

Te Kuha Mining Operation Geotechnical Concept Study for Stevenson Mining

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REFERENCES

Avery, M. (2015). **Te Kuha Project Mine Design and Planning**. Internal MS PowerPoint presentation for Stevenson Mining Limited prepared by Avery Consulting. Provided via email to Landpro.

Deere, D.U., Hendron, A.J., Patton, F.D. and Cording, E.J. (1967). **Design of Surface and Near Surface Construction in Rock**. In Failure and breakage of rock, proc. 8th U.S. symp. rock mech., (ed. C. Fairhurst), 237-302. New York: Soc. Min. Engrs, Am. Inst. Min. Metall. Petrolm Engrs.

Dutton, A. (2013). **Te Kuha Draft Regional Geology Map**. Internal map prepared by CRL Energy Ltd for Stevenson Mining. Provided via email to Landpro.

Flintloft, M. (2013). **Te Kuha – Preliminary Groundwater Investigation**. Commissioned report C13079/1 by Aqualine Research Limited to CRL Energy Limited on behalf of Stevenson Mining. Provided via email to Landpro.

Johnson, J., D. (2002). **Proposed Te Kuha Opencast Mine Evaluation of Slope Stability for Feasibility Design**. Commissioned report 19852.001 by Tonkin & Taylor Ltd to Rangitira Developments Ltd. Provided via email to Landpro.

1 Introduction

1.1 Overview

The proposed Te Kuha coal mining operation has a number of geotechnical challenges to contend with due to its complex geology and exposure to multiple paleo-landslides. This report considers the feasibility of mining at Te Kuha with regard to the existing geotechnical issues. A lack of detailed geotechnical testing does limit this evaluation, a number of assumptions are required and ultimately resulting in an over-conservative approach which may be optimised as the model is validated over time. A number of sensitivity analyses indicate that the current pit design is stable or at least near stable, requiring only minor adjustments to manage instability issues. Detailed geotechnical design of the mining stages will be required as the operation prepares to start.

Te Kuha is considered geotechnically feasible, furthermore, the unconventional up-dip mining sequence can potentially deliver a number of benefits to stability, water management and hazard elimination with appropriate monitoring and mitigation strategies in place.

1.2 Purpose of Documentation

Assess the likely highwall stability of the proposed mine layout with specific consideration to mining “up dip” to the North in the Paparoa pit. This includes sensitivity analyses of the worst case arrangements as per the current plan and the likely impact of geological structures.

Comments in relation to geotechnical considerations on likely hazards, water management, overall land stability and waste dumps have also been requested.

1.3 Site Location and Description

The proposed open pit operation lies ~9km South East of Westport in the Northern Paparoa Ranges adjacent to the Lower Buller River.



Figure 1 - Aerial Photograph of Region with Proposed Location for Te Kuha Mine

The mine plan consists of two overlapping pits currently identified as the Paparoa Pit (mining up-dip South to North along ridgeline) and the Brunner Pit (mining up-dip West to East at the Northern area of the operation). Extraction is scheduled over ~12 years upon commencement with a combination of advance stripping and backfill of trailing pits.



Figure 2 - Hillside Showing Te Kuha Mine Footprint and Tarn

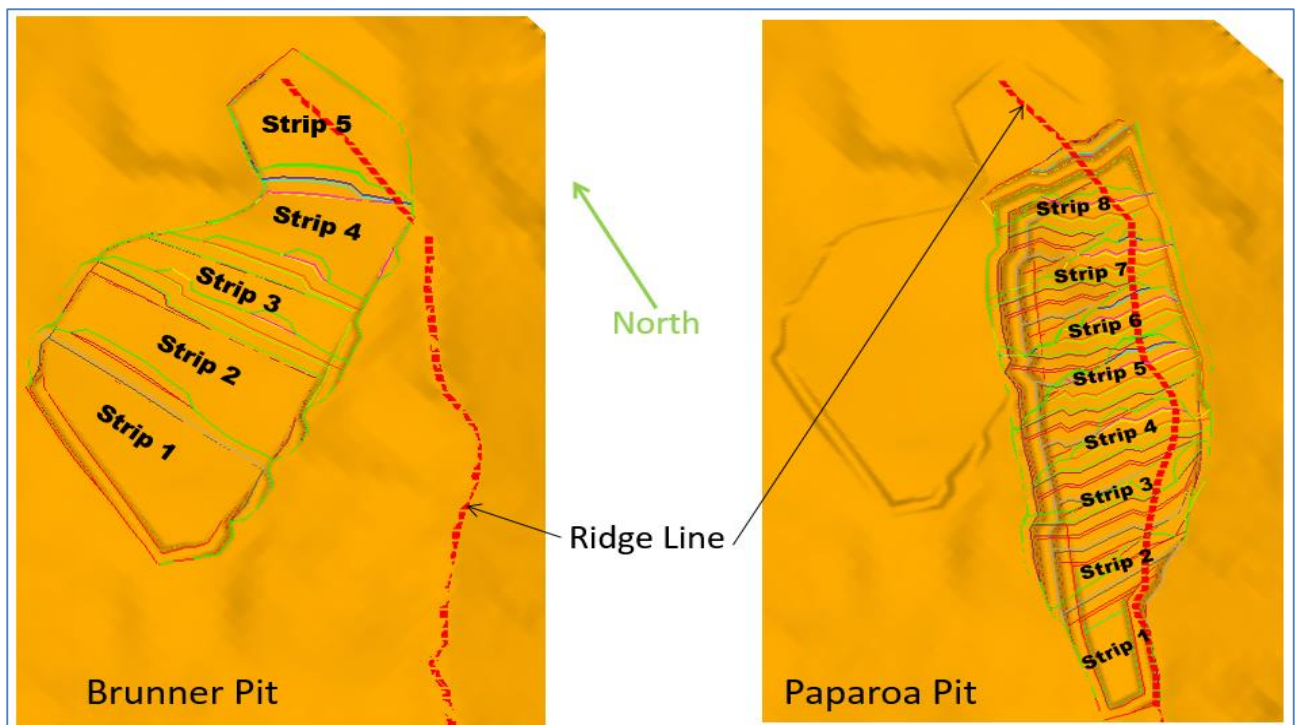


Figure 3 - Plan View of Proposed Pits and Sequence as per Avery (2014)

The site is inaccessible other than by helicopter at time of report, this has limited data gathering to helicopter transportable drill rigs and field mapping. Vegetation on the hill ranges from dense to very dense with few open areas, vegetation coverage is consistent resulting in limited outcropping. Site elevation ranges between 600m and 800m with initial work starting at the lower ends of both pits.

