TITLE: Burton Highwall Challenge

OPERATION: Burton Coal Mine, owned by Peabody and operated by Thiess

AUTHOR: Thiess Burton Geotechnical Team

ABSTRACT

The Burton Coal Project mining operations currently occur in the Burton Widening Pit, a steep, open-cut terrace mine with a long, narrow working area. Forecasts indicate the highwall will be approximately 240 metres deep when operations reach the bottom of the pit. The pit's complex geology and footprint demand meticulous planning to ensure highwall stability and prevent vehicle congestion. The management team has assessed the site's potential safety risks and has implemented a number of initiatives to ensure a safe and productive work environment. One such initiative is an industry-leading monitoring system that can predict with a high level of accuracy when and where slope instability might occur. This is providing operators with the confidence that the systems and controls are in place to secure their safety as they work underneath the highwall.

INTRODUCTION

The Burton Coal Project is located approximately 150 kilometres south-west of Mackay in the northern Bowen Basin, producing up to 5.6 Mtpa of high quality hard and semi-hard coking and thermal coals for export markets. Current operations are focused in the Burton Widening Pit and involve the re-development of the original Burton Pit to a depth of up to 240 metres in geologically challenging conditions. Following a period of heavy rainfall in early 2013, a multi-bench highwall instability developed, requiring extensive geotechnical analysis and pit re-design to enable production to continue. To ensure the stability of the highwall going forward, the final catch bench was extended an additional 25 metres to provide a buttressing effect. In anticipation of the changed working conditions, a thorough risk assessment was carried out, which identified the need for safety critical monitoring via the use of a slope stability radar. A rigorous work procedure was developed and integrated into the existing geotechnical risk management system to ensure the safety of personnel and equipment.

MINING SCENARIO

Mining in the Burton Widening Pit targets the Permian-age Burton seam; an 11m thick coalescence of the Leichhardt and Vermont seams. Waste material consists of backfilled spoil on the western lowwall side of the pit and fresh overburden on the eastern highwall side. The mining method utilises a fleet of hydraulic excavators and rear dump trucks to develop the pit in a north to south direction. A terraced configuration has been adopted to progressively backfill the pit to final landform after de-coaling. A typical pit cross-section is presented in Figure 1.

