RESIDUAL VOID MANAGEMENT PLAN

SITE: Millennium Coal Mine

DATE: June 2019

REF: MIL-ENV-RVMP (Version 3)

Document Owner	Document Approver
Senior Environmental Advisor	Daryn Railey
General Description	
Millennium Mine Residual Void Management Plan prepared in accordance with condition F6 and F7 of Environmental Authority EPML00819213.	
V3 Amendments - RVMP updated to address Material Particulars relevant to the management of a void or rehabilitation of land identified in DES correspondence 11 January 2019.	

Contents

1. Introduction

Peabody Australia (Peabody) operates eight open-cut and underground coal mines throughout Queensland (QLD) and New South Wales (NSW) producing a broad range of metallurgical and thermal coals for domestic and international customers. Millennium Coal Mine (MCM) is an open cut mining operation located approximately 140 km south-west of Mackay in Central Queensland. The nearest regional centre is Moranbah, which is located approximately 22 km to the west, as shown in **Figure 1**.

The project is operated by Millennium Coal Pty Limited (MCPL), a wholly owned subsidiary of Peabody Energy Australia (PEA). The mine has been operating since 2005 with approval to produce at a rate of 5.5 million tonnes per annum (Mtpa).

The run-of-mine (ROM) coal is currently extracted from four granted mining leases (ML) namely, ML70313 Millennium West, ML70344 Mountain Pit, ML70401 North Poitrel and ML70457 Mavis Downs. The ROM coal is washed in a coal handling and preparation plant (CHPP) on an adjoining infrastructure lease, ML70312 Millennium East. The CHPP is owned by BHP Mitsui Coal Poitrel Mine (100%) and is operated by the Red Mountain Infrastructure (RMI), as Millennium Coal recently sold its 50% share via a sale agreement to BMC Poitrel, which took effect on 7 February 2018.

As part of Peabody's mine closure guideline, and to comply with conditions F6 and F7 of Environmental Authority (EA) EPML00819213, Millennium Coal is required to prepare a Residual Void Management Plan.

2. Purpose and Scope

The aim of the Residual Void Management Plan (the Plan) is to ensure compliance with the requirements set out in conditions F6 and F7 of EA EPML00819213 and detail the overarching post-closure management of the site. The requirements of conditions F6 and F7 are presented in **Table 1** below, along with a cross-reference to the Sections within this Plan that provide the information that meets these requirements.

In addition to the EA requirements, Peabody has considered the current QLD Government policy on progressive and final rehabilitation requirements for site-specific mining projects under the *Environmental Protection Act 1994* (DEHP Guideline ESR/2016/1875, Rev 2,01, 2018). These guidelines provide for the following site outcomes i.e. safe to humans and wildlife, geotechnically stable, non-polluting to the surrounding receiving environment, and able support a self-sustaining post-mining land use. Demonstration of how each of these outcomes is met is presented throughout this report. Peabody's approach has been to address potential environmental impacts, achieve the highest practicable level in the rehabilitation hierarchy, and work with relevant stakeholders to create an acceptable post-mining land use.

Table 1 – Requirements of Conditions F6 and F7 and Cross-references

Condition	Requirement	Section Reference
F6	*Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other that the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.*	All Sections of this report. In addition to environmental harm to land and waters, Section 3.1 details management of stakeholder impacts.
F7	*Complete an investigation into residual voids and submit a report to the administering authority proposing acceptance criteria to meet the outcomes of in Condition F6 and landform design criteria prepared at least eighteen (18) months prior to mine closure for review and comment. On acceptance of the criteria proposed in the residual void management plan, the criteria must be specified in the environmental authority. The investigation must at a minimum include the following:*	As per sections listed below. The Plan was submitted to the QLD Department of Environment and Science (DES) for review and comment in late February 2018. The Plan has therefore been submitted within the required timeframe.
F7(a)	*A study of options available for minimising residual void area and volume;*	Section 9
F7(b)	*Develop design criteria for rehabilitation of residual voids;*	Section 9.1
F7(c)	*A void hydrology study, addressing the long-term water balance in the voids, connects to groundwater resources and water quality parameters in the long-term;*	Section 12
F7(d)	*A pit wall stability study, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events;*	Section 13
F7(e)	*A study of void capability to support native flora and fauna; and*	Section 14
F7(f)	*A proposal for end-of-mine void rehabilitation success criteria and residual void areas and volumes.*	Section 15 for end-of-mine void rehabilitation success criteria. (Residual void areas and volumes presented in Section 9.)
	These studies will be undertaken during the life of the mine and will include detailed research and modelling. *Note: As required by Condition G32(c), at the completion of decommissioning and*	These studies have been ongoing since the EIS stage of the Project and have been ongoing during the life of the mine. Detailed research and modelling studies supporting this Plan are attached in the following appendices:

	rehabilitation, residual voids must be protected from Probable Maximum Floods (PMF) from nearby watercourses such that the protection is sustainable for the foreseeable future.	• **Appendix A** – Stage 2 Final Void Modelling • **Appendix B** – Spoil Water Contribution to Millennium and Mavis Pit Final Voids • **Appendix C** - Residual Void Slope Stability Study • **Appendix D** – Assessment of Residual Void Water Capacity to Support Native Flora and Fauna Protection from PMF from nearby watercourses is considered in Section 16.

3. Life of Mine, Rehabilitation and Mine Closure Process

During the life of Millennium Mine, which commenced open cut coal mining operations in 2006, the intensity of mining operation (ROM production) has been increasing from approximately 1 mtpa in 2006 to 4.4 mtpa in 2016. During this time the rehabilitation intensity has been increasing when available areas are ready for reshaping, topsoil and seeding. Given the inherent high strip ratio compared to other mining operations in the local area, Millennium Mine could only maintain its production intensity for a finite period, which has resulted in the cessation of conventional truck and shovel mining operations in late September 2018. As conventional truck and shovel mining slowed the rehabilitation intensity has increased year-on-year since 2015, and in 2018, Millennium Coal completed 427.7ha (597% increase compared to 2017) of rehabilitation utilising existing production equipment and personnel. Although conventional mining has ceased, and highwall mining is the only mining method being utilised at Millennium Coal until Q3 – Q4 2019, the rehabilitation intensity and planned Post Closure and rehabilitation maintenance intensity is continuing to increase, which has been presented in **Figure 2** below.

4. Related Management Plans

This Plan is related to the Rehabilitation Management Plan and Post Closure Management Plan with respect to the final voids.

The Post Closure Management Plan will be implemented for a nominal period of either at least 30 years following final coal processing on site, or a shorter period if the site is proven to be stable and non-polluting. The term of this Plan is therefore commensurate to the period of the Post-closure Management Plan in so far as it provides information on the stability and pollution risk of the final voids.

The final voids rehabilitation success criteria presented in Section 15 informs the Rehabilitation Management Plan in part. Assessment and management of the final voids' progress towards their rehabilitation success criteria will be implemented in accordance with the requirements of the Rehabilitation Management Plan.

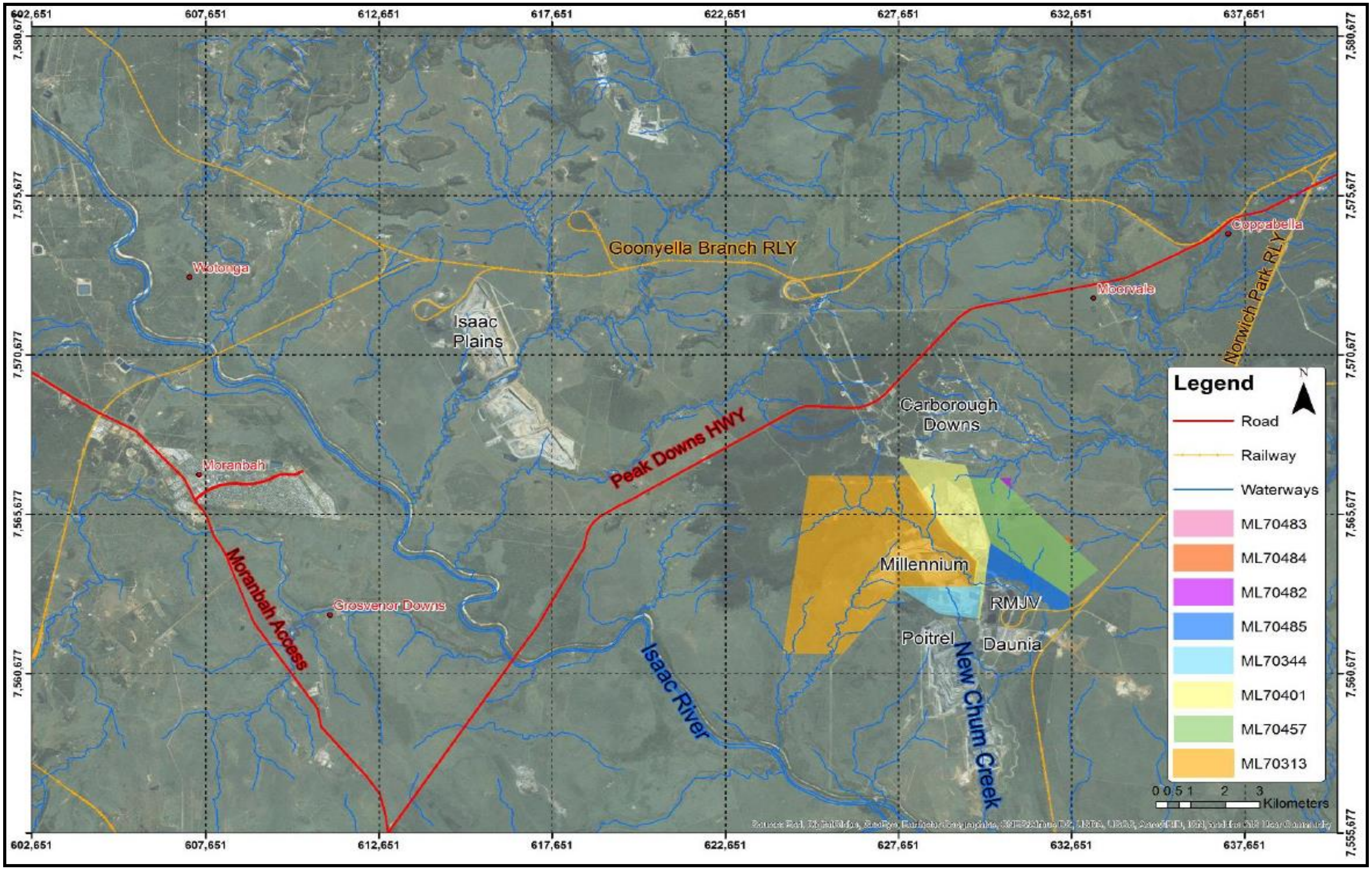

Figure 1 – Millennium Mine Locality and Mining Leases

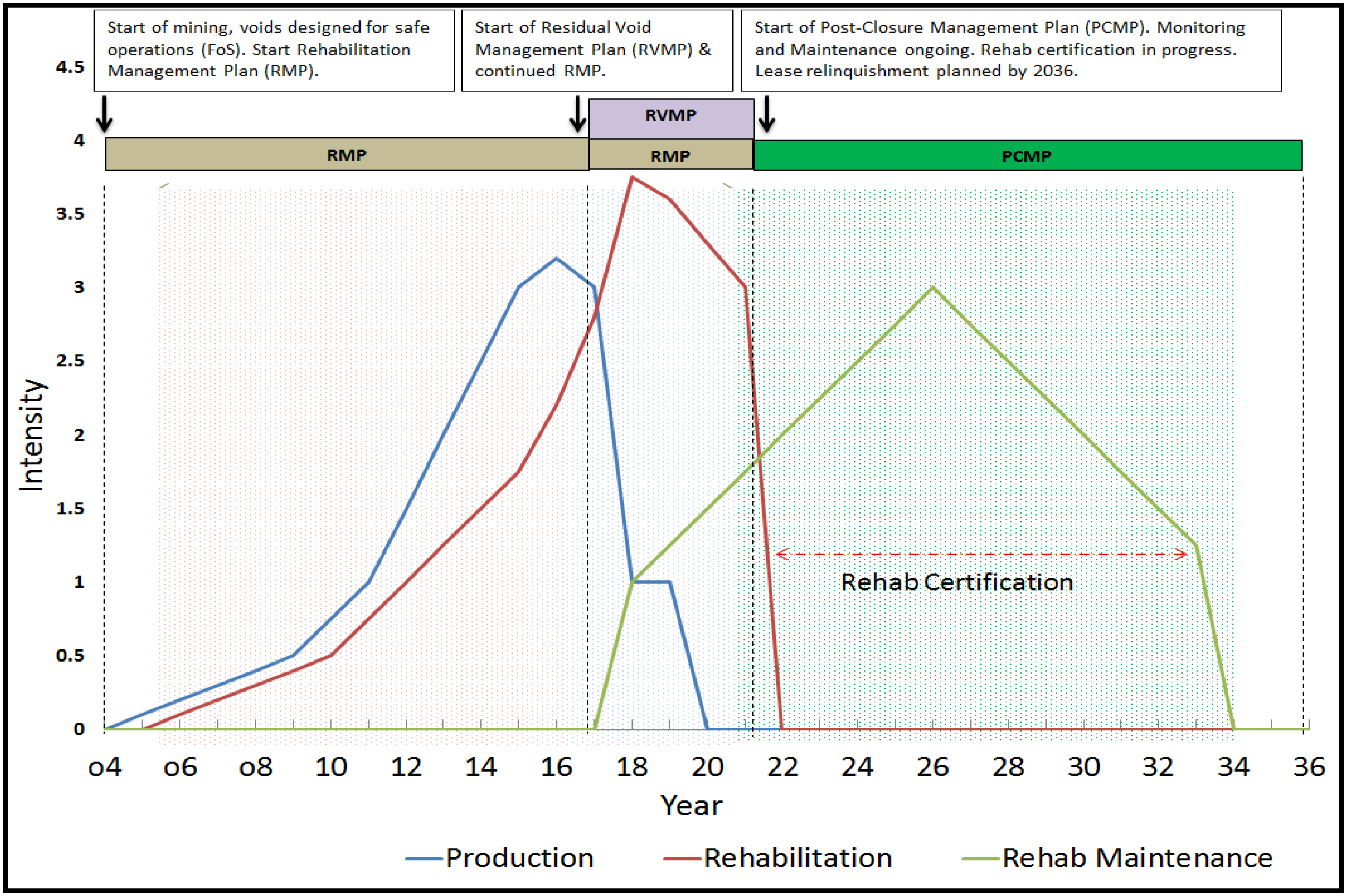

Figure 2 – Life of Mine, Rehabilitation and Mine Closure Process

5. Background

Open cut mining operations at Millennium Mine commenced in 2005 and consisted of one (1) mining area, known as Millennium C Pit, which recovered the Leichardt (4.5m), Millennium (1m) and Vermont (1.3m) coal seams through conventional truck and shovel method. The Millennium Expansion Project (MEP), which involved the extension of the existing Millennium Pit and inclusion of a new mining area, known as Mavis Pit, which consisted of three (3) mining areas, being Mavis D Pit, Mavis E Pit and Mavis S Pit was proposed in 2009. The MEP commenced in 2011 utilising conventional truck and shovel and dozer push methods, but Mavis Pit consisted of only one (1) coal seam, being the Leichardt. Both Millennium Pit and Mavis Pit are hydrogeologically separated by a significant fault structure, known as the New Chum Creek Fault, which splits the two mining areas in an approximate north – south direction, which has resulted in the Leichardt seam being lifted close to the surface (LOX line) on the western edge, but then steeply dips towards the east whereby the coal is located approximately 200m below natural ground level at the Mining Lease boundary.