A total of 29 boreholes have been drilled, TK01 to TK11 were completed as part of the original exploration study in 1986, TK12 to TK29 were drilled as part of the recent exploration project. Core photos from TK21 to TK26 have been made available and lithology / defect logging are available for all 29 boreholes.

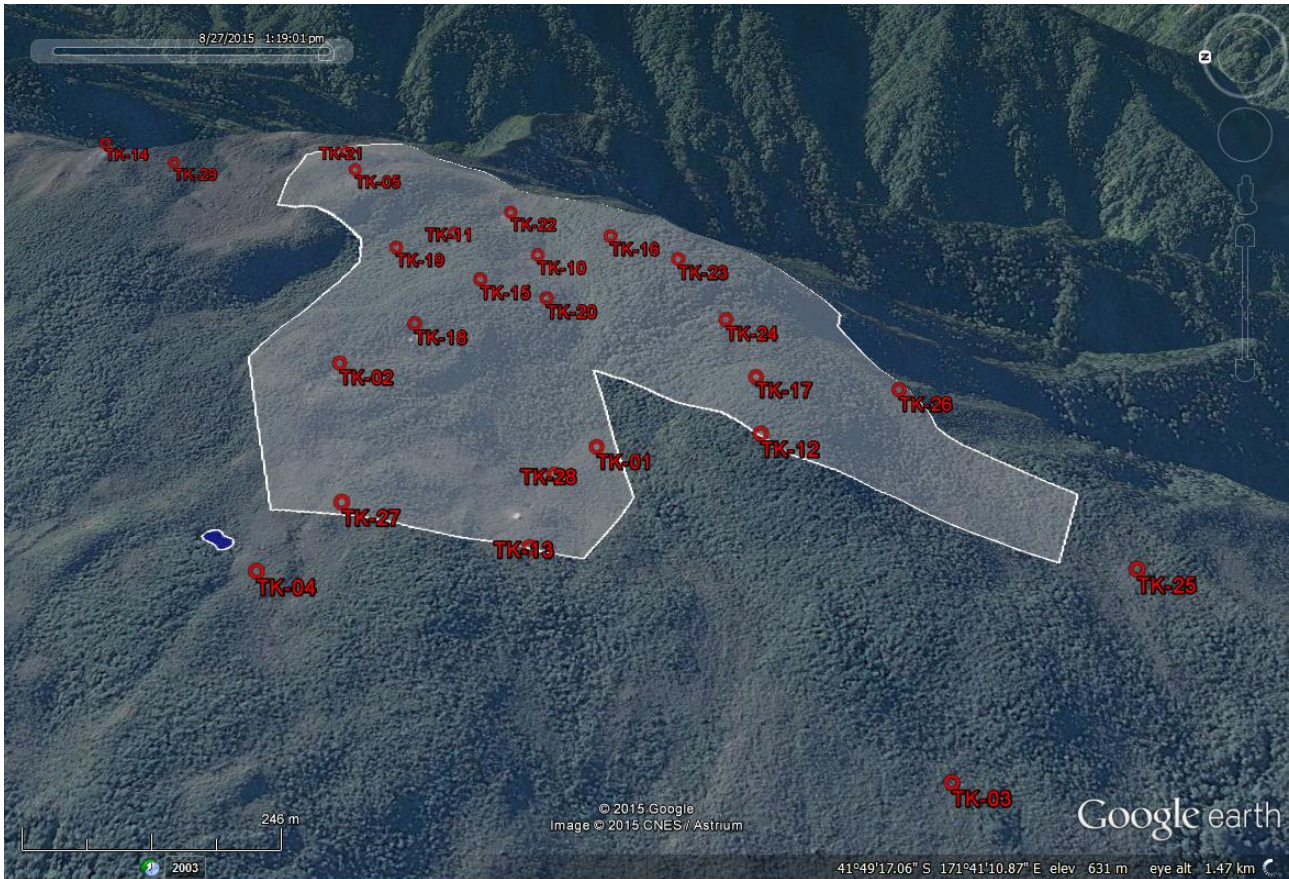


Figure 4 - Te Kuha Project Boreholes

The geology of Te Kuha is considered complex due to the variation in seam positions, the associated large faults, ranging seam dips and presence of multiple slides on the Western face.

There is a large volume of geological information available for the site from outcrop mapping and the two exploration programs, however, geotechnical data is limited to Rock Quality Designation (RQD as per Deere *et al*, 1967) and geological field strength estimations. These data only infer material behaviour but are suitable for conceptual assessment, a more rigorous geotechnical testing program will be required for operational implementation where specific designs for all walls is recommended.

1.4 Site Inspection

A site inspection was carried out on 28 August 2015 by Geologist A. Dutton and Geotechnical Engineer C. Mans to make a general assessment of the site, look at the identified slides, inspect reported voids in outcrops, investigate surface water around the planned dump sites (particularly the tarn) and assess if a suitable dam location exists towards the Northern boundary.

Inspection was carried out on foot with a final fly over in the helicopter to assess any areas which were considered inaccessible, practically speaking.

