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Tomingley Gold Extension Project (SSD-9176045) Erosional Stability Assessment

FINAL REPORT

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Cover
Tomingley Gold Wyoming 1 pit (August 2022)

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Revision History

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Summary

In this report, Aquaterra International Pty Ltd provides advice to the NSW Department of Planning and Environment on the erosional stability of the proposed Tomingley Gold Extension Project, located at Tomingley, NSW. Information reviewed for the report and assessment includes the Environmental Impact Statement (EIS) and with specific reference to the documents provided in the REQUEST FOR QUOTATION.

The documentation review, current pit behaviour and data assessment demonstrates that the walls in the Wyoming 1 pit are subject to both mass and erosional failure. It is indicated that these failures will radiate out from the pit and have the potential to influence landuse beyond the current pit boundary. The failures also have potential to cause concern for Waste Rock Emplacements (WREs), such as that proposed for the San Antonio Roswell (SAR) pit, Residue Storage Facilities (RSFs) to the west of the Wyoming 1 pit, and access roads, including the Newell Highway.

The pit wall instability is caused by poor strength of the overlying surface material and unravelling of the existing geology, resulting in mass failures. The surface material consisting of alluvium and saprolite is highly erodible and prone to both tunnel erosion and high rates of surface erosion via sheetwash and gully processes. The process will be accelerated as groundwater fills the voids, further destabilising materials at the base of the void. Over decades to centuries the pit walls will fail in the process to form a stable slope and two lakes will result if the current mine plan proceeds.

In order to keep the pits open for future access and mining options, a plan for wall stability needs to be developed with the view that this leads to closure. At present the the post-closure rehabilitation plans do not adequately consider likely void geotechnical and erosional evolution of the pits and the risk of the void edge expanding. Further assessment is needed to better understand if the current setbacks of the WREs and RSF together with access roads and Newell Highway is satisfactory. At present there is a need for detail as to how the landscape evolution modelling was conducted. A whole of post-mining landscape assessment of the northern site (focussing on the Wyoming 1 pit) and proposed southern SAR pit is strongly suggested which would highlight long term closure risk. Further detail is required on the void sediment and water balance as this will influence void water volume and pit wall stability.

1 Background and Objectives

The Resource Assessments team at the Department Planning and Environment (DPE) is seeking advice on erosional stability assessment of the proposed Tomingley Gold Extension Project, as described in the Environmental Impact Statement (EIS) and other supporting documents provided by the Applicant (Tomingley Gold Operations Pty Ltd).

Current pit behaviour and data assessment demonstrates that the pit walls are subject to both mass and erosional failure. These failures will radiate out from the pit and have the potential to greatly influence landuse beyond the current pit boundary. The failures also have potential to cause concern for waste material emplacements, tailings storage, access roads and surrounding public infrastructure (the Newell Highway).

Specifically, the purpose of this report is to provide advice on the erosional stability of the walls of proposed final voids for the already existing Wyoming 1 and proposed San Antonio Roswell (SAR) voids. In addition, commentary is made on the current and future status of the Waste Rock Emplacements (WREs) (Refer Map 1).

To support this report a site visit by Aquaterra International Pty Ltd to Tomingley Gold was held on 22 August 2022 accompanied by mine staff, Resources Regulator and DPE staff. Waste Rock Emplacements (WRE's), pits, and Residue Storage Facility (RSF1) were inspected. The weather on the day was clear with good access.

Map 1: Tomingley Gold Operations (Source: NearMap, viewed 5/9/22)

2 Outputs sought

Outputs sought by the DPE are:

a. review the adequacy and appropriateness of erosional stability analysis conducted and proposed criteria for the final landform slope design of the voids for the project, including robustness of the inputs used in making conclusions;

b. advise if further information is required; and

c. provide draft and final expert advice including recommendations to the DPE for input into the DPEs assessment report.

3 Site history

Tomingley is a small town with a population of approximately 330, located in the Central West region of NSW, on the Newell Highway, 54 kilometers south west of Dubbo, and 425 kilometers west of Sydney. The town is known for it's gold mining resources, and was established for this reason.

The area was first explored in 1817 by Oxley, with settlers claiming pastoral runs in the area (Chappel, 1989). Gold was discovered in Tomingley in 1879, and in 1883 the Tomingley Gold Mining Company was established (OzArk Environment & Heritage). Tomingley was proclaimed a village in 1884 (Chappel, 1989).

The climate of Tomingley is warm temperate, with summer average temperature of 33^{o}C and winter average of 16^{o}C. Annual average rainfall of the area is 400-600mm (www.bom.gov.au).

The Tomingley Gold project covers an area of approximately 440 square kilometres, stretching 60km north-south either side of the Newell Highway (Figure 1). The Tomingley mine, known as Tomingley Gold Operations (TGO) is a wholly-owned subsidiary of Alkane (ASK: ALK), located immediately south of the town of Tomingley. The mine has operated since 2014 with open cut operations and progressing to underground mining in 2019.

Mine activity since 2014 includes open cut and underground mining (since 2019), initially of the Wyoming and Caloma deposits. TGO continues to explore opportunities to extend the life of the mine and processing plant. (www.alkane.com.au).

Proposals to develop two gold deposits immediately south of Tomingley are being prepared (the focus of this report). This is proposed to extend mine life to at least 2031.

4 Geology and soils

The geology of current and proposed extended TGO are the Mingelo Volcanics of Ordovician age which are comprised of andesitic phyric lavas and flow breccias with pyroclastic and volcaniclastic rich units.

The surface alluvial cover is of Quaternary to Tertiary age and up to 70 m deep across the mine. However it was stated by mine staff that the alluvium and saprolite cover is much deeper for the proposed San Antonio Roswell (SAR) pit.

In general, the surface cover consists of Quaternary Alluvium in the upper 10-20 m of the ground surface with brown, pale grey clays with variable amounts of sand and gravel, mainly low to medium plasticity with a very stiff to hard consistency. Below this is Tertiary Alluvium which is characterised as grey mottled red and orange silty clays with sands and gravels, medium and high plasticity and very stiff to hard consistency (Landloch, 2021a, b).

Underlying the alluvium is a saprolite layer which is unconformably overlain by alluvial sediments. The saprolite and weathered rock has a soil-like consistency and structure with pale grey, white and or mottled orange colouration. The material is a mix of silty clays, sandy gravelly clays, sandy clayey silt with minor, very low strength rock fragments, and clays typically having a very stiff to hard consistency and medium to high plasticity.

A focus of this report are the Wyoming 1 Open Cut pit with an areal extent of approximately 30 ha with a depth of approximately 185 m and the proposed SAR North Pit which disturbs a surface area of approximatey 70ha and will have a depth of approximatley 307 m.

Detail on surface soils and land capability is provided in Tomingley Gold Extension Project Land and Soil Capability Assessment Major Project Application No. PA 09_0155. Part 7a. (2021).

5 Background information

Relevant information on this project is provided below:

Tomingley Gold Extension Project – Environmental Impact Statement (EIS) Documents

Document Name	Link to the DPE's website
Volume 1 - Appendix 6 - Wyoming One Slope Stability Analysis	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220209T021004.071%20GMT*
Volume 1 - Appendix 7 - Open Cut Erodibility Assessment	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220125T213612.216%20GMT*
Volume 1 - Appendix 9 - SAR North Pit Long Term Slope Stability Analysis	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220209T021006.822%20GMT*
Volume 1 - Appendix 12 - Landform Design – SAR Waste Rock Emplacement	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220125T213613.636%20GMT*
Specialist Report - Volume 2 - Part 7a - Land and Soil Capability Assessment	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220125T213552.535%20GMT*

Background documents:

Document Name	Link to the DPE's website
Project SEARs	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120211121T220911.976%20GMT*
Conditional Gateway Certificate	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120211118T053038.738%20GMT*
EIS – Executive Summary	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220125T213540.546%20GMT*
Volume 1 - Appendix 4 - Additional Information Supporting the Project Description (mine design, final landform)	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9176045%2120220125T213606.757%20GMT*
Resources Regulator - EIS advice	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-37679460%2120220406T215726.765%20GMT*
Applicant's Submissions Report	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=EXH-37376495%2120220517T004434.688%20GMT*

Resources Regulator - Submissions Report advice	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-43087765%2120220613T222246.319%20GMT*
RFI 4 – Applicant's Response to Resources Regulator advice on Submissions Report (this document is currently being reviewed by the Resources Regulator):	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=RFI-45276718%2120220708T042706.893%20GMT*
The existing Tomingley Gold Operations Project (MP09_0155) development approval	*https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=MP09_0155-MOD-6%2120220610T042100.544%20GMT*)

The above information provides significant detail on mine current and potential operation and its effects on the surrounding community and landscape. The focus of this review is pit wall stability and long-term landscape behaviour. There are several studies that have directly addressed this issue and are of relevance.

In particular, a recent and relevant stability analysis of the Wyoming 1 pit was undertaken by AMC (2021). This pit will remain as a void and will be bunded and fenced and will remain open in perpetuity. The main aim of this report was to assess the long-term geotechnical stability of the Wyoming 1 pit. This report (AMC, 2021) provides background, field observations as well as slope stability data.

Further surface erosion detail is provided in Landloch (2021a; b). The Landloch reports provide design guidance on WRE hillslope length (Landloch, 2021a) based on soil erosion assessments and modelling. Further work (Landloch, 2021b) examines the wall erosional stability of the proposed SAR pit from a surface erosion perspective.

A soil survey and land capability assessment is provided in Tomingley Gold Extension Project Land and Soil Capability Assessment Major Project Application No. PA 09_0155. Part 7a. 2021.

The Tomingley Gold Operations Pty Ltd (2021) report provides additional detail and feedback from both the community and Tomingley Gold Operations response to the community inputs.

5.1 Field visit

A field visit was conducted on 22 August 2022. The visit commenced with viewing the mine operations from the WRE overlooking the Wyoming 3 pit (Figure 1). The Wyoming 1 pit was viewed at several locations from the pit edge (Figures 2 to 5). The Caloma 1 pit was viewed (Figure 6) with the inspection concluding at the Residue Storage Facility (RSF). Oberservation was also made of soil behaviour along mine roads (Figure 7).

Of particular note was (1) the mass failures in the Wyoming 1 pit (2) the variable depth of alluvium and saprolite together with the relic geologic structure and (3) the erosion processes of sheetwash erosion, gully erosion and tunnel erosion in the alluvium and saprolite.

6 Review of slope processes and failure information

6.1 Mass wasting

Since early development of the pits, wall instabilty has been noted. AMC (2021) present a photograph of wall collapse in 2016 at Wyoming 1 pit (see Figure 3.2 in AMC (2021)).

AMC (2021) report that the slopes within the saprolite and weathered rock horizon have stability concerns both at bench scale and wall scale. Aquaterra's site visit on 22-08-2022 demonstrated this (Figures 2 to 4). This was also noted and described in the document WSP Australia 2018. Localised collapse in the saprolite was typically attributed to relict geological structure (WSP, 2018). It was inferred that rainfall and surface water also played a major part in the initial collapse and ongoing slumping and erosion in some areas of the pit slopes.

AMC (2021) state that both the south east collapse and the chlorite schist unravelling have the potential to promote large scale instability that could impact the location of the long-term pit crest.

In 2017, PSM carried out a site visit to review the Wyoming 1 pit slopes, and some cracking in the benches and berms forming the west wall were noted (as referred to in AMC, 2021).

Past studies in the Tomingley pits have indicated that the alluvium and saprolite soils are highly dispersive, sodic and often non-saline (PSM 2016). Exposed or disturbed dispersive soils have a high erosion potential when in contact with water. This is further described in Landloch (2021a, b).