Depth of cover at Millennium Mine varies, but is generally between 80 – 90m below natural ground level and the maximum depth of Millennium Pit and Mavis Pit will effectively be reached by September 2018, although subject to charge due to ongoing mining plan optimisation processes.

The conceptual post-mine land use will be a mosaic of self-sustaining pasture and woodland species that will support cattle grazing primarily through the use of improved grass species. Out-of-pit spoil dumps and top of dumps will be rehabilitated to support cattle grazing, which also include areas within the final void that have been established above the modeled water level that will support and/or sustain cattle grazing.

6. Stakeholder Consultation

The primary stakeholder to this Residual Void Management Plan is the existing underlying landowner of the freehold land (Mavis Downs), who has nominated their Property Manager as the main contact for consultation on landform design, land rehabilitation, post-mining land use and other closure related planning and execution issues. Peabody has engaged with this landowner and Property Manager since 2017 in respect of the specific requirements for the post-mining land use. The objective of rehabilitation is to return the land to the landowner so that it supports their ongoing cattle production business.

Consultation topics with the affected landholder have included the following:

- Land forming for cattle grazing i.e. maximise flat grassland areas;
- stock access routes, including grading of slopes into and ex-residual voids;
- watering points, including water quantities and quality;
- grass mixes to be sown for fodder;
- retention of level, compacted areas to provide lay-downs areas or cattle yards;
- establishment of shade areas;
- fencing requirements; and
- beneficial re-use of retained infrastructure (e.g. roads, dams, concrete pads etc).

This consultation has provided both parties with a full understanding of the future land use requirements for the land and allowed for opportunities to maximize the future value of the land for grazing post-closure and ML surrender.

Peabody has also consulted with DES during the preparation of this Residual Void Management Plan. The Plan was first submitted to DES in late February 2018. Comments were received from DES on 26 July 2018. The Plan was subsequently revised and resubmitted in October 2018. On acceptance of the revised Plan by DES, Peabody will seek to amend Condition F3 of the EA to include actual rehabilitation landform criteria and disturbance areas for the final voids.

No other primary stakeholders have been identified, other than Peabody Energy Australia internal stakeholders, as being affected by this Plan.

7. Pre-Mining Environment

Land at Millennium Mine has historically been used only for beef cattle grazing, although the last 20 years has also seen significant coal mining and exploration works undertaken in the surrounding region. Most of the land occupied by Millennium Mine has been cleared for improved pasture, with Buffel Grass well established in most soil units. There is no evidence of any cropping undertaken in the area, other than possibly limited areas of forage production. The landscape at Millennium comprises undulating rural land with isolated rocky knolls. Surface water runoff drains to the west and south-east and is dissected by New Chum Creek running from north-west to south-east through the lease and into the Isaac River and West Creek on the western side of Millennium Pit. Most of the site has been cleared for the improvement of pastures for grazing. This has resulted in very little remnant vegetation remaining in this area, except for some areas associated with New Chum Creek.

Grazing suitability at Millennium Mine is limited by restricted soil and water availability, erosion susceptibility and limited soil fertility. Much of the area is prone to erosion caused by overstocking, however land management practices at Millennium Mine appear to have been sound and dense pasture cover on most soil units is present.

8. Spoil Characteristics

Analysis of waste rock samples from the existing Millennium Mine generally found the majority of the waste rock has negligible sulphur content and a net acid neutralising capacity due to a high content of calcium carbonate. This view is supported by anecdotal evidence at Millennium Mine, with no visible indications of pyritic oxidation in rehabilitated waste rock to date and no expression of such occurrences in water sampling results. Metal and elemental levels in the existing waste rock are at expected background levels and have low to moderate salinity and sodicity. Overall the results indicate that the waste rock has sufficient acid neutralising capacity to ensure acid drainage is not generated. Table 2 describes the regional stratigraphy at Millennium Mine.

Table 2 – Regional Stratigraphy at Millennium Mine

Summary of Stratigraphic Sequence			
Age	**Unit**	**Lithology**	**Thickness**
Quartenary	Recent Alluvium (Qa).	Soils, clays, silts, sands and gravels.	Up to 5 m
Tertiary	Suttor Formation (Ts).	Medium to coarse, cross-bedded quartz sandstone, conglomerate, sandy claystone, river channel conglomerate, overlying basalt.	6-120 m
	Basalt (Tb).	Weathered basalt soils, moderately weathered and fresh basalts.	Up to 80 m
Triassic	Clematis Sandstone (Re).	Cross-bedded medium to coarse quartz sandstone felsopathic in places, some fine and pebble quartz conglomerate.	Up to 450 m
	Rewan Formation (Rr).	Coarse green lithic sandstone, pebbles in places, some fine and pebble conglomerate and red and green mudstone.	5-70m
Upper to Middle Permean	Rangal Coal Measures (Pwj).	Coal seams, carbonaceous shales and mudstone, light grey litho felsopathic conditions, grey to dark grey siltstones and mudstones.	100-200 m
	Fort Cooper Coal Measures (Pwt).	Brown to green micaceous volcanolithic sandstone, conglomerate, carbonaceous shale, coal with thin beds of greyish white cherty tuff.	400 m
	Measures (Pwb).	Lithic labile sandstone, siltstone, carbonaceous shale, coal, local cherty mudstone and minor conglomerate.	250-750 m

The Permian Rangal Coal Measures are approximately 100m thick and comprise of light grey, cross bedded, fine to medium grained labile sandstones, grey siltstones, mudstones and coal seams. They are the uppermost Permian unit experienced at Millennium Mine.

9. Residual Void Area and Volume Minimisation Options

During 2017 and 2018, a detailed review of the conceptual final landform was undertaken by Millennium Coal and Peabody Australia to determine the most cost-effective methods of removing overburden, reducing void size (area and volume) and maximizing future land use opportunities during the existing and future mining operations.

Detailed analysis by Peabody Australia and Millennium Mine's Mining Engineers during these conceptual final landform options has focused on maximising the economic coal reserves using traditional truck and shovel method and non-traditional highwall mining methods, such as auger and highwall mining (Addcar) systems. During this analysis, assumptions have been developed and utilised to inform options. Assumptions have been based in the mine plan at the time of each final landform scenario, which included the advancement of Mavis D Pit to the north to within 300m of the underground Carborough Downs Coal Mine and backfilling of Millennium B Pit to natural ground level, which did not eventuate due to operational constraints and prohibitive costs.

An outcome of the continued mine plan review process was the partial backfilling of Mavis E Pit, which commenced in Q3 2017 and involved backfilling of the northern mined coal blocks as the last southern coal blocks were being mined using traditional truck and shovel method. This mining process allowed for short haulage distance, lower cost options to be incorporated and subsequently resulted in the northern void area being backfilled to natural ground level. Implementation of this option allowed for the final void area to be reduced by approximately 24ha.

Operational requirements, advancement in the medium-term Life of Mine Plan (LOMP), changes in haulage distances and variations in coal blocks due to geotechnical hazards (i.e. faults) have all resulted in the conceptual final landform scenarios evolving and changing to ensure the effective viability of the current and future mining operations at Millennium Mine. The short term mine plan (i.e. <16 weeks) and LOMP have dictated the final void area via ongoing mine plan optimisation; however, as void option analysis progressed a target was set by the Chairman of the Millennium Mine Closure Steering Committee to evaluate the incorporation of in-pit spoil areas that could be rehabilitated and used for cattle grazing post-closure. As such, this option was first included as part of the final landform Scenario 4 option, which identified 63ha available for rehabilitation of in-pit spoil dumps that could ultimately be available for cattle grazing post-closure (Table 3).

Additional considerations included the requirements of the post-mining land owner/occupier, such as water storage requirements, stock access and provision of flat areas for grazing. Compliance with the requirements of the EA informed consideration and evaluation of final landform options. Ultimately, the mine is required to be 'cash flow positive' to sustain the large overheads that are imposed with any mining operation. Medium to long-term coal price forecasts, strip ratio increase, high overheads (e.g. take or pay, mining fleet age, maintenance) and business analysis determined that Millennium would not be cash flow positive beyond 2018, which resulted in the staged mine closure process commencing in February 2017.

Table 3 – Conceptual Final Landform Void Area Analysis

	Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
Scenario Assumptions	**Mar-17 LiDAR Mavis OOPD Excluded**	**Mavis OOPD Included Raise B Pit In-pit Dump**	**Mavis OOPD Included Steepen Lowwall angle to reduce void**	**Mar-17 LiDAR Mavis OOPD Included D Pit North advancement removed**	**Mavis OOPD Included Raise B Pit Inpit Dump "In-Pit Usable Area" targeted**	**Jun-17 LiDAR Mavis OOPD included "In-Pit Usable Area" targeted**	**Jun-17 LiDAR Mavis OOPD included All in-pit re-profile is 1V:4H**	**Nov-17 LiDAR Mavis OOPD included E Pit extended A Pit North excluded D Pit North excluded All in-pit re-profile is 1V:4H**	**As per Scenario 7 Highwall Treatment to 1V:4H**	**Apr-18 LiDAR**	**Apr-18 LiDAR Aim to increase "in-pit usable area" in A Pit**	**Jun-18 LiDAR Lowwall profiled to Max water level Est. Dec-18 profilling position**
Spoil Re-Profiling												
Millennium Pit	2,310,589	2,350,708	2,189,810	2,247,022	2,520,708	2,456,855	3,822,266	3,938,910	3,938,910	3,053,806	3,204,199	2,780,937
Mavis Pit	3,265,903	3,755,305	4,309,039	4,253,940	3,961,305	4,123,077	5,698,650	5,371,817	5,371,817	5,686,421	5,686,422	2,391,716
Total (m3)	**5,576,492**	**6,106,013**	**6,498,849**	**6,500,962**	**6,482,013**	**6,579,932**	**9,520,916**	**9,310,727**	**9,310,727**	**8,740,227**	**8,890,621**	**5,172,653**
Final Void Area												
Millennium Pit	163	146	139	152	146	162	165	169	207	165	166	171
Mavis Pit	220	233	210	215	233	239	240	219	259	216	216	218
Total (Ha)	**383**	**379**	**349**	**367**	**379**	**401**	**405**	**388**	**466**	**381**	**382**	**389**
In-Pit Usable Area												
Millennium Pit	0	0	0	0	34	43	42	37	37	27	30	28
Mavis Pit	0	0	0	0	29	44	42	13	13	12	12	19
Total (Ha)	**0**	**0**	**0**	**0**	**63**	**87**	**84**	**50**	**50**	**39**	**42**	**47**
Final Void less Usable Area (Ha)	**383**	**379**	**349**	**367**	**316**	**314**	**321**	**338**	**416**	**342**	**340**	**342**

A decision matrix is provided in **Table 4** that summaries the key operational and business factors that have resulted in the final landform Scenario 11 being the most optimal outcome for the site. Although some scenarios are very similar due to changes in LiDAR, for example, the same design parameters have been incorporated to determine the overall volume of spoil material to be reshaped and the cost to achieve that final landform design. Additional amendments between the varies scenarios have also resulted in a positive outcome for the site, such as the partial backfilling of Mavis E Pit to natural ground level at the northern end, which was originally planned/designed to remain as a void. Similarly, the creation of the Millennium A Pit in-pit spoil dump has resulted in a large flat top of dump being created on the RL225 level, which will be rehabilitated and returned to cattle grazing. This area was originally planned/designed to remain as a void and the spoil material hauled to the top of dump above natural ground level on the RL305 and RL285 level.

Examples of the mine plan and void optimisation process have been included in **Figures 2** to **6** for a whole-of-mine overview of the changes that have occurred over the duration of the Millennium Mine Closure Steering Committee period.

The final voids at Millennium Mine have been designed to recover the most amount of economical coal using both traditional truck and shovel method and non-traditional highwall mining method, which requires an appropriate amount of open surface area to allow for the highwalls to be benched during traditional truck and shovel mining to reduce the likelihood of geotechnical failure and provide for a safe work place. Additionally, non-traditional highwall mining requires a minimum of 50m from the toe of the highwall at the coal seam level to the toe of the lowwall to ensure that the highwall miner can safely access the exposed coal seam and extract coal from below a benched highwall that is geotechnically stable after traditional truck and shovel mining has finished. These factors are the primary inputs for the final void size at Millennium Mine and can't be engineered out during both traditional and non-traditional mining methods.

There are only two methods to possibly reduce the size and volume of the residual void, which are:

1. **Drill and blast the final highwall and endwalls**
   - This can only occur when highwall mining is finished;
   - Once the highwall and endwalls are blasted, dozer push would be required to backfill the residual void to achieve a more natural ground surface level;
   - This option would increase the site's overall disturbance footprint as the volume of blasted overburden required to fill the voids would extend past the current highwall position by approximately 100m;
   - This option would consume a significant area of undisturbed land which is currently capable of sustaining existing and future cattle grazing as the post mine land use;
   - Blasting at Millennium B Pit would extend into the New Chum Creek buffer area and would permanently alter this natural creek and vegetation corridor;
   - Blasting at Millennium A Pit would result in the natural Mesa (rock formation) being altered; and
   - This method would result in long, shallow depressions that would capture runoff due to settlement of the underlying waste material, resulting in periodic inundation to a degree that would limit establishment of a sustainable productive pasture cover.