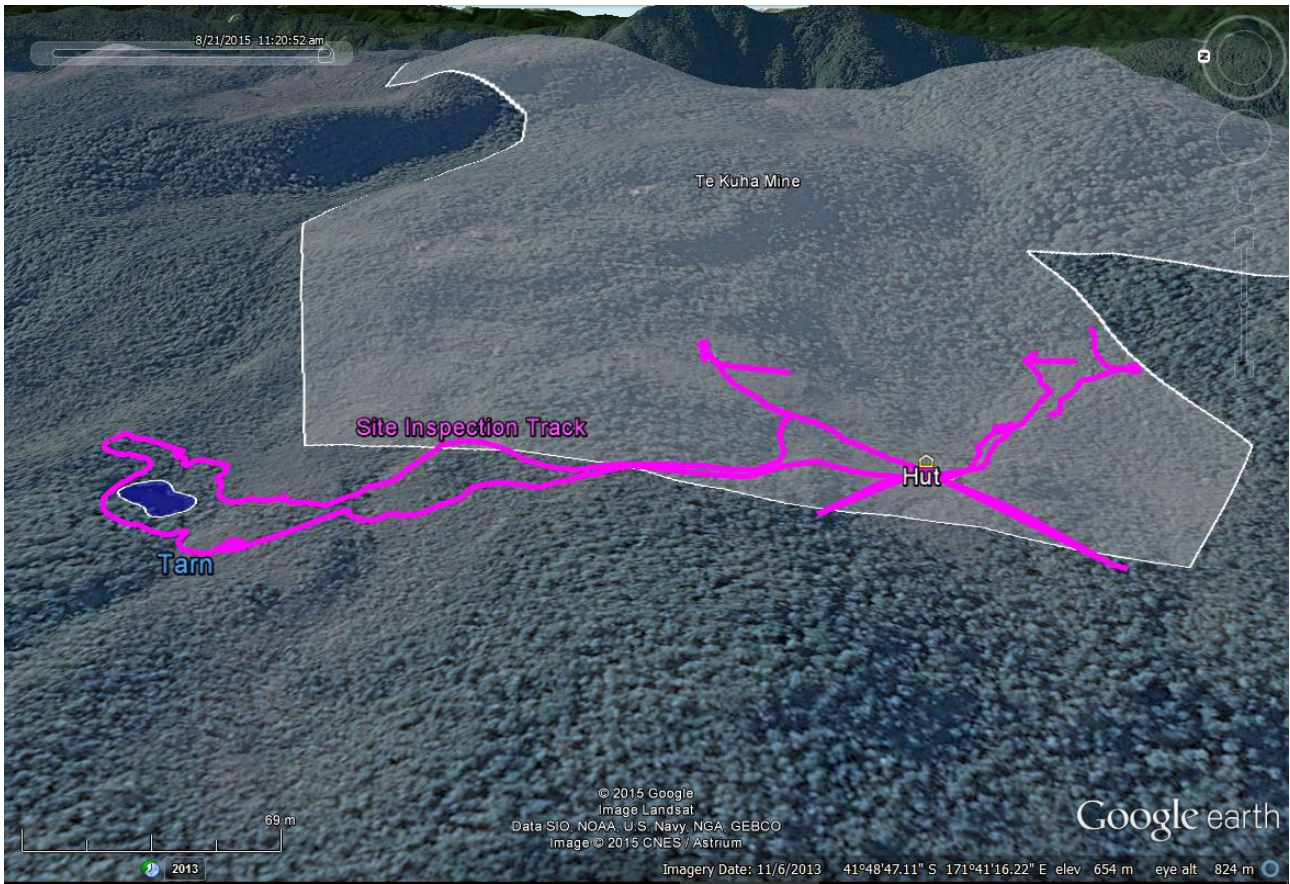


Figure 5 - Site Inspection Track from 28/08/2015 Showing Mine Footprint and Tarn

The site is densely vegetated and surface topography ranges in steepness from flat in areas to very steep (~45°), a couple of sheer cliff faces were identified on the western slope but generally limited to 10m height or less. Significant earth works will be required for mine access and haulage as part of operational preparation, initial surface excavation should not prove problematic with the weathered profile being fairly soft material and the more competent materials being blocky in nature.



Figure 6 - Photo of Western Hillside Looking South

There appears to be two slides present on the Western slope which may impact on mining operations, these are designated H01 and H02. The slides are densely vegetated with minimal disturbance visible, some minor slippage of vegetation and muds can be seen but appears superficial and most likely associated with surface water. Exposed rock material within main body of slides is blocky in nature forming voids, exposed surfaces are planar and most likely due to the principal jointing structure. H01 intersects the mine footprint while H02 is located near the proposed material dump site.

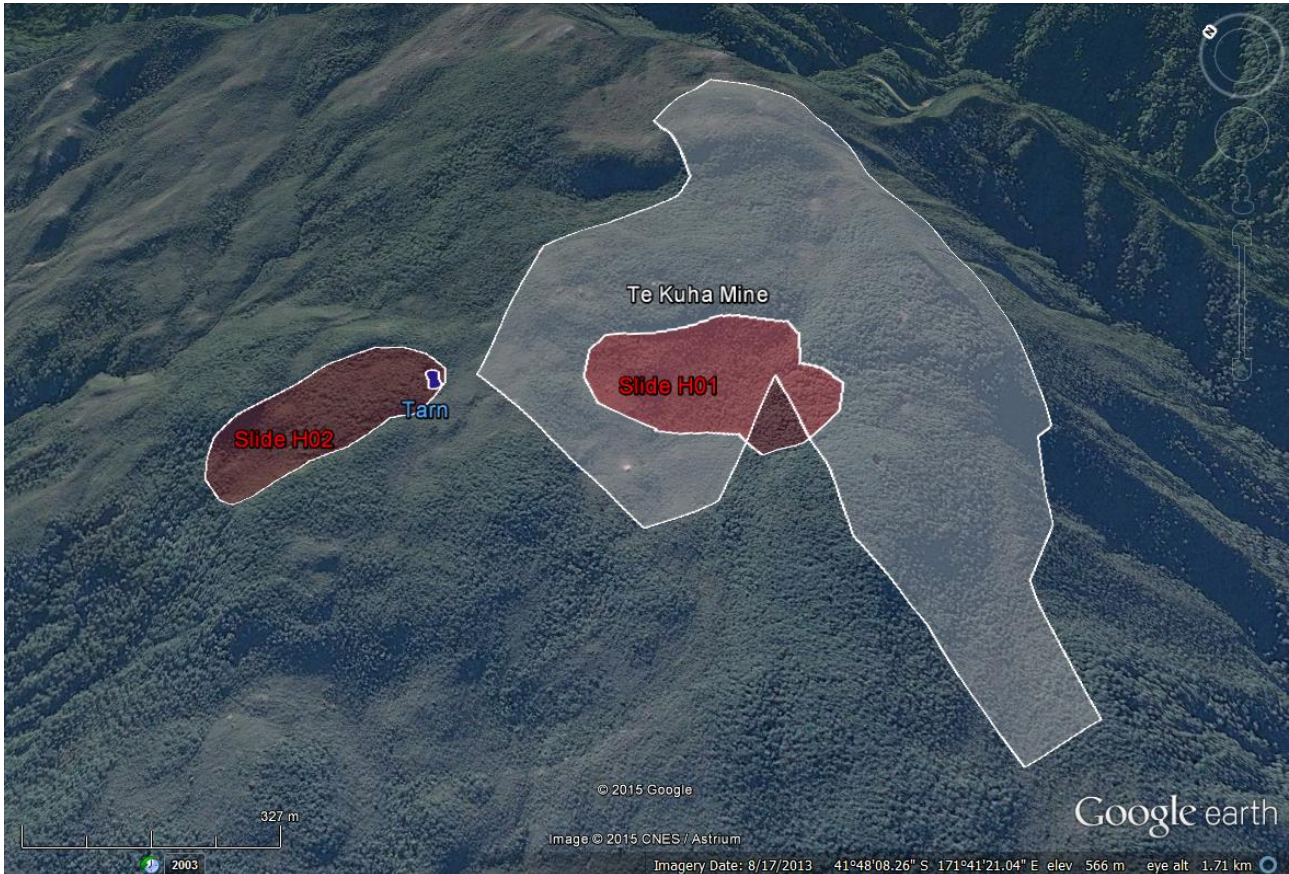


Figure 7 - Landslides Proximal to Operation

Voids within outcrops have been reported as part of the original mine evaluation document (Johnson, 2002) and from recent geological mapping. Most outcropping would be described as block and jointed, however, large voids (~100mm open) were not found to be consistent throughout but rather appear concentrated around the bodies of the slides.

