'NPM - 4'

Heritage Computing Pty Ltd ● ABN 75 392 967 126 ● T/A HydroSimulations
PO Box 241, Gerringong NSW 2534. Phone: (+61 2) 4234 3802 noel.merrick@heritagecomputing.com

DATE: 20 December 2014

TO: Mr Llewellyn Lezar
Head of Mining Operations
Adani Mining Pty Ltd
Level 25, 10 Eagle Street
Brisbane QLD 4000

FROM: Dr Noel Merrick

RE: **Adani - Carmichael Coal Project: Assessment of Fracturing in the Groundwater Model**

OUR REF: HC2014/33

The attached report is provided in response to an action item at the conference with Peter Ambrose QC in Brisbane on 8 August 2014. At that conference, I offered to provide an independent assessment of the likely fractured zone height to be deployed in the groundwater model.

Specifically, the scope of work was:

- consideration of the height of the fracture zone adopted in the groundwater model, in conjunction with the data in the MSEC report.

To conduct the assessment, I have relied on a relatively new algorithm by Ditton and Merrick (2014), presented at a conference in July 2014. The method also includes a tentative algorithm for fractured height estimation where multi-seam mining is to be conducted. There is as yet no rigorous verification of the multi-seam correction method, as calibration relies on only one available point of measurement (in the Hunter Valley of New South Wales).

The single-seam and multi-seam algorithms allow the estimation of likely fractured heights for individual longwalls, as the methods take into account panel width, depth of cover, mining height and effective beam thickness. Depending on the inclusion of the last attribute, the approach has two distinct conceptualisations known as the Geology Model and the Geometry model. The former should be more reliable, as local geology is considered, but there is no easy way to estimate the effective beam thickness. A worst case thickness of 10 m has been adopted in this assessment.

My findings are:

- no specific estimate was made by MSEC for the effect of multi-seam mining on the fracturing height (as no algorithm existed at the time);
- the uniformly adopted fracturing height of 160 m in the GHD model would incur fracturing to ground surface at 11 percent of longwall panels;
- the geometry model gives an average 133 m for the fracturing height across 59 longwall panels;
- the geometry model suggests no fracturing to surface;
- for the geometry model, the fracturing height would be increased by about 21-36% above the height expected with single-seam mining;

- the geology model gives an average 232 m for the fracturing height across 59 longwall panels;
- the geology model suggests fracturing to surface at 42 percent of longwall panels;
- for the geology model, the fracturing height would be increased by about 27-47% above the height expected with single-seam mining; and
- the fractured zone height estimates are considerably uncertain, especially in a greenfield situation in the Galilee Basin.

Yours sincerely

LPMerrick

Dr Noel Merrick

Director

1. CARMICHAEL COAL PROJECT FRACTURED ZONE ASSESSMENT

The strata movements and deformation that accompany subsidence will alter the hydraulic and storage characteristics of aquifers and aquitards. As there would be an overall increase in rock permeability, groundwater levels will be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient without drainage of water (in accordance with Darcy's Law).

The groundwater model for the Carmichael Coal Project has simulated the fractured zone that develops above a mined coal seam as a time-varying enhancement of overburden permeability. The unknowns in this representation are the height of that part of the fractured zone that drains water freely to the mine void below, through a connective fracture network, and the degree of enhancement of the permeability values.

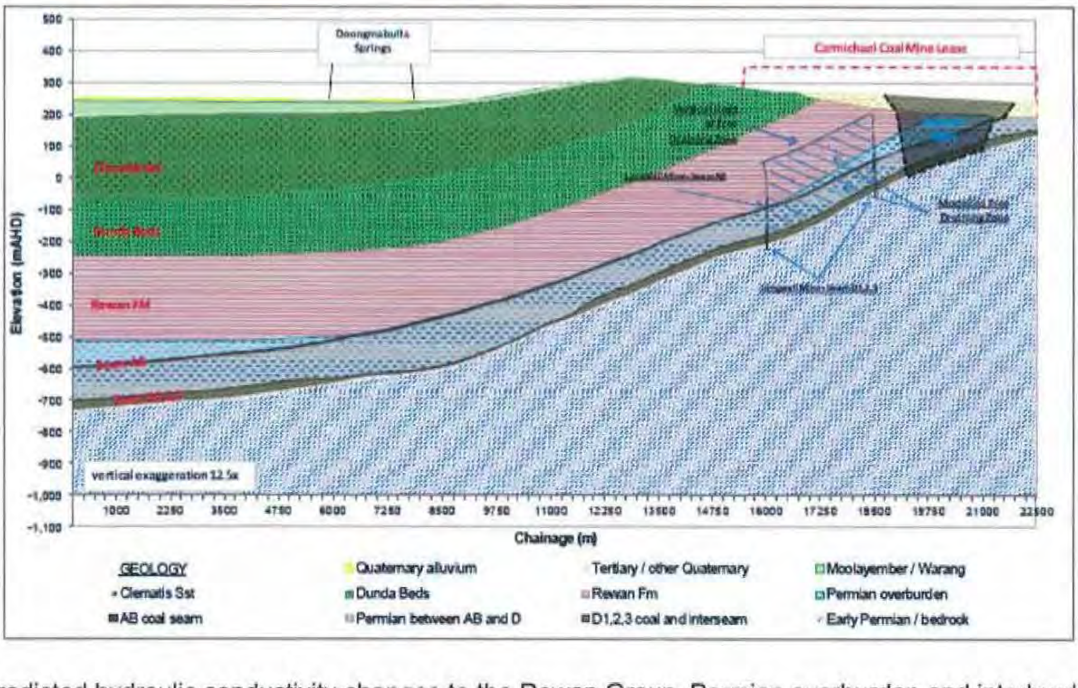
GHD Implementation of the Fractured Zone

The groundwater assessment for the Carmichael Coal Project represented the fractured zone in the groundwater model by means of enhanced vertical permeability to a height of 150 m above the mined coal seams. GHD (2013) refers to this zone as the Free Draining Zone. There are to be five underground mines extending in a north-south direction to the west of the open-cut pits (**Figure 1**). It is understood that multi-seam mining of AB and D seams is to be employed in all five mines, apart from six panels in Mine 1 and three panels in Mine 5 where no AB seam mining is planned (**Figure 1**).