2. Rehandle existing waste spoil dumps

- Traditional truck and shovel method would be required to load and haul spoil from waste dumps to the coal floor and backfill from the bottom to near natural ground level;
- Loading and hauling spoil from waste dumps would require removal of existing rehabilitation that is suitable for cattle grazing as the post mine land use;
- Traditional truck and shovel method would result in significant volumes of diesel being consumed, along with other consumables such as oil, grease and tyres;
- The removal of topsoil and rehabilitation from existing waste dumps would dilute and degrade the quality of the topsoil available for re-spreading on the backfilled landform;
- This method would take at least four years to complete, assuming the mining production fleet was available for use; and
- This method could cost up to $1 billion to complete (assuming $6/m^3$).

Options to minimise the residual voids at Millennium Mine have been considered over the life of the mine and, more recently, as part of the planned staged closure process. The balance between recovering economic coal using traditional and non-traditional mining methods has been taken into consideration and the final landform outcomes incorporated into options analysis throughout this process to provide the best business, environmental and post mine land use outcome, which is to support sustainable cattle grazing on non-mined and rehabilitated land and water storage within the final voids. Millennium's efforts have resulted in the final void area being reduced and additional cattle grazing area being developed whilst maximising the recovery of coal. A decision matrix that evaluates final landform options is provided below.

Table 4 – Millennium Mine Final Landform Decision Matrix

		Millennium Mine Final Landform Scenario Decision Matrix																					
		Final Landform Scenario 1		Final Landform Scenario 2		Final Landform Scenario 3		Final Landform Scenario 4		Final Landform Scenario 5		Final Landform Scenario 6		Final Landform Scenario 7		Final Landform Scenario 8		Final Landform Scenario 9		Final Landform Scenario 10		Final Landform Scenario 11	
Mine Plan Factors	Importance (0 - 10)	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score	Rating (0 to 5)	Score
Spoil Reprofiling Volume (m3)	9	1	9	1	9	1	9	1	9	1	9	1	9	0	0	0	0	1	9	0	0	4	36
Spoil Reprofiling Cost ($)	9	4	36	4	36	1	9	1	9	1	9	1	9	0	0	0	0	1	9	0	0	4	36
Reprofiling Push Distance (m)	7	1	7	0	0	1	7	1	7	1	7	0	0	0	0	0	0	1	7	3	21	3	21
Final Void Area (Ha)	8	3	24	3	24	4	32	3	24	0	0	0	0	1	8	0	0	3	24	3	24	3	24
Usable In-Pit Area (Ha)	8	0	0	0	0	0	0	4	32	5	40	5	40	3	24	3	24	2	16	3	24	3	24
Void Area Less Usable Area (Ha)	8	0	0	0	0	0	0	4	32	5	40	4	32	3	24	2	16	2	16	3	24	3	24
	Total Score		76		69		57		113		105		90		56		40		81		93		165

Legend:

Rating - 0 (poor outcme) to 5 (very good outcome)

Importance - 0 (unimportant) to 10 (very important)

Table 4 presents six mine planning factors that were assessed when evaluating final landform options. The first three factors displayed within Table 4 address technical and economic factors that were considered when evaluating each landform scenario. Volumes and push distances determine the cost of completing bulk earthworks. Mine planning personnel seek to optimise these factors using modelling software and are guided by parameters set out in the site's Environmental Authority. The design scenarios were also informed by geotechnical advice on the stability of proposed slopes and hydrology studies that informed the final pit lake level and volume once equilibrium is reached.

Iterations of the final landform scenarios also considered economic factors by seeking to maximise the area of usable land after completion of mining activities. This consideration included ensuring that where feasible, out of pit and in-pit areas are shaped and re-vegetated to pasture to support grazing as the intended post-mining land use. The area of usable land below original ground level is inconsequential given the size of the property holdings of the underlying land holder (Winchester Downs), of which Millennium occupies a small area and the inherently low grazing productivity of land in the region.

The various options to configure the final voids presented limited potential to influence environmental outcomes. Key considerations in the design were to minimise the area of land occupied by final voids in addition to increasing in-pit useable land and to ensure that the pit lakes acted as permanent sinks, thus avoiding the potential for outflow of saline water from the pit lakes entering the downstream catchments. Altering the final grades for low walls and high walls to achieve additional land with more moderate grades, other than in areas identified as having potential for grazing, was not contemplated in the options analysis described in Table 4 as flattening slope angles would require disturbance of previously undisturbed or rehabilitated ground with little or no benefit to compensate for loss of usable areas adjoining the pit voids. Altering the pit shell area to achieve lesser slope angles would also increase the catchment area of the pit lake with a corresponding reduction in the overland flow of clean water into the downstream catchments. This may have an adverse environmental or economic impact on the downstream catchments and grazing operations.

The minor variations between differing landform options that were evaluated at Millennium has little or no influence on social outcomes. The area occupied by the Millennium Mine is part of the extensive Winchester Downs land holdings. Upon Mining Lease surrender the land will be re-incorporated Winchester Downs operations and managed to graze beef cattle. The region is sparsely populated, and the principle land use activities are mining and cattle grazing. Proposed landform options have been discussed with the Winchester Downs manager as the options analysis evolved and no concerns have been raised to date.

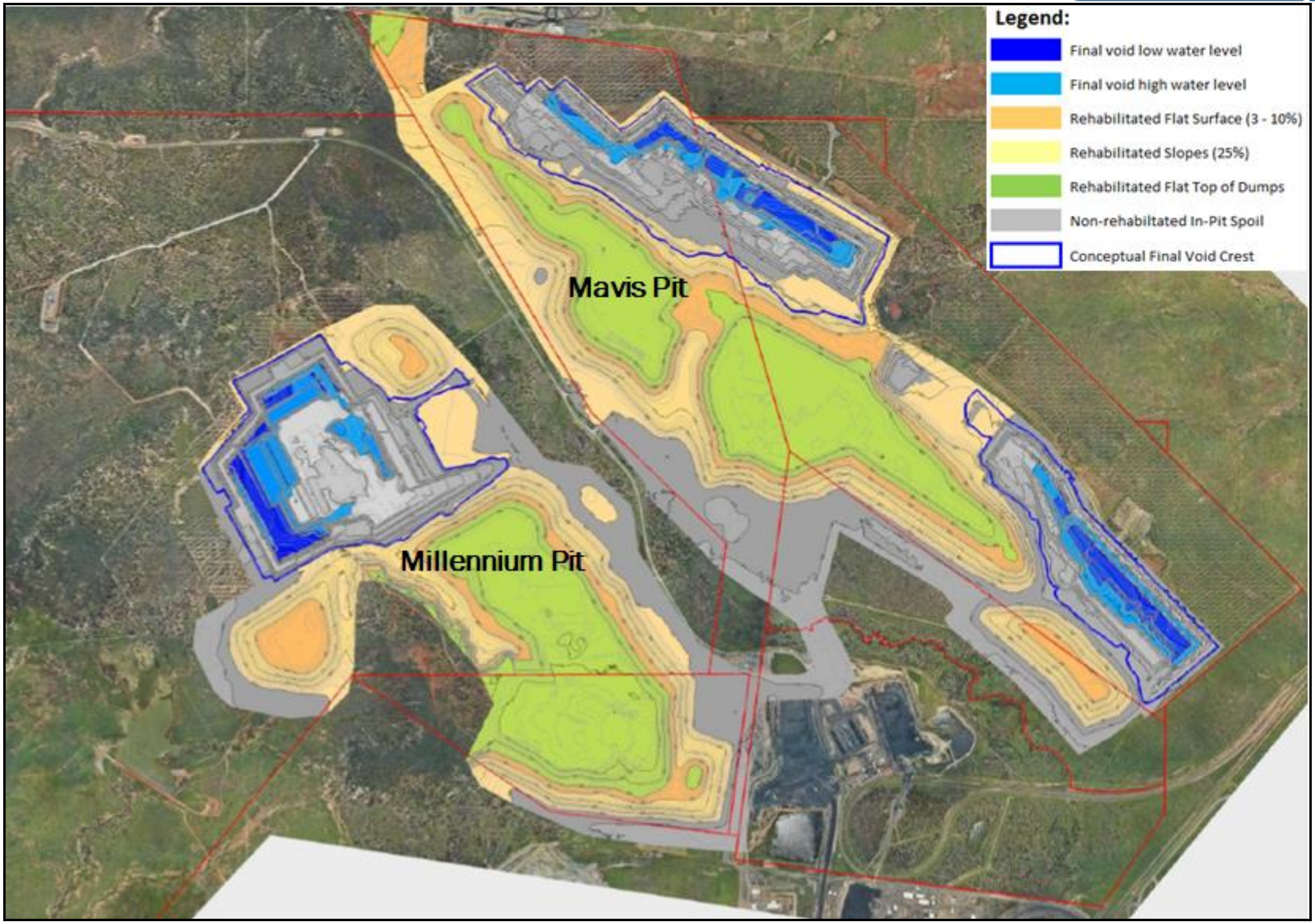

Figure 3 – Millennium Mine Conceptual Final Landform (Scenario 1)

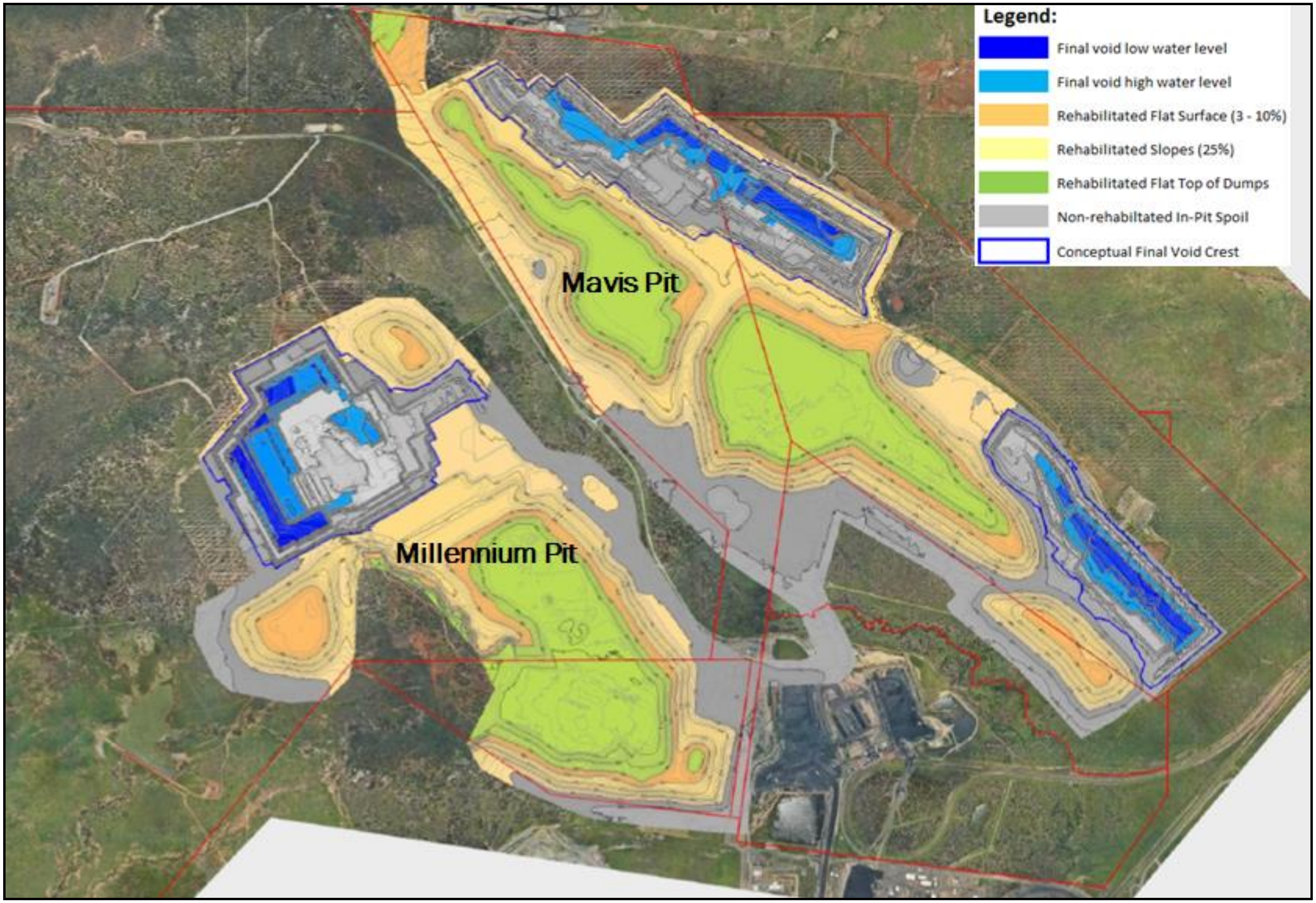

Figure 4 – Millennium Mine Conceptual Final Landform (Scenario 2)