Several small, mostly inconsequential, creeks and water courses were identified during the site inspection. The tarn appears to be partially fed by a natural drain running down a Northwest slope, a dry water course was found on the Northeast end of the tarn which presumably acts as an overflow channel during heavy rainfall. The tarn was effectively full at the time of the visit, some rainfall had occurred but the overflow had not been activated, the water level indicates that the tarn does not drain quickly via subsurface voids or fractures. Anecdotal evidence from A. Dutton does suggest that the tarn drains quicker than evaporation is likely to allow for which infers that the tarn is subject to seepage. Dedicated water level and rainfall monitoring at the tarn would be required for any greater confidence.

A small creek drains along the Northern gully (**Figure 8**) adjacent to the tarn, both slopes into the gully appear free of any obvious deformation and no evidence of sub-surface connectivity to the tarn could be found. This gully could be a suitable location for a dam.



Figure 8 - View of Northern Gully Looking Southeast, Showing Potential Dam Site (2:1 Exaggeration)

2 Geological and Geotechnical Background

2.1 Geological Information

The Paparao and Brunner formations are typical coal deposition environment consisting largely of sandstones and siltstones with some minor gravel conglomerate and mudstone components. The weathered profile in the planned mining areas is generally limited to ~5m above the Paparao seam with the upper ~10m consisting of highly weathered material, decreasing to slightly weathered, lower in the profile.

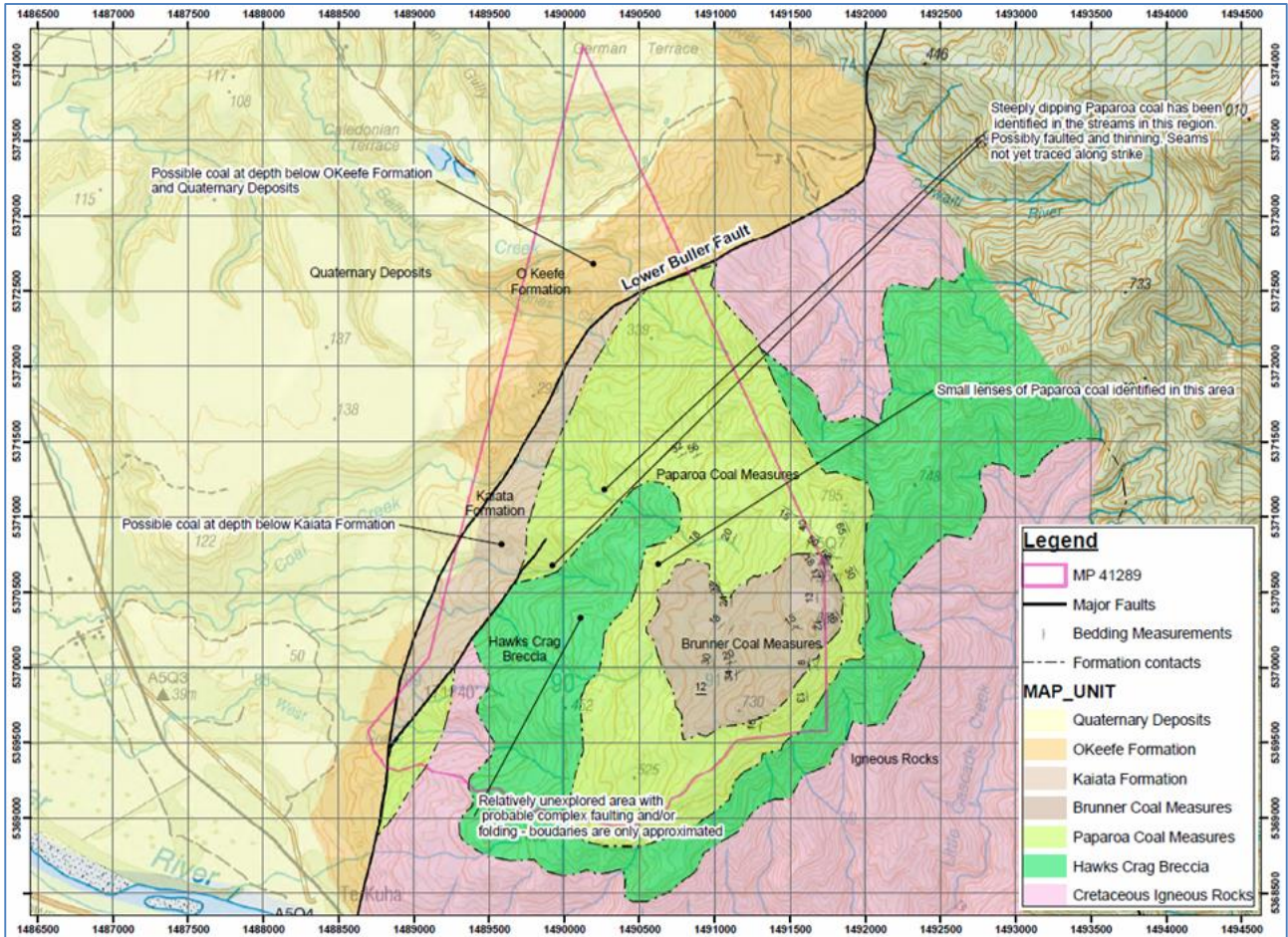


Figure 9 - Te Kuha Regional Geology Map as per Dutton (2013)

