Appendix D Subsidence Report Peer Review Letter

MINE ADVICE
A.B.N. 15 152 928 222

15th February 2022

Garry Gough
Ensham Resources

Garry,

SUBJECT: Peer Review Outcomes – GGPL Mine Layout and Surface Subsidence Assessment Report, Ensham Life of Mine Extension, Zones 2 and 3

This report contains the findings of an independent peer review of a Gordon Geotechniques Pty Ltd (GGPL) technical report entitled "*Subsidence Report for the Ensham Life of Mine Extension – Zones 2 and 3*", (the report) dated February 2022, which has been prepared for Ensham Resources Pty Ltd (Ensham). It is confirmed that the author has been provided with a final copy of the report in question and has had various communications and discussions with the author, Nick Gordon, on matters of clarification as part of carrying out this peer review.

The basic tenet of the report relates to the design of remnant mine workings in two proposed future mining areas, Zones 2 and 3, that are part of the extension of the current Ensham mining area, the proposed mining method being as per that currently in use at the mine (i.e. bord and pillar development, followed by both secondary floor coaling where seam thickness allows, and/or bell-outs around the periphery of production panels).

Whilst the report does not specifically describe the nature of overlying land use other than the presence of the Nogoa River and Anabranch, it is self-evident that the associated mine layout design objectives are two-fold, namely:

(i) that coal pillars left in place post-mining are consistent with being long-term stable thereby reliably preventing a pillar and overburden collapse, and

(ii) that the likely surface settlements due to the proposed mining with coal pillars remaining long-term stable are within tolerable, albeit currently undefined, levels.

It is confirmed that the report comprehensively addresses both issues, as is now summarised.

1. Long-Term Remnant Coal Pillar Stability

The pillar stability assessment as contained in the report considers three key mine stability parameters, namely pillar Factor of Safety (FoS), pillar width to height ratio (w/h) and the settlement of the overburden in respect of whether it is likely to be unstable and so load remnant coal pillars under full-tributary area loading, or not. This is judged to be a comprehensive assessment and design approach whereby the stabilising contribution of both the coal pillars and the overburden are fully recognised and given due consideration.

The use of pillar FoS (as determined using the UNSW Pillar Design Procedure or UNSW PDP under the assumption of full tributary area loading to surface (FTA Loading)) in combination with pillar w/h ratio (as outlined in **Hill 2005**) has been the mainstay of the pillar design at Ensham to-date and there is no obvious

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imperative as to why this needs to be changed for the Life of Mine Extension area. However, given potential surface constraints as previously described, it is judged to be prudent that GGPL have brought in an overburden settlement stability criterion to supplement the **Hill 2005** approach, the resultant displacement-based overburden FoS being a measure of the extent by which the assumed pillar loading condition of FTA Loading will eventuate in reality (see **Section 2**). As stated by GGPL, the assumption of FTA Loading is a "*conservative*" pillar loading assumption, the overburden displacement FoS providing an indication as to the level of the associated conservatism which can then be considered alongside the pillar FoS when evaluating overall system stability for the overburden and coal pillars in combination.

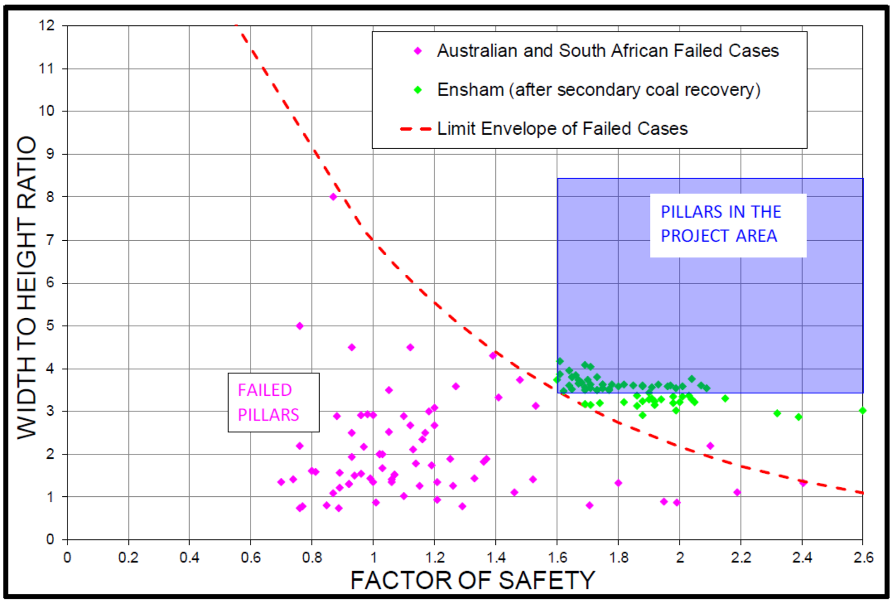


FIGURE 1. Factor of Safety vs Width:Height Ratio for Zones 2 and 3, Ensham LoM Extension Area

Figure 1, reproduced from the GGPL report, contains the range of pillar FoS and w/h ratio design outcomes within Zones 2 and 3 of the Life of Mine (LoM) Extension Area. As is clear from **Figure 1**, the proposed remnant pillar designs have no precedent in terms of a pillar collapse based on the **Hill 2005** combined pillar stability criteria of FoS and w/h. This design outcome is assessed to be a minimum requirement and needs to be supplemented with other relevant considerations in order to gain a more comprehensive understanding of the actual robustness of the proposed designs in terms of ensuring long-term stability of the remnant mine workings.

The report also includes an analysis of the stability of the floor strata below coal pillars and the extent to which it might be prone to a bearing-capacity type failure under the applied vertical loads through the remnant pillars. The analysis outcomes lead to the conclusion that such a failure scenario is in the "*practically impossible*" qualitative risk-likelihood category hence it is eliminated as a credible mechanism by which either pillar stability or surface settlements due to mining could be adversely affected post-mining.

The report also includes a first-ever assessment of the potential time-frame that can be assigned to the term long-term pillar stability. Based on the analyses undertaken the report concludes that a time-period in excess of 200 years can be credibly assigned, the author confirming his agreement with the method of analysis and critically, the conclusion arrived at in the context of what can reasonably be inferred from the method of analysis that has been selected.

2. Surface Settlements Due to Mining

As was outlined in detail in **Reed *et al* 2017**, the overburden needs to displace or settle a certain amount before it becomes critically unstable to surface such that FTA Loading of coal pillars applies in reality. If the overburden does not reach this critical level, it can be reliably inferred that it retains a level of self-supporting ability which adds significantly to the overall stability of the remnant mine workings, over and above that inferred from the pillars in isolation. In recognition of this, the GGPL report addresses two key issues:

(i) the presence or absence of near-seam thick, puggy low stiffness/highly compressible clay materials that would significantly influence the magnitudes of surface settlement due to mining (all other factors being equal), and

(ii) an estimate of surface settlement magnitudes due to the proposed mining, this being based on estimating the vertical compression of the coal pillars, roof strata and floor strata in combination.

It is self-evident that the presence of near-seam thick, puggy claystone material as described in (i) would add to any surface settlements calculated in (ii), thereby decreasing the overall stability of the overburden (all other factors being equal). This is why it is imperative to determine whether such material is likely to be present or not, the finding in the GGPL report being that it is generally absent at Ensham. This is a positive attribute in terms of post-mining stability of the remnant mine workings.

The report utilises a standard analytical method for estimating coal, roof, and floor strata compressions due to mining, the combination of which provides for the pre-mining prediction of surface settlements due to mining. Having reviewed the method of analysis, the manner by which the required values of Young's Modulus and E have been determined and recognising that rock stiffness increases as a direct function of confinement, it is assessed that the predicted surface settlement values can be considered as credible worst-case scenarios.

Maximum surface settlements are calculated to be 35 mm or less. The measured overburden and surface subsidence displacement data sets contained in both **Frith and Reed 2017** and **2019**, indicate that the onset of overburden instability to surface occurs at surface settlements of no less than 150 mm between barrier pillars, this being taken to be the critical level of overburden settlement whereby FTA Loading of the overburden to surface might start to develop. Comparing this value to the predicted maximum surface settlements due to mining of < 35 mm, returns an overburden stability FoS in excess of 4 (i.e. 150/35), which incorporates a significant error margin in terms of the overburden becoming critically unstable above the remnant mine workings.

It is noted that Ensham have introduced a surface subsidence monitoring system (fixed RTK-GPS system) that aims to minimise the influence of reactive surface soils on subsidence measurements which have previously resulted in accuracies of no better than ±20 mm being applied to such measurements. This level of measurement uncertainty is problematic when attempting to correlate and verify pre-mining predictions with actual values post-mining. That Ensham have invested in this technology and demonstrated measurement accuracies of ± 5 mm assists greatly in having the highest level of confidence that pre-mining predictions of surface subsidence will not be exceeded in practice.

In terms of the potential for large-magnitude surface movements that would inevitably manifest if a chimney or sinkhole failure were to propagate up from the mine workings and reach the surface, the report contains a detailed assessment of sinkhole potential. The conclusion from the analyses is endorsed by the author, namely that it is not a credible subsidence mechanism within the Zone 2 and 3 areas, primarily by virtue of the cover depths involved and that unsupported spans within the mine workings are limited to those of headings, intersections and bell-outs.

3. Summary

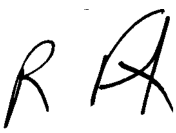
Based on the geotechnical characterisation and design analyses contained in the GGPL report, the author concurs with the conclusions arrived at, noting that a combination of pillar FoS > 1.6 under FTA Loading, pillar w/h values > 3.5 and overburden stability FoS between barriers of > 4, are fully consistent with the design requirement for long-term stable remnant mine workings. The predicted maximum surface settlement of 35 mm associated with the retention of long-term stable pillars is agreed with and is considered to represent the credible worst-case outcome in this regard.

As a final point of note, the GGPL report has considered and addressed the time-dependent pillar spalling model of **Canbulat 2010**, concluding that given the absence of swelling clays within the intended coal seam working sections, it has no obvious application at Ensham. This is fully endorsed by the author, in addition to the general concern, as outlined in **Frith and Reed 2019**, that the Canbulat model is flawed in its fundamental premise, namely that the failed pillar cases on which it is based collapsed due to time-dependent pillar spalling, rather than simply being inadvertently and unknowingly under-designed in the initial instance.

It is confirmed that in the professional opinion of the author, the GGPL report is fit for purpose in terms of being used as an input into any subsequent short, medium and long-term subsidence impact assessments that may be undertaken in relation to Zones 2 and 3 within the LoM Extension area at Ensham.

Please contact the under-signed if you require anything further in these matters.

Yours sincerely,



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REFERENCES

Canbulat, I. (2010). **Life of Coal Pillars and Design Considerations.** Proc. 2nd Ground Control Conference, Sydney, pp 57-66.

Frith, R. Reed, G. (2017). **Coal Pillar Design When Considered a Reinforcement Problem Rather Than a Suspension Problem.** International Journal of Mining Science and Technology https://doi.org/10.1016/j.ijmst.2017.11.013

Frith, R. Reed, G. (2019). **The Limitations and Potential Design Risks When Applying Empirically-Derived Coal Pillar Strength Equations to Real-Life Mine Stability Problems.** International Journal of Mining Science and Technology 29 (2019) 17–25.

Hill, D. (2005). **Coal Pillar Design Criteria for Surface Protection.** Proceedings of the Coal Operators' Conference. Brisbane, Queensland: University of Wollongong.

Reed, G. McTyer, K., Frith, R. (2017). **An Assessment of Coal Pillar System Stability Criteria Based on a Mechanistic Evaluation of the Interaction Between Coal Pillars and the Overburden.** International Journal of Mining Science and Technology 27 (2017) 9–15.