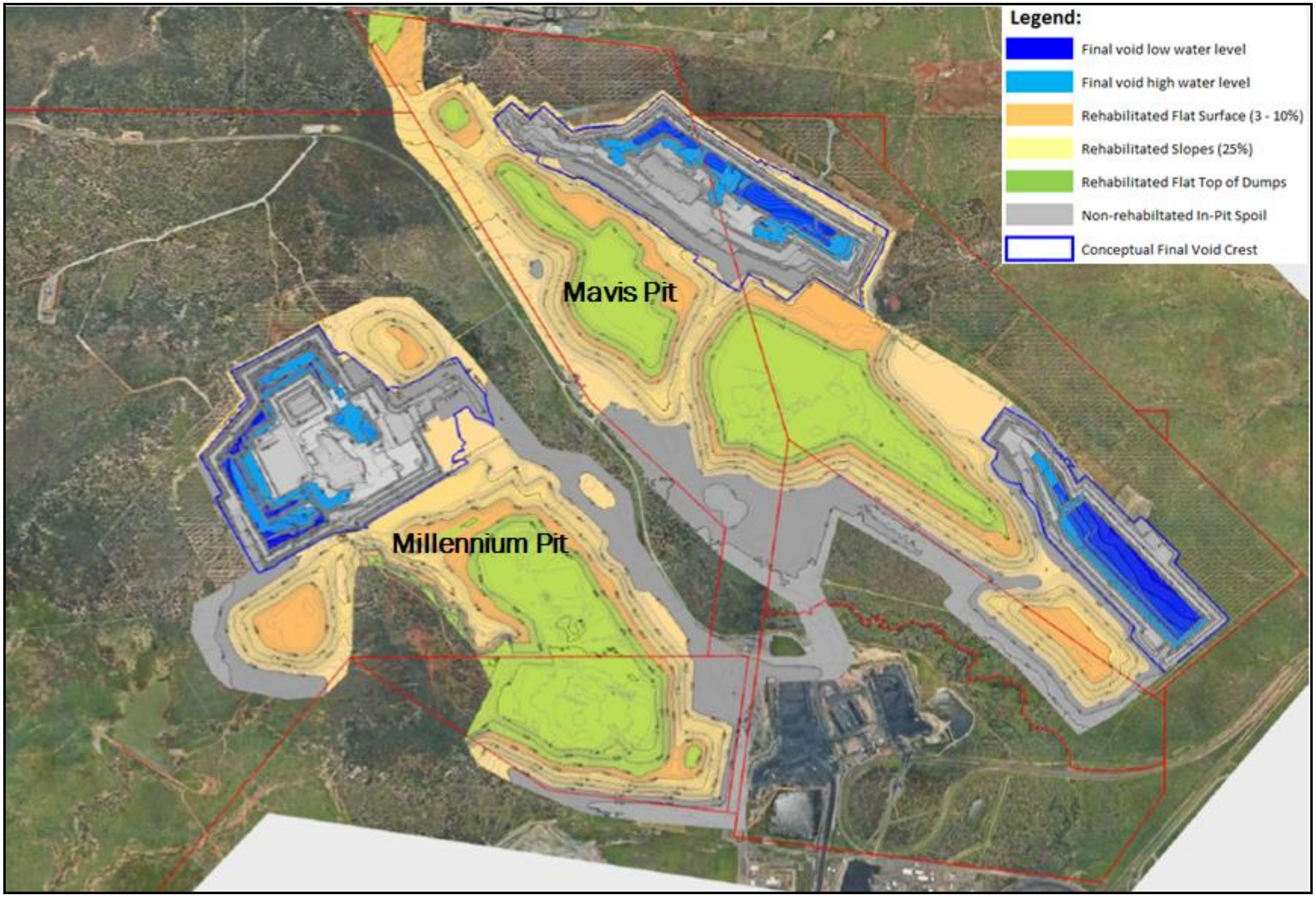

Figure 5 – Millennium Mine Conceptual Final Landform (Scenario 3)

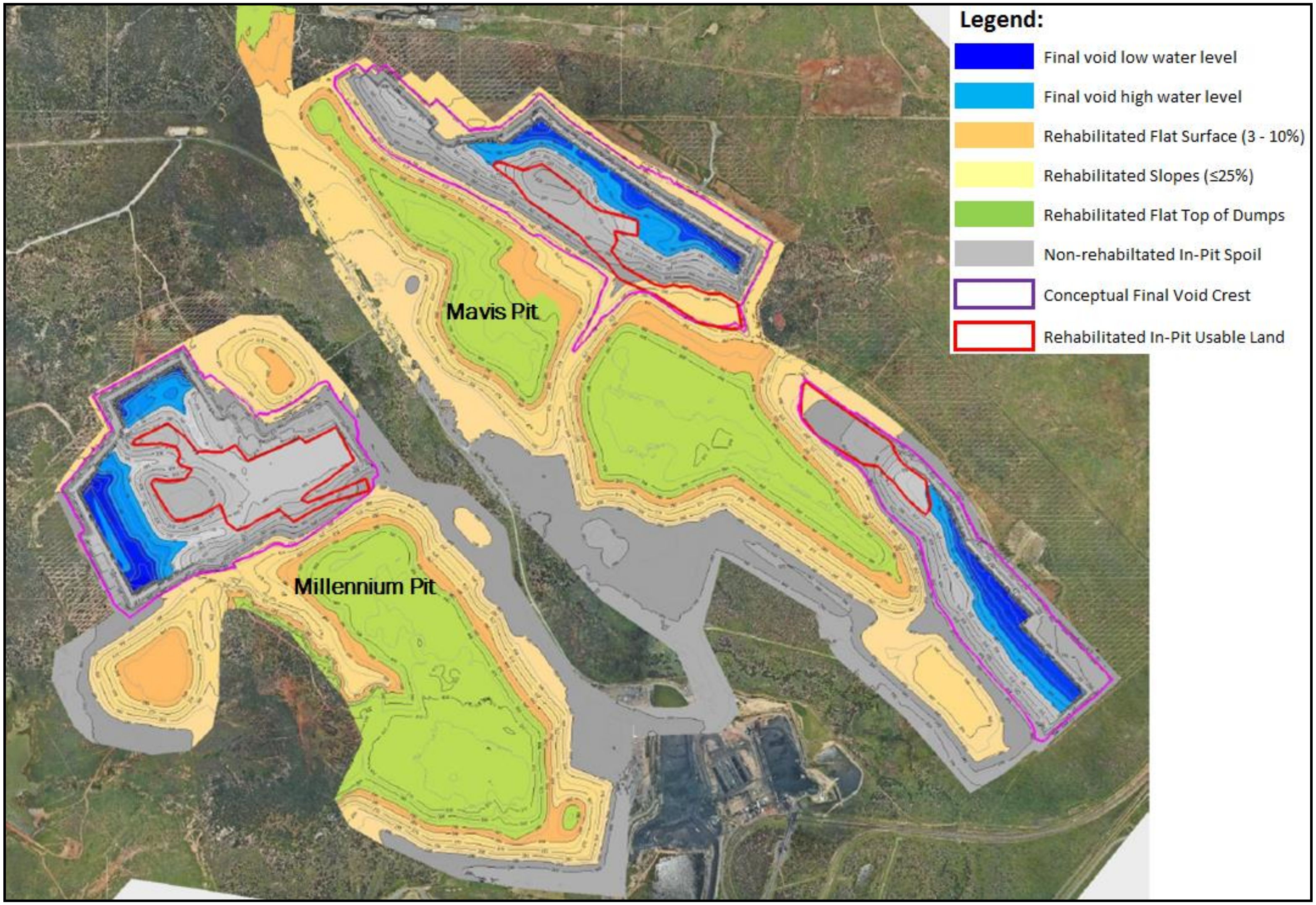

Figure 6 – Millennium Mine Conceptual Final Landform (Scenario 6)

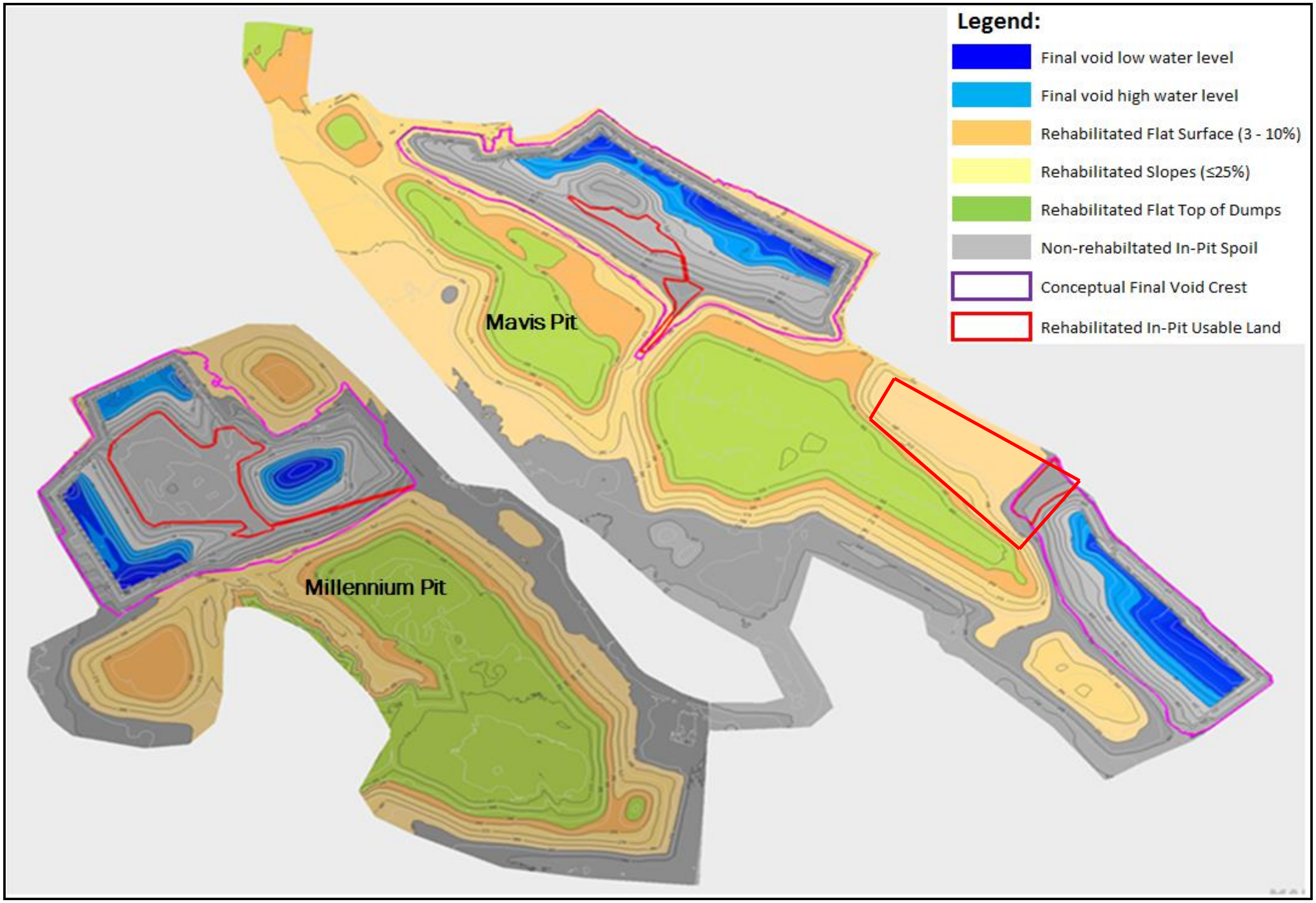

Figure 7 – Millennium Mine Conceptual Final Landform (Scenario 7)

9.1. Final Void Backfill Options and Volume Analysis

A mining engineering assessment of the volume required (LCM) to backfill existing voids to natural ground level at Millennium Mine has been undertaken for Millennium A Pit, Millennium B Pit, Mavis D Pit and Mavis E Pit. Spoil material could only be sourced from spoil dumps above natural ground level in Mavis D and E Pit as the lowwall material is only 50m from the toe of the pit floor. Millennium Pit spoil material would predominately be sourced from spoil dumps above ground level although an in-pit spoil dump was constructed that has resulted in a flat, usable area on the RL225, which would reduce the volume of spoil material required.

Although uneconomic to achieve, and based on Scenario 11, the volume (m^3) required to backfill each section of Millennium Mine is detailed in **Table 5**.

Table 5 –Final Landform Void Backfill Analysis Volumes

	Scenario 11
Millennium A Pit	45,141,962
Millennium B Pit	27,059,555
Mavis D Pit	65,374,728
Mavis E Pit	29,411,800
Total	**166,988,045**

10. Preferred Final Void Option

Eleven (11) conceptual final landform options have been developed during the options study aimed at minimising residual voids and volume at Millennium Mine. Of these options, Peabody has implemented Scenario 11, subject to final review and modification, on the basis of outcomes from ongoing research, mine planning experience, landholder consultation, and upon acceptance of the Rehabilitation Management Plan and Residual Void Management Plan by DES (as required by Conditions F5 an F7 of the EA respectively).

Condition F3 of the EA, and its associated Tables 17 and 18, provide for a *Projected Surface Area* of the final voids, ramps, high walls and low walls at 281 ha. This *Projected Surface Area* is noted within the EA as being based on conceptual design details i.e. those prepared at the time of the Project's Environmental Impact Statement (December 2010). The 281 ha was therefore a forecast final void area at that time and the EA allows for this area to be modified subject to the outcomes of ongoing research and experience gathered during the life of the mine.

Scenario 11 will result in a residual void (including ramps, high walls and low walls) of 389 ha. Details of the total void area and in-pit useable area for Scenario 11 are presented in **Table 6** and **Table 7** below. Following DES' review and acceptance of this information, Peabody proposes to submit an EA amendment application to DES to replace Table 17 and 18 of the EA as proposed in Table 3 and 4 of the Post Closure Management Plan

Table 6 –Final Landform Void Area Analysis

	Base Case	Scenario 11
Millennium Pit	163	171
Mavis Pit	220	218
Total Void Area (ha)	**383**	**389**

Table 7 – Final Landform In-pit Usable Area Analysis

	Base Case	Scenario 11
Millennium Pit	0	28
Mavis Pit	0	19
Total Usable Area (ha)	**0**	**46**