Relevant extracts from the groundwater assessment report (GHD, 2013):

"In the earlier version of the groundwater model reported in the EIS (GHD 2012) the Rewan Group was simulated as a single model layer (model layer 6) and thus the historic model used for steady-state calibration comprised eleven layers. Model layer 6 was then split into two separate layers to allow better representation of the horizons within the Free Draining Zone which is likely to develop above the proposed longwall panels (MSEC, 2012, see Figure 28)."

Figure 28 Geological cross-section and extent of free draining zone



"Predicted hydraulic conductivity changes to the Rewan Group, Permian overburden and interburden associated with induced sub-surface fracturing caused by the underground mining were simulated using the TMP package."

"A separate study of subsidence by MSEC (MSEC, 2013 and with reference to the Subsidence Management Report, Volume 4, Appendix I) suggests that a free draining fracture zone with a maximum height of approximately 150 metres above each of the mined seams is likely to develop above the underground longwall mine workings. This free draining fractured zone is likely to be characterized by intense vertical fracturing thus creating potential for direct groundwater inflows from the overlying layers to the workings."

"Conceptual models for the free draining fractured zone (MSEC, 2012; Guo et al., 2007) suggest an increase in vertical hydraulic conductivity whilst variation in horizontal hydraulic conductivity is generally considered likely to be negligible. Guo et al. (2007) suggest that the vertical hydraulic conductivity in the free draining fracture zone may be increased by a factor of up to 50. Furthermore the relative change in vertical hydraulic conductivity is likely to be higher towards the base of the fracture zone than at the top."

"For modelling purposes the free draining fractured zone has been simulated by increasing the natural (pre-mining) vertical hydraulic conductivity by a factor of 50 for the lower 50 percent of the zone and by a factor of 10 in the upper 50 percent. This is considered to be consistent with the factors suggested by Guo et al. (2007) and with the conceptual model of reducing hydraulic conductivity enhancement with vertical distance from the mined areas. The development of the free draining fractured zones in the Permian overburden (model layer 8), Rewan Group (model layers 6 and 7) and in the Permian interburden (model layer 10) follow the underground mining schedule (as described in Section 5.6.4)."

In other words, a step function has been applied for vertical hydraulic conductivity (Kz), with Kz increased 50 times from the top of the coal seam to a height of 75 m above, and by 10 times from 75 m to 150 m above the top of the coal seam. It is not clear how multi-seam mining in Mine 1 is handled? Is the 150 m height applied only to the AB seam? In reality, the effect of mining the D seam will be to increase the height of fracturing above the AB seam. Also, it is not clear whether or not enhanced storage properties were applied in the fractured zone.

"The predictions of impact on the GAB areas to the west of the mine therefore take account of this potentially important mining-induced change in hydrogeological properties. However, additional runs of the predictive groundwater model carried out with and without inclusion of a free draining fracture zone suggest only a relatively minor component (less than 4 percent) of the predicted total impact can be attributed to longwall mining induced fracturing of the overlying strata." "...whilst surface cracking is often observed in exposed bedrock areas in NSW, similar types of cracking are not anticipated in the Carmichael Coal project area due to the presence of unconsolidated Quaternary and Tertiary sediments at outcrop across the underground mining area".

MSEC Advice on the Fractured Zone

Relevant extracts from the subsidence assessment report (MSEC, 2013):

"The height above the seam of the relatively free draining fractured zone is an important issue and it appears to be dependent on many factors, most notably including: the longwall panel width, the seam thickness extracted, the thicknesses and geomechanical properties of the overlying strata units, the presence of faults and natural jointing, the presence of layers of clay, claystone, shale, siltstone, mudstone, tuff and tuffaceous horizons that can restrict the vertical flow of groundwater, and, where very wide supercritical panels are being extracted, the bulking and compaction factors of the goafed material."

"The height of free draining fractured zone cannot be definitively measured using borehole extensometers alone..."

"The height of fracturing cannot be definitively determined after comparing borehole piezometers and permeability testing at selected horizons before and after mining alone..."

"A further extensive analysis of surface and sub-surface subsidence, cracking and groundwater data from the Newcastle region was undertaken by Ditton & Frith (ACARP C5016, 2003) and these authors developed a subsurface fracturing model that was based predominantly on work published by Whittaker and Reddish (1989)...". "This model identified the existence of two distinct zones of fracturing above super-critical width extractions (*continuous* and *discontinuous* fracturing)."

"The definition of the extent of *continuous* fracturing that was used in the Whittaker and Reddish model refers to the height at which a direct connection of the fractures occurs within the overburden and the workings; it represents a direct hydraulic connection for groundwater inflows. The height is very different to the potential height of fracturing which can extend higher, but, within which the remote fractures and cracks are not connected. The definition of the extent of *discontinuous* fracturing refers to the height at which the horizontal permeability increases as a result of strata de-lamination and fracturing, i.e. a slight temporary reduction in head without full water loss or direct connections to the workings."

"Klenowski (ACARP C5016, 2000) stated that for ponded water at cover depths of greater than 160 metres, remedial works will generally not be required and standard underground pumping systems should be capable of handling minor increases in flow. This is a very useful consideration for the Carmichael Project as few areas over the proposed longwalls are shallower than 160 metres."

"Experience has shown that it is extremely difficult to mine longwall coal when goaf water flow rates of greater than 20 l/sec occur along the face line. In such cases, dams and transportable pumping systems need to be installed in gate roads or sumps adjacent to gate roads. Where possible, mine designs should accommodate goaf water flows away from longwall faces."

"While many authors seem to use seam thickness as the preferred mining parameter that influences cracking heights and dilation, such as Kendorski (1993), Forster and Enever (1992) and Ditton and Frith (ACARP C10023, 2003), many other authors have noted the importance of depth of cover, (Klenowski ACARP C5016, 2000), and others suggested that it is more logical to normalise measured fracture heights to panel width and not extraction thickness, e.g. Mills and O'Grady (1998) and Seedsman (ACARP C13009, 2006)."

"Accordingly, it is recognised that it may not be appropriate to use heights of cracking or connectivity models that were developed based solely on one factor, say seam thickness or geometry of the mined panel..."

"More recent studies have highlighted that generalised mine design recommendations should not be applied blindly and that careful consideration must always be given to site specific geology and geological features. The specific geology of each case should be closely considered as the presence or absence of strong channels or impermeable layers completely changes generalisations based on panel width or seam thickness." " It is therefore recommended that a detailed assessment by an appropriate specialist ground water consultant be undertaken at the appropriate stage to confirm, refine and further elaborate upon this preliminary assessment. One of the most important tasks of this specialist is to confirm the presence of an appropriate aquitard or aquiclude layer within the top portions of the overburden."

"The difficulty in assessing the likely height of fracturing and height of hydraulic connectivity at this project is that the geological setting for the Carmichael project is significantly different from the geological settings in almost all the published literature on subsidence, likely height of fracturing and height of hydraulic connectivity in Australia. The models published in literature have been developed for locations with predominantly sandstone overburden or using data from cases with significant sandstone overburden. The overburden at the Carmichael project predominantly includes the Rewan formation which is described as an aquitard in the GHD Hydrogeology Report (Nov 2012) and this formation is a base unit of the Great Artesian Basin. In addition, there are significant thicknesses of clay dominated materials in the tertiary age deposits." " Because of this geological profile, the predicted subsidence for this project is significantly greater than for normal sandstone dominated profiles."

"The overburden above the Proposed Longwalls at the Carmichael Project include significant thickness of Tertiary and Triassic (Rewan Formation) sediments, which are generally of low strength and poor spanning capability than those found in the coalfields of NSW..."

"The heights of fracturing that are summarised in Table 5.4, above, are also based on single seam extraction. With an interburden thickness of 70 metres to 130 metres between the AB1 and D1 seams, the extraction of the D1 seam will result in fracturing to the overlying AB1 seam and reworking of the fractured zone above the AB1 seam, increasing the height of the fractured zone. As a result, it is anticipated that the height of fracturing at the Carmichael Project will be at the upper end of the range of height estimates for the various published methods and potentially even higher."

"Accordingly the expected height of fracturing at the Carmichael Project, is expected to extend from the AB1 seam to the surface over much of the proposed longwall footprint. It must be stressed, however, that the anticipated height of fracturing does not imply that hydraulic connectivity will extend to the same height, especially since the overburden materials at the Carmichael Project contain layers which behave as aquicludes or aquitards."

"It is expected that where sufficient depth of cover and thickness of Rewan formation and/or Tertiary clay are present, there will be a low risk of direct hydraulic connection from the surface to the seam. Conservatively adopting 160 metres based on Klenowski (ACARP C5016, 2000) would be considered a reasonable height for preliminary modelling of the height of direct hydraulic connection. Above this height, it is anticipated that there will be increase in the strata permeability due to fracturing through beds and bedding plane dilation, however the likelihood of hydraulic connectivity from the surface to the seam is anticipated to be low given the presence of aquiclude and aquitard materials in the overburden. Adopting increases in vertical permeability as suggested by Guo et al (ACARP C14033, 2007) would provide a reasonable basis for preliminary modelling."

MSEC has settled on a fractured zone height of 160 m as determined by Klenowski for the German Creek and Oaky Creek mines. It is not clear what algorithm has been used. Although MSEC quotes Klenowski as favouring a relationship with panel width, a height of 160 m happens to be exactly 60 times the mining height of the AB seam, which is the Kendorski recommendation for the top of the Dilated Zone, and double Kendorski's Fractured Zone. Alternatively, a height of 160 m is 0.52 times the panel width of 310 m. No algorithm has been applied that takes into account multiple causative parameters.

There are only two known algorithms that aim to estimate the altitude of the deformed zone above an underground mine in terms of more than one causative factor. The algorithms have been put forward in consulting reports by Steve Ditton of Ditton Geotechnical Services Pty Ltd (DGS) and in a journal paper by Paul Tammetta of Coffey Geosciences Pty Ltd3[1]. HydroSimulations has differentiated their formulas to reveal the sensitivity of fractured zone height to each causative factor. The two approaches have similar sensitivities for cover depth but differ for panel width and mining height. For mining height they are very different and trend in different directions. The latest formulation of the Ditton model was presented at the Australian Earth Sciences Convention in Newcastle NSW in July 2014 (Ditton and Merrick, 2014)[2].

Both authors have found a relation between the height of some representation of the "fractured zone" and three key attributes of the mining system:

- Mining height [T (Ditton) or t (Tammetta)];
- Cover depth [H (Ditton) or h (Tammetta)]; and
- Longwall panel width [W (both authors)].

In addition, the Ditton model includes effective stratum thickness [t'] as a surrogate for roof rock integrity in one of his two developed models. The second model that uses only mining geometry, with no geology term, is directly comparable to the Tammetta model.

Ditton Model Formulas

The Ditton conceptual model of deformation zones, illustrated in **Figure 2** (Ditton and Merrick, 2014), consists of four zones:

- the A-Zone or "Continuous Cracking" zone - equivalent to the caved zone plus the connective-cracking part of the fractured zone;
- the B-Zone or "Lower Dilated" zone - equivalent to the disconnected-cracking part of the fractured zone, or the lower part of the constrained zone;
- the C-Zone or " Upper Dilated" zone - equivalent to the upper part of the constrained zone; and
- the D-Zone or "Surface Cracking" zone - equivalent to the surface zone.

[1] Tammetta, P. , 2012, Estimation of the Height of Complete Groundwater Drainage Above Mined Longwall Panels. Ground Water, online article 10.1111/gwat.12003, Blackwell Publishing Ltd, 12p.

[2] Ditton, S. and Merrick, N, 2014, A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

The rocks in the A-Zone would have a substantially higher vertical permeability than the undisturbed host rocks. This will encourage groundwater to move out of rock storage downwards towards the goaf. In the B-Zone, where disconnected-cracking occurs, the vertical movement of groundwater should not be significantly greater than under natural conditions, but horizontal permeability would be expected to be enhanced through dilation of bedding planes.

Depending on the width of the longwall panels and the depth of mining, and the presence of low permeability lithologies, there would be a constrained zone in the overburden that acts as a bridge. Rock layers are likely to sag without breaking, and bedding planes are also likely to dilate. As a result, some increase in horizontal permeability can be expected.

In the surface zone, near-surface fracturing can occur due to horizontal tension at the edges of a subsidence trough. Fracturing would be shallow (<20 m), often transitory, and any loss of water into the cracks would not continue downwards towards the goaf. The extract from MSEC (2013) agrees that "surface waters lost to the subsurface re-emerge downstream via lateral faults". As "lateral faults" is a strange concept, are dilated bedding planes or opened joints intended as the mechanism?

The new Ditton model includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and local geology factors to estimate the A-Zone and B-Zone horizons above a given longwall panel. Segregation between the A-Zone and B-Zone is based on a threshold vertical strain of 8 mm/m.

Formulas are offered for two models:

> Geometry Model, which depends on W, H and T; and
>
> Geology Model, which depends on W, H, T and t' (where t' is the effective thickness[3] of the stratum where the A-Zone height occurs).

The formulas for fractured zone height (A) for single-seam mining are:

> Geometry Model: $A = 2.215\, W'^{0.357} H^{0.271} T^{0.372} \quad +/- [0.1 - 0.16]\, W'$ (metres)
>
> Geology Model: $A = 1.52\, W'^{0.4} H^{0.535} T^{0.464} t'^{-0.4} \quad +/- [0.1 - 0.15]\, W'$ (metres)
>
> where W' is the minimum of the panel width (W) and the critical panel width (1.4H).

The 95th percentile (maximum) A-Zone heights are estimated by adding aW' to A, where *a* varies from 0.1 for supercritical panels to 0.16 (geometry model) or 0.15 (geology model) for subcritical panels.

The models have been validated to 34 measured Australian case-studies (including West Wallsend, Mandalong, Springvale, Able, Ashton, Austar, Berrima, Metropolitan and Wollemi/North Wambo Mines in New South Wales and two mines in the Bowen Basin, Queensland) with a broad range of mining geometries and geological conditions included. The database also includes three cases in which connective cracking reached the surface (South Bulga, Homestead and Invincible Collieries). Statistics for the database are presented in **Table 1**.

[3] Typically 15-40 m

Table 1. Statistics for the Ditton Model Database for Australian Coalfields.

STATISTIC	Panel Width [W (m)]	Cover Depth [H (m)]	Mining Height [T (m)]
Mean	191	254	3.0
Standard Deviation	65	138	0.8
Minimum	110	75	1.9
Median	179	213	2.8
Maximum	355	500	6.0

The variation of the A-Zone height for each factor is illustrated in **Figure 3** to **Figure 6**. In each figure, the other three parameters are held constant at their database median values.

Ditton (2014, pers. comm.) has a procedure for estimating the increased fractured zone height for multi-seam mining, in which the mining height (T) in the above formulas is replaced by an effective mining height (T') for the upper mined seam that accounts for the additional subsidence caused by mining other seams. This relies on theoretical estimates of subsidence for single or multiple seams. The ratio of the increase in subsidence (due to mining another seam) to the subsidence for a single seam is taken to apply also to the increase in the effective mining height[4].

Representative statistics for characteristic ratios derived for the Ditton database are listed in **Table 2** and **Table 3**. A common first-order estimate of fractured zone height is afforded by the ratio A/W, which is 0.45 for the Ditton concept at the median (**Table 2**). The Ditton B-Zone ratio is 0.60 at the median (**Table 3**). Another common first-order estimate of fractured zone height is afforded by the ratio A/T, which is 21-37 for the Ditton concept (**Table 2**). For the parameters W, H and T in turn, the median B-height exceeds the median A-height by 33%, 100% and 34% (**Table 3**).

Table 2. Exceedance Probabilities for Ditton Continuous Fracture Zone (A-Zone) Height for Australian Coalfields.

EXCEEDANCE PROBABILITY	Height of Fracture Zone / Panel Width [A/W]	Height of Fracture Zone / Cover Depth [A/H]	Height of Fracture Zone / Mining Height [A/T]
20%	0.38	0.23	21
50%	0.45	0.43	32
80%	0.73	0.69	37

[4] One unpublished case study in the Hunter Coalfield NSW showed an increase in the effective mining height of about 70%. This had the effect of increasing the A-height by 27%.

Table 3. Exceedance Probabilities for Ditton Discontinuous Fracture Zone (B-Zone) Height for Australian Coalfields.

EXCEEDANCE PROBABILITY	Height of Fracture Zone / Panel Width [B/W]	Height of Fracture Zone / Cover Depth [B/H]	Height of Fracture Zone / Mining Height [B/T]
20%	0.47	0.60	27
50%	0.60	0.86	43
80%	1.07	0.95	71

Fractured Zone Heights

The Ditton formulas have been applied to each of the Carmichael longwall panels assuming the following values for the causative parameters:

- Panel width: W = 310 m;
- Mining Height: T = 2.7 m (AB seam); T = 3.25 m (D seam);
- Depth of cover: variable H according to Table 5.5 and Drawings MSEC627-09 and MSEC627-10 in MSEC (2013);
- Effective beam thickness: t' = 10 m (worst case);
- Multi-seam subsidence differentials: ΔS = 1.3 m (median); ΔS = 1.6 m (average); standard deviation 0.6 m.
- Effective mining height increase: ΔT = ΔS / 0.6 = 2.2 m (median); ΔS = 2.7 m (average); and
- Effective mining height of AB seam for multi-seam mining: T' = 4.9 m (median); T' = 5.4 m (average).

Table 3 shows the results. The average A-zone height varies from 133 m to 232 m for the Ditton geometry and geology models, respectively, compared to 160 m adopted uniformly in the GHD model. The Ditton results are very sensitive to the estimate of effective beam thickness, and a worst case has been adopted here. Using the geology model, it is likely that fracturing to surface (linking with surficial cracking of at most 10 m) would occur at 25 (42%) of the 59 longwalls. Using the geometry model, no fracturing to the surface is possible. In the GHD model, fracturing to surface would be expected at 11 (19%) of the 59 longwalls.

Multi-seam mining has a significant effect on the combined height of fracturing above the uppermost mined seam. For the geology model, the A-zone height is increased by about 27-47% above the height expected with single-seam mining. For the geometry model, the corresponding A-zone height increase is about 21-36%. The fractured zone height estimates are considerably uncertain, as there is not yet any rigorously verified method of estimation. The method applied here (as developed by Ditton) rests on only one calibration point.

The expected locations of fracturing to surface are illustrated in **Figure 7**.

Table 3. Ditton Continuous Fracture Zone (A-Zone) Heights and Depths.

LONGWALL	Cover Depth [m]	Geology Model Fracture Height [m]	Geology Model Depth to Fracture Zone [m]	Geometry Model Fracture Height [m]	Geometry Model Depth to Fracture Zone [m]	Fracture to Surface	Multi-Seam Mining
DLW101N	120	105	15	78	42	Possible	N
DLW102N	160	138	22	94	66	No	N
DLW103N	200	170	30	108	92	No	N
ABLW101N	160	202	0	127	33	Yes	Y
ABLW102N	210	246	0	145	65	Yes	Y
ABLW103N	260	263	0	148	112	Yes	Y
ABLW104N	300	264	36	145	155	No	Y
ABLW105N	330	275	55	147	183	No	Y
ABLW106N	370	284	86	149	221	No	Y
ABLW107N	400	280	120	145	255	No	Y
DLW101S	120	105	15	78	42	Possible	N
DLW102S	160	138	22	94	66	No	N
DLW103S	190	162	28	104	86	No	N
ABLW101S	140	180	0	118	22	Yes	Y
ABLW102S	180	223	0	136	44	Yes	Y
ABLW103S	220	254	0	147	73	Yes	Y
ABLW104S	270	265	5	148	122	Yes	Y
ABLW105S	320	265	55	144	176	No	Y
ABLW106S	370	263	107	140	230	No	Y
ABLW107S	410	264	146	138	272	No	Y
ABLW201	220	248	0	145	75	Yes	Y
ABLW202	240	250	0	144	96	Yes	Y
ABLW203	290	258	32	143	147	No	Y

ABLW204	320	258	62	141	179	No	Y
ABLW205	350	272	78	145	205	No	Y
ABLW206	380	288	92	150	230	No	Y
ABLW207	400	297	103	152	248	No	Y
ABLW301N	250	247	3	141	109	Yes	Y
ABLW302N	280	248	32	139	141	No	Y
ABLW303N	300	252	48	139	161	No	Y
ABLW304N	320	255	65	139	181	No	Y
ABLW305N	340	268	72	144	196	No	Y
ABLW301S	250	252	0	144	106	Yes	Y
ABLW302S	270	245	25	139	131	No	Y
ABLW303S	290	254	36	141	149	No	Y
ABLW304S	300	256	44	141	159	No	Y
ABLW305S	320	268	52	145	175	No	Y
ABLW401	200	238	0	142	58	Yes	Y
ABLW402	220	251	0	146	74	Yes	Y
ABLW403	240	257	0	147	93	Yes	Y
ABLW404	260	256	4	144	116	Yes	Y
ABLW405	280	256	24	143	137	No	Y
ABLW406	290	255	35	141	149	No	Y
ABLW407	310	267	43	145	165	No	Y
ABLW501N	220	251	0	146	74	Yes	Y
ABLW502N	240	254	0	146	94	Yes	Y
ABLW503N	270	265	5	148	122	Yes	Y
DLW501S	130	113	17	82	48	Possible	N
DLW502S	170	146	24	97	73	No	N
DLW503S	180	154	26	101	79	No	N

ABLW501S	120	156	0	107	13	Yes	Y
ABLW502S	140	178	0	117	23	Yes	Y
ABLW503S	160	197	0	125	35	Yes	Y
ABLW504S	190	224	0	136	54	Yes	Y
ABLW505S	210	234	0	139	71	Yes	Y
ABLW506S	230	248	0	144	86	Yes	Y
ABLW507S	250	243	7	139	111	Yes	Y
ABLW508S	270	247	23	140	130	No	Y
AVERAGE	***252***	***232***	***29***	***133***	***118***		

REFERENCES

GHD, 2013, Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report. Report G:\41\26422\WP\449522.docx, 13 November 2013.

Heritage Computing, 2013, Galilee Coal Project Groundwater Assessment. Report HC2013/7 for Waratah Coal Pty Ltd.

MSEC, Mine Subsidence Engineering Consultants, 2013. Carmichael Project – Revised Subsidence Assessment. Report Number: MSEC627. 28 July 2013.

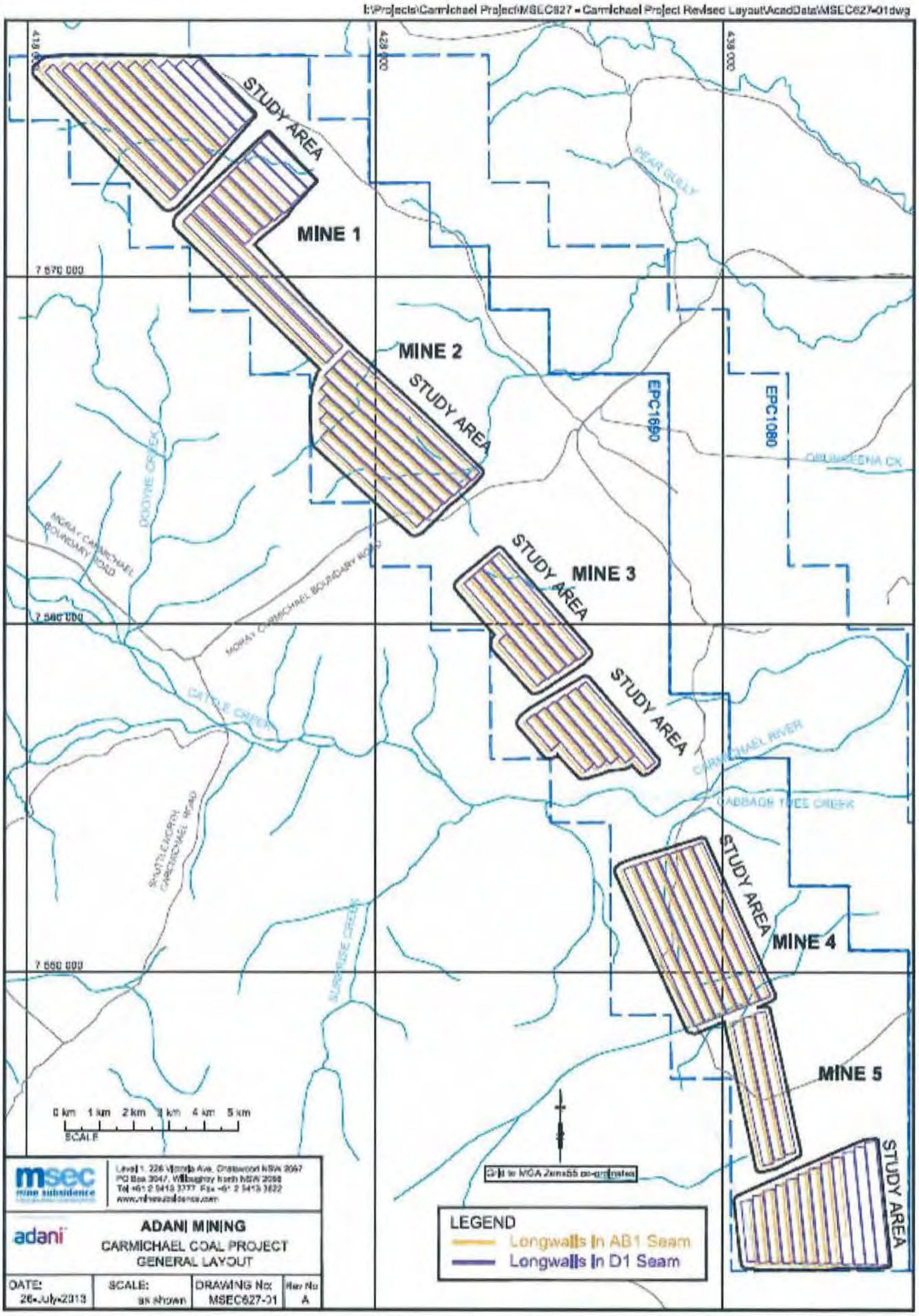


Figure 1. Carmichael Longwall Panels

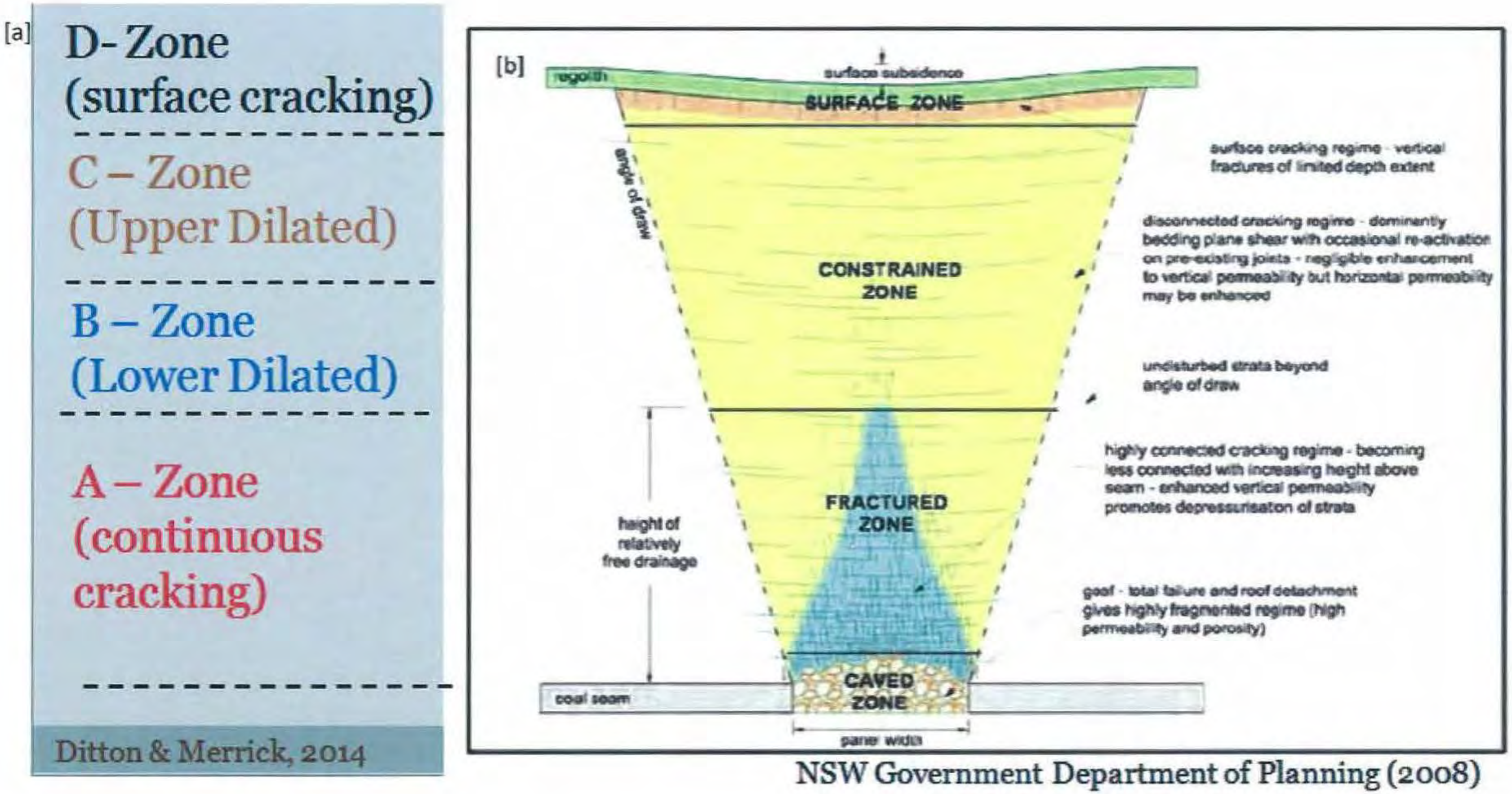


Figure 2. The Ditton Conceptual Model of Deformation above a Mined Coal Seam

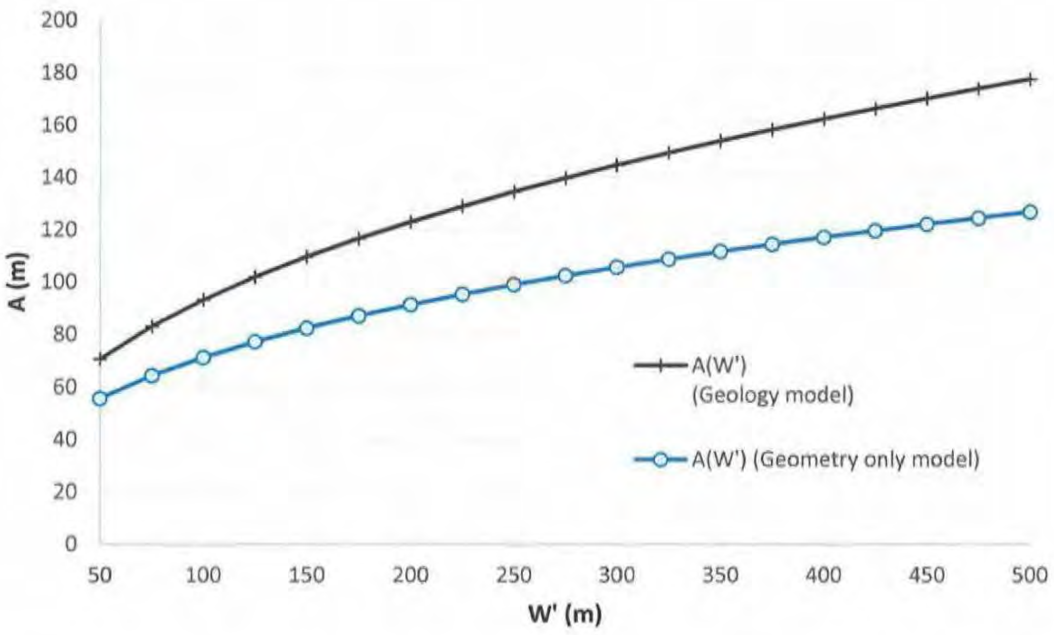


Figure 3. Variation of A-Zone Height for Varying Effective Panel Width for the Ditton Models