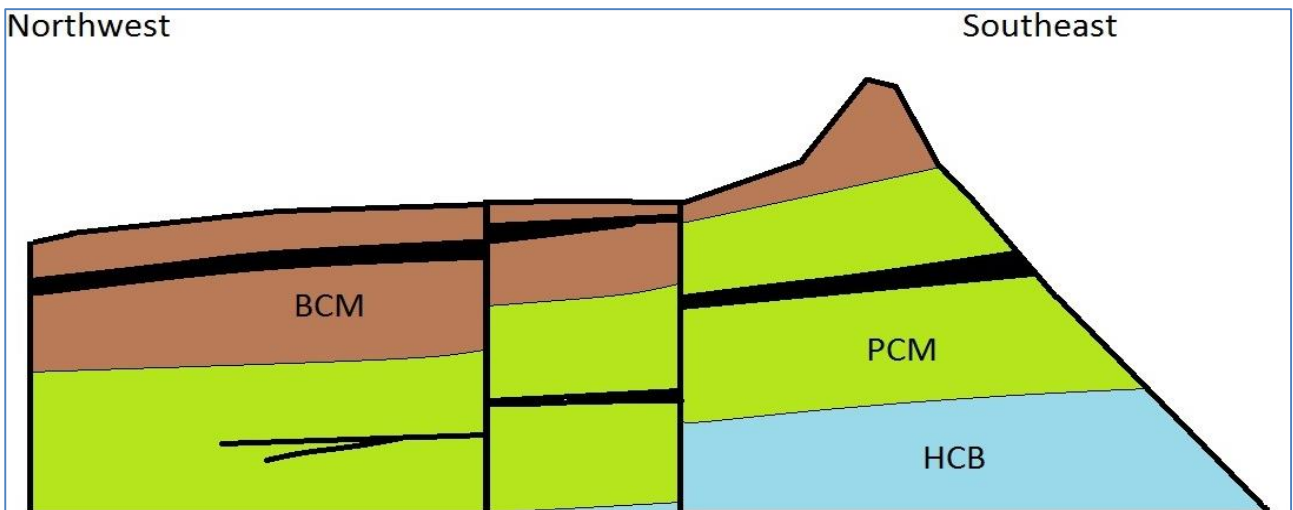


Figure 10 - Te Kuha Faulted Cross-Section as per Dutton (2013)

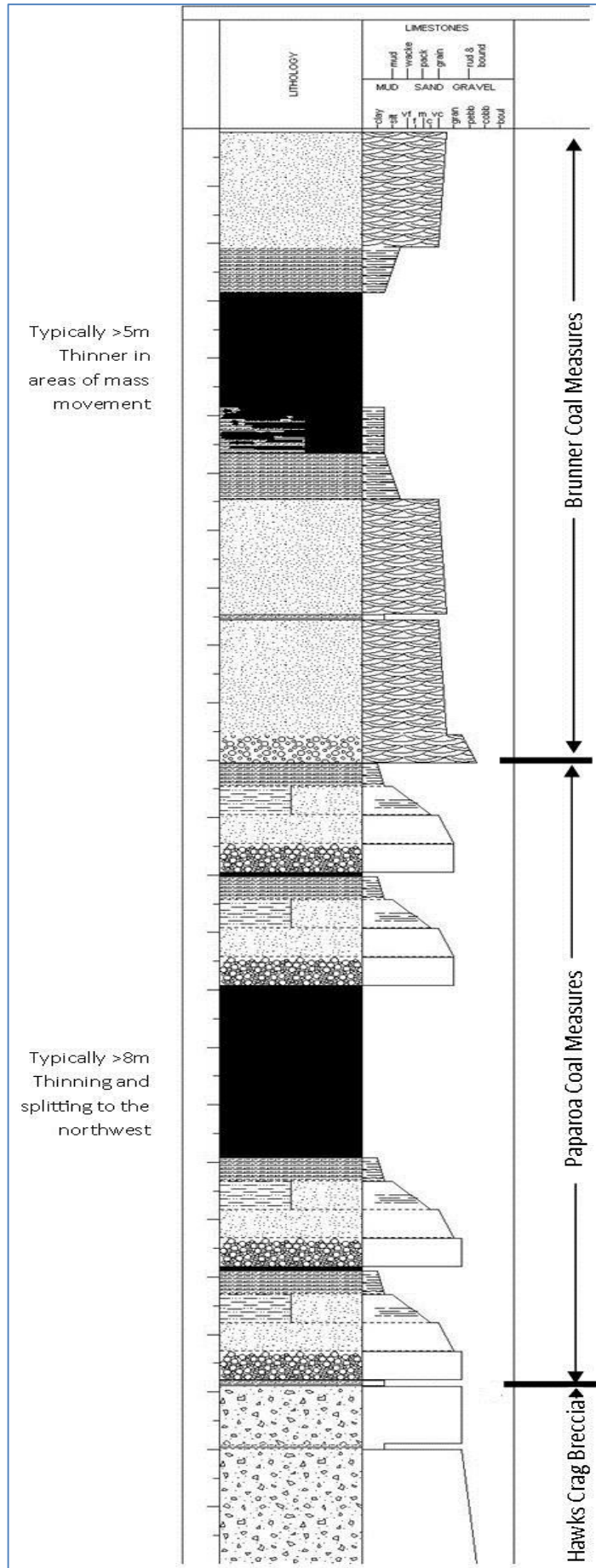


Figure 11 - Te Kuha Generalised Stratigraphic Column with Lithology as per Dutton (2013)

2.2 Hydrology

Te Kuha is reported as having two groundwater systems (Flintloft, 2013), a shallow surface drainage system and a deeper system which roughly follows the stratigraphic contours ~55m below surface. Both systems are rain driven with the deeper system exposed on the eastern hillside at around the 600m contour.

The surface system currently contributes to the Western tarn where seepage and spillage may have minor impact on the slides identified on the hillside. Several other small creeks (some shallow sub-surface via voids) were identified during the site inspection but did not collect at either the head or toe of slide H01.

2.3 Geotechnical Information

The generalised lithology (**Figure 11**) has been used for construction of the stability models, generic cohesion and friction angle values for coal measure lithologies have been used for purposes of assessment. The slightly weathered and fresh materials have been down-rated via GSI (Geological Strength Index) to account for the moderately spaced jointing pattern (~1m).

The two slides discussed earlier do not appear active, it is difficult to make an accurate assessment of their condition or potential because of the inaccessibility of the area. The slides pose two different problems with regard to planned activities and as such management of the hazards should reflect this. The slides may be inactive or minimally active but they have created a subsurface water path, running water could be heard from the voids inspected in the main body of H01.

Slide H01 will interfere with mining activities as extraction takes place. Unconsolidated blocky material should be expected where pit walls overlap the slide, however, the majority of the slide will be removed during mining which would effectively remove the hazard. Excavation through and around H01 can be managed with appropriate buffers and sequencing until the slide is removed, the small remaining portion will be the toe and foot which should not present any risk once loading has been removed.

The initial material dump is planned in the area of the tarn which sits on the crown of slide H02, the presence of the tarn exacerbates any instability issues as the saturated materials and migrating water will reduce material friction angle and can lubricate the failure plane further. Filling in this area and promoting better water drainage is expected to reduce risk, in contrast, loading material onto the crown will increase risk (magnitude will be dependent on the volume of material, area applied over and moisture content). In general terms, moving water away from the slide failure plane is expected to have the more significant impact.