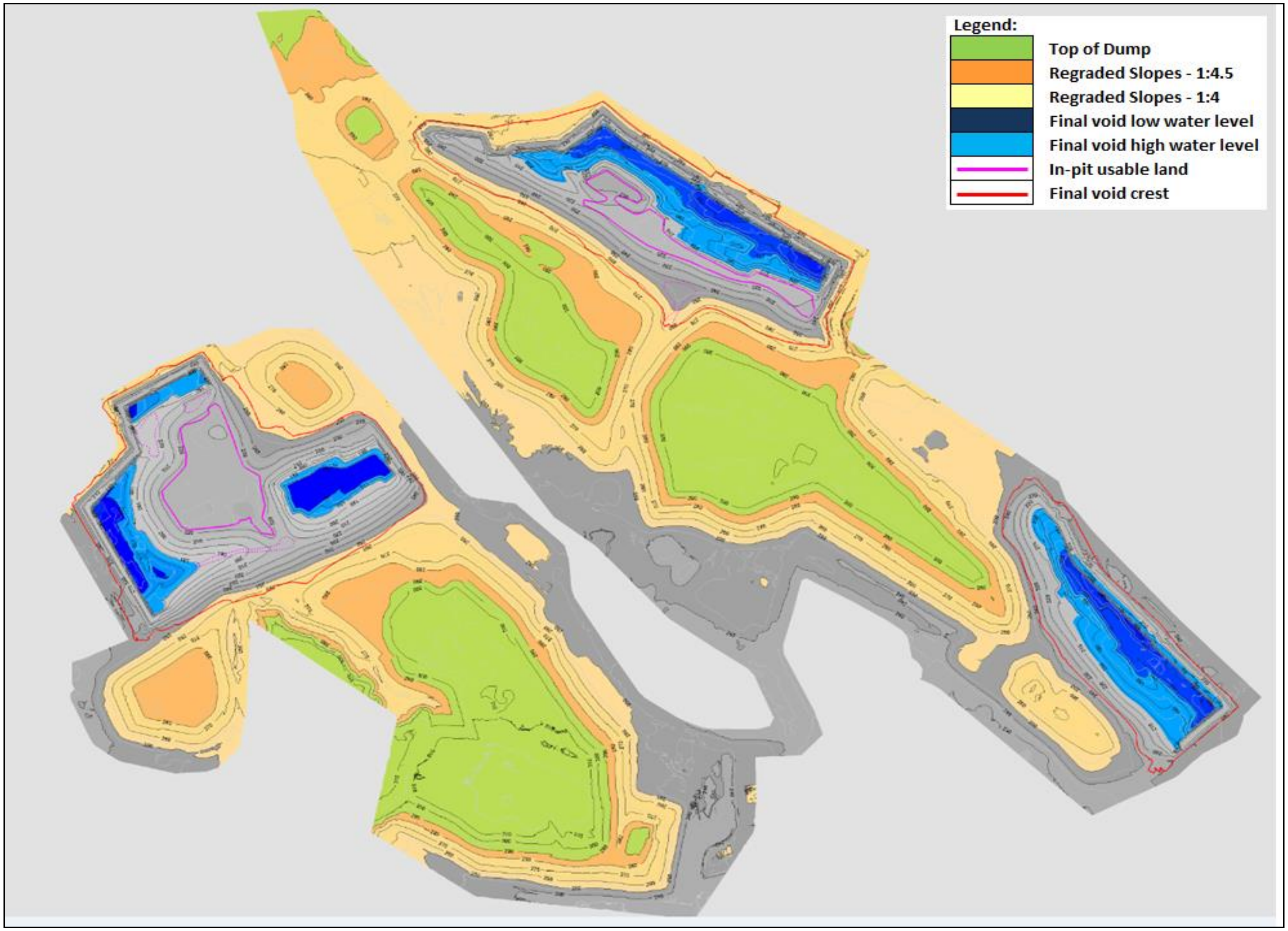

Figure 8 – Millennium Mine Conceptual Final Landform (Scenario 11)

11. Rehabilitation Design Criteria of Residual Voids

Considerable work has been undertaken in developing and evaluating conceptual final landform design options for Millennium Mine, which are described in Section 6, and provide the planning aspects of the residual voids to minimise their size and future impact from a post-mine closure perspective. Consultation with the landowner's Property Manager during 2017 and 2018 has provided a greater understanding and overview from a post-closure perspective whilst allowing for opportunities to be incorporated into the current design criteria to maximize the use of the rehabilitated landforms.

11.1 Review of EA Slope Angle Requirements

Table 18 of the EA specifies that highwall slopes in competent rock can remain as constructed if they are geotechnically stable or otherwise benched with 15m berms at 20m intervals. This would be equivalent to a maximum overall slope angle of approximately 63^0 for benched slopes. Lowwall spoil dumps are to be benched or reshaped accordingly to ensure geotechnical stability. External spoil slopes (landform) must not exceed 1 vertical to 3 horizontal (18^0). The specified and as-formed slope angles are presented in **Table 8** below.

Table 8 – EA Slope Angle Requirements (EA, Table 18)

Slope Type	EA requirement	As constructed
Highwall – competent rock	geotechnically stable	70^0 benches; 15m berms
Low wall – void side	geotechnically stable	benched, 25^0 overall
Landform – external dump side	max 1 v : 3 h	re-graded to 1 in 4 (14^0)

A Residual Void Stability Study for Millennium Mine was completed by GCS (August 2017) **Appendix C**. In this study, it was noted that the as-constructed highwall slope profiles at Millennium Mine are typical of open-cut coal industry designs that have proven adequate for general final void application. Typically, rock associated with coal measures is too strong to undergo shear failure under gravitational loading and requires the presence of pre-existing separation planes, such as pervasive joint planes, faults or dykes to create conditions of potential instability. In the absence of any adverse structure, 70^0 or vertical highwalls can be expected to stand indefinitely without risk of major collapse. Instances of where faults intercept or occur close to pit walls are treated on an individual basis with the standard design modified as necessary to ensure any instability can be managed. The Millennium Mine design is thus compliant in providing geotechnically stable highwalls for operations. The same criteria could also therefore be applied to the final highwall slope from a post-closure perspective.

Lowwall dumps at Millennium Mine are built up in benches at an angle of repose to a maximum lift height of 35m between berms. This is a typical well-proven industry design for rock fill dumps on flat or gently dipping ground, such as that found at site. The lowwalls therefore comply with the EA requirement for geotechnical stability. In-pit dumps are generally susceptible to mass failure if the floor is sloping, particularly if there are weaknesses in the floor. Steeper dips are a feature of some parts of Mavis Pit, but there are design variations involving floor treatment or re-assessment of the design if the dip exceeds a threshold value of 12.5^{0}.

Taken together, the slope angles within the existing voids complied with the EA and also provided safe operating conditions during mining. The slopes have been assessed as being geotechnically stable for retention as a final void.

11.2 Proposed Rehabilitation Design

The rehabilitation design criteria utilised at Millennium Mine associated with residual voids are complementary of the existing rehabilitation criteria that has been used at Millennium Mine to successfully rehabilitate out-of-pit spoil dumps (**Figure 9** and **Figure 10**). Whilst the operational stability designs are compliant with the requirements of the EA already, the following examples of rehabilitation design shall be implemented to further reduce the risks of instability and safety hazards of the residual voids above and beyond the EA requirements:

In-pit ramps:

- Regrade ramps below natural surface level from angle of repose to a final landform slope of 33.5% (3:1) only above the modelled final void high water level;
- Regrade ramps above natural surface level to a final landform slope of 25% (4:1) will be topsoiled to a depth of 200mm, ripped and seeded with either pasture grass and/or native tree species;
- Surface to in-pit ramps that connect to flat sections of the in-pit dumps (e.g. Millennium A Pit RL225 dump and Mavis D and Mavis E Pit) will be retained to allow for safe stock and farm vehicle related access to these useable areas; and
- Regrading of ramps below the modeled final void high water level will not occur as these areas will be submerged when the pit lake forms.

Lowwall:

- Regrade Millennium Pit to the modelled final void high water level of RL179 and Mavis Pit to RL202 to a final landform slope of 33.5% (3:1) below natural ground level;
- Regrade Millennium Pit and Mavis Pit lowwalls to a final landform slope of 25% (4:1) above natural ground level;
- Regraded lowwalls above the modeled final void high water level will be topsoiled to a depth of 200mm from RL305 to RL285, ripped and seeded with either pasture grass and/or native tree species;
- Regrading of lowwalls directly above in-pit ramps that connect to flat sections of the in-pit dumps (e.g. Millennium A Pit RL225 dump and Mavis D and Mavis E Pit) will be retained to allow for safe stock and farm vehicle related access to these useable areas; and
- Regrading of lowwalls below the modelled final void water level will not occur as these areas will be submerged when the pit lake forms.

Highwall:

- Highwall treatment, such as drill and blast and/or dozer push regrading, will not occur at Millennium Mine unless a section of highwall is geotechnically unstable and no other exclusions and/or controls can be effectively implemented to reduce the likelihood or consequence of the highwall being left in an unstable insitu state; and

- A safety berm will be established, where not already in place, and a four (4) strand barbed wire, star picket security fence installed along the length of the highwall crest to effectively mitigate against unathorised entry of people near the highwall and limit stock access (Figure 9).

Through the mine planning and mine closure process areas of opportunity that have been identified to partially or fully backfill sections of the active and/or inactive voids have been completed at Millennium Mine. These areas, such as Mavis E Pit, have resulted in the final void surface area reducing by approximately 19 hectares and a target total area of approximately 46 hectares is expected by mine closure for in-pit usable land that can be rehabilitated to support cattle grazing in Millennium Pit and Mavis Pit. Further consultation with the landowner and their Property Manager regarding the areas to be rehabilitated, especially in-pit lowwalls and ramps, will continue to occur on an ongoing basis. The outcome of this consultation may result in the existing rehabilitation criteria detailed above being modified to suit the landowner's needs from a post-closure and rehabilitation and decommissioning perspective.

Primary inputs of the rehabilitation design criteria are to mitigate against geotechnical instability of the in-pit spoil material and highwalls, which have been originally designed using an engineering Factor of Safety (FoS) process during the mine's operational phase.

Through the advancements of the active mine planning process and mine closure options, future changes to these criteria may occur over the life of the active mine and pre and/or post-mine closure, which may also be influenced by the landowner and their needs/requirements from a post-mine closure perspective.

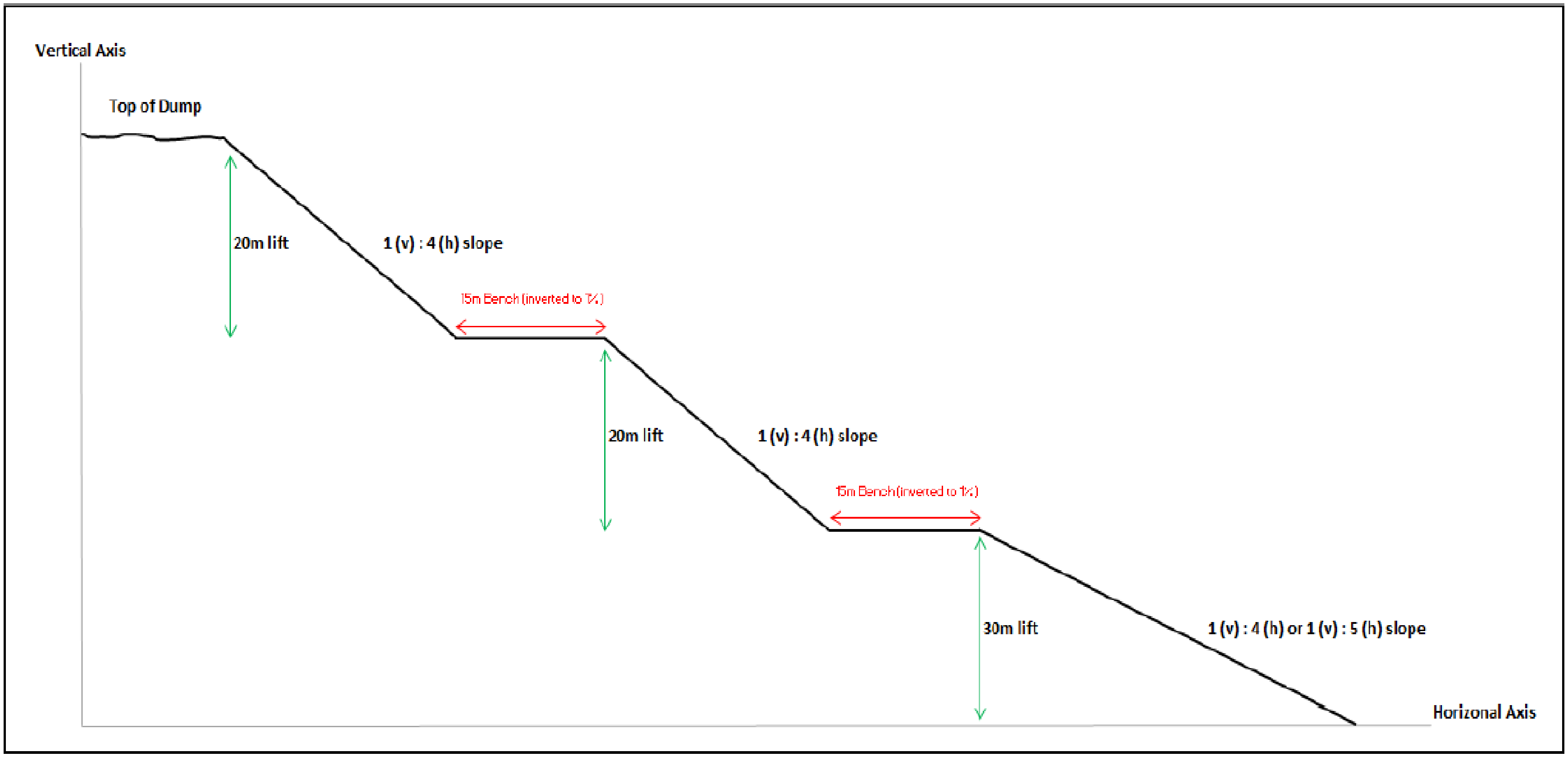

Figure 9: Rehabilitation Design Criteria of Residual Void (Lowwall)

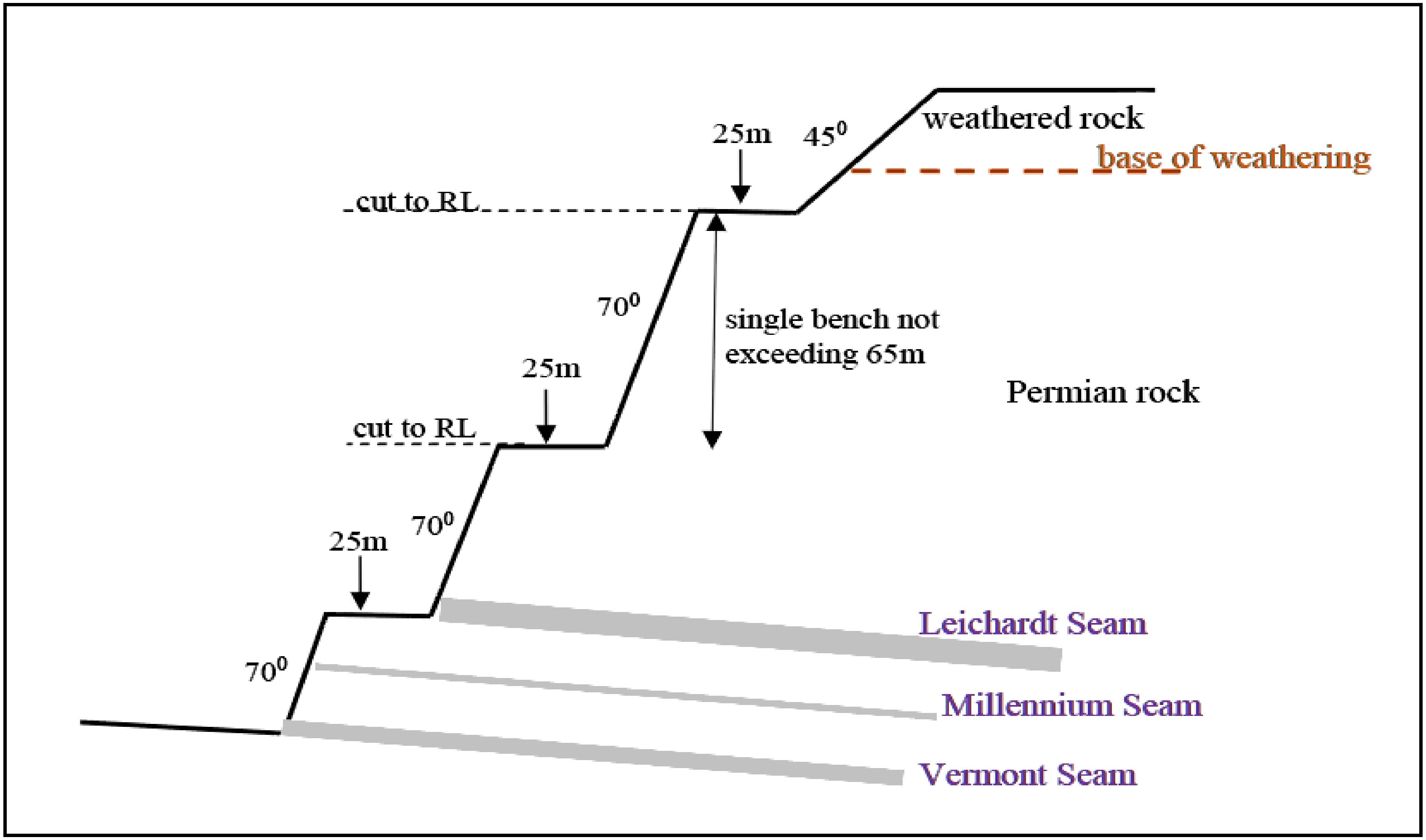

Figure 10: General Design Criteria of Residual Voids (Highwalls)

