number of slope stability calculations have been carried out and the results, which are presented in Appendix E, indicate that failure could extend some distance beyond the crests of the excavated slopes. In reality, the accumulation of loose debris along the toe will serve to confine further instability. Negative pore pressures and lateral restraint will also have a stabilizing effect in the short to medium term (i.e. the likely exposure time at Hithorn site).
5.4.3 Summary of Main Points

(i) **Advance Excavations.** The bench faces should be maintained within the maximum reach of the earthmoving equipment and these should be scaled to remove as much loose material as possible. A safety bench of not less than 10m in width should be formed along the toe of each bench face. Attention is again drawn to the possible sudden collapse of near surface deposits of glacial till (‘boulder clay’) due to the presence of fissures.

(ii) **Excavation Highwalls.** The glacial deposits should also be excavated in benches along the highwalls, but with the added stipulation that the final slopes are fully graded in accordance with the profiles given in Section 5.4.1.

(iii) Additional measures will be required in the unlikely event that water bearing granular deposits are encountered (e.g. by providing toe drains; excavating slacker profiles and/or forming wider safety benches to accommodate any mobilized material; constructing confinement bunds or replacing poor quality material with rockfill). Further advice should be sought from the geotechnical specialist should the need arise.

(iv) A rockhead bench should be formed (see Section 5.6).

(v) Soil and overburden storage mounds should be located at a safe distance from the crests of the excavation slopes (see Section 5.3).

(vi) Pedestrian access to the excavations should be restricted and where required (e.g. for essential survey work), a risk assessment should be carried out.

5.5 Excavations in Made Ground

Surface mine backfill will be exposed along a short upper section of the north-western excavation highwall. The majority of the fill with be granular in nature. The fill materials will have undergone significant self-weight compaction and consolidation since their placement and experience has shown that steeply inclined excavation bench faces can remain stable in the short term. The following recommendations are made:

(i) the fill should be excavated in benches so that face heights do not exceed the maximum reach of the excavator;

(ii) adequate safety benches of not less than 10m in width should be maintained where the material is being excavated in more than one lift.

(iii) dumptrucks should be parked at a safe distance and reversed into position during excavating and loading operations;

(iv) pedestrian access should be avoided;
(v) no vehicles should operate within 5m of the crest of an underlying bench face and edge protection of not less than 1.50m in height should be maintained at all times; and

(vi) the highwall slope should be graded at not greater than 1v in 1½h (33.7°) and every effort should be made to remove loose blocks.

5.6 **Rockhead Gradients and Rockhead Benches**

Instability has been known to develop along the interface between the superficial deposits and the underlying bedrock where it dips adversely into the excavations. Such failures are, however, relatively uncommon because of the high friction angles. The Rockhead Contours Plan indicates that the rockhead surface is generally inclined into the excavation highwalls and where this is not the case there is either no adverse component or the dip is very gentle (i.e. lower than 1v in 10h or 5.7°). Favourable conditions will also be encountered in the advance slopes.

Despite the apparent stable configuration of the rockhead surface around the excavation area, it is **strongly recommended that a rockhead bench of not less than 5m in width is provided along the excavation highwalls. A bench of at least 10m should be maintained in the advance slopes.** These safety benches will serve to confine any material displaced from the overlying superficial deposits which must be excavated in accordance with the recommendations given in Sections 5.4.1 and 5.4.2.

5.7 **Excavations in Bedrock**

5.7.1 **General**

Coal Measures strata are characterized by the presence of well developed joints and very weak mudstone or soft clay horizons. These can have a profound effect on the stability of excavated slopes. The dip of the strata, localized faulting and the presence of old workings may also give rise to instability.

The design of any excavation slope in the bedrock should take into consideration:

(i) the maximum reach of the excavating plant deployed at the site;

(ii) the stability of the bench faces when typically formed at 1v in ½h (63.4°);

(iii) the adequacy of the individual safety benches in containing displaced material; and

(iv) the overall stability of the slope.
Experience has shown that where the strata dip is relatively low, excavation highwalls that are formed with an overall profile of 1v in 1h (45°) will generally provide adequate stability. It is recommended that safety benches of not less than 4-5m in width should be provided at a vertical interval of not greater than 8-10m in the bedrock strata. The safety benches will become partly filled with loose debris following their construction, but they should provide adequate containment prior to backfilling so that plant and personnel are not placed at risk. As a general rule, however, it is recommended that the individual benches should be cleared of loose debris prior to the formation of the underlying excavations. Where the strata are found to be weak or faulted and highly fractured, it may prove necessary to construct wider safety benches and/or provide containment bunds of not less than 1.5m in height. This can only be further assessed as the site is developed. A number of areas have been identified as potentially problematic (Table 10) and further advice should be sought from the geotechnical specialist as and when required.

A benched profile with an overall slope of 1v in 1h (45°) should be considered as an absolute maximum for the advance slopes.

5.7.2 Toppling, Wedge Type and Planar Failure

5.7.2.1 Toppling Failure

There may be a greater risk of toppling failure where the excavation highwalls and bench faces are aligned subparallel to one of the two major joint sets. These are thought to trend WSW-ENE and NNW-SSE based on the trend of the Grange Moor Fault and observations made at other sites. Experience has shown that toppling failures are not particularly large, because of the joint spacing, but they can occur very quickly and present a serious hazard to plant and personnel. The risk and consequences of failure can be partly mitigated by maintaining the bench faces at a height that falls within the maximum reach of the excavators and by providing adequate safety benches to contain any displaced material.

An assessment of the likely risk of toppling failure along the excavation highwalls and advance slopes is given in Table 10.

5.7.2.2 Wedge Type Failures

Wedge type failures can develop where faults, joints and other discontinuities (e.g. mining induced fractures) intersect. Experience has shown that the risk of failure is particularly high where faults acutely intersect excavated slopes as will be case along part of the north-western highwall (Table 10). The anticipated steep inclination of the joints should preclude the development of relatively small wedge type failures in the bench faces, but their occurrence cannot be entirely ruled out. Every effort should be made to remove faulted and disturbed strata so that the excavations can be formed in competent rock. The excavation area has been designed to allow access across the full width of the Grange Moor Fault zone.
In some circumstances, it may prove necessary to widen the safety benches to provide greater containment where it is not possible to remove unstable or potentially unstable material. Further advice should be sought from the geotechnical specialist. The risk can be partly mitigated by maintaining the bench faces at a height that falls within the maximum reach of the excavators.

5.7.2.3 Planar Failure

Planar failure can occur where the bedrock strata dip adversely into the excavations. The risk can be mitigated by working down-dip along the excavation cuts (Table 10). However, the strata will dip adversely from the western and north-western highwalls. Localized adverse dips may also be present around the Grange Moor Fault. The groundwater is already drawn down along the western and north-western perimeters of the excavation area and this will reduce the risk of failure. Further comment is made in Table 10.

5.7.3 Buckling and Slab Failure

The bedrock strata may dip more steeply where they have been faulted or affected by old workings (Section 5.8.6), but in general they are unlikely to be sufficiently inclined to create a significant risk of buckling and slab failure as described by Cavers (1981), Adhikary et al. (2001) and Giani (1992). Even so, the risk can be mitigated by forming bench faces and benched slopes in accordance with the recommendations given in this report.
### Table 10 Assessment of Excavated Slopes in Bedrock Strata

<table>
<thead>
<tr>
<th>Location Map</th>
<th>Slope Location</th>
<th>Toppling Failure</th>
<th>Wedge Type Risk</th>
<th>Planar Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Highwall</td>
<td><strong>Possible.</strong> The highwall will be subparallel to most of the faults in the Grange Moor Fault zone and probably one of the major joint sets. Lateral restraint will be removed by other minor faults and the second major joint set.</td>
<td><strong>Possible.</strong> The strata will be variously inclined in the Grange Moor Fault zone and may be intersected by minor faults running at right angles or acutely to the highwall.</td>
<td><strong>Possible.</strong> Localized adverse dips may be present where the strata are faulted.</td>
<td></td>
</tr>
<tr>
<td>Eastern Highwall</td>
<td><strong>Possible.</strong> The highwall may be subparallel to one of the major joint sets. Lateral restraint will be removed by the second major joint set. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Possible.</strong> Wedge type failures may develop where the northern part of the highwall is intersected by the Grange Moor Fault zone. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Generally low.</strong> The strata are inclined into the highwall and are partly dewatered or will be rendered so by pumping. Localized failure may occur where the strata are affected by old workings (Section 5.8).</td>
<td></td>
</tr>
<tr>
<td>South-eastern Highwall</td>
<td><strong>Generally low.</strong> The highwall is not thought to be aligned with any of the major joint sets. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Possible.</strong> Wedge type failures may develop where the northern part of the highwall is intersected by the Grange Moor Fault zone. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Generally low.</strong> The strata are inclined into the highwall or there is no adverse component of dip. They are partly dewatered or will be rendered so by pumping. Localized failure may occur where the strata are affected by old workings (see Section 5.8).</td>
<td></td>
</tr>
<tr>
<td>Southern Highwall</td>
<td><strong>Possible.</strong> Part of the highwall may be subparallel to one of the major joint sets. Lateral restraint will be removed by the second major joint set.</td>
<td><strong>Generally low.</strong> The joints are steeply dipping and there are no faults or old workings.</td>
<td><strong>Low.</strong> The strata dip adversely from the western part of the highwall, but the dip is insufficient to create instability (Appendix E).</td>
<td></td>
</tr>
<tr>
<td>Western Highwall</td>
<td><strong>Possible.</strong> The highwall may be subparallel to one of the major joint sets. Lateral restraint will be removed by the second major joint set. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Generally low.</strong> The risk may be higher due to the presence of old workings (Section 5.8).</td>
<td><strong>Generally low.</strong> The strata are adversely inclined, but the dip is insufficient to create instability (see Appendix E). The strata are already dewatered. Localized failure may occur where they are affected by old workings (Section 5.8).</td>
<td></td>
</tr>
<tr>
<td>North-western Highwall</td>
<td><strong>Generally low.</strong> The highwall is not thought to be aligned with any of the major joint sets.</td>
<td><strong>Possible.</strong> Wedge type failures may develop where the northern part of the highwall is intersected by the Grange Moor Fault zone.</td>
<td><strong>Low.</strong> The strata are adversely inclined, but the dip is insufficient to create instability (Appendix E). The strata are already dewatered.</td>
<td></td>
</tr>
<tr>
<td>Advance Slopes</td>
<td><strong>Possible.</strong> The advance slopes may be subparallel to one of the major joint sets. Lateral restraint will be removed by the second major joint set. The risk may be higher due to the presence of mine workings and ribside failures (Section 5.8).</td>
<td><strong>Possible.</strong> Wedge type failures may develop where there are old workings and the advance slopes are intersected by ribside failures.</td>
<td><strong>Generally low.</strong> In the northern part of the excavation area, the strata will be variously inclined into the advance slopes or there will be no adverse component of dip. In the southernmost part, there will be a slight adverse dip in some areas, but this will be insufficient to cause instability (Appendix E). However, localized failure may occur where the strata are affected by old workings and ribside failures (Section 5.8).</td>
<td></td>
</tr>
</tbody>
</table>
5.8 **Underground Mineral Workings**

5.8.1 **General**

The 1/10,560 scale old workings plans (Appendix C) show that coal has been extracted from the Ashington (4D00), Diamond (E000), Top Main (F200), Yard (G210/G120) and Bottom Yard (G120/G110) seams. Greater detail is shown on the 1/2500 scale Abandoned Mine Plans.

5.8.2 **Collapse of Roof Strata above Pillared Workings**

The extent of collapse and void migration above pillared workings depends upon the physical properties of the roof strata and, in particular, their ability to form an arch. Generally, sandstone is more competent than mudstone and siltstone, but long term weathering can modify their strength characteristics. Various studies have been carried out to determine the likely extent of void migration in terms of the room or gallery dimensions. Tinscelin (1958) considered the de-stabilizing effect of fissures on supporting pillars and proposed the following relationship:

\[ D_c = \frac{m \delta_1}{\delta - \delta_1} \]

where \( D_c \) is the height of the roof collapse, \( h \) is the thickness of the seam or height of the extraction; and \( \delta, \delta_1 \) are the bulk density of roof strata and collapsed debris respectively. If the bulk density of the collapsed debris is 1.8 Mg/m\(^3\) and that of the in-situ rock is 2.3 Mg/m\(^3\), the equation predicts that collapse will extend 3.6m in height for a 1.00m extraction.

Walton and Taylor (1977) have suggested that voids can migrate to heights in excess of three times the gallery width, whilst Garrard and Taylor (1988) have derived the following relationships based on a survey of old workings exposed at surface mines in north-east England:

\[ D_c = 9.8h \quad \text{and} \quad D_c = 2.68p \]

where \( p \) is the width of the roadway or extracted void.

Piggott and Eynon (1978) have proposed that for a given width of mine opening (\( p \)) and roadway length (\( l \)), the height to which collapse can continue is a function of the extracted thickness and the bulking factor (\( B \)) for the overlying strata. This is equivalent to \( (V_c - V_o)/V_o \), where \( V_o \) and \( V_c \) are the volumes of unbroken and collapsed roof material respectively. The authors suggest that the bulking factor for Coal Measures strata falls within the range 30 to 50%.

Piggott et al. (1977) suggest that at least one competent bed between the workings and the surface with a minimum thickness of 1.75 times the appropriate span width is sufficient to arrest the collapse process, but this cannot be substantiated.
Thorburn and Reid (1977) have proposed a simple relationship for an initial evaluation of ground surface movement ($T$) based on the ground geometry and the porosity of the collapsed material as follows:

$$T = 2h - Rn/(1-n)$$

where $R$ is the thickness of the overburden and $n$ is the porosity in the range 0.25 to 0.40.

The relationship assumes that the supporting coal pillars do not experience failure and considers only a prismatic element of strata with vertical sides. Vertical settlement prediction is, however, very complex and the expression should only be used to assess, rather than calculate movements.

Whittaker and Reddish (1989) have observed that collapse is most likely to occur where two roadways intersect so that for a cruciform (four way) intersection:

$$D_c = \frac{4(2ph^2\cot\theta + hp^2)}{(B - 1)\pi d^2}$$

where $B$ is in the range 1.3 to 1.5; $d$ is the diameter of the collapse chimney in the range $p$ to $\sqrt{p}$; and $\theta$ is the angle of repose of the collapsed materials. The equation predicts that $D_c$ lies in the range 3$h$ to 10$h$, although the authors suggest that 7$h$ is probably the upper limit (i.e. 7$m$ for a 1$m$ extraction).
5.8.3 **Collapse of Roof Strata above Longwall Workings**

The abandoned mine plans show that a significant proportion of the coal has been removed by longwall mining. All the coal appears to have been extracted by advancing the working face through the coal seam. The overlying strata will have collapsed as the face supports were moved forward in a systematic fashion leaving the support roadways (i.e. the main and tailgates) intact on either side of the extraction panel. These provided access to and from the face and essential ventilation. They will have been maintained throughout the mining operation, but will have closed or collapsed since the workings were abandoned, despite the provision of steel supports. The immediate roof strata above the extracted panels will have been fractured and collapsed and there will have been significant bulkage. Bedding separation and joint dilation will have occurred at higher levels and the effects of mining subsidence have been translated to ground surface. A trough-like subsidence profile will have been formed above each panel similar to that shown below. The rock strata will have been dislocated and in some instances sheared where high tensile stresses were developed leading to so called, ‘ribside failures’.

The degree and extent of these effects is determined by the physical properties of the strata, the depth and width of the workings, the extraction thickness and the angle of draw. The latter is approximately 35° in the Northumberland Coalfield.

5.8.4 **Pillar Failure**

There are only a few documented instances of pillar failure in coal workings, but their deterioration and collapse can result from the combined or separate effects of spalling and weathering, which are relatively slow processes, and/or as a consequence of additional loading. Pillar failure has been known to occur decades after the abandonment of mine workings and clearly leads to increased fragmentation of the roof strata.

Pillars are required to sustain the redistributed weight of the overburden, and consequently the overlying and underlying strata are subject to compression. Stress concentrations develop along the edges of pillars, which may cause the margins to spall and eventually fail, particularly where the mineral is highly jointed. This action reduces the constraint on the core of the pillar and increases the stress, which, in turn, leads to further deterioration. The process is accelerated if additional loads or stresses are applied at ground surface or as a consequence of further coal extraction. If the stresses become critical in relation to the existing pillar loading and strength, and one pillar fails, the redistribution of the loading may lead to a domino effect.

5.8.5 **Floor Heave**

Seateartths can heave where they are exposed in the floor of a mine roadway and are able to absorb water. The constituent clay minerals swell in the absence of vertical constraint and this can lead to the complete infilling of the void. Bearing capacity failure may also occur along the margins of the supporting coal pillars. This in turn leads to the re-distribution of stresses and the potential for further subsidence by either roof or pillar failure. Experience has shown that floor heave can occur at depths of less than 35m.
Zone in which the roof strata will be affected by subsidence. This is largely determined by the angle of draw which is typically 35°.
5.8.6 Implications for Highthorn Site

Sections 5.8.2 and 5.8.3 and possibly 5.8.4 suggest that fractured and potentially unstable strata will be encountered at some height above the abandoned mine workings. Care should be exercised when applying any of the empirical relationships provided, but it is clear from the Generalized Vertical Section (Figure 4) and that the excavations in the Ashington (4D00) seam could be adversely affected by collapse above the workings in Diamond (E000) seam; perhaps more so because of the variable nature of the seam parting. Instability may also occur above any of the worked horizons as the overburden is reduced. **Extreme caution should therefore be exercised when operating large plant.**

Particular attention is drawn to effects of ribside failures along the margins of the longwall panels. These are zones in which the rock strata have been variusly disturbed, sheared and fractured. The effect could well extend through the entire excavation above the Yard (G210/G120) workings. Recent experience at Butterwell D. P. surface mine has shown that they can de-stabilize excavation bench faces. The old workings plans in Appendix C indicate that ribside failures are likely to be present within the south-eastern highwall and in the advance slopes.

To summarize, the presence of old workings at Highthorn site may give rise to one or more of the following failure mechanisms.

(i) Sliding of collapsed and broken strata. Adverse dips will increase the risk of translational slide following the compaction of the arch infill or buckling of the roof strata. Slab slides may develop where very weak clay horizons or high pore pressures are present in the underlying strata.

*The strata at Highthorn site are already partly dewatered and further dewatering will be carried out.*

(ii) Materials may slide into the excavation where collapse of the overlying strata extends into the superficial deposits.

*The deposits of glacial till are generally stiff and experience has shown that they can resist collapse and prevent the migration of voids. There are no crown holes at Highthorn site.*

(iii) Toppling of strata may occur where jointing or faulting is well developed and the excavations remove the lateral confining pressures. Wedge type failures may also develop.

*There is a well developed jointing system at Highthorn site and a number of faults are present on the site. The risk of toppling and wedge type failure may be higher where ribside failures acutely intersect the advance slopes and excavation highwalls.*
Sudden failure of the strata spanning the old workings may be initiated by blasting vibration, the removal of confining pressures or dewatering.

*It is expected that some blasting will be required at the site, although the charge levels will have to be strictly controlled due to the proximity of various occupied buildings. It is possible that toppling failure and rockfalls may be initiated by this activity and measures should therefore be taken to protect site personnel. It is common practice to withdraw plant and personnel to a distance of not less than 15m from the excavated slopes during routine blasting operations. This should be continued at Highthorn site.*

Some of the strata are presently dewatered, but pumping will be required to further reduce the groundwater levels, deal with minor inflows and control surface runoff. The risk of sudden collapse due to changes in pore pressure will be reduced if the workings are dewatered in advance of the excavations.

Large planar failures may develop where shears and ribside strains are present above areas of total extraction.

Reference has been made in Section 5.8.3 to the likely presence of ribside failures where longwall mining has been carried out. The effects may be translated throughout the succession from the workings in the Yard (G210/G120) seam and in a limited area from the workings in the Little Wonder (J300/J200) that are present beneath the excavation pavement.

Experience has shown that the collapse and fragmentation associated with mining subsidence can initiate significant instability of excavated slopes. This is especially true where well developed joints, faults, weak strata or even relatively minor adverse dips are present. **Extreme care will therefore be required during excavation and coaling operations.** Failure can be sudden and provide little or no warning. It is therefore important that adequate safety benches are formed and the height of the excavation faces is restricted.

5.8.7 Disused Mine Shafts and Drifts

Records show that there are no mine openings on the site. **In the unlikely event that any unrecorded structures are encountered, they should be treated in accordance with a specification approved by the Coal Authority.** The Authority should be given full details of their proven location, its dimensions and the treatment works undertaken. Extreme care is required during the excavation of the shafts and drifts as they may be inherently unstable. Attention is also drawn to the possible occurrence of mine gas (see Section 9).

*Suitable guidance is given in NCB (1982) and CIRIA (1984).*
5.9 **Backfill Tip and Loosewall Slopes**

5.9.1 **General**

The gradient of the loosewall slopes will largely depend on the natural angle of repose of the constituent materials, the manner in which they are deposited and the slope of the pit floor. Stable slopes can be formed at an angle of between 34 to 37º (about 1v in 1½h) using good quality rockfill, but a slacker grade of about 1v in 2h (26.6º) is required for glacial clay. Experience has also shown that basal sliding of the backfill is possible where the apparent dip of the excavation pavement is steeper than 1v in 12h (4.8º) and is directed outwards from the loosewall toe. The presence of groundwater, very weak mudstone or soft clay in the pavement strata, or the placement of weak or saturated materials at the base of the loosewall will worsen the situation.

5.9.2 **Backfilling at Hithorn Site**

The Composite Working Method Plan (Dwg. No. HJB/BA795/PA06) and the structure contour plans for the various seams indicate that the planned alignment of the excavation cuts, the excavation pavement should not extend adversely from the loosewall toe. However, localized adverse dips may be present where the strata have been disturbed by faulting, in particular in the northern part of the excavation area around the Grange Moor Fault.

The following recommendations are made with regard to the construction of the backfill tip and loosewall slopes:

(i) The exhausted mineral workings should be cleared of all soft or loose debris and standing water so that the backfill has a firm foundation.

(ii) In the event that faulting has given rise to localized adverse dips, as might be the case in the northern part of the excavation area, level platforms should be cut into the pavement or the strata ripped or blasted to form a key for the backfill.

(iii) Any weak or very weak materials in the excavation floor should be removed using a dozer and, if necessary, the pavement should be ripped or blasted to provide a key for the backfill.

(iv) Every effort should be made to ensure that the basal part of the loosewall comprises rockfill, with the weaker clayfill or a mixture of the two materials placed towards the top. This will improve stability. Provision should be made for the temporary storage of any wet materials to allow their drainage prior to their incorporation in the backfill tip. Very weak material should be thoroughly mixed with better quality fill, placed at a high level and located away from the loosewall slope where it is least likely to affect stability.
Given the large proportion of glacial clay that will be encountered on the site, it is advised that the backfill tip is constructed by block tipping within bunded areas. This is because the crests of the loosewall slopes may not have sufficient strength to allow the tipping of materials across edge protection bunds. All fill material should be deposited by tipping not closer than 5m from an open edge under the supervision of an attendant dozer. The material should then be pushed forward by the dozer to extend the tip surface or pushed up to form an edge protection bund of not less than 1.50m in height. Additional quantities of fill can then be deposited by block tipping within the bunded area, levelling with a dozer to create a layer of 2-3m in thickness and then repeating the process to form terraces of 6 to 8m in height. The outer slope of the tipped material should not exceed 1v in 1½h (33.7º) for rockfill and 1v in 2h (26.6º) for clayfill.

Ordinarily, safety benches of not less than 10m in width should be provided and maintained between each terrace so that the loosewall has an overall grade of not greater than about 1v in 3h (18.4º). However, it is recognised that there may be times when tipping space is more constrained, whereupon some of the safety benches can be partly or wholly filled provided that the outer slopes of the terraces are not over-steepened.

The tipping areas should be of sufficient size to allow safe turning, reversing and tipping manoeuvres (taking into consideration the type and size of plant deployed). Newly prepared tipping areas should be well graded, free of obstruction and standing water. Portable lighting should be used during hours of poor natural light.

Overburden that is deposited adjacent to the excavation slopes should be tipped short to create a rocktrap as shown below. The rocktrap should be maintained as the level of the fill is increased and until such time that the height of the exposed face or slope is less than 6m in height.
(Note. A wider rocktrap may be required if routine inspections identify an area of unstable or potentially unstable ground. Additional advice should be sought from the geotechnical specialist if required.) Coarse rockfill can be placed in the rocktrap as the tip is raised so that any groundwater ingress from the slopes can be drained.

(ix) Tipping operations should not be carried out immediately above other working areas. Measures should also be taken to ensure that backfill material does not roll or slide into active excavation areas, at any time, by providing adequate standoffs of not less than 30m and, if required, temporary bunds of not less than 1.5m in height.

(x) The backfill tip and loosewall slopes should be accessed using stable haul roads and ramps whose average grade should not exceed 1v in 10h (5.7º) wherever possible. These should be properly protected using edge protection bunds constructed to not less than 1.50m in height. (Further advice with regard to the construction of haul roads is given in Section 6).

(xi) Surface runoff should be properly managed to minimize the effects of erosion and prevent the accumulation of standing water. The upper surface of each terrace should be profiled so that it can drain. The runoff should be properly managed so that it is directed along temporary drainage channels to points where it can be suitably collected and pumped to the treatment lagoons.

(xii) Comprehensive tipping rules should be compiled by the Site Manager and these should be reviewed by the geotechnical specialist.

(xiii) The loosewall and backfill tip should be inspected in accordance with the frequencies recommended in Section 10. All operatives should be encouraged to remain vigilant during tipping operations and report any defects that may develop.

It is highly unlikely that the backfill will give rise to bearing capacity failure because of the high shear strength of the foundation (i.e. in situ mudstones, siltstones and sandstones). Abandoned longwall workings are present at depth beneath the southern part of the excavation area in the Little Wonder (J300/J200) seam (Appendix C), but these are unlikely to de-stabilize the backfill. This is because of the depth of cover and the fact that subsidence will be largely complete. Any ribsides shears will be confined.
6. **HAUL ROADS**

The haul roads should be maintained in a stable condition and should, wherever possible, be free of standing water. For a two-way system, the minimum road width should correspond to 3.5 times that of the largest operating plant. (This is equivalent to approximately 17m for Caterpillar 777 dumptrucks with wing mirrors.) A single track road should have a minimum width twice that of the largest plant.

Adequate edge protection must be provided and maintained at all times where ramps are formed and haul roads are bounded by potential hazards (e.g. ground that slopes away at more than 1v in 3h or 18.4°). Bunds should be formed using rockfill at a height that is at least equivalent to half the diameter of the largest vehicle wheels or 1.50m, whichever is greater. **Bunds of greater height may be required on bends and along the toes of access ramps and the risks should be assessed by the site management at regular intervals.** Suitable guidance is given in the Quarries Regulations (1999). Good visibility should be maintained at all times so that, for example, smaller vehicles can still be seen by larger plant where these cannot be segregated.

The haul roads should not encroach within about 5m of the crest of an excavation bench face. The provision of an adequate edge protection bund should ensure that this is always the case. A wider standoff may be required if unstable ground conditions are encountered during routine inspections (Section 10). Advice should be sought from the geotechnical specialist if necessary.

If it is required to run haul roads in close proximity to the toe of an excavation bench face, a rocktrap of not less than 4m in width and not less than 1.50m in depth should be constructed (i.e. by providing a suitable bund).

Ideally, good quality rockfill should be used in the construction of access ramps as other materials may give rise to instability. Where substantial deposits of fill are required (greater than 3m), the material should be deposited in layers of not more than 0.5m in thickness and suitably trafficked by dozers to achieve some compaction. This will reduce the worst effects of differential settlement and improve the overall strength of the fill.

Haul road and ramp gradients should be minimized so as to maintain plant operating efficiency and reduce spillage from dumptrucks. A **maximum gradient of 1v in 10h (5.7°) is recommended.**

Where soft to firm glacial clay is being excavated or tipped, suitable rockfill will have to be spread to create a more stable running surface. The very stiff clay that lies towards the base of the deposits may prove more resistant. Haul road surfaces should be continually graded to reduce tyre wear and improve safety. Water should be applied evenly to suppress dust, but not create slippery surfaces.
7. MANAGEMENT OF SURFACE RUNOFF AND GROUNDWATER

7.1 Excavation and Working Areas

Every effort should be made to prevent the accumulation of standing water on haul roads and in active excavation and tipping areas by constructing temporary drains or grips. Sustained flows of water may require more permanent channels. Provision should be made to drain surface runoff through edge protection bunds by providing gaps that are sufficiently narrow to prevent the passage of even the smallest vehicle on site, although the HSE has recently expressed a preference for pipes to be provided. Care should be taken to ensure that the water does not drain across potentially unstable areas or in a manner that might otherwise create a hazard to plant and personnel.

Surface and groundwater should be drained to temporary sumps formed in the excavations where it should be abstracted using suitable pumping equipment. Every effort should be made to minimize the concentration of suspended solids in the abstracted water by carefully positioning the pumps and intake pipes. The pumps should also be positioned at a safe distance (10m) from excavation bench faces so that maintenance crews are not placed at risk from falling rock. If necessary a suitable rocktrap should be constructed. The pipeworks should be properly maintained to prevent uncontrolled leakages. Extreme care should be taken during the positioning of pipeworks up and along the excavation highwalls and a safe system of work should be provided. Unstable or potentially unstable areas should be avoided.

Areas of backfill should be designed to shed water unless the restored surface has been specifically designed to incorporate permanent watercourses and wetland areas.

Uncontrolled discharges of potentially contaminated water should be prevented. Similar controls are required during the placement of soils. Ideally, water should continue to be treated using the settlement lagoons (Section 7.3) until the restoration drainage system has been fully established.

7.2 Construction of Cut-Off Ditches

Cut-off ditches should be constructed to prevent the discharge of untreated surface water from the site (e.g. along the toes of the soil screening mounds). These ditches should be typically ‘V’ shaped in cross section, about 1.5 to 2.5m wide at ground level and approximately 1 to 1.5m in depth. For the most part, the ditches should be excavated at an overall grade of less than 1v in 50h (1.2°). Where this is not possible, measures should be taken to prevent scour by the placement of aggregate or rockfill and/or the construction of weirs. Further treatment works (e.g. lining with clay or geomembranes) may be required where soft or granular materials such as old opencast backfill are encountered so as to reduce infiltration. This might otherwise affect the stability of any adjacent excavation slopes. Excavating small sumps at regular intervals can provide additional storage capacity, reduce localized flow velocities and hence the rate of erosion.
7.3 **Water Treatment Areas**

Water that is drained or abstracted from the site should be directed into the water treatment areas shown on the 1/15,000 scale Composite Working Method Plan. These will comprise a series of interconnected settlement lagoons. Additional treatment capacity may be provided by constructing settlement lagoons on the advance or on the backfill tip and/or to the east of the excavation area if the mine workings have to be dewatered other than by additional pumping at Lynemouth. The rate and quality of the treated discharge water will be determined by the Lead Local Flood Authority (**LLFA**) and the Environment Agency as part of the permitting process. At the time of compiling this report, two discharge points have been stipulated by the LLFA on the lower reach of Hemscott Burn to cater for the flow from the two treatment areas shown on the plan.

The water treatment lagoons should be constructed below ground level. If silt, sand and/or gravel are encountered, the lagoons will have to be lined with suitable clay to prevent excessive infiltration. The inner slopes of the lagoons should be formed at not greater than 1v in 1½h (33.7°) in order to maintain stability.

The water treatment areas should be regularly inspected to ensure that they remain stable, an adequate freeboard is maintained and the various inlet and outlet channels are clear. Lifebuoys and warning signs should be posted and maintained, together with a suitable fence or barrier (e.g. four-strand barbed wire).
8. MINERAL STOCKPILES

Raw and processed coal and fireclay will be stockpiled at the site. The following recommendations are made with regard to safety and stability:

(i) the stockpile area must be formed on stable ground that is inclined at less than 1v in 12h (4.8º);

(ii) adequate drainage must be provided and maintained;

(iii) sufficient loading room should be provided between the stockpiles; and

(iv) wherever possible, site based traffic should be segregated from incoming road vehicles by providing, amongst other things, adequate signage.

Raw and processed coal is generally free flowing and will readily form slopes at its natural angle of repose. However, there is a risk that potentially unstable excavation faces may be created where fine, moist or frozen material is present. Ideally, the stockpile heights should be maintained at or close to the maximum reach of the front end loader(s) (typically 6 to 8m). If it is required to construct stockpiles that exceed this height, suitable edge protection should be provided along the perimeters of the tipping areas and access ramps. All tipping should be carried out within edge protection bunds and the material pushed forward using a front end loader. The coal should be recovered in terraces or the material pushed down to maintain a working face that falls within the required safe height. Alternately, the material can be cast down or loaded out using a backactor with adequate reach operating from a stable platform formed within the stockpile. Adequate edge protection should also be provided and maintained along access or approach ramps to all processing plant reception hoppers.

Fireclay material is not free flowing and the stockpiles should be constructed in layers of 1 to 2m in thickness by block tipping and spreading. The outer slopes should be formed at not greater than 1v in 1½h (33.7º). Edge protection should be provided along the perimeter of the stockpiles as soon as they reach more than 1m in height and should be extended along the access ramps. The excavation faces must be maintained within the maximum reach of the operating plant by excavating the stockpiles in terraces or by pushing or casting the material down to a safe loading height.
9. MINE GAS

Abandoned mine workings will be encountered in the surface excavations and it is likely that mine gas will be present where they are already dewatered. It is strongly advised that the following recommendations are implemented.

1. Within the Site Boundary

Any gas that is present in the abandoned mine workings will dissipate in the atmosphere when they are exhumed in the excavations. It is possible, however, that potentially hazardous accumulations may still remain where the workings remain partly enclosed. **All operatives should therefore follow the site safety rules at all times. Personnel must not enter any workings until they have been properly exposed for the purposes of coal recovery.** (It follows therefore that those exposed in the excavation bench faces must not be entered.) There are no recorded mine openings on the site, but particular care should be exercised during treatment works should any be found outside the excavation area or at pavement seam level. Gas monitoring will be required and a risk assessment should be carried out. The risk of gas emission is greatly increased during or following sharp falls in barometric pressure. The Meteorological Office can provide suitable forecasts of any sudden changes in the weather.

2. Outside Highthorn Site

Large areas of dewatered old workings lie adjacent to the site and it is likely that mine gas is being emitted where the cover of glacial clay is thin and/or suitable conduits are present. The rate of emission may be reduced in some areas by the operation and subsequent restoration of the site, whilst in others it may remain unchanged. In the event that a complaint is received by Banks or a warning is sounded by any alarms that may be installed in local properties, for which specific recommendations have been made in the Mine Gas Risk Assessment (DAB Geotechnics, 2015b), the Environmental Health Officer (Northumberland County Council) and the Coal Authority must be contacted immediately. An appropriate line of action can then be agreed. This could entail an initial survey of the property or properties using suitable mine gas monitoring equipment. Further action may then be taken based on the findings of the investigation.
10. SAFETY INSPECTIONS AND GEOTECHNICAL ASSESSMENTS

10.1 Safety Inspections

The recommended inspection frequencies are presented in Table 11.

<table>
<thead>
<tr>
<th>Feature</th>
<th>DAILY Inspections by Appointed Competent Person</th>
<th>WEEKLY Inspection by Site Manager or Delegated Representative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavations and excavated slopes</td>
<td>Yes. All working areas (including excavation slopes adjacent to haul roads.</td>
<td>Yes. All excavation slopes.</td>
</tr>
<tr>
<td>Soil storage mounds</td>
<td>Yes. During construction and removal (excavation).</td>
<td>Yes, during tipping and excavation operations. Monthly at other times.</td>
</tr>
<tr>
<td>Overburden storage mounds</td>
<td>Yes. During all tipping and excavation operations.</td>
<td>Yes, during tipping and excavation operations. Monthly at other times.</td>
</tr>
<tr>
<td>Backfill tip and loosewall</td>
<td>Yes. All tipping areas, access ramps, etc.</td>
<td>Yes. Continuously until backfilling is completed.</td>
</tr>
<tr>
<td>Haul roads</td>
<td>Yes. Particular attention should be paid to condition of the road surface and the adequacy of the edge protection.</td>
<td>Not required.</td>
</tr>
<tr>
<td>Water treatment areas</td>
<td>Yes. During their construction and operation and until they are removed. (Check inflow and outflow channels, freeboard height and visually assess discharge water quality).</td>
<td>Not required.</td>
</tr>
<tr>
<td>Coal and fireclay stockpiles</td>
<td>Yes. All stockpiles.</td>
<td>Not required, provided that none of the stockpiles exceeds 15m in height or 1 hectare in area.</td>
</tr>
</tbody>
</table>

Table 11 Recommended Inspection Frequencies

10.2 Geotechnical Assessments

The Geotechnical Assessment Report should be reviewed at quarterly intervals after the commencement of surface mining operations or at a higher frequency if there are any adverse changes in ground conditions and slope stability.
11. **SUMMARY**

1. H. J. Banks & Co. Ltd. has identified shallow coal and fireclay reserves at its Hithorn site and plans to recover these by surface mining.

2. The superficial deposits largely comprise glacial till or, 'boulder clay', together with some fluvio-glacial laminated clay. These deposits will influence the stability of the excavated slopes, the soil and overburden storage mounds and the loosewall slopes, but suitable mitigation measures can be undertaken to counter the effects (Sections 5.3, 5.4 and 5.9).

3. The bedrock strata comprise a succession of mudstones, siltstones, sandstones, seatearths and coal seams. The Grange Moor Fault and a number of subparallel structures extend across the northern part of the excavation area and downthrow to the south by up to about 45m. The downthrown strata dip towards the east, south-east and north-east at between 1v in 56h (1.0°) and 1v in 12h (4.8°). There are at least two major, subvertical joint sets in the strata which have also been fractured by mining subsidence.

4. Some of the bedrock strata on the site are already dewatered, but further dewatering will be required to enable the safe recovery of some of the coal reserves. This will be achieved by either increased pumping at Lynemouth by the Coal Authority or conventional pumping at the site. The overlying superficial deposits are under-drained and have been for some considerable time.

5. The soil and overburden storage mounds should be constructed and excavated in accordance with the recommendations given in Section 5.3.

6. The excavation slopes in the glacial and fluvio-glacial deposits and old opencast backfill should be formed in accordance with the recommendations made in Sections 5.4 and 5.5.

7. Rockhead benches must be provided in all excavated slopes that extend into the bedrock (Section 5.6).

8. A benched profile with an overall slope of not greater than 1v in 1h (45°) should be constructed in the bedrock strata, with each bench face no higher than the maximum reach of the excavating plant. A safety bench of not less than 4-5m in width should be formed at vertical intervals of not more than 8-10m (Section 5.7.1).

9. The excavation bench profiles may have to be modified along some sections of the highwalls and advance slopes because of the possible development of toppling and wedge type failures (Section 5.7, Table 10).
10. Abandoned mine workings will be encountered on the site as shown on the 1/2500 scale Abandoned Mine Plans and 1/10,560 scale Old Workings Plans (Appendix C). These will impact the stability of the bedrock strata (Sections 5.7 and 5.8). However, experience has shown that safe working conditions can be maintained if the recommendations given in Section 5.7.1 are followed. No uncharted workings have been found in the exploratory boreholes and there are no recorded mine openings on the site.

11. Potentially hazardous gas is likely to be present where the abandoned mine workings are already dewatered. Further comment regarding the safety of site personnel is made in Section 9 and attention is also drawn to the Mine Gas risk Assessment (DAB Geotechnics, 2015b).

12. Recommendations have been made in Section 5.9.2 with regard to the placement of backfill materials and the construction of a stable loosewall.

13. Section 6 refers to the construction of haul roads and the measures that are required to maintain the safety of plant and personnel.

14. The Site Manager should compile comprehensive excavation and tip rules and these should be reviewed by the geotechnical specialist.

15. Recommended inspection frequencies are provided in Section 10.

16. This report’s compliance with Schedule 1 of the Quarries Regulations (1999) is set out below.

To summarize, the security of public and private properties and the safety of members of the public will not be compromised if the site is developed as planned and the recommendations given in this report are fully adopted. It follows therefore that the integrity of the A1068 and C110 public roads, Highthorn and Hemscott Hill Farms, the coastal sand dunes and the foreshore at Druridge Bay will remain unaffected.
### Item 1: Site Survey

An accurate plan prepared on a scale not less detailed than 1/2500 scale showing:

(a) the boundaries of the quarry or premises upon which the proposed excavations and tips are to be situated;

(b) the site of the proposed excavations and tips;

(c) any contiguous land or structures which might be affected by the proposed excavations or tips;

(d) all mine workings (whether abandoned or not), buried quarry workings, known cave systems, active or former landslips, springs, artesian wells, watercourses and other natural and man-made features including tunnel pipes or culverts which might affect the safety of the proposed excavations or tips or which might be relevant for the purpose of determining whether excavation or tipping operations can be carried out safely;

which plan shall be contoured to Ordnance Datum Newlyn at a vertical interval not greater than 5 metres and orientated to and correlated with an Ordnance Survey National Grid and marked with squares corresponding to the 100 metre squares shown on Ordnance Survey sheets on a scale of 1/2500.

### Item 2: Site Investigations

A record of all relevant site investigation information including surveys, tests, boreholes and groundwater measurements made for the purpose of the geotechnical assessment, together with the results of any testing including the strength of materials within and beneath the proposed tips or within the proposed excavated slopes. The record shall include any known historical information relevant to the site investigation.

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**Schedule 1 of the Quarries Regulations (1999)**

AEG Ltd.’s Factual Report (*Appendix B*)

Drillers’ logs and down-the-hole geophysical logs.

Piezometer records (Table 9 of the Geotechnical Assessment Report) and in the Hydrological and Hydrogeological Assessment (DAB Geotechnics Ltd., 2015a)

Sections 3 and 4 of the Geotechnical Assessment Report.
<table>
<thead>
<tr>
<th>Item</th>
<th>Requirements</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3</strong></td>
<td><strong>Cross Sections</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sufficient accurate cross sections on a scale not less detailed than 1/1250 of the site of the proposed excavation or tip showing the existing ground surface and all relevant superficial materials and bedrock underlying the said site and:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) any variation in the thickness, level or character of the superficial deposits and bedrock materials based on the site investigation; and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) the position of any surface whether natural or manmade which may affect the safety of the proposed excavations or tips.</td>
<td></td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>Plans based on site investigation</strong></td>
<td>Early editions of the 1/10,560 and 1/2500 scale OS Maps; 1/2500 scale Drift Thickness Plan; 1/2500 scale Rockhead Contours Plan; 1/2500 scale Seam Contour Plans for the Ashington (4D00), High Main or Diamond (E000), Top Main (F200) and Bottom Yard (G100) seams; Figures 3 and 6 of the Geotechnical Assessment Report; AEG Ltd.’s Factual Report (Appendix B).</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td><strong>Assumptions made before analysis</strong></td>
<td>Sections 5, 10 and 13 of Geotechnical Assessment Report.</td>
</tr>
<tr>
<td></td>
<td>A record of any assumption relevant to the assessment of ground conditions relating to the safety of the excavation or tip made by the geotechnical specialist including a record of any relevant information which was not available when undertaking the assessment.</td>
<td></td>
</tr>
<tr>
<td><strong>6</strong></td>
<td><strong>Findings of analysis</strong></td>
<td>Section 5 and Appendices D and E of the Geotechnical Assessment Report.</td>
</tr>
<tr>
<td></td>
<td>A record of the calculations carried out in order to determine the safety of the excavation or tip, including any variables or parameters used in those calculations and the reasons for using them and the findings of those calculations expressed as the factor of safety or the probability of failure or other recognised basis of assessing stability.</td>
<td></td>
</tr>
</tbody>
</table>

**Schedule 1 of the Quarries Regulations (1999)**
<table>
<thead>
<tr>
<th>Item</th>
<th>Requirements</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><strong>Design coming out of analysis</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>An accurate plan on a scale of not less than 1/2500 recording:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) in relation to the proposed tips, the design of the tip, including the area of land covered or to be covered, the gradients of that land, the designed contours at vertical intervals of not more than 2 metres, the side slopes and boundaries of the tips, and the designed position and nature of construction of any wall or other structure retaining or confining the tips; and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) in relation to the proposed excavations, the design of the excavation, including the height or proposed height of the slope, the position and width of any benches and representative contours of the excavation at vertical intervals of not more than 5 metres.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><strong>Requirements during and after construction</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A record of the nature and extent of inspection, supervision and safety measures necessary to ensure the safety of the excavations or tips and a specification of necessary engineering works and safety measures. A record of the action to be taken regarding defects specified in the report.</td>
<td>Sections 5, 6, 7, 8, 9 and 10 of the Geotechnical Assessment Report.</td>
</tr>
</tbody>
</table>

**Schedule 1 of the Quarries Regulations (1999)**
12. REFERENCES


13. **SIGNATURE OF GEOTECHNICAL SPECIALIST**

**Notes**

1. The various plans and documents referred to in this report should be considered as appendices. Many of these were not produced by the geotechnical specialist. It has not been possible to check all of the information.

2. There has been no site specific testing of the bedrock strata, but this is not considered to be essential given the experience that has been gained during the operation of other surface mines in the area. Reference has also been made to various research documents and standard texts.

Signature: ....

D A Blythe MA PhD CEng CGeol MIMMM FGS MIQ

Date: ......28th May 2015.....

Designation: Principal, DAB Geotechnics Ltd.