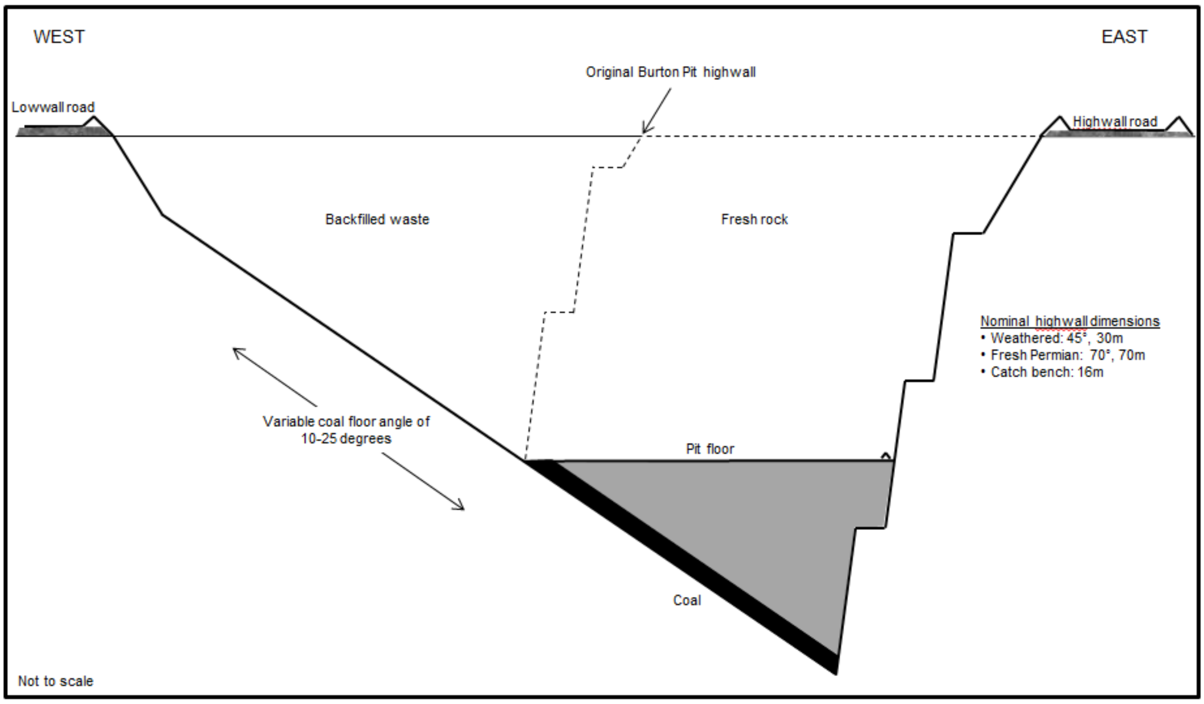


Figure 1 Typical Burton Widening Pit cross-section

Fresh overburden is predominantly lithic sandstone and siltstone, sandstone-siltstone laminates, silty mudstone and minor carbonaceous mudstone of Late Permian and Early Triassic age, typically dipping between 10 and 25 degrees to the north east conformably with the coal seam. Exploration has identified extensive faulting, including normal, thrust and strike-slip faults, as well as widespread intra-formational shearing of the coal floor. Baseline geotechnical studies completed prior to excavation of the pit predicted lowwall instability along the floor shears and the potential for large scale mobilisation of a rock wedge in the highwall at the intersection of two normal faults in the northern end of the pit. On site, this wedge became known as the Block 1 Wedge, while the two faults were known as the Corridor Fault (CF) and Southern Fault (SF). Another fault was identified approximately 200m to the south of the Southern Fault but was not expected to contribute to highwall instability. This fault became known as the Ramp 2 Fault (R2F) due to its proximity to the Ramp 2 pit access. A photograph of the Corridor Fault to Ramp 2 Fault highwall on the 17 December 2012 is presented in Figure 2.

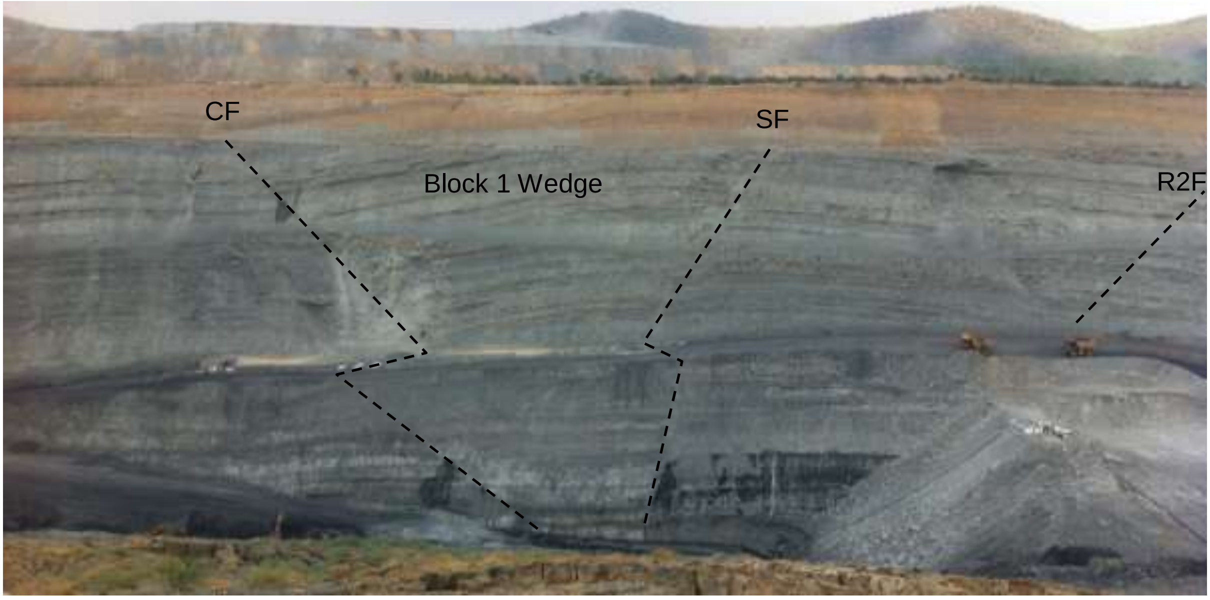


Figure 2 Photograph of the Corridor Fault to Ramp 2 Fault highwall on 17 December 2012

INITIAL EXCAVATION OF THE BLOCK 1 WEDGE

In anticipation of large scale instability in the Block 1 Wedge, a slope stability radar was deployed in the early stages of pit development to provide high resolution measurement of displacements and safety critical monitoring as required. Supplementary monitoring tools including survey prisms and vibrating wire piezometers were also installed to monitor three-dimensional slope displacements and groundwater levels respectively. Throughout the initial excavation, small scale rock mass and defect controlled wedge instabilities occurred, predominantly in the vicinity of the Corridor Fault. In August 2012, displacement of approximately 1mm/day was measured in the Block 1 Wedge but did not extend any further south than the Southern Fault.

THE AUSTRALIA DAY HIGHWALL EVENT

In the afternoon of 23 January 2013, heavy rainfall over the Burton Widening Pit necessitated temporary pit evacuation. While the pit was vacant, a full pit height highwall instability developed, initially at the slope toe midway between the Southern Fault and Ramp 2 Fault but quickly extending north to the Corridor Fault. At approximately midnight, a warning alarm on the slope stability radar alerted site personnel to the development of the instability. Over the following several days, large sections of the wall detached at various locations between the Corridor Fault and Ramp 2 Fault with the most significant fall occurring in the Block 1 Wedge on Australia Day. A total of 185mm rainfall was recorded between the 23-25 January, although it is unknown how much of this occurred prior to the onset of slope deformation. The slope stability radar remained operational throughout the entire event and an average deformation curve between the Corridor Fault and Ramp 2 Fault is presented in Figure 3. A time lapse of slope stability radar deformation plots is presented in Figure 4 to demonstrate the development of the instability. A photograph of the Corridor Fault to Ramp 2 Fault highwall on 27January 2013 is presented in

Figure 5.

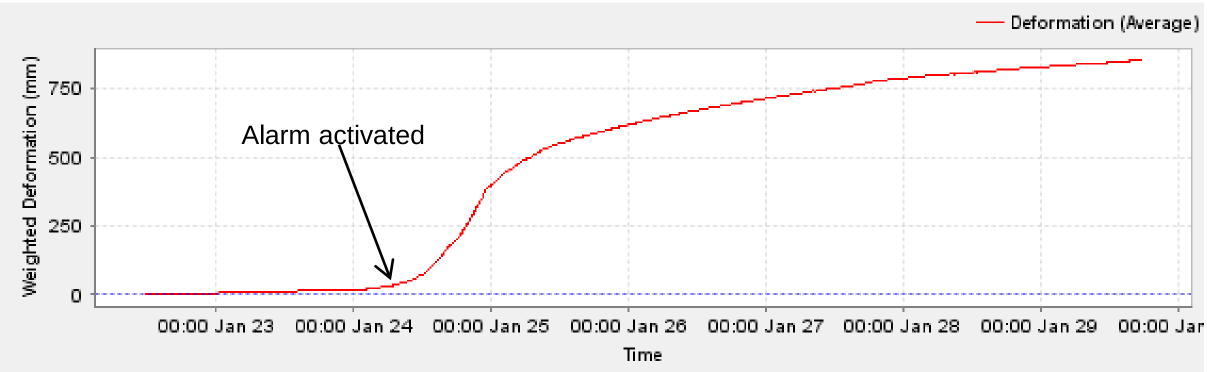


Figure 3 Average deformation curve captured for the Australia Day Highwall Event

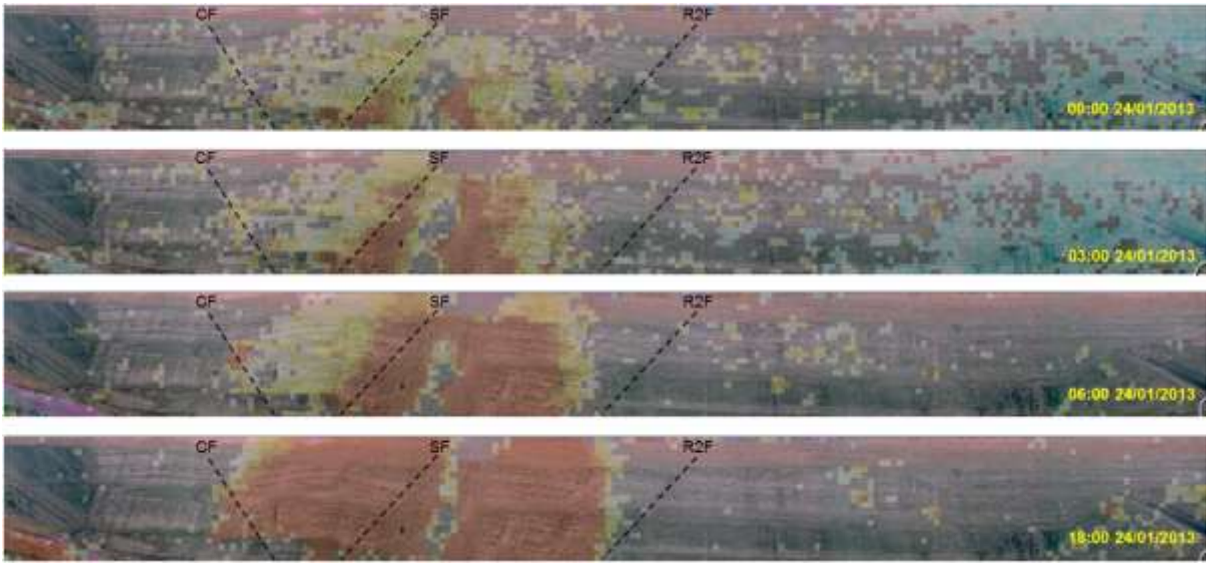


Figure 4 Time lapse of slope stability radar deformation plots demonstrating the development of highwall instability on 24 January 2013

Figure 5 Photograph of the Corridor Fault to Ramp 2 Fault highwall on 27 January 2013

GEOTECHNICAL ANALYSIS

In the weeks following the event, photogrammetric mapping was carried out to reassess the orientations of rock structures adopted in the geotechnical baseline studies. Additionally, the baseline seismic survey was revisited to check if any faults had been missed during the original interpretation. To further develop the existing geological database, four boreholes were drilled behind the highwall crest between the Corridor Fault and Ramp 2 Fault. Upon completion of drilling, an inclinometer and string of vibrating wire piezometers was installed into each borehole to enable monitoring of deep-seated slope deformations and groundwater levels. Despite the challenges associated with drilling through disturbed ground, a high quality set of geophysical logs was obtained and all monitoring equipment was successfully installed.

Following the data gathering period, a number of experienced industry consultants were engaged to assess the geological, hydrogeological and geotechnical aspects of the event and to develop a re-design that would enable recovery of the remaining coal below the instability. A comprehensive set of analyses was presented, including:

- Limit equilibrium models
- Numerical models
- Rockfall simulations

The results of these analyses led to the adoption of a highwall buttress method to provide overall stability of the slope for a period of time long enough to enable safe recovery of coal (Figure 6). The key features of the design were:

- The identification and delineation of a High Risk Area and a Residual Rockfall Risk Zone
- A 5m rockfall catch trench at the immediate toe of the failed rill material
- A 25m fresh rock buttress in addition to the existing 16m final catch berm width
- A softwall excavated at 50° in ground that had been blasted prior to the highwall instability

- A 5m wide berm and 2m high catch bund at the immediate toe of the softwall
- A final batter at the original pit shell design angle of 70°

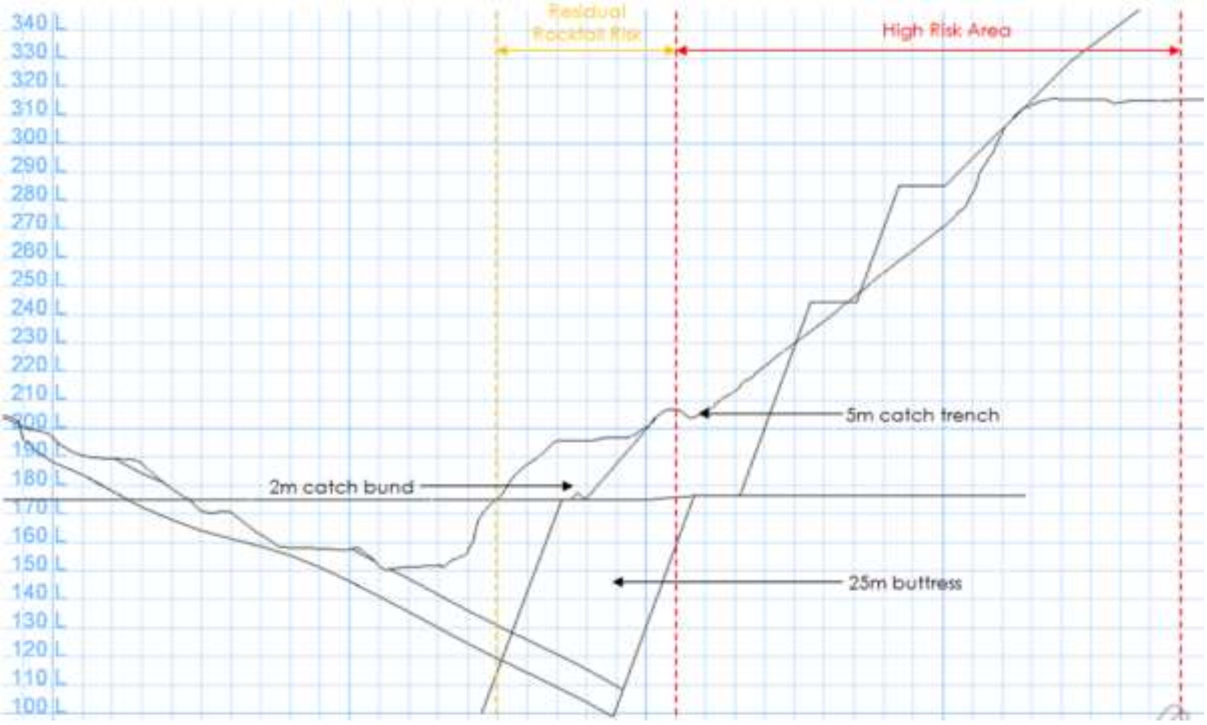


Figure 6 A representative cross-section showing the final design for the Burton Widening Highwall Buttress

GEOTECHNICAL RISK MANAGEMENT

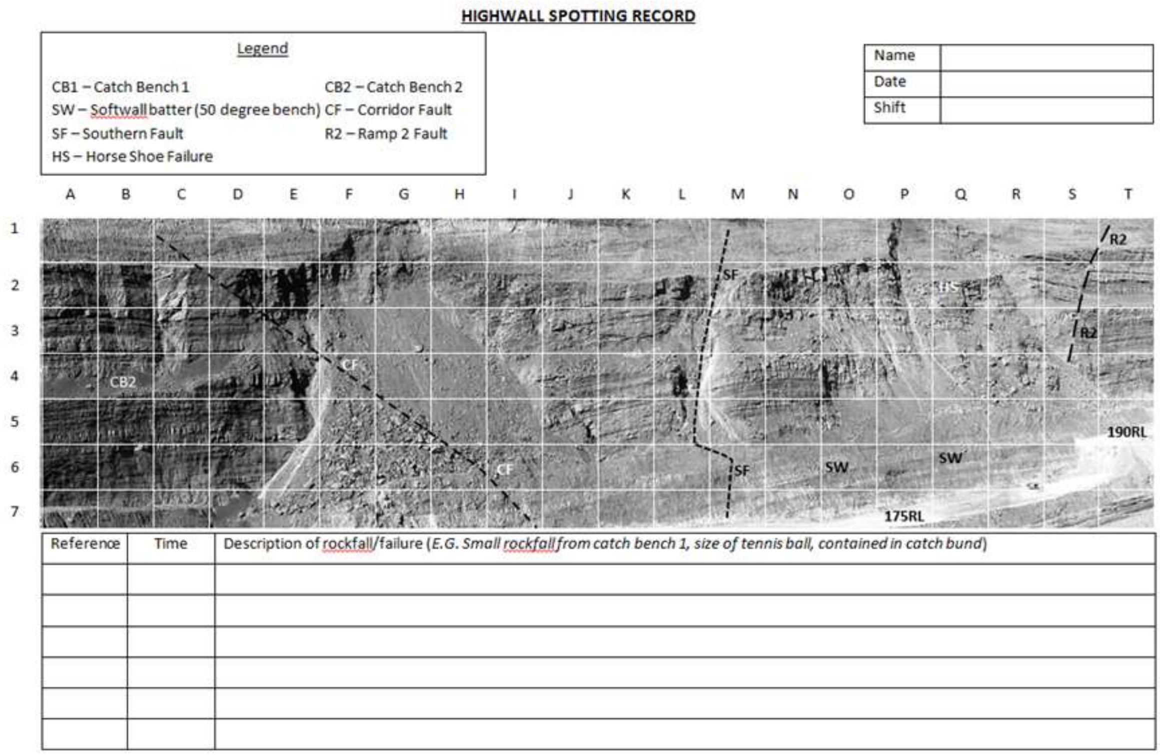
A thorough risk assessment was carried out on the buttress area located below the highwall displaying signs of instability. The assessment formed the basis of a Standard Operating Procedure, developed to ensure the safe excavation of personnel and equipment if required.. Some of the more significant and innovative controls included:

- Use of remote controlled dozers to construct the 5m rockfall catch trench within the high risk zone
- Use of specialised drilling equipment to enable pre-split drilling of the final batter
- Fall On Protection Systems (FOPS) installed on all equipment working north of the Ramp 2 Fault

Additionally, to enable effective use of monitoring controls, a definition for Fall of Ground was established and divided into three categories based on surface area: Major Failure, Minor Failure and Rockfall. When setting alarms on a slope stability radar, it is necessary to define the number of adjoining pixels that must concurrently exceed acceptable displacement thresholds before an alarm can activate. This is to prevent false alarms from being triggered by minor atmospheric events that cause small numbers of adjoining pixels to incorrectly report displacement. Experience in the Burton Widening Pit has shown this is typically limited to less than five pixels in normal diurnal atmospheric conditions, where each pixel is approximately 5m by 5m ($25m^2$), and this was therefore set as the limit for Major Failure.

Minor Failure was defined as less than five pixels but greater than one pixel, while Rockfall covered anything less than one pixel.

As Minor Failure and Rockfall were below the surface area threshold for safety critical slope stability radar monitoring, alternative controls were specified for work carried out within the Residual Rockfall Risk Zone. For Rockfalls, a physical barrier such as a catch trench or bund was required. For Minor Failure, a spotter was used under the logic that any such event would be preceded by one or more Rockfall events. The spotter was required to complete a shiftly highwall spotting record to document the location, size and severity of each Rockfall event (Figure 7). The Geotechnical Engineer analysed the data generated from the highwall spotting records to identify zones of increased Rockfall risk. A summary of Fall of Ground types, their defining surface areas and key controls is provided in Table 1.


HIGHWALL SPOTTING RECORD

Legend

CB1 – Catch Bench 1
CB2 – Catch Bench 2
SW – Softwall batter (50 degree bench)
CF – Corridor Fault
SF – Southern Fault
R2 – Ramp 2 Fault
HS – Horse Shoe Failure

Name	
Date	
Shift	

Reference	Time	Description of rockfall/failure (*E.G. Small rockfall from catch bench 1, size of tennis ball, contained in catch bund*)

Figure 7 Highwall spotting record form

Table 1 Summary of Fall of Ground types, their defining surface areas and key controls

Fall of Ground Type	Surface Area	Key Control
Major	>5 pixels (>125m^2)	Safety critical slope stability radar monitoring
Minor	>1 pixel, <5 pixels (25 to 125m^2)	Spotter
Rockfall	<1 pixel (<25m^2)	Physical barrier (catch trench or bund)

ONGOING STABILITY ISSUES AND ADDITIONAL GEOTECHNICAL ANALYSIS

During the initial re-design work, quantifying the time-dependent components of the ongoing instability was challenging. Although survey control showed the bunds and catch trenches had been constructed to design, the available catch capacity gradually reduced over time due to ongoing slope movement and rilling. Approximately six months after the design was first implemented, the Block 1 Wedge had deteriorated to the point where it was recognised that further rockfall analysis was warranted. The results of the analysis showed that rocks could be projected up to 24m from the highwall toe in an isolated 50m long section but would be arrested within the normal standoff elsewhere. Coal recovery could therefore be maximised by establishing a standoff zone and one-way access past the section of extreme rockfall risk to access the remaining coal. A cross-section showing the results of the rockfall analysis is presented in Figure 8.

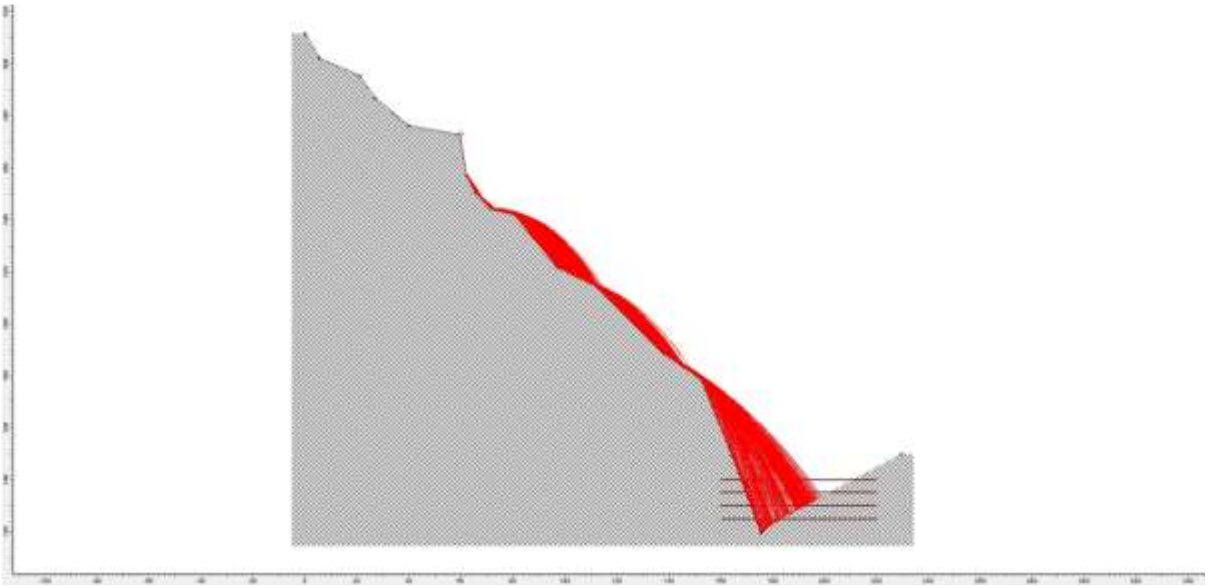


Figure 8 Results of rockfall analysis carried out to establish limits of rockfall standoff zone below deteriorating Block 1 Wedge

Throughout the highwall events already discussed, long-term gradual creep of the coal floor on the lowwall side of the pit had been ongoing. While the pit was relatively shallow with a wide working floor, the risk was considered low to moderate. However, as the working floor approached final pit depth, coal floor displacements became greater in magnitude and occurred more rapidly, eventually leading to several floor heave events after de-coaling. Due to the success of the slope stability radar in monitoring and providing advance warning of the highwall instability, a second radar was sourced to monitor the lowwall side of the pit. After an initial period of data gathering, geotechnical analysis enabled the onset of floor heave to be predicted based on accelerations observed in the coal floor. A photograph taken after one such floor heave event is presented in Figure 9. A total of four floor heave events were predicted and evacuated without incident during the excavation of the highwall buttress. The final cut of coal was excavated from the highwall buttress in early June 2014 with in-pit dumping commencing shortly thereafter and a slope stability radar in place for continued operations below the unstable highwall (Figure 10).

Figure 9 Photograph taken 11 March 2014 looking north after a floor heave event of up to 3m height that had resulted in the loss of up to 10m working width

Figure 10 Photograph taken 14 June 2014 showing slope stability radar continuing to monitor highwall instability

CONCLUSION

As shallow, more economically accessible deposits are exhausted around the world, open pits will become deeper with more ambitious slope designs and inherently more geotechnical risk. The ability to adequately manage geotechnical risks will be fundamental to the financial viability of these pits in the face of reducing commodity prices and operating margins. In conjunction with thorough risk assessment procedures and well-structured management systems, slope monitoring tools provide the confidence to navigate such geotechnical challenges while maintaining high levels of productivity. The Burton Widening project is an example of the successful implementation of geotechnical management strategies in a deep, steep and long pit with highly challenging geology. The collective knowledge gained by all personnel who have been involved in the excavation of the highwall buttress ensures geotechnical hazards will continue to be proactively identified and controlled.

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