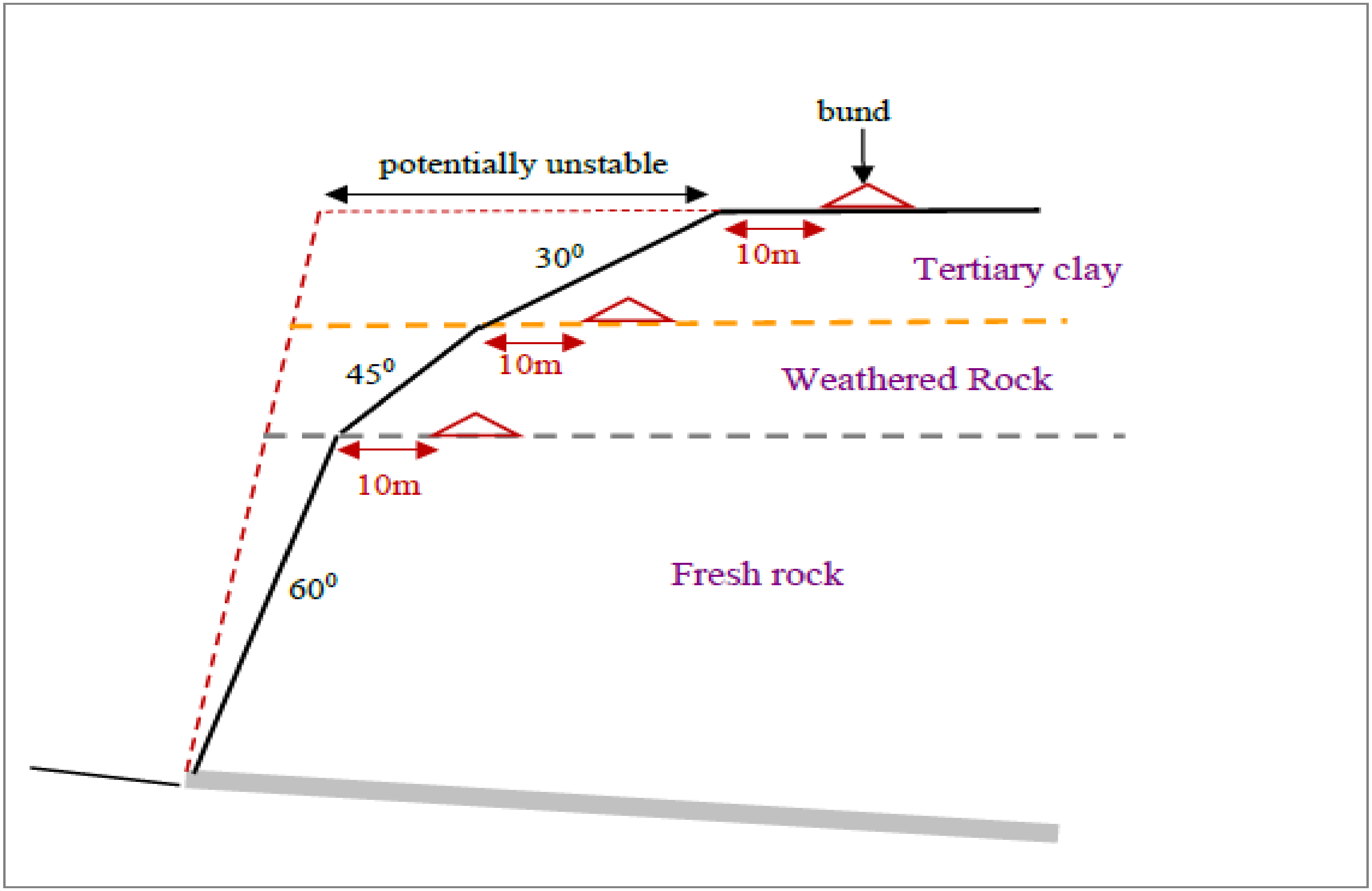

Figure 11 Abandonment Bund Location Guide

12. Residual Void Hydrology Assessment

A detailed final void water modelling assessment has been completed by Hatch (Millennium Coal Mine – Stage 2 Final Void Modelling, report number H355535, February 2018) as part of this Residual Void Management Plan, which is included in **Appendix A**. Additionally, a separate groundwater assessment by JBT Consulting has been prepared (Millennium Mine – Spoil Water Contribution to Millennium and Mavis Pit Final Voids, report number JBT01-062-004, January 2018), which is included in **Appendix B**.

The focal points for this assessment are the fluctuations of the water level within each final void as to determine the potential risk of voids filling and releasing water to the receiving environment through overtopping in an uncontrolled manner. Additionally, the fluctuations in final void salinity levels, assessed as electrical conductivity (EC), has been modelled, which is predominately driven through the sessional fluctuations in climate between the wet and dry season and prolonged wet and dry seasons, such as cyclones and droughts.

Modelling was carried out using a daily time-step within each final void over a 1,000-year period. The model also tracked the bulk volume of mixed salt captured and stored within the system. It also considered historical data to model rainfall, including an average annual rainfall of 587 mm, with maximum and minimum annual totals of 1,320 mm and 225 mm respectively. The modeling therefore includes trends in rainfall periods such as floods and droughts, with several such periods of persistent flood and drought being modeled. The modeling did not encompass consideration of climate change as the objective of the study was to establish the maximum water level. As climate change impacts are predicted to results in reduced annual rainfall volumes, their exclusion from the modelling provides a conservative estimate of final void water levels.

12.1 Long-term Water Balance of Residual Voids

Each distinct final void area, being Millennium Pit, Mavis D Pit and Mavis E Pit has been assessed and reported separately.

Mavis D Pit:

Mavis D Pit, being north of Mavis E Pit, will likely reach equilibrium after approximately 50 – 100 years. Once equilibrium has been reached, the water level fluctuations are driven by seasonal variances within an envelope defined within the maximum water level of RL202 and minimum water level of RL181. At RL200, Mavis D Pit and Mavis E Pit are connected at the mined coal floor, which has been backfilled to natural ground level within this distinct area.

The peak crest level of the Mavis D Pit will be RL256. At equilibrium the freeboard between the pit lake and crest of the pit will be approximately 54m. The predicted final void water levels do not reach the pit crest level, and as such an overflow and/or release are not predicted.

Mavis E Pit:

Mavis E Pit, being south of Mavis D Pit, will likely reach equilibrium after approximately 100 – 150 years. Once equilibrium has been reached, the water level fluctuations are driven by seasonal variances within an envelope defined within the maximum water level of RL202 and minimum water level of RL174. At RL200, Mavis E Pit and Mavis D Pit are connected at the mined coal floor, which has been backfilled to natural ground level within this distinct area.

The peak crest level of the Mavis E Pit will be RL238. At equilibrium the freeboard between the pit lake and crest of the pit will be approximately 36m. The predicted final void water levels do not reach the pit crest level, and as such an overflow and/or release are not predicted.

Millennium Pit:

Millennium Pit, which is hydrogeologically separated from Mavis E and Mavis D Pit, will likely reach equilibrium after approximately 100 years. Once equilibrium has been reached, the water level fluctuations are driven by seasonal variances within an envelope defined within the maximum water level of RL179 and minimum water level of RL161.

The peak crest level of the Millennium Pit will be RL244. At equilibrium the freeboard between the pit lake and crest of the pit will be approximately 66m. The predicted final void water levels do not reach the pit crest level, and as such, an overflow and/or release are not predicted.

12.2 Groundwater Connections

Historically, groundwater inflows at Millennium Mine have been extremely minimal given the geological features and progression of Millennium Pit and Mavis Pit forming a significant cone of depression (i.e. groundwater sink), plus taking into consideration the effects of surrounding mines within close proximity, being Carborough Downs Coal Mine (underground), Poitrel Mine (open cut) and Daunia Mine (open cut). As such, groundwater inflow rates have not been modelled into any final voids, however, modelling has included a groundwater sensitivity scenario testing constant inflow rates of 0.8L/s in Millennium Pit, 0.5L/s in Mavis D Pit and 0.8L/s in Mavis E Pit.

Saturated spoil material within each final void will function as a continuous porous median aquifer and water is assumed to equalize between the final voids in Mavis D and Mavis E Pit and the three mined areas in Millennium Pit, being Millennium A54, A46 and B Pit. Additional factors influencing the groundwater connections within final voids included the porosity of the spoil material, which will determine the maximum storage potential, the specific yield of the spoil material, which will determine the volume of water that can drain from the spoil and the specific retention, which will determine the time water is held within the spoil (**Appendix B**).

As groundwater resources at Millennium Mine are generally not experienced due to evaporation being significantly greater than observed inflow rates, which are predominately observed as wetting of the highwalls near faults, there is no substantive effect on the local and/or regional groundwater system. Given the complexity of the spoil material and final voids interacting as an aquifer, additional modelling and investigations will be required on an ongoing basis to further understand and/or quantify their interaction and that of surrounding groundwater aquifers, which is the insitu coal seam that has not been mined in Millennium Pit, Mavis D and Mavis E Pit. Post-closure groundwater monitoring of the insitu coal seam may be required to better determine any physical or geochemical changes as a result of ongoing final void water storage, which will further advance the existing predictive modelling.

At present, however, no impact of surface water ingress affecting groundwater resources is predicted. Millennium Mine, being Millennium Pit and Mavis Pits, is a groundwater sink and water within these voids is unlikely to seep through any known aquifers and affect the surrounding environment. The groundwater recharge zone for Millennium Pit is from the west (i.e. Isaac Plains Coal Mine area) and the ephemeral New Chum Creek, which is a result of the New Chum Creek fault structure. As Millennium Pit is 90 – 95m below ground it will allow for any groundwater to be contained within the final void, which acts as a sink. Once surface water and groundwater fills into the Millennium Pit void, the hydraulic head is likely to preclude significant groundwater ingress from the void.

Mavis Pit, which is along the outcrop of coal, is generally defined as the recharge zone of the local area. As such, groundwater contained within the strata and/or coal seam will preferentially flow back into the voids of Mavis D Pit and Mavis E Pit. Additionally, the drawdown effect of the nearby Carborough Downs Underground coal mine will draw contained groundwater towards their underground workings, especially from Mavis D Pit.

Historically, the groundwater quality at Millennium Mine from bores located within the Leichardt coal seam typically range between 26,600 – 29,000 µS/cm (highly saline) with a pH of 6.7 – 7.8 (neutral). Surface water captured and retained within the voids at Millennium Mine typically range between 900 – 4,800 µS/cm with a pH of 8.3 – 8.6 (neutral). There is a low likelihood of negative impacts on groundwater aquifers, such as the Leichardt coal seam, within the final voids from surface water stored given the higher water quality and the final voids acting as sinks.

12.3 Long-term Water Quality Parameters

An evaluation of water availability and quality affecting cattle production on Mavis Downs was undertaken on behalf of Peabody by Integrated Animal Production in August 2017.

Water requirement by cattle is influenced by a number of factors including body weight, dry matter intake, physical activity, lactation and temperature. Daily water consumption by cattle equates to 10% of the animal's body weight (i.e. 500 kg cow consumes 50 L/d of water). In addition to providing hydration, water also contributes to essential dietary requirements, including:

- Sulphate;
- Salts (calcium, magnesium and sodium); and
- Fluoride.

Importantly, excessive intake of these minerals can result in adverse health effects which may affect production rates. Excessive intake could occur, for example, if cattle were to drink saline (>6,000 µS/cm) water within the final voids for an extended period of time, although cattle can adapt to increased salt levels in water. However, cattle that are lactating or newly introduced to the water supply with no alternative water source would be more susceptible than other cattle. It will therefore be necessary to ensure cattle can be excluded from accessing saline water or have alternate sources available.

As described in Section 8 above, there are negligible levels of sulphur content within the host rock at the Millennium Mine. The rock also has a net acid neutralising capacity due to the high content of calcium carbonate. No visible indications of acid and metalifferous drainage have been observed in rehabilitated waste rock or within quantitative water quality sampling results from the site. Based on this understanding of the site, there is limited risk of heavy metal contamination occurring within the residual void lakes or, therefore, into the surrounding receiving environment. In addition, the void hydrology study has demonstrated that no water will be released from the voids into the surrounding environment.

Despite the negligible risk of heavy metal contamination from the residual void water, the effects of heavy metal contamination on cattle could be financially significant to the landowner. When ingested, for example through drinking contaminated water, the heavy metals bio-accumulate within cattle. Humans that in turn consume affected beef also bio-accumulate the heavy metals. Given the significance of health and financial risks arising from heavy metals contamination, Peabody shall monitor heavy metals from each of the final voids in order to confirm the risk is negligible.