Johnson (2002) classified the site into multiple mass movement blocks from an ancient failure, the formation of voids appear consistent with strained zones as indicated in **Figure 12**, the interpretation also provides insight into how slides H01 and H02 are likely to have formed. The boundaries shown indicate the higher risk areas (more broken) and where monitoring activities should be concentrated.

The principal faulting direction is North-Northwest (**Figure 13**) with the secondary set running East. The major structures are well aligned to the mass failure interpretation with displacements up to 50m predicted. Faulting of this magnitude is almost always accompanied by minor sets of associated faulting and shearing systems. Normal faulting (as opposed to thrust faulting) is expected to be the dominant type due to the nature of the mass failure.

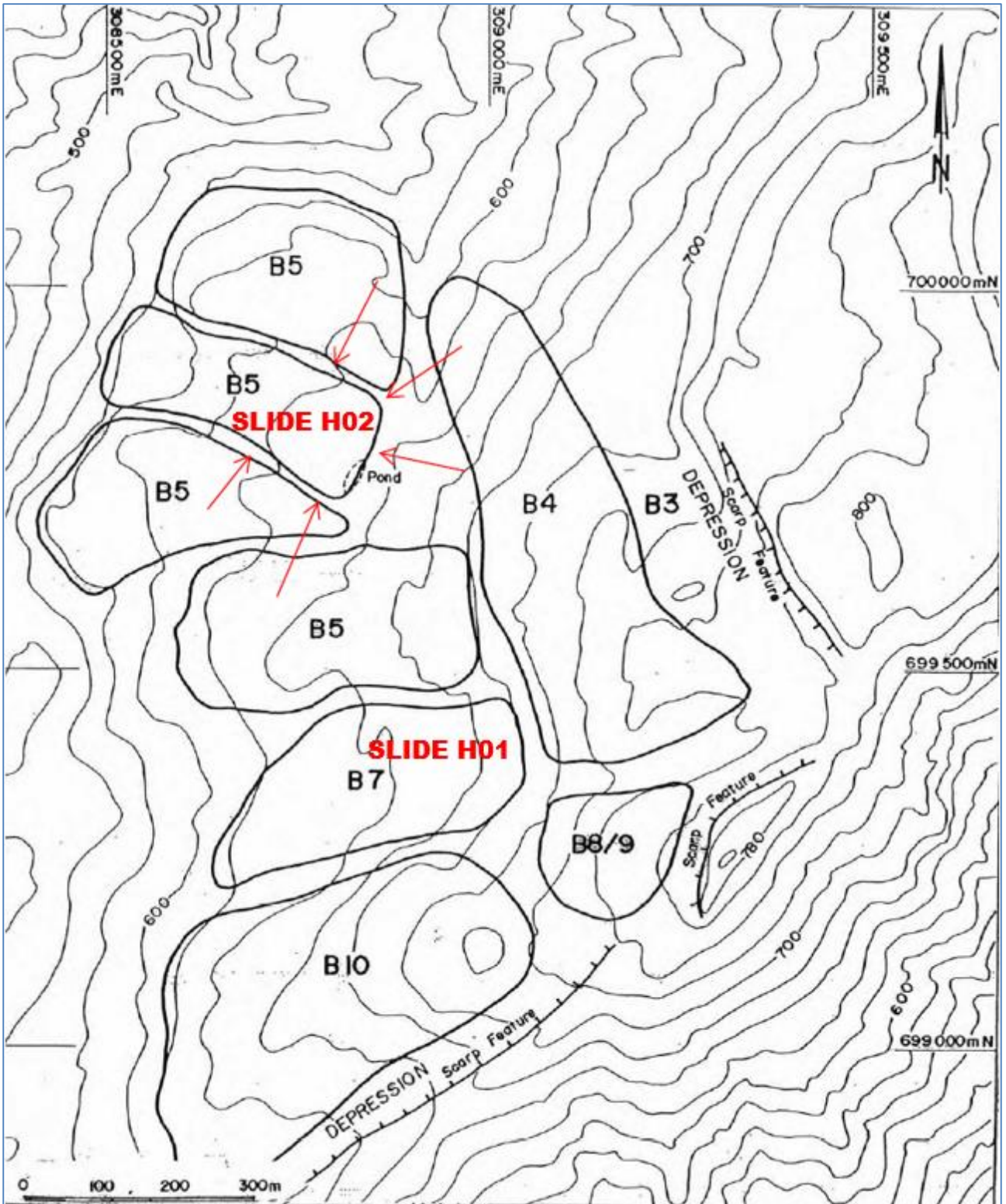


Figure 12 - Te Kuha Mass Failure Interpretation from Johnson (2002)

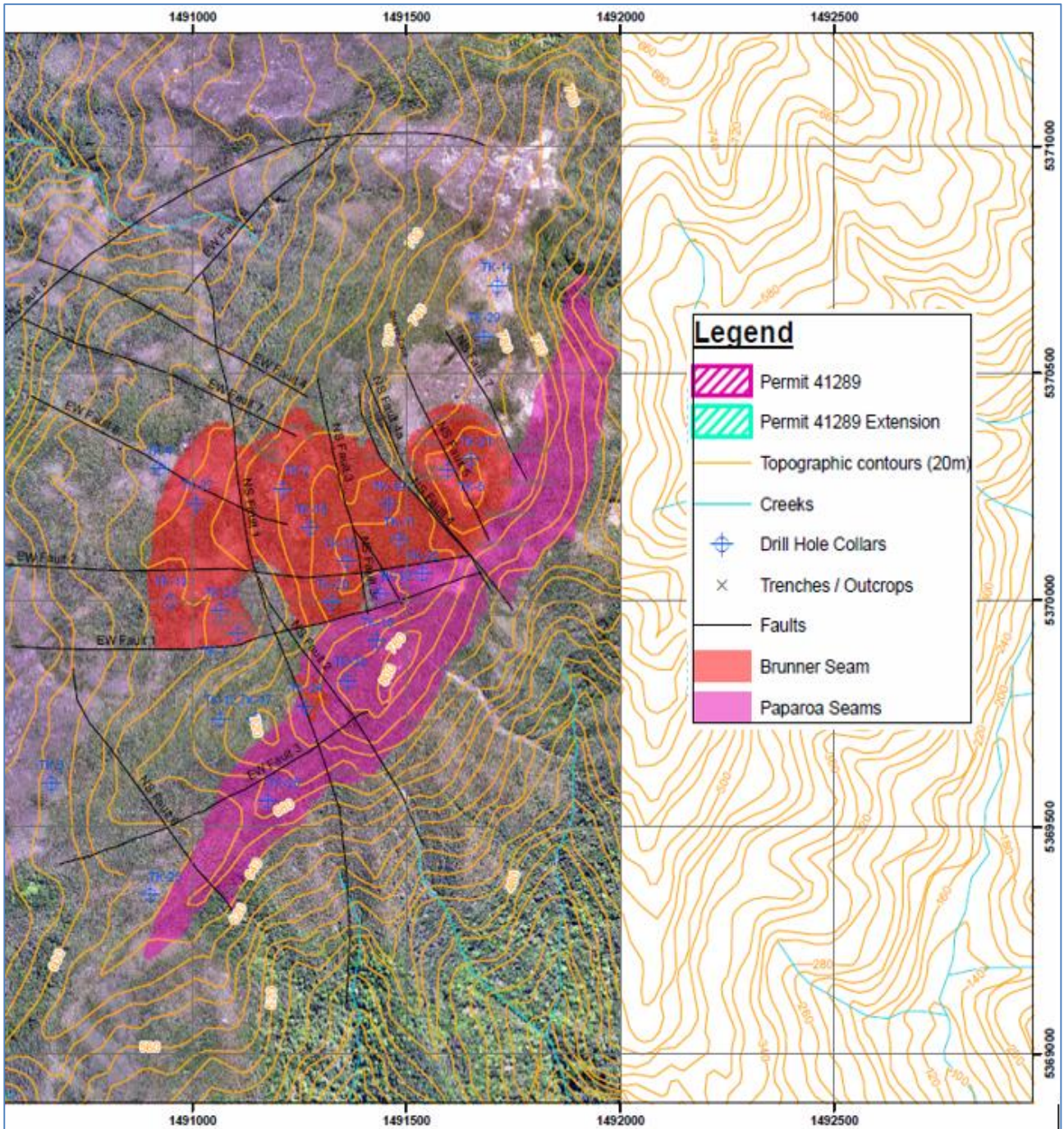


Figure 13 - Te Kuha Fault as per Dutton (2013)

3 Stability

A number of reasonable assumptions have been made due to the lack specific geotechnical data required for stability modelling. General input parameters for common lithology types were selected from RocLab software based on the median recommended values, down-ratings for jointing were applied via GSI where appropriate and each coal seam included a 2m lower horizon down-rated to replicate the most likely failure mechanism (shear failure at base of seam). The generic models at various stages through the life of the pit (**Figures 14 to 16**) were modelled without faulting to assess base conditions, supplied wall and bench dimensions were used to assess current likelihood of stability. Phreatic surface for the model was roughly aligned with the lower Paparoa coal measure, seismic factor of 0.2g and a fracture depth of 2m was used. Modelling was carried out using Galena 6.0 with the material properties set out in **Table 1**.

Table 1 - Material Properties for Stability Model

Material	Density (kN/m ³)	Cohesion (kPa)	Friction Angle (°)
Spoil Dry	18	20	25
Soil Dry	20	50	30
Highly Weathered Sedimentary Rock	22	40	30
Slightly Weathered Sedimentary Rock	24	150	35
Fresh Sedimentary Rock	24	350	38
Coal	15	30	35
Coal (shear failure)	15	0	30

Analyses were carried out in the form of a sensitivity study with circular and non-circular failure planes incremented along the model beginning at first benches and extending to include entire walls. The parameters used in the model are considered conservative for general operation, assuming geotechnical testing reasonably corroborates the model inputs, there is likely to be opportunity for optimisation.

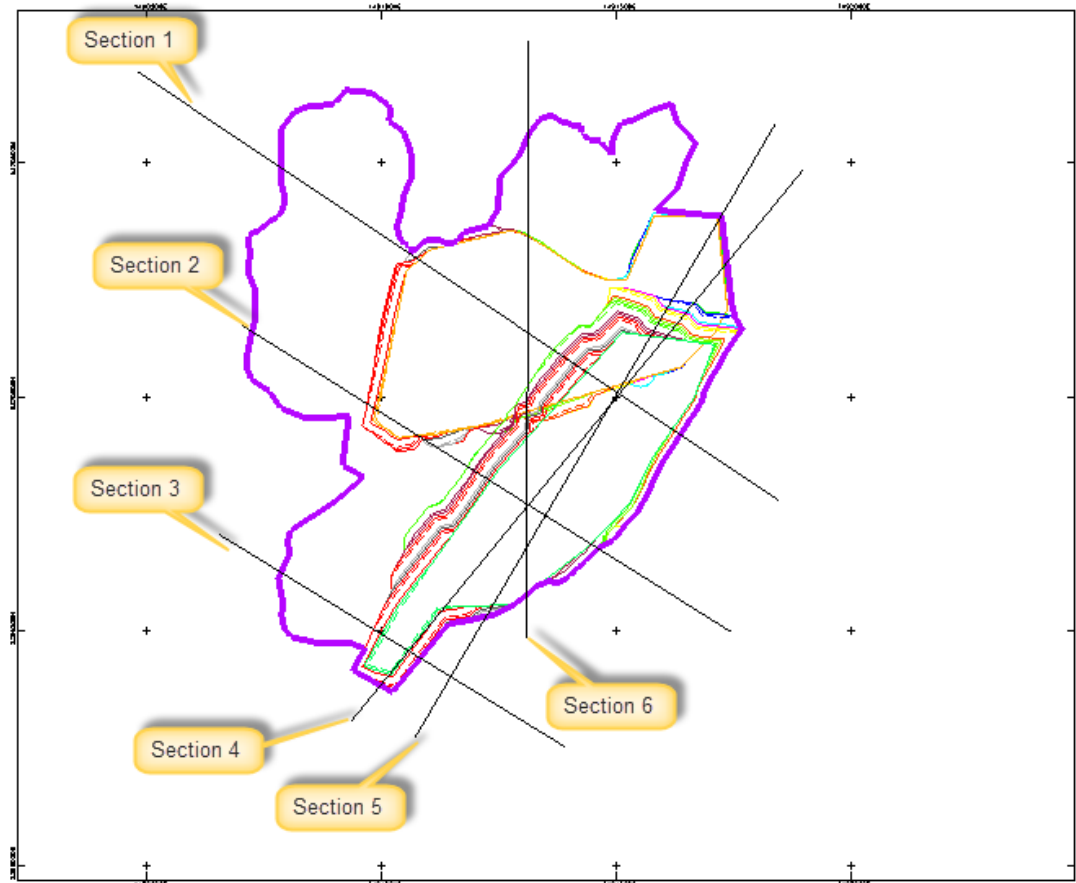


Figure 14 - Section Summary

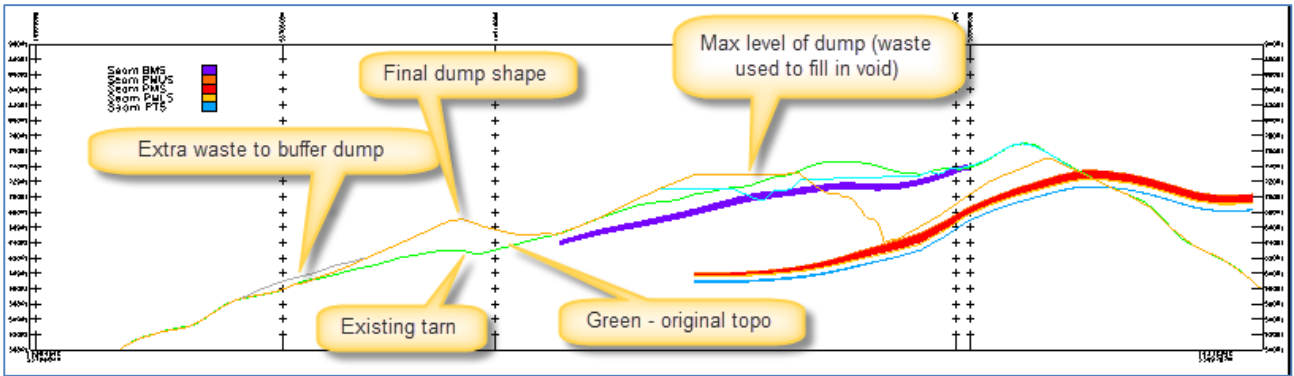


Figure 15 - Cross Pit Model (Section 1), Paparoa and Brunner Pit Overlapped

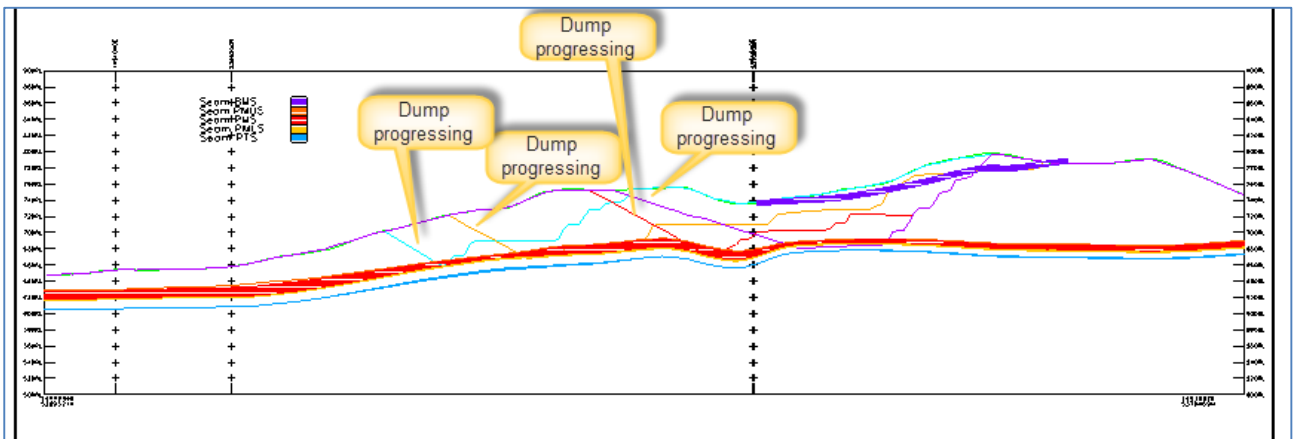


Figure 16 - Paparoa Pit Model (Section 4)

Factor of Safety (FoS) values returned by the model ranged from 0.9 up to 5.5 with the majority of outcomes over 1.2, these outcomes infer that the current pit design, generally speaking, is either stable or very near stable. As expected, the lower FoS values were associated with the Eastern wall and the steeply dipping stratigraphy, an adjustment of the Eastern wall angles to 50° (currently planned at ~60°) returned no FoS values <1.2.

Some rough sensitivity checks of faults were carried out by introducing shear planes in close proximity to the walls / benches. FoS results indicate that localised instability can be generated but is limited to individual benches, this type of failure is most likely to be generated by the interaction of the major structures and jointed blocky materials.

The exposed sections of the slide were also replicated by conservatively treating the wall material as spoil, the affected zones are minimal (and limited to the Western walls) but will be prone to instability, adjustment of wall angles at these locations should stabilise these sections and increasing bench widths will effectively eliminate rock-fall hazards.

Similar to Johnson (2002), this model found the current hillside and slopes to be fundamentally stable. Removal of the overburden via mining activity marginally improves stability according to the model, this would be due to the decreased weight acting on the downhill sections.

4 Conclusions

The current pit design can be said to be stable or very near stable with the exception of localised hazards such as geological structures and slide H02. Opencast mining operations at the Te Kuha site are geotechnically feasible provided that specific designs (based on accurate geotechnical data) are carried out for all stages of the mining operation. Specific designs should consider mitigation measures to either improve stability where appropriate or at the very least eliminate exposure.

Mass failure is extremely unlikely, however, if it were to occur slippage would propagate West along the steeply dipped bedding (up to 30°) rather than South towards the rear of the pit (apparent dip <10°).

Mining sequence, particularly overburden stripping, has the potential to significantly reduce the geotechnical risks. Over-stripping adjacent to slide H01 and faults will reduce highwall exposures, introducing steeper benches or bunds to eliminate rock-fall risk. In extreme cases consolidation works or retaining structures may be required. The proposed up-dip mining sequence will enable most of slide H01 to be removed without exposing the pit floor to instability risks.

Water management is the critical aspect to control both the slides and general pit stability. The up-dip mining sequence has the added benefit of providing greater control over water management. Improved drainage and well thought out water diversion should decrease the volume of ground water, subsequently improving the stability of slide H02 and also reducing the overall likelihood of mass failure. Mining down-dip would allow for ponding at the toe of the highwall which will impact its stability, furthermore, seepage would most likely connect with slide H01 and possibly H02. All efforts should be made to reduce, or at the very least not increase, water ingress into either slide.

Detailed monitoring should be carried out for any new operation, in the case of Te Kuha, the geotechnical focus should include regular survey of slides H01 and H02 and the mass failure blocks interpreted by Johnson (2012). Remote tell-tale devices are relatively inexpensive and will assist to provide further assurance. The highest risk area is loading of dump material onto the crown of slide H02, monitoring frequency in this area should be high, at least initially, and alternative dump strategies should be available in the event that significant movement is detected.