[H, T and t' held constant at database median values]

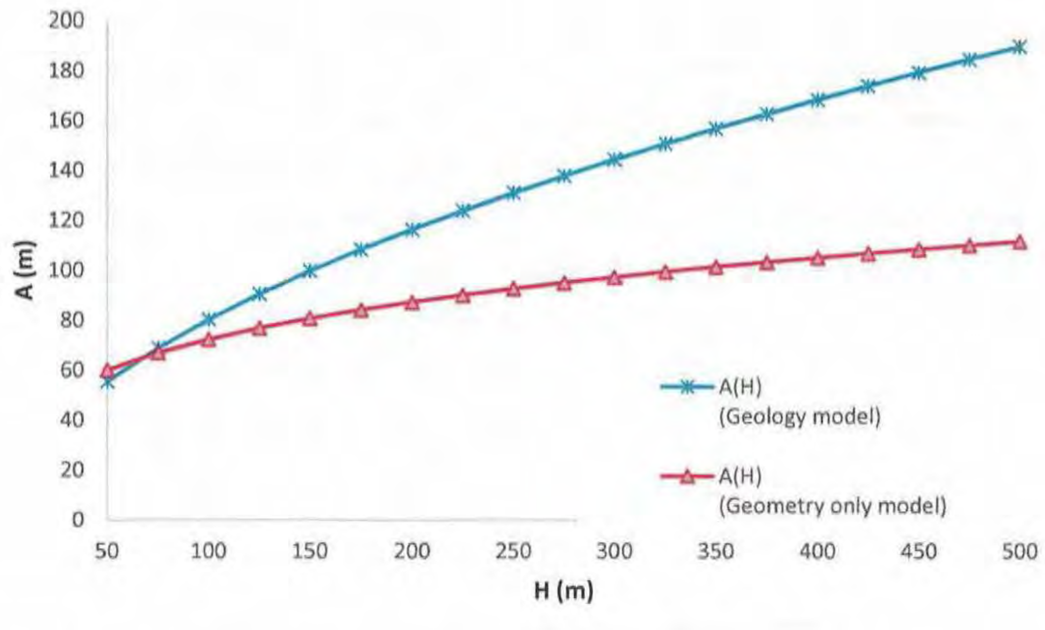


Figure 4. Variation of A-Zone Height for Varying Cover Depth for the Ditton Models

[W', T and t' held constant at database median values]

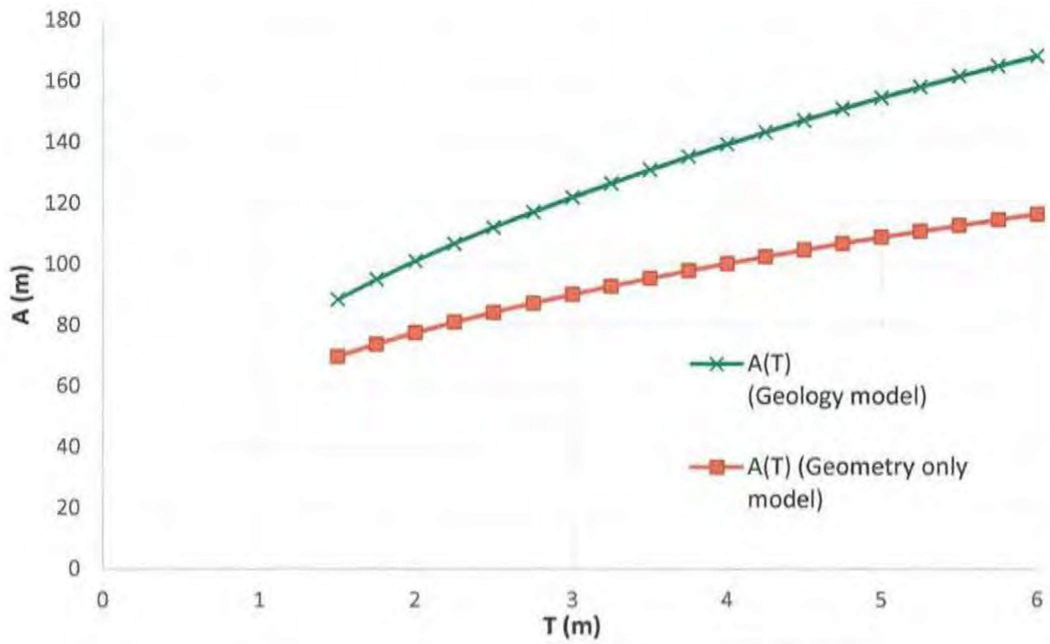


Figure 5. Variation of A-Zone Height for Varying Mining Height for the Ditton Models

[W', H and t' held constant at database median values]

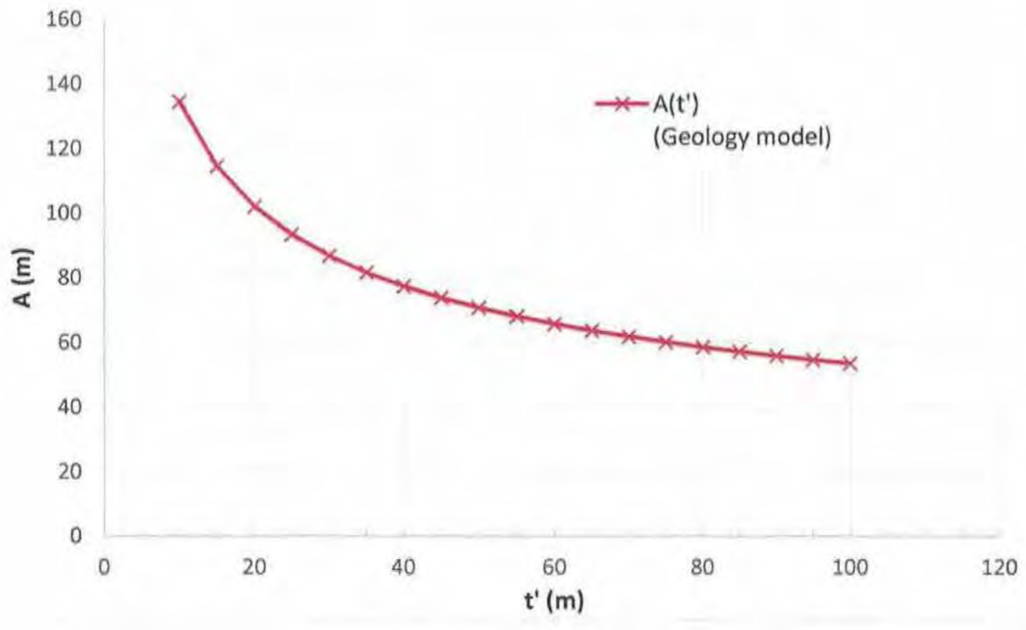


Figure 6. Variation of A-Zone Height for Varying Effective Stratum Thickness for the Ditton Model
[W', H and T held constant at database median values]

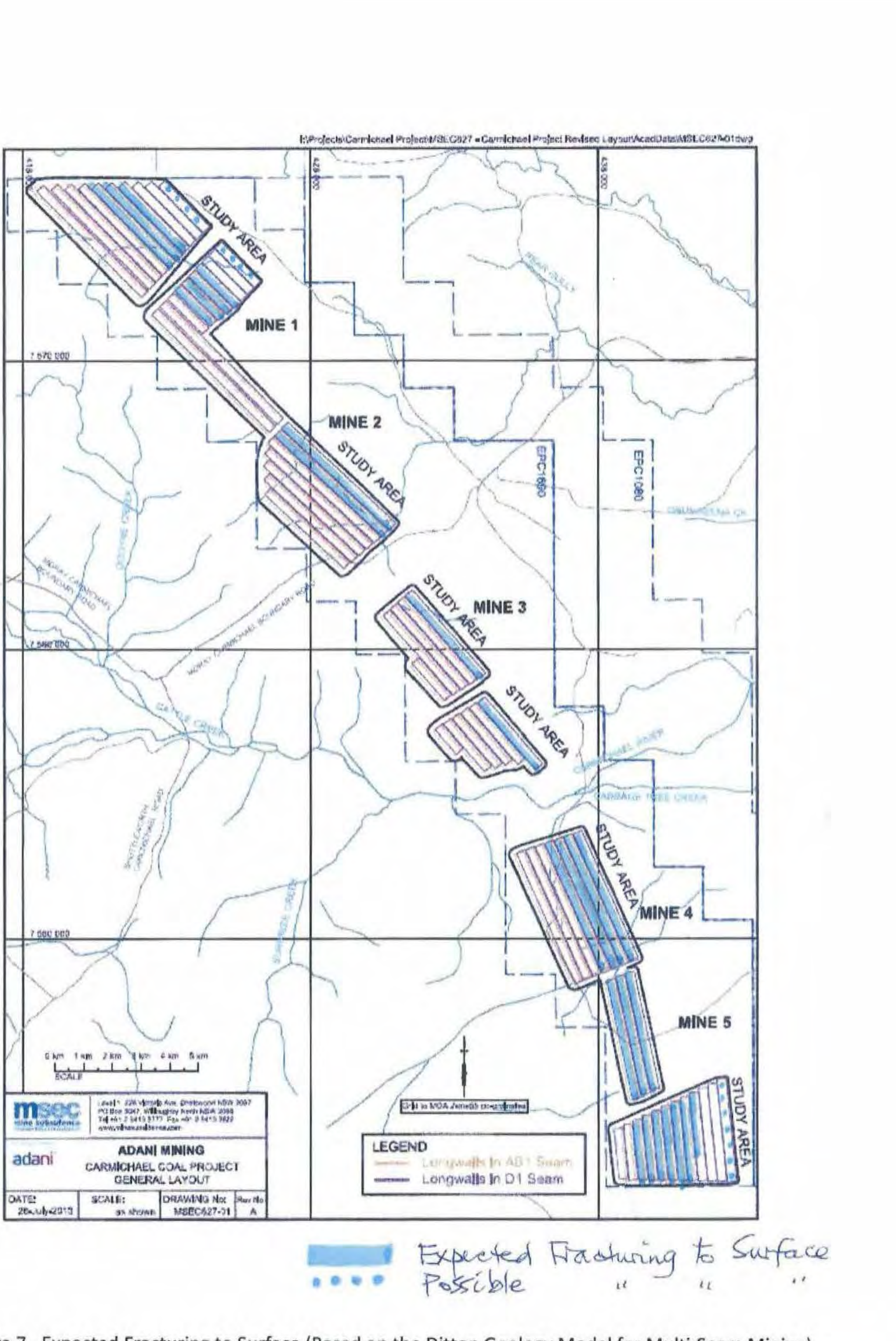


Figure 7. Expected Fracturing to Surface (Based on the Ditton Geology Model for Multi-Seam Mining).