On this basis, stock water quality guidelines are appropriate monitoring parameters for water within the residual voids. This level of protection will also benefit the widespread and incidental flora and fauna which may use the waterbodies as habitat.

Salt Mass in the Voids

Climate driven fluctuations of salinity of the bulk water volume have been estimated for the period when equilibrium of final void water levels has been reached (Hatch, 2018). An EC range has been established using the total salt mass in each final void along with the long-term minimum and maximum volumes in each void.

Mavis D Pit:

Once equilibrium has been reached within Mavis D Pit, the EC level fluctuates with seasonal variance and is generally between 4,000 µS/cm (above average wet season) and 9,900 µS/cm (prolonged dry season resulting in drought conditions).

Mavis E Pit:

Once equilibrium has been reached within Mavis E Pit, the EC level fluctuates with seasonal variance and is generally between 4,100 µS/cm (above average wet season) and 14,300 µS/cm (prolonged dry season, such as a drought).

Millennium Pit:

Once equilibrium has been reached within Millennium Pit, the EC level fluctuates with seasonal variance and is generally between 5,200 µS/cm (above average wet season) and 13,200 µS/cm (prolonged dry season, such as a drought).

Evaluation

The ANZEEC 2000 water quality limit for grazing stock is 5,970 µS/cm. The modelling results above demonstrate that final void water quality will be below the ANZEEC limits during above average wet seasons. During periods of low rainfall, the EC levels will increase due to evaporation and concentration of salts within the water. This phenomenon is not restricted to the pit lakes as similar trends occur within all existing dams in the region.

Validation of modelled final void water quality will be an ongoing process at Millennium Mine given the complex nature of the chemical interactions experienced due to influences of spoil material, coal seams, insitu strata and evaporation. In terms of managing cattle grazing on site, the landowner will have the ability to exclude cattle from the final pit voids if required and supply water from other water sources, such as Western Dam and Mavis Pit stock dams.

Water Quality Monitoring

Water quality monitoring of the pit lake will be undertaken in accordance with Table below and occur quarterly. This scope mirrors condition C17 within the EA, the intent of which is to protect cattle from accessing water that may adversely affect their health.

Peabody will monitor these parameters annually for the duration of this Plan.

In the event that any pit void lake exceeds the contaminant limits defined in **Table 9**, then Peabody will implement measures, where practicable, to prevent access to that water storage by all livestock.

The monitoring data will be reviewed on an annual basis. The review will include an assessment of quality data, and the suitability of the monitoring scope. The data should be applied so that modifications can be made to the management of residual void water where quality trends are found to vary from the predicted values in a way that is likely to cause a significant increase in the resultant environmental harm.

Table 9 – Pit Lake Water Quality Monitoring (taken from Condition C17 of the EA)

Quality Characteristic	Unit	Test Value	Contaminant Limit
pH	pH unit	Range	Greater than 4, less than 9[1]
EC	μS/cm	Maximum	5,970[2]
Sulphate	mg/L	Maximum	1,000[2]
Fluoride	mg/L	Maximum	2.0[2]
Aluminum	mg/L	Maximum	5.0[2]
Arsenic	mg/L	Maximum	0.5[2]
Cadmium	mg/L	Maximum	0.01[2]
Cobalt	mg/L	Maximum	1.0[2]
Copper	mg/L	Maximum	1.0[2]
Lead	mg/L	Maximum	0.1[2]
Nickel	mg/L	Maximum	1.0[2]
Zinc	mg/L	Maximum	20[2]

Note:
[1] Contaminant limit based on ANZECC & ARMCANZ (2000) stock water quality guidelines.
[2] Page 4.2-15 of ANZECC & ARMCANZ (2000) "Soil and animal health will generally not be affected by water with pH in the range of 4-9"
Note: Total measurements (unfiltered) must be taken and analysed.

13. Pit Wall Stability

The primary control to mitigate against geotechnical instability of the final void highwalls, which have been originally designed using an engineering Factor of Safety (FoS) process during active mining operations, generally allows for an insitu highwall to stand without collapse both during and immediately post-mining.

A final void pit wall stability assessment of Millennium Mine has been completed by Geotechnical Consulting Services. The assessment included the physical inspection of highwalls and lowwalls with respect to final void conditions and was undertaken in May 2017 (**Appendix C**). The general findings of this assessment were that there were no significant issues in regards to mass slope instability and as a consequence there were no general recommendation for remedial treatment of final highwalls at the time of the inspection.

With respect to the current condition of highwalls at Millennium Mine, the following summary was provided regarding pit slopes, being:

- The standard slope designs meet the EA requirements for as-constructed pit slopes to be geotechnically stable with regard to the ground conditions at Millennium Mine;
- The highwalls are inherently stable against mass failure, but local instability can occur where fault planes daylight in the wall, and any new exposed final highwalls should be subject to geotechnical inspections to check for geological structure that could give rise to instability;
- In-pit low wall dumps are stable with a more than adequate long-term Factor of Stability, including a condition of partial submergence to the predicted 10-year water level; and
- There are no issues relating to potential risk of geotechnical instability due to run-off entering the void.

Additionally, as open cut mining has ceased in Millennium Pit and Mavis E Pit, a further review of each associated final void highwall and pit stability is recommended upon completion of all mining related activities, being both open cut and highwall mining, to provide a geotechnical assessment of the final highwall that will remain at and beyond mine closure.

14. Native Flora and Fauna Capability

14.1. Pre-mining Ecological Conditions

The Project EIS (2010) identified that the area occupied by the residual voids previously comprised land dominated by exotic grasses and used for cattle grazing. Two fragmented patches of Not-Of Concern Regional Ecosystems were located on Mavis Pit. In terms of ecology, three listed species were confirmed at the site, and two more were considered as possibly occurring (**Table 10**). None of these species were identified within Millennium Pit or Mavis Pit, where the residual voids are located.

Table 10 – Likelihood of Vertebrates from EIS

Common Name	Scientific Name	Nature Conservation Act 1994 (Qld)	Environment Protection and Biodiversity Conservation Act 1999 (C'wth)	Likelihood
Rainbow bee-eater	*Meriops meriops*	-	Migratory	Confirmed
Brigalow scaly-foot	*Paradelma orientalis*	Vulnerable	Vulnerable	Confirmed
Little pied bat	*Chalinolobus picatus*	Rare	-	Confirmed
Ornamental snake	*Denisonia maculate*	Vulnerable	Vulnerable	Possible
Squatter pigeon (southern)	*Geophaps scripta scripta*	Vulnerable	Vulnerable	Possible

No aquatic macrophytes were recorded within any of the natural waterways surveyed during the EIS. This was attributed to several factors relating to the abiotic conditions of the waterways i.e. high scour, steep sided banks, high turbidity and highly mobile substrate.

Despite the lack of macrophytes, however, macroinvertebrates were recorded in relatively high numbers within the natural waterways. Similarly, the fish community was also large, with 121 individual fish from five species recorded at the site (**Table 11**).

Table 11 – Fish Species Recorded at the site during EIS in order of relative abundance

Common Name	Scientific Name
Eastern rainbow fish	*Melanotaenia spendida spendida*
Spangled perch	*Leiopotherapon unicolor*
Bony bream	*Nematalosa erebi*
Southern purple-spotted gudgeon	*M. adspersa*
Firetail gudeon	*Hypseleotris galii*

Two amphibians were recorded within the site, neither of which are of conservation significance:

- Stripped marsh frog (*Limnodynastes peroni*); and
- Ornate burrowing frog (*L. ornatus*).

The Western Dam provides aquatic habitat values and was observed supporting common waterfowl, including grey teal, Australian wood duck, pacific black duck, royal spoonbill, darter and Eastern great egret.

During operations, a number of birds and fish have been noted within the waterbodies created by mining. These include aquatic birds such as ducks, pelicans, cormorants, brolgas, emus and black swans, as well as fish such as bony bream. These species are known to be opportunistic are likely to be the initial colonizing species of the site post-closure.

14.2. Residual Void Ecology

Ecological opportunities within the residual voids will be incidental to the grazing conditions created by the final landform and land use. The residual voids will not therefore be managed specifically for ecological values. The residual voids will provide for common and opportunistic species, and the communities present will be similar to those that existed pre-mining.

The final voids at Millennium Mine will be located to the west and east of New Chum Creek, which is a vegetation protection (exclusion) area 100m either side of the creek bed. Additionally, remnant vegetation corridors are located within close proximity of the Millennium Pit void, which will further aid and support the reintroduction of native fauna post-mine closure from surrounding areas.

The variety of species and the number of individuals present utilising final voids at Millennium Mine will be cyclical in nature. More diverse communities recruited during wet periods are expected to diminish to a less diverse, highly salt tolerant community during extended dry periods, such as droughts, and with seasonal changes in salinity stratification of pit water stored within each final void (Appendix D).

The primary influencer on recruitment of flora and fauna within final voids is the salinity of pit water, which will fluctuate during the year, thus increasing the likelihood of species diversity changing in response to these fluctuations. An assessment of the residual voids to support native flora and fauna was completed by Gauge Industrial & Environmental (Assessment of Residual Void Water Capability to Support Native Flora and Fauna – Millennium Mine, December 2017). The results of this study are summarised below, with particular focus on salinity tolerance limits which is likely to be the key abiotic factor affecting the aquatic ecology of the residual voids.

14.2.1. Fringing Vegetation

The vegetation immediately surrounding mine voids may develop root systems deep enough to access water contained within the voids that form on the regraded low wall, in pit rehabilitated waste dumps and/or in pit access ramps. The Hart, et al (1991) review of salinity effects on riparian trees (limited to Eucalyptus, Melaleuca and Casuarina species) indicates salt-sensitivity starts around EC 3,000, and with the majority of species (including *Eucalyptus tereticornis*) sensitive at approximately EC 9,000, and some species tolerating EC >22,000.

Many of the tree species common to the study region were included in a south-east Queensland study which found they were moderately to highly salt tolerant, requiring root zone salinities of EC 6,000 – 14,000 to inhibit growth by 25% (Dunn, et al., 1994). *Eucalyptus tereticornis* and *Casuarina cunninghamiana* are considered tolerant of soil salinities up to EC 8,000 – 12,000 (QDPI, 1998; FAO, 2002; Anderson, 2003). Riparian species such as *Eucalyptus camaldulensis* and *Melaleuca halmaturorum*, with extensive root systems in contact with several sources of subterranean water of varying salt concentrations, have been observed to utilise the less saline microhabitats (James, et al., 2003).

During higher season rainfall conditions, the modelled final void salinities are expected to provide a source of water that will support salt tolerant fringing riparian vegetation with root systems deep enough to access the void. Under dry conditions, such as drought conditions, the void water may become too saline for all but the most salt tolerant species.

14.2.2. Native Fauna

Fish:

Most native freshwater fish are derived from recent marine ancestors and are tolerant of salinities up to EC 14,000 – 19,000 or greater, although adverse effects on eggs can occur at EC 3,000-6,600 (Hart et al, 1991; Bacher and Garnham, 1992; Dunlop, et al, 2005; Nielsen, et al, 2003).

Native fish common to the area (DERM, 2010) include species tolerant of salinities greater than EC 15,000 and up to EC 40,000 (Pusey, et al, 2004). The voids are expected to support native fish following wet conditions, either as breeding populations or individuals introduced by natural recruitment (for example, by transfer by waterfowl). After prolonged dry periods, such as droughts, diminished fish breeding may reduce numbers, however the voids are expected to support a variety of native fish species.

Invertebrates:

High salinities can be lethal to small, multicellular organisms (e.g. flatworms) and macroinvertebrates without impermeable exoskeletons (e.g. gastropods). A general threshold of EC 3,000 produces lethal effects in macroinvertebrates and adverse effects on macroinvertebrates, particularly those without impermeable exoskeletons (Dunlop, et al., 2005). However, many native macroinvertebrate species are of marine ancestry, and relatively tolerant of elevated salinity (Dunlop, et al., 2005).

The modelled salinities during wet periods (EC 3,100 to 6,300) are expected to affect sensitive invertebrates, particularly macroinvertebrates. As salinity increases during dry periods, a shift too moderately to highly salt tolerant communities is likely, with a subsequent reduction in species diversity. As invertebrates have short lifecycles, and many macroinvertebrates are aerially mobile, a more diverse macroinvertebrate community is expected to re-establish following fresh water inputs.

Macrophytes and Algae:

Freshwater algae are sensitive to increasing salinity although some have adopted life stages and undergo morphological and physiological changes to survive a broad range of salinities (Nielsen, et al, 2003). The majority of algae do not tolerate salinities above EC 15,000 (Bailey and James, 2000).

Aquatic macrophytes are susceptible to raised salinity, with sub-lethal effects (lethal to some species) occurring at salinities above EC 1,500 – 3,000; and the upper limit for most freshwater macrophytes being EC 6,000 (Nielsen, et al, 2003; Dunlop, et al, 2005).

Birds:

The mine voids are expected to support native bird life as a source of food (e.g. fish, algae and crustaceans), and if necessary, their mobility permits the use of alternative, fresher water sources for drinking from existing surface water runoff storage dams, such as Western Dam and previous sediment dams at Millennium Pit and Mavis Pit, which have been converted into stock watering dams.

Amphibians:

Amphibians are particularly sensitive to salt, although the limited tolerance data available (for *Rana esculenta* and *R. temporaria*) suggests salinities above EC 10,000 are tolerable (Dunlop, et al., 2005).

Evaluation

The final voids are expected to provide incidental value to biodiversity and ecology. This is because the final land use will be cattle grazing rather than nature conservation.

However, the residual voids are expected to support native flora and fauna, including macrophytes, algae, invertebrates, fish, amphibians and birds. The residual voids will provide habitat to opportunistic species within an environment where water is typically limited and intermittent. In the event salinity levels become too high for certain species to tolerate, then those species are expected to be replenished as the habitat is naturally recolonized over time from surrounding areas.

Birds expected to occupy the final voids include the following waterfowl: grey teal, Australian wood duck, pacific black duck, royal spoonbill, darter and Eastern great egret. Common grassland species found within grazing habitats are also expected to occur (e.g. butcherbird, pied lapwing, kestrel and black kite).

15. End-of-Mine Rehabilitation Success Criteria

The primary objectives for rehabilitation at Millennium Mine of both spoil dumps and final voids will be for a stable landform, non-polluting to the receiving environment and self-sustaining so as to reduce ongoing maintenance by the landowner, Peabody Australia and the Queensland Government.