AMC (2021) state that 'A key contributor to the ongoing instability of this area is rainfall and surface water flow over the slope. This area is anticipated to deteriorate over the long-term and is likely to encroach on the alluvium.' In reference to the West Wall of the Wyoming 1 pit, AMC (2021) state that 'Over the long-term the wall is expected to experience localised collapse and unravelling of the weathered rock.'

Additionally, AMC (2021) state that for Wyoming 1 the ongoing deterioration of the alluvium and saprolite will lead to failures at a bench and multi-bench scale. The risk of failure will increase as groundwater level increases. Weathered rock and its unravelling will also continue. This failure may be exacerbated by rainfall.

However, it is noted that a significant failure occurred in 2016 (AMC, 2021) under dry conditions. The rate of failure is likely to slow over time as slopes lower and the groundwater system equilibrates (described further below).

For the Wyoming 1 pit, slope stability analyses conducted by AMC (2021) states that a rock mass style failure mechanism through the alluvium and saprolite is likely to occur. This suggests that this has the potential for long-term crest cut-back of up to

23m for the west wall, 36m for the east wall and 64 m for the southeast wall of the Wyoming 1 pit.

Of further concern was the southeast wall of Wyoming 1 with the stability of the alluvium and saprolite considered marginal with collapse of these materials in the short-term likely. AMC (2021) state that 'It is recommended that TGO immediately implement appropriate exclusions and management procedures to reduce the safety risks relating to further collapse of the alluvium and saprolite in the southeast slope if not already in place. Further details provided by AMC (2021) are:

'Slope remediation could be required for the southeast wall area to remain as part of the current approved final landform.

'Without implementation of management measures, such as good surface water drainage and re-vegetation, long-term erosion has the potential to lay the slopes back at nominally 20º through the alluvium and saprolite.

'The most effective option to improve wall stability and reduce the potential for rock mass style failure in the southeast corner will be to flatten the slope through the alluvium and saprolite.'

AMC (2021) also raise concerns with groundwater filling of the void and state 'It is recommended that long term slope stability be re-addressed if there is any significant change in pit wall conditions and when the Jacobs groundwater report is finalised.'

The behaviour of the Wyoming 1 and Wyoming 3 pits provide insights into the likely behaviour of the yet to be constructed SAR pit. Given the increased overall depth, and increased depth of alluvium and saprolite of the SAR pit, the wall failure and erosion issue will likely be similar in process but larger in scale.

6.2 Erosion processes and assessment

Landloch (2021a and b) have provided a detailed assessment of the erosion properties of cover soils used for the WRE as well as provided design guidance for hillslope lengths for the WRE. The role of vegetation is also examined. Landloch (2021a,b) find that the local soils are highly erodible and that for Chromosols/Sodosols a surface cover with at least 60% vegetation is needed for erosional stability.

Tomingley Gold Extension Project Land and Soil Capability Assessment Major Project Application No. PA 09_0155. Part 7a (2021) (Table 8.1) in assessing land capability found that all soils present were either moderately or highly erodible. This finding is supported by observation during the site visit (Figure 7).

Of significant issue here and not identified in other reports is the prevalance of potential tunnel erosion and gullying. Tunnel erosion forms on compacted areas and/ or areas of ponding where water migrates to depth via preferential flow paths (i.e. surface cracks, rabbit burrows, tree root holes). Water concentrated via these flow paths allows sodic clays to disperse and with sufficient slope the dispered soil is able to migrate downslope with the removed material forming tunnels.. Over time and with continued runoff the tunnel enlarges such that the roof collapses and gullies form. The formation and evolution of tunnel erosion is both a chemical and physical soil erosion process and is commonly found with sodic soils derived from Triassic sandstone, Permian mudstones and re-deposition of these sediments in Quaternary deposits. Such soils are called Sodosols, these being present at the site (Tomingley Gold Extension Project Land and Soil Capability Assessment Major Project Application No. PA 09_0155. Part 7a, 2021).

Tunnels appear to be present in both the alluvium and saprolite and are also evident in the surface surrounding the pit. The tunnels will collapse forming gullies. Given that the tunnels are present at multiple levels in the pit, they have the potential to produce cascading failures. Once formed, a gully will continue to expand until (1) a base layer of underlying resistant material is reached (i.e. bedrock) or deposited material (i.e. a depositional fan) prevents further lowering. The gully then begins its stabilisation and integration process as it merges with the surrounding landscape, or (2) the upslope contributing area to the gully does not provide sufficient runoff to generate erosive force. Upslope contributing area can be controlled by constructing runoff controls such as runoff diversion bunds and drains. However, these need to be well-designed and maintained. Post-closure it would only be possible to maintain these control structures on the surface. It would not be possible to maintain such structures in the void.

Therefore, given the highly erodible and dispersive nature of the materials in the pit and no base level control, it is likely that tunnel erosion will lead to cascading failures of the benches and pit wall. A cascading failure in the pit due to gully development, given there is no base level control, could result in a gully cutting through any surface level water control structure leading to a gully migrating away from the pit. This could ultimately result in a new streamline evolving away from the pit.

There is also evidence of tunnelling behind water control structures that appear to have been undercut (Figure 6). While this is easily managed during mine operation, this type of behaviour demonstrates that if ponding occurs behind drainage control structures, tunnelling may occur and a gully incising through the structure. The only way to ensure this does not occur would be to ensure that all runoff is diverted away from the pit. However localised ponding and risk of tunnelling would be impossible to prevent.

Landloch (2021a,b) recognise surface erosion is a significant issue with high erosion rates predicted for the site. Observation of surface materials demonstrates this to be the case. These surface processes in combination with tunnelling and resultant gullying are likley to greatly increase erosion rates. These erosion rates are likely to be greater than those predicted by Landloch Landloch (2021a,b).

The LEM assessment of the SAR pit (Landloch, 2021b) poses several questions regarding model output. It is not clear or explained what the base level is for the modelling (linear horizontal green line at approximate elevation 190m). Is this groundwater or infill level? If it is in-fill, at what depth will the void water level be? If it is fill level, the modelling should produce a depositional fan like structure - not a horizontal surface. This will then become the new baselevel for erosion.

Further, it is not explained how the model has produced such steep slopes near the pit surface. In particular Figure 9 (bottom) has slopes that appear to be unrealistically linear (Landloch, 2021b). There are similar questions regarding the outputs in Figure 11 (Landloch, 2021b).

Rather than display cross-sections, a three-dimensional image of the void evolution may provide clearer understandings.

Of importance here, Landloch (2021b) state

‘The predicted expansion rates of the pit edge from erosion assume an abandonment bund is installed around each pit at a distance of 20 m from the safety bund (except at the interface of the SAR WRE and the SAR North Pit). From an erosion perspective, the abandonment bund needs to function as a ‘catchment break’ to prevent surface runoff from outside the bund flowing into the pit, thereby reducing the magnitude of erosive energies applied to the pit walls. In practice it may not be possible, or desirable, to prevent water entering the Voids. Therefore, any concentrated flows directed into the Voids will need to be managed and controlled via structures that are resistant to erosion from these flow conditions.’

Also, ‘expansion of the pit edge will be driven by the most erosive material. As Saprolite materials erode at a higher rate, this will lead to undercutting and localised collapses at the interface with the Alluvium.’

As stated above, ponding behind runoff control structures may be impossible to prevent over the long-term leading to potential failure of the structure and gully inititation and evolution.

7 Landscape behaviour and prognosis

Field behaviour and material analysis demonstrates that the pit walls are both geotechnically and erosionally unstable (AMC, 2021; Landloch, 2021a;b). The process of the pits evolving to a more stable state must be considered as combination of mass failure in conjunction with erosion.

A positive feature of this site is that the pits are located in a relatively flat environment and any instability will be centred on the pit. That is, all sediment can be contained within the pit and failure will radiate out from the pit. However, this assessment has not considered in detail the erosional stability of the WREs or the RSF which may be affected by the evolution of the pit.

At issue is the rate of failure of the pit walls and the distance to which this failure will extend from the current disturbance area.

7.1 Mass failure

Given current conditions, the pit walls will fail as described in previous reports and demonstrated in AMC (2021). Failure has occurred early in pit development and is therefore well recognised. These failures occurred under average and or below average rainfall conditions. How the pit walls will behave post-closure with above average rainfall (a possible climate change scenario) and no active management suggests at least the same rate of failure or greater.

A further issue is the gradual infill of the voids by both sediment and groundwater. Once mining is finished and voids begins to fill with groundwater, this will saturate the void walls increasing the instability of the materials from the base of the pit. This increased instability will lead to more wall failures and material filling the void, leading to less water volume in the void. With increased water height, a greater surface area will lead to increased evaporation and eventually an equilibrium water level will be reached.

Over time (decades to centuries) the pits will evolve to form stable slopes commensurate with material strength and stability with the water level height. AMC (2021) suggest 20^{o} slopes. The pits will ultimately evolve to lakes or wetlands that will be permanent features of the landscape.

The evolution of the open pits will occur by unravelling and mass failure of the pit walls, with tunnel erosion leading to gullying and sidewall collapse as well as surface erosion which will shape the collapsed surface. As the void fills with sediment and groundwater level increases this will lead to saturation of materials leading to increased instability. Given the increased depth and size of the SAR these processes will occur at a large scale.

The mass failure process and outcome therefore could be said to be well-understood. What is not so well understood is the extent of these failures and the extent of the influence of these failures radiating from the pit.

7.2 Erosion

The materials of the surface and pit walls are highly erodible and display sheetwash, rill and gully erosion. Tunnel erosion is also evident.

Incidences of tunnel erosion were observed in the Wyoming 1 pit (Figures 2 and 3). These typically form with inlets on berms and outlets on the batter. As erosion continues these tunnels can collapse and form gullies. A feature of this site is the multiple tunnels and resultant gullies at all bench levels in both the alluvium and saprolite. Tunnels and gullies were also present on the surface (Figures 3 to 6).

Landloch (2021) examined erosional stability of the SAR pit and provided some insight into the rate and extent using a computer based Landscape Evolution Model (LEM). However, this modelling did not take into account mass failure and unravelling of the pit wall, nor the effects of tunnel erosion. No LEM can predict either process either individually or combined and the Landloch (2021b) report makes no mention of these modelling limitations. Further, the modelling also did not consider the likely increased erodibility of the mass wasted material.

There are several further questions surrounding the Landloch (2021a) report and the modelling undertaken. Firstly, there are no erosion and hydrology parameters reported to allow review of the correctness or otherwise of these inputs to the LEM. While the predicted erosion rates appear to be reasonable based on site inspection, the modelling does not take into account mass wasting and increased erodibility of the materials which will occur at this site. Given surface erosion alone, the rate of erosion of the pit edge seems reasonable, neglecting mass failure and tunnelling (and not having model parameters available for review). Further, tunnel erosion occurs across a range of depths and for both alluvium and saprolite. There is the potential for cascading failures of this material over time leading to expansion of the pit edge.

In summary, questions surrounding the SAR North pit and the modelling (Landloch, 2021a,b) include:.

(1) Model parameters are not provided and the domain over which the model is applied is not described.
(2) It is not clear how such steep slopes are predicted for the SAR North Pit (Figures 9, 10 and 11) without the slope cutting back into the eroded highwall resulting in a lower slope. If this slope was produced by erosion, it is likely that it would fail by a mass failure.
(3) It is not clear how such linear slopes are produced in Figures 9 and 11.

The Wyoming 3 pit (Figure 1) may provide guidance and a method to improve wall stability for the Wyoming 1 pit and future SAR North pit. In the Wyoming 3 pit the walls have been pushed down and then clad with a rock armour. As described in PSM (2016) an option to stabilise the slopes could be to lay the slopes back to 20 degrees and cover with an armour.

8 Further issues

8.1 Long-term surface water management

The predicted outcomes from Landloch (2021a;b) both assume surface and groundwater management as per abandonment. In particular, surface water management understandings are now based on current and maintained water control structures. Over time (i.e. 100 years) these structures will degrade. There is the potential that over time as these structures degrade additional flow may enter the voids. Surface water addition may enhance slope failure and lead to increased expansion of the pit edge.

8.2 Rehabilitated Waste Rock Emplacements

The materials within the pit display erosion by sheetwash, gullying as well as tunnel erosion. Observation of the disturbed natural surface demonstrates an inherently high natural erosion rate as reported in Landloch (2021a). The site visit demonstrated that the pits had dozens of what appeared to be both tunnels and collapsed tunnels. The erosion risk of these materials is high. These materials are now encapsulated in the WREs.

The WREs have been constructed to a conventional design of linear slopes and contour drains and rock lined drop structures. The emplacements had a good vegetation cover (i.e. Northern emplacement). While only a brief inspection (Northern WRE at time of inspection) there was no erosion observed on the hillslope except where the road cutting had produced a small gully head cut. This demonstrated the erosion potential of the surface cover and slopes.

Landloch (2021a) demonstrate that vegetation is needed to maintain a satisfactory soil cover. Given the highly weathered and nutrient poor and dispersive nature of the underlying material it is unlikely that a functional and productive soil profile will evolve in the short to medium term (i.e. decadal to centennial time scales) given the weathered and sub-optimal plant growth potential. If the soil and vegetation cover fail, this highly erodible material will be exposed and will likely erode rapidly. Therefore maintenance of this surface cover is essential.

There is also some consideration needed of the hydrology of the WRE flat cap on the emplacements. How is excess water on the cap managed? If this water ponds and infiltrates into the alluvium and saprolite (given its dispersive properties) at a position close to the edge of the cap, then there is the potential for erosion.

While Tomingley Gold Operations Pty Ltd (2021) provides information on waste rock characterisation with a focus on acid base account testing, there appears to be several materials at the site that have acid generating potential. Where these materials are located in the WRE needs to be identified and managed with suitable vegetation cover for the long-term.

Landloch (2021) states that for erosional stability vegetation is needed. This agrees with the site observations. Close inspection and monitoring of the WREs is required.

8.3 Future Waste Rock Emplacement form and function

Present WREs are constructed in conventional form of linear hillslopes with drainage control. These landscapes have very different form to that of a natural hillslope which have a series of convex and concave slopes with water shed by non-linear streamlines with positioning and dimensions in keeping with both materials and climate.

It is noted in Tomingley Gold Operations Pty Ltd (2021) that residents requested a more visually natural WRE rather than conventional linear hillslopes for the planned expansion of the SAR site.

Further, the Resources Regulator encourages all mines to examine more naturally shaped landforms via the consideration of geomorphic design principles for final landform shaping.

The final landform proposed for the SAR WRE appears to be a pyramoidal structure with largely linear hillslopes (Figure A2, Landloch (2021b)). There is some curvature on the north-east face with this being located away from any public view. However, the hillslope facing the Newell Highway is linear. This does not comply with the basic tenets behind geomorphic design. It is also likely that to manage runoff from such a design, drainage structures will need to be constructed adding to the linearity.

This hillslope will be in full view of the public and be a poor advertisement for the mining industry. This design does not comply with public requests for a more natural landform.

8.4 Post-closure landform evolution

The documents examined here provide proposals for post-mining landscape form and geomorphic evolution. However, these studies have examined the Wyoming 1 and proposed SAR WRE and void. There has been no whole of post-mining landform assessment.

All information suggests that given the current cover on the WRE they will remain stable if the soils and vegetation can be maintained. However, all reports state that the pit walls are both geotechnically and erosionally unstable. A suggested stable slope for the pit wall is 20^{o}.

It is recommended that consideration be given to a whole of landform assessment using a Landscape Evolution Model where the pit walls are stepped back at 20^{o} and then allowed to erosionally evolve. This would provide some insight into potential gully evolution and risk to the WRE and in particular the RSF which is close to the Wyoming 1 pit as well as the Newell Highway.

8.5 Study Exclusions

This study has not considered

1. erosional stability of the WREs
2. erosional stability of the RSF
3. pit evolution and setbacks of the RSF from the voids and other infrastructure

9 Recommendations

a) It is not possible to assess the correctness or otherwise of the LEM predictions as model parameters and modelling domain is not provided. There is further detail needed as to how the landscape evolution modelling was conducted. In particular, the determination and values of the hydrology and erosion parameters as well as the logic and suitability of the modelling domain needs to be explained in much more detail.

b) Complete an assessment of the combined effects of both sheetwash, tunnel and gully erosion, not just sheetwash erosion as modelled here for the pit wall. The behaviour of the current landform provides insights into the combined effects of these processes.

c) A whole of post-mining landscape assessment of the northern site (focussing on the Wyoming 1 pit) and proposed southern SAR pit is strongly suggested using the (1) the proposed pit design and (2) assuming a slope of 20º (or justify alternative slopes) for the pit walls. A landscape evolution model assessment would be conducted on these designs to examine potential erosion and destabilisation of the RSF (Wyoming 1 pit) and WRE and Newell Highway for the SAR pit.

d) Erosion and groundwater ingress will reduce the volume of the void over time. There needs to be an assessment of the loss of void volume and increased void water levels and the potential for increased erosional wall instability.

e) As the void fills, the water surface area will increase with the potential for wave action to enhance erosion at the water level. Given the high erodibility of the wall materials, this would provide insights into the need for protection measures such as rock armour at the appropriate water level.

10 Conclusion

The Tomingley mine operates in an environment with a cover of unstable and highly erodible material. Failure of the pit wall is well recognised and understood. At mine closure, similar to any mine void, the pit walls will lower over time to a more stable form. In this environment the processes of mass failure and erosion will provide a relatively rapid change in pit boundary as the void walls mature to a more stable form.

The process will occur by mass wasting of the walls together with surface, tunnel and gully erosion. Given the lack of base level control for gully stabilisation and the dispersive properties of the alluvium, there is considerable potential for gullies to migrate from the pit edge. The progression to a stable form will be aided by instability caused by groundwater inflow to the void further destabilising the base of the slope.

Further assessment as outlined above is required to better understand post-mining closure risk to the environment as well as risk to public infrastructure.

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Figure 1: Wyoming 3 Open Cut as viewed from Waste Rock Emplacement 2

Figure 2: Wyoming 1 Open Cut looking east. Underground access portal can be viewed in the middle to the right of the image. Structure and fabric of the walls can be observed with mass failures on the opposite side.

Figure 3: Wyoming 1 Open Cut looking north-west. A large mass failure (centre), and a smaller failure (right) can be observed. Tunnels from tunnel erosion and gullies can be observed in both alluvium and saprolite.

Figure 4: Wyoming 1 Open Cut looking south (top) and north-west (bottom). Gully erosion can be observed on the edge of the pit demonstrating the high erodibility of the materials

Figure 5: Wyoming 1 Open Cut looking north. Image displays a large gully with vertical sides and headcut.

Figure 6: Caloma 1 Open Cut looking north-west (top) displaying structure and failures (top). Image displays a large gully with vertical sides and headcut. Bottom image (looking north) displays tunnel and gully erosion in the surface material. Of note is the tunnel through the bund.

Figure 7: Cutting through natural material on southern side of mine road passing under the Newell Highway. Tunnel and rill erosion can be observed in the natural material on the left while large rills can be observed on the fill material (right) used as an abutment for the bridge.