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Dear Gary,

Dendrobium Area 3B – Review of Subsidence Predictions and Impact Assessments Addendum Letter Report for MSEC792 (Rev. C)

We are pleased to provide this addendum letter report that reviews the subsidence predictions and impact assessments for Dendrobium Area 3B. This letter provides additional information to that presented in our Report No. MSEC792 (Rev. C) and provides responses to the comments on that report.

Review of the surface impacts observed at Dendrobium Mine

The mining impacts that have been recorded by Illawarra Coal were provided to MSEC in a spreadsheet file called "*Dend_Impact_Summary.xlsx*". We have now reviewed these reported impacts based on the predicted ground movements at each of these sites.

The relationship between maximum measured soil crack and rock fracture widths versus the maximum predicted vertical subsidence is illustrated in Figure 1 and versus maximum predicted curvature in Figure 2. The vertical subsidence and curvature are the maximum predicted values within 20 metres of each impact site at the completion of the longwall that was active when the impact was first identified. It is noted, that there was a series of cracks up to 1.5 metres wide located above the commencing end of Longwall 3 (not shown in these figures for clarity) that developed as a result of downslope movement on the steep slopes, the shallower depth of cover (less than 200 metres at that location) and fretting of the crack edges.

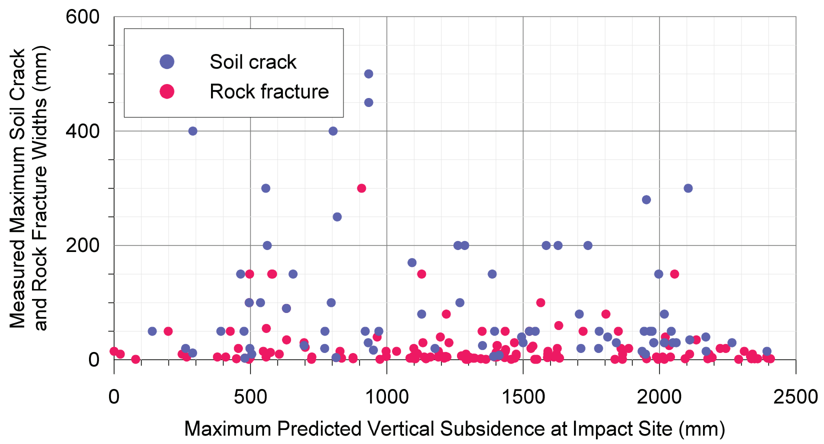

Figure 1 – Maximum measured soil crack and rock fracture widths versus maximum predicted vertical subsidence at the impact sites

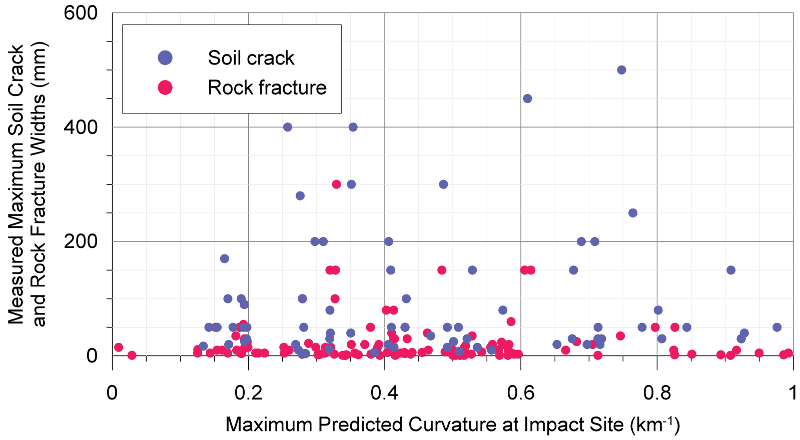

Figure 2 – Maximum measured soil crack and rock fracture widths versus maximum predicted curvature at the impact sites

The larger soil crack and rock fracture widths (i.e. greater than 100 mm) occurred across the full ranges of the predicted vertical subsidence and predicted curvature. Large surface crack and rock fracture widths occurred even where the predicted vertical subsidence was less than 1 metre. These sites were typically located within the tensile strain zones where the predicted hogging (i.e. convex) curvatures were at the higher end of the predicted range.

The site data indicates that larger cracking and fracturing (i.e. greater than 100 mm widths) can occur over the full ranges of the predicted vertical subsidence and curvature. More significant impacts typically occur due to steeply sloping terrain that results in increased horizontal movements in the downslope direction. These downslope movements result in localised and elevated tensile strains at the tops and sides of the slopes and localised and elevated compressive strains at the bases of the slopes. The natural surface slopes become less incised from Dendrobium Area 1 to Area 2, with Dendrobium Area 3 having a more gentle landscape.

Surface water impact sites (i.e. flow diversions and/or pool water loss) are compared to the maximum predicted total closure (valley closure plus conventional closure movements) and maximum predicted vertical subsidence in Figure 3. The shallow groundwater impact sites (i.e. piezometers) are compared to maximum predicted total closure and maximum predicted vertical subsidence in Figure 4.

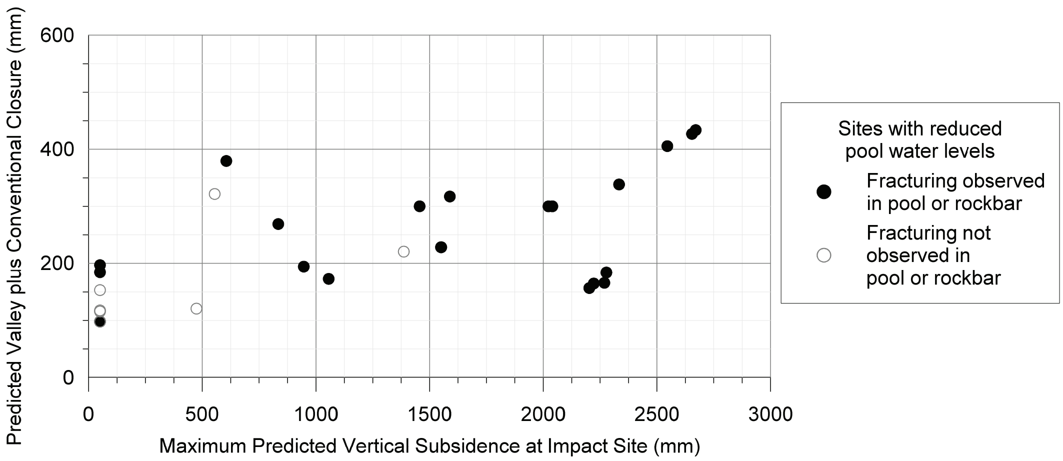

Figure 3 – Maximum Predicted Valley plus Conventional Closure versus Maximum Predicted Vertical Subsidence at the Surface Water Impact Sites (Flow Diversion or Pool Loss)

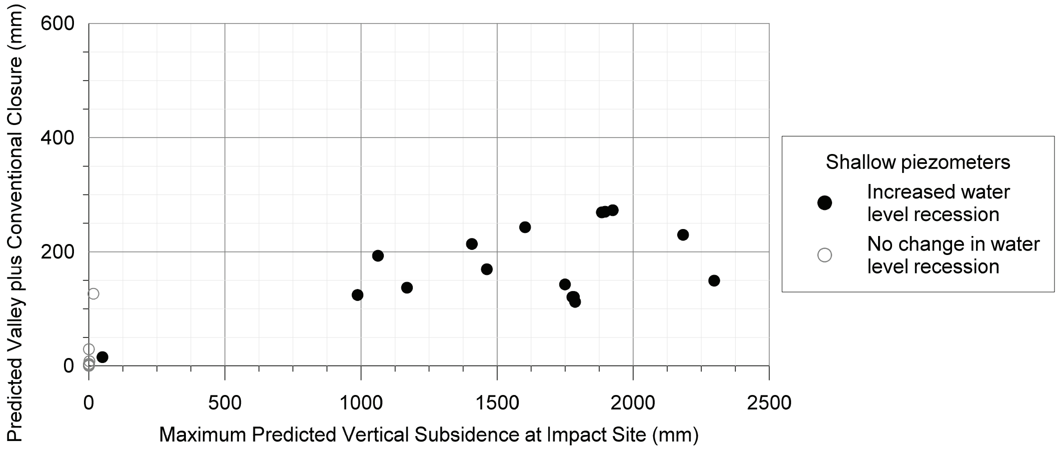

Figure 4 – Maximum Predicted Valley plus Conventional Closure versus Maximum Predicted Vertical Subsidence at the Shallow Groundwater Impact Sites (Piezometers)

The surface water impact sites occurred in locations having a wide range of predicted vertical subsidence and closure movements. There are three surface water impact sites (two along stream SC10C and one along Donalds Castle Creek) that have low levels of predicted ground movements (i.e. less than 100 mm vertical subsidence) as shown in Figure 3. These sites are located above solid coal immediately downstream of the extracted longwalls. These sites may have also been affected by fracturing that developed further upstream and above the extracted longwalls.

The hollow data points shown in Figure 3 represent reduced pool water levels in the absence of fracturing. The impacts at these sites can occur due to reduced flows from fracturing that develops further upstream, i.e. a flow diversion upstream resulting in lower surface water flows at the downstream sites.

The shallow groundwater impact sites occurred in locations having a wide range of predicted vertical subsidence and closure movements. There is one shallow groundwater impact site that has low levels of predicted ground movements (i.e. less than 100 mm vertical subsidence) as shown in Figure 4. This site is located above solid coal immediately downstream of the maingate of Longwall 11. This site may have been affected by fracturing that developed further upstream and directly above the adjacent longwall. The remaining impact sites were all located directly above the mining area.

The hollow data points in Figure 4 represent shallow groundwater piezometers that have not been impacted by subsidence movements in Dendrobium Area 3B. These sites all occurred outside the extents of the longwalls where only low levels of vertical subsidence were predicted (i.e. less than 50 mm).

The results suggests that impacts to shallow groundwater occur directly above or immediately adjacent to the extracted longwalls. These impact sites occurred over a wide range of predicted vertical subsidence, between 1 and 2.2 metres for the piezometers located directly above the extracted longwalls, and less than 50 mm for the one site located outside and immediately adjacent to the mining area.

Review of predicted subsidence parameters based on varying longwall widths and chain pillar widths

The predicted subsidence parameters in Dendrobium Area 3B have been reviewed based on varying longwall widths and chain pillar widths. The results are shown in Figure 5 for maximum predicted vertical subsidence, Figure 6 for maximum predicted tilt and Figure 7 for maximum predicted curvature.

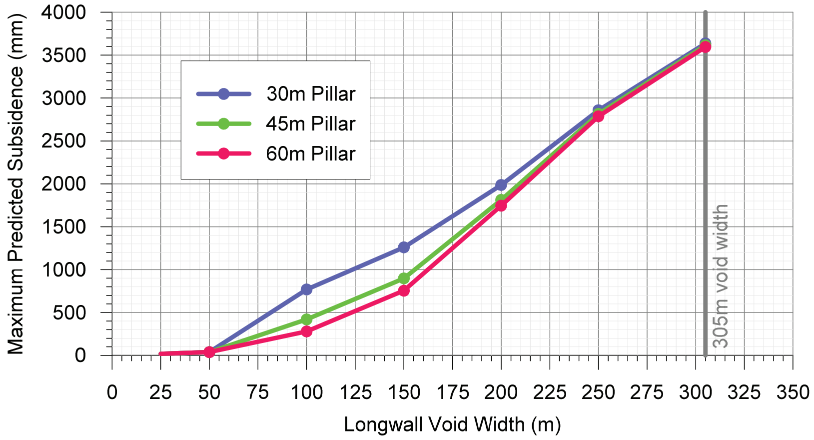

Figure 5 – Maximum Predicted Vertical Subsidence versus Longwall Void Width

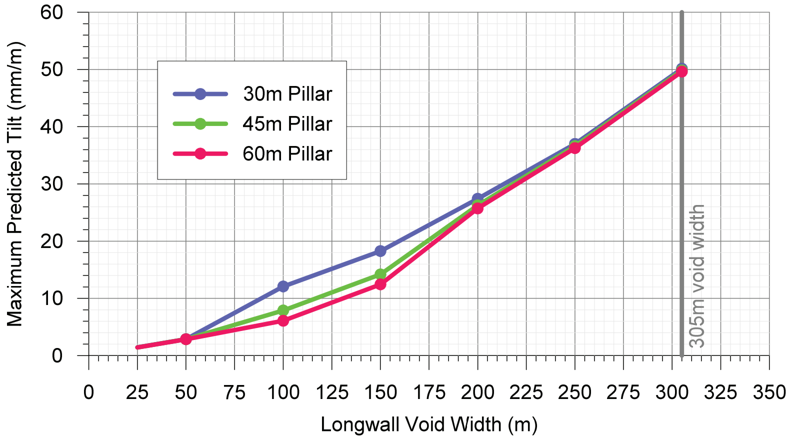

Figure 6 – Maximum Predicted Tilt versus Longwall Void Width

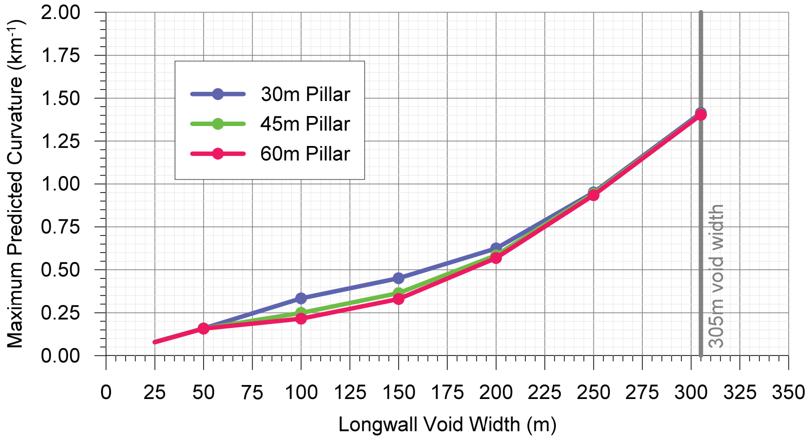

Figure 7 – Maximum Predicted Curvature versus Longwall Void Width

It can be seen in Figure 5 that, based on a 45 metre chain pillar, the maximum predicted vertical subsidence is around 3 metres based on 250 metre wide longwalls, 2 metres based on 200 metre wide longwalls and 1 metre based on 150 metre wide longwalls.

The maximum observed ground movements due to mining in the Bulli Seam in the Southern Coalfield at depths of cover ranging between 500 and 600 metres are typically 1 to 1.3 metres for vertical subsidence, 7 to 10 mm/m for tilt and 0.15 to 0.25 km^{-1} for curvature. In order to achieve similar levels of ground movements as those observed due to Bulli Seam mining, the longwalls void widths would need to be reduced to around 150 metres based on vertical subsidence and to around 100 metres based on tilt and curvature.

Observed movements in valleys elsewhere in the Southern Coalfield

The ground movements have been monitored at many sites where stream valleys are located directly above mining in the Bulli Seam within the Southern Coalfield. A summary of cases from the Bulli Seam mining is provided in Table 1.

Table 1 – Streams located directly above Bulli Seam mining in the Southern Coalfield

Location	Valley Height within Half the Depth of Cover (m)	Maximum Observed Subsidence (mm)	Maximum Observed Closure (mm)	Maximum Observed Compressive Strain (mm/m)
Appin (Area 1) - Ousedale Creek	12 to 29	775	250	-12.6
Appin (Area 2) - Back Gully	9	1,175	320	-10.9
Appin (Area 2) - Ousedale Creek	34	1,050	230	-8.5
Appin (Area 4) - Rocky Ponds Creek	34	1,200	180	-4.5
Appin (Area 4) - Rocky Ponds Tributary 1A	34	1,200	80	-2.1
Appin (Area 4) - Simpsons Creek	29	1,200	250	-12.2
Tower (North) - Cataract River	22 to 30	400	250	-8.9
Tower (North) - Cataract River Tributary 1	33	775	80	-2.5
Tower (North) - Cataract River Tributary 1A	33	775	80	-3.7
Tower (North) - Cataract River Tributary 1B	23	775	70	-2.6
Tower (North) - Nepean River	23	300	330	-5.3
West Cliff (Area 2) - Brennans Creek Dam Tributary 2	23	925	390	-9.7
West Cliff (Area 2) - Tributary 3 & 4	23	900	280	-6.5
West Cliff (Area 4) - Georges River	23	1,350	370	-9.5
West Cliff (Area 5) - Chicken Creek	23	850	90	-1.2
West Cliff (Area 5) - Leafs Gully	9	850	80	-2.1
West Cliff (Area 5) - Mallaty Creek	9	850	280	-17.2

Compressive strains up to 17.2 mm/m have been measured within stream valleys due to Bulli Seam mining in the Southern Coalfield. The valley related movements resulted in compressive strains much greater than 2 mm/m which are sufficient to result in fracturing of the topmost bedrock. The maximum observed vertical subsidence for these cases varied between 0.3 and 1.35 metres.

Responses to comments

The Department of Planning and Environment has provided comments on the submission by Illawarra Coal on the revised subsidence predictions and impact assessments for Longwalls 12 to 18 in Area 3B at Dendrobium Mine. The responses to the comments that relate to Report No. MSEC792 are provided below.

Comment: *"MSEC has reported conventional subsidence parameters significantly greater than those based on the earlier model, ie. 30% for vertical subsidence, 25% for tilt and 40% for curvature. Similar increases for upsidence and valley closure have not been reported. The Department seeks clarification on and reasons why increases are not predicted for these parameters.*

b) Explains how it is possible that such increases have not resulted in consequent increases in predictions in upsidence and valley closure. If this has been achieved by a reduction in the "factor of safety" for the prediction, the basis for this reduction needs to be justified."

Response: Horizontal movements that develop due to mining comprise a number of components. The horizontal movements that develop when mining beneath relatively flat terrain are often referred to as the 'conventional movements'. Additional or greater horizontal movements also develop when mining beneath steep topography or valleys due to the downslope movements and valley related effects.

The horizontal movements that are measured within stream valleys therefore include both the conventional component and the valley related component. Report No. MSEC792 provides separate predictions for the conventional closure and the valley related closure. The reason that these components are reported separately is that the strains can manifest differently from these two components. The conventional component generally results in tensile strains developing near the longwall edges and compressive strains developing near the longwall centre. Whereas the valley related component generally results in localised and elevated compressive strains developing close to the base of the valley and elevated tensile strains developing towards the top of the valley.

The horizontal movements that develop due to the conventional component are directly related to the magnitude of the vertical subsidence. A 30 % increase in the vertical subsidence therefore results in a similar increase in the conventional horizontal movements and, hence, the conventional closure. The predicted conventional closures for the streams that are provided in Report No. MSEC792 have been increased based on the higher levels of predicted vertical subsidence.

The horizontal movements that develop due to the valley related component are also affected by vertical subsidence. The valley related movements were predicted using the method outlined in ACARP Research Project Nos. C8005 and C9067 (the 2002 ACARP method). No reduction factors have been used. The influence of vertical subsidence on the valley related component reduces as the magnitude increases based on the 2002 ACARP method. As the vertical subsidence increases the valley related component also increases, but at a reducing rate. The prediction curve based on the empirical data tapers and, when the vertical subsidence is greater than around 1 metre, only small additional valley related movements are predicted with increasing vertical subsidence.

One limitation of the 2002 ACARP method is that the prediction curves were developed where there was limited monitoring data for cases where the vertical subsidence was greater than 1 metre. Hence, there is greater uncertainty in the 2002 ACARP method at the magnitudes of subsidence that occur at Dendrobium Mine. Nevertheless, the predicted conventional component of closure increases proportionally to the vertical subsidence and, therefore, it is considered that this would account for the greater potential for closure movements across the valleys at Dendrobium Mine.

A comparison between the observed and predicted closure for the monitoring lines in Dendrobium Area 3B was provided in Fig. 3.16 of Report No. MSEC792. The predicted closures included both the conventional and valley related components. The comparisons showed that the observed movements were less than predicted in all but two cases. It is considered therefore that the prediction methodology provided adequate predictions of the overall closure within the valleys based on the available ground monitoring data.

Comment: *c) Provides greater detail of how the updated predictions for non-conventional subsidence parameters have been achieved and clarifies whether these are consistent with findings presented in the recent ACARP Research Project No. C'18015 report (Effects of Mine Subsidence, Geology and Surface Topography on Observed Valley Closure Movements, and development of an updated Valley Closure Prediction Method, July 2014).*

Response: The predicted valley related movements for the SMP Application and Report No. MSEC459 (Rev. A) were determined using the methods outlines in ACARP Research Project C8005 and C9067 (the 2002 ACARP method). The revised methodology presented in ACARP Research Project C18015 (the 2014 ACARP method) was published in November 2014, i.e. after the completion of Report No. MSEC459. Report No. MSEC792 also adopted the 2002 ACARP method to remain consistent with the SMP Application and Report No. MSEC459.

The 2014 ACARP method provides seven additional factors that could be used to refine the predicted valley related movements. These factors are based on: whether the valley had been previously undermined; the geology of the valley floor and valley sides; angle of the longwall to the valley; consideration of headland features; thickness of the valley floor strata; survey mark spacing; and the location of the valley top.

These additional factors adopted in the 2014 ACARP method allow the predicted valley related movements to be reduced based on the site specific conditions. It was not considered appropriate to consider these reduction factors until sufficient ground monitoring data was gathered at Dendrobium Mine to support their application. The comparisons between observed and predicted closures for the monitoring lines at Dendrobium Mine suggest that the 2002 ACARP method provides adequate predictions without introducing the additional factors presented in the 2014 ACARP report.

In any case, the predicted closures obtained using the 2014 ACARP method are similar to those obtained using the 2002 ACARP method. This is illustrated in Figure 8 (reproduced from Fig. R.9 of Report No. C18015), with the y-axis representing the predictions obtained using the 2014 ACARP method and the x-axis representing the predictions obtained using the 2002 ACARP method. Please note that the label for the y-axis refers to the “2011 predicted incremental closure”, as the 2014 ACARP method was based on the data collected up until the end of 2011.

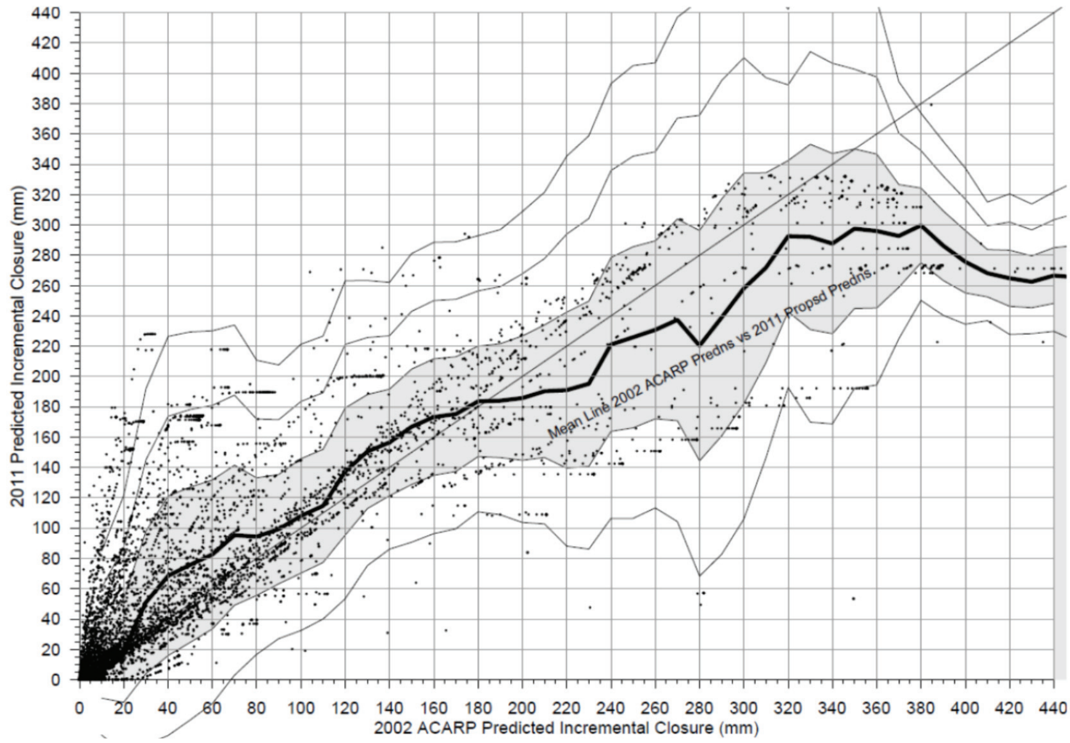

Figure 8 – Comparison of the predicted closures obtained using the 2014 ACARP method and the 2002 ACARP method

The rolling mean of the predictions obtained using the two ACARP methods is shown by the solid black curve in the above figure. It can be seen that this curve generally follows a one-to-one relationship, indicating that the predictions obtained using these two methods are similar. At higher levels of closure (i.e. greater than 180 mm), the predictions obtained using the 2014 ACARP method are slightly less than those obtained using the 2002 ACARP method.

I trust that the information provided is of assistance. If you have any questions or require further information, please email or call me on (02) 9413-3777.

Yours sincerely

James Barbato

James Barbato
Mine Subsidence Engineering Consultants