Geotechnical stability:

Highwalls associated with each residual void area will remain geotechnically stable and safe, which will result in no toppling or significant failure in areas not known to have inherent geotechnical instability due to existing fault structures. As required monitoring will be conducted as part of the post-closure management of Millennium Mine to determine geotechnical stability and/or identify areas of concern, which are unlikely to occur given the stable characteristics of existing highwalls at Millennium Mine.

Erosion stability:

Rill, gully and sheet erosion due to surface runoff should not be significant and capable of 'self-healing' through the recruitment of surrounding vegetation to provide ongoing erosion protection. Routine monitoring will be conducted as part of the post-closure management of Millennium Mine to determine areas of erosion, which are may occur during the early stages of rehabilitation until competent vegetation is established.

Surface water drainage:

Existing surface water that is diverted around Millennium Pit and Mavis D and Mavis E Pit will be retained as part of the final landform/landscape to effectively control and mitigate the ingress of excess surface water into the residual voids.

Land use capability:

The final landuse class that is being targeted at Millennium Mine will be low intensity cattle grazing with a mosaic of remnant vegetation providing habitat and fauna corridors between Millennium Pit and Mavis Pit and the surrounding local region. Additionally, through the rehabilitation process of all associated areas of Millennium Mine, it is anticipated that maintenance of these areas will not require any more input by the landowner and land user than that already required on land used for cattle grazing which hasn't been significantly disturbed by mining activities.

Receiving waters quality:

Surface water runoff from rehabilitated areas will be managed during the decommissioning and closure phase pursuant to the EA and the Erosion and Sediment Control Plan (ESCP). As routine monitoring post-established rehabilitation is likely to demonstrate, the consequence of sediment laden or saline runoff from rehabilitated area is low and highly unlikely to be a concern of the receiving waters and/or downstream users. The majority of surface water runoff from rehabilitated spoil dumps will be captured within converted sediment dams that will be utilised for stock watering purposes during the year by the landowner.

15.1. Rehabilitation Success Criteria

Rehabilitation success criteria proposed for Millennium Mine as part of a post-closure mining environment take into consideration the pre-mining environment, existing established rehabilitation successfulness and predicted post-closure rehabilitation success based on observed and documented outcomes (Table 12). As rehabilitation is a location-by-location specific task requiring detailed designs, site preparation and replacement of topsoil over a large surface, which is predominately on a 25% (4:1) slope, the ability to effectively propose prescriptive criteria is not recommended. As such, the proposed success criteria, which are to be incorporated within the EA, are to be reviewed on a regular basis, but not exceed every three (3) years, which will allow for a comprehensive review of each rehabilitated area that ultimately forms one or more larger area.

15.2. Rehabilitation Monitoring

Rehabilitation monitoring, which commenced in 2015, focuses on the physical inspection of representative locations that have been treated with varied rehabilitation methods. Variables include application of grass and tree species, age, topsoil type and quality, rock mulch and non-rock mulched slopes between 25% and 33.5%, and top of dump locations, which are generally flat and/or slightly dipping at between -1% to -3%.

The primary objective of the existing rehabilitation monitoring program, which will be continued post-mine closure at Millennium Mine, is to monitor existing vegetation, soil and erosion data to be captured and analysed to determine the performance of rehabilitation against Peabody Australia's rehabilitation aim, and the landholder's expectation, of returning land to economically viable post-mining land uses (cattle grazing), as well as achieving the rehabilitation goals set out in the Queensland Department of Environment and Heritage Protection Guideline – Rehabilitation requirements for Mining Resources Activities (Version 2). Rehabilitation monitoring at Millennium Mine will generally consist of the below minimum processes, being:

1. **Landform stability analysis**
   - LiDAR surface analysis, surface water flow path analysis and surface change analysis (settlement, erosion and/or deposition).
2. **Field data collection**
   - Transect establishment and photographic monitoring;
   - Vegetation type, species and pasture capacity;
   - Upper-storey, mid-storey and lower-storey cover density and richness;
   - Groundcover and basal cover characteristics;
   - Erosion type, severity and propagation orientation; and
   - Soil condition and quality, where applicable.
3. **Data analysis**
   - Vegetation condition and diversity;
   - Ground and vegetative cover;
   - Landform stability; and
   - Soil condition, stability and pasture productivity.

Table 12 – Residual Void Rehabilitation Success Criteria

Domain	DES Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
Final Voids	Safe to humans and wildlife.	All rehabilitation to be safe to all humans and wildlife.	Hazards reduced to as low as reasonably practicable through the inclusion of highwall abandonment bunds, and highwall and lowwall fencing as agreed by the underlying landowner representative. Cattle and wildlife are able to safely and repeatedly access and use the rehabilitated land.	Evidence that human safety issues have been assessed and addressed as appropriate. Residual Void Slope Stability Assessment completed. Annual LiDAR survey and certification by appropriately qualified geotechnical person confirm: • Highwalls within Millennium Pit and Mavis Pit are within the mining engineering slope designs ±5 degrees as required during mining/excavation. • Spoil Dumps (in-pit) overall regarded slope angle will generally average 25%, but not exceed 33.5% (as approved within the EA). • Overall regraded slope angle will generally average 25%, but not exceed 33.5% and only to the modelled final void high water level of RL178 in Millennium Pit and RL202 in Mavis D and Mavis E Pit. • In-pit ramps regraded to a final landform slope of 25% (4:1) only above the modeled final void high water level. Abandonment bund(s) installed at appropriate setbacks as recommended by a Competent Person. Security fence and signage installed near the highwall abandonment bund.

Domain	DES Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
				Copy of landowner sign off accepting rehabilitation designs of the residual void areas (or parts).
	Non-polluting.	All potential contaminants to be contained on site.	Landform design to have considered final void area and volume, and hydrological modelling used to assess risk of non-containment of water. Assessment to include Probable Maximum Flood risk. Hydrogeological assessment undertaken to confirm risk of groundwater contamination as low as reasonably practicable. No deterioration of surrounding groundwater aquifers, relative to baseline conditions.	Evidence that the final void hydrological assessment completed, which is inclusive of over topping of voids and maximum flood risks have not occurred. Water quality monitoring results indicate no contamination of surface water or groundwater resources, other than natural increases in salinity concentrations during dry periods as predicted by water quality modelling. Evidence that investigations into any surface water or groundwater quality exceedances have been completed and any mitigating measures successfully implemented to control future risks to as low as reasonably practicable. Evidence that cattle can be successfully excluded from water within the residual voids in the event water quality exceeds stock watering quality levels.
	Stable	Landform design and construction to minimise potential erosion	Final landform is stable in the long term.	Annual LiDAR survey and certification by the Rehabilitation Monitoring Program the: • Highwall gully and rill erosion does not exceed 1.5m deep and extend from the top crest to the bottom of the weathered Permian zone (e.g. 30m below natural surface elevation). • Gully and rill erosion in all other areas does not exceed 1.5m deep and extend from the top crest to bottom toe of slopes. • The rehabilitated land is considered stable

Domain	DES Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
				relative to comparative areas, based on the experience of the CPESC.
	Able to sustain an agreed post-mining land use	Completion of rehabilitation to meet landform design criteria.	Measurements of residual void area and usable land within this area meet the Scenario 11 Final Landform Plan design. Agreement on final land use with the underlying landowner/ property management Presence and density of key fodder species Presence of stock grazing, accessing water and resting Presence of common flora and fauna.	A review by Annual LiDAR survey confirms: • Extent of residual void area at 389 ha. • Extent of flat grazing land within voids at 46 ha. Copy of written agreement by final landowner accepting final land use. Post-topsoil application reconciliation confirms: • Slopes greater than 10% spread with topsoil to a depth of approximately 200mm and areas/slopes less than 10% spread with approximately 100mm of topsoil, where applicable. • Regraded lowwalls above the modeled final void high water level will be topsoiled to a depth of approximately 200mm from 305 RL to 285 RL, ripped and seeded with either pasture grass and/or native tree species. • Regrade ramps above the modeled final void water level will be topsoiled to a depth of approximately 200mm, ripped and seeded with either pasture grass and/or native tree species. Evidence that annual rehabilitation monitoring results confirm: • Biomass of rehabilitation seeded with pasture grass to have 3,500 - 8,000kg/ha per sample

Domain	DES Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
				plot location after Year 5 of rehabilitation. • Number of stems per planted/seeded tree species in 10m x 10m sample plot is sufficient to allow stock shade. • Common and widespread flora and fauna confirmed present within the rehabilitated habitats.

16. Probable Maximum Flood (PMF) Protection

At the completion of decommissioning and rehabilitation of Millennium Mine, which is likely to be completed by 31 December 2021, the residual voids will be protected from Probable Maximum Flood (PMF) from nearby watercourses (i.e. New Chum Creek) such that the protection is sustainable for the foreseeable future.

Although not an immediate requirement, Millennium Mine has completed the PMF modelling, which has determined at the completion of decommissioning and rehabilitation that a PMF protection structure and/or final landform structure is required along the eastern side of Millennium Pit. The majority of the PMF level can be contained by incorporating the existing haul road as a final landform structure, which has been achieved through a haul road re-grade that was completed in Q3 2018. This re-grade resulted in the existing height of the haul road being raised to a level that is approximately 0.8 – 1m above the PMF level.

This final landform structure will function as a re-graded dump and will be used to provide a stock access route post-closure. Accordingly, this final landform structure is to be considered within the rehabilitation success criteria for the spoil dumps (out-of-pit). It will also be included within the final landform modeled as part of future PMF modelling.

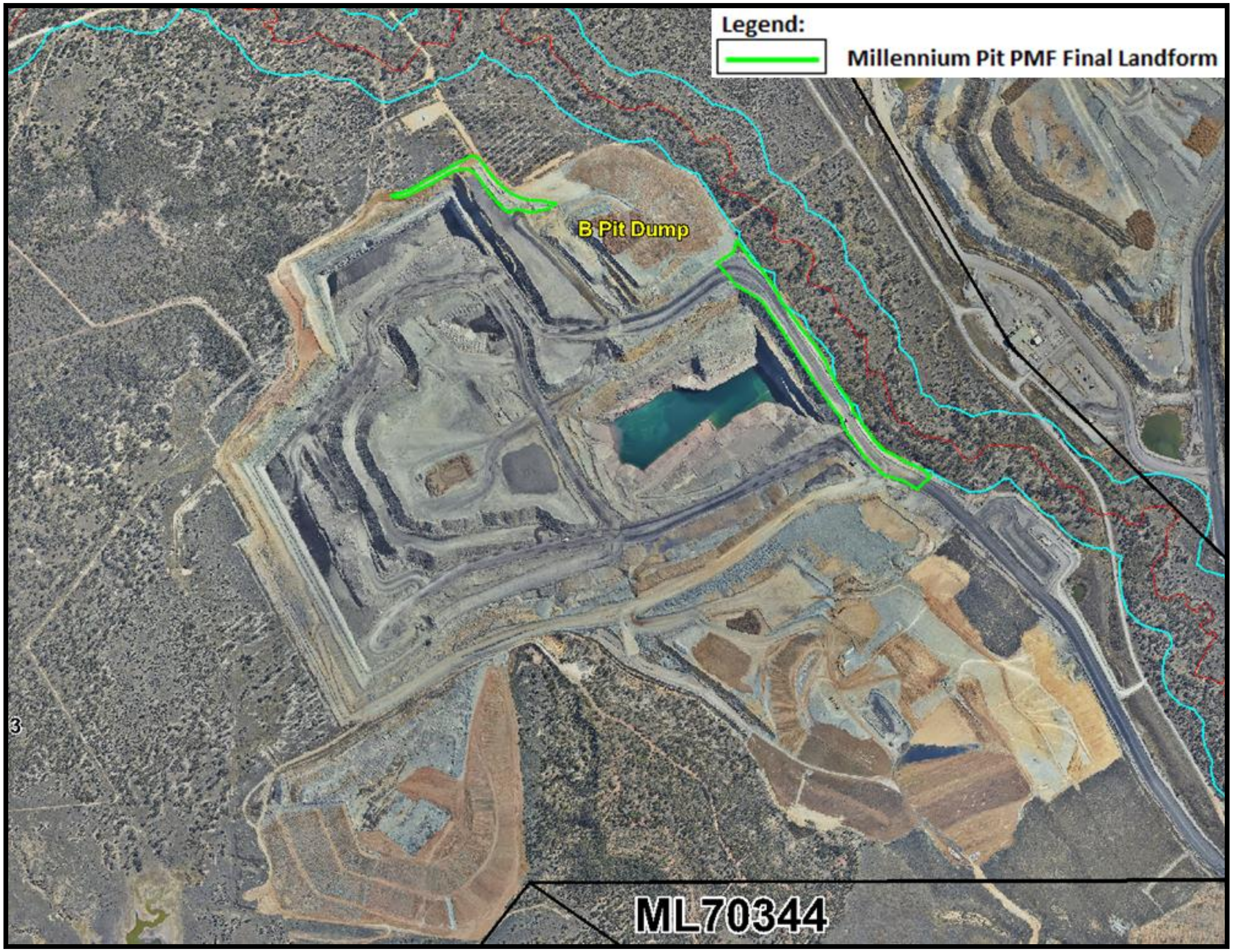

Figure 12 – Millennium PMF Final Landform Structure

Appendix A – Stage 2 Final Void Modelling

Report

Millennium Coal Mine - Stage 2 Final Void Modelling

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2018-02-15	0	Approved for Use	K. Bethune	S. Reynhardt	S. Reynhardt	Not Required
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
				Discipline Lead	Functional Manager	Client

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1. Introduction

Millennium Coal Mine (MCM) is an open cut coal mine operation located 140 km southwest of Mackay and 22 km west of Moranbah in Queensland's Bowen Basin. Currently, the mine produces a coking and low to mid volatile pulverized coal injection (PCI) coal. Run of mine (ROM) coal from MCM is transported to the adjacent Red Mountain Joint Venture (RMJV) infrastructure lease (ML 70312) for processing. The RMJV manages the shared coal processing assets in partnership between MCM (50%) and BHP Mitsui Coal Poitrel project (50%). Peabody has 100% ownership of MCM and is responsible for the management, operation and closure of the mine.

In accordance with the MCM environmental authority (EA), Peabody is required to prepare a residual void management plan (refer to Condition F7) that must, at a minimum, include the following items:

1. A study of options available for minimising residual void area and volume.
2. Develop design criteria for rehabilitation of residual voids.
3. A void hydrology study addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term.
4. A pit wall stability study considering the effects of long term erosion and weathering of the pit wall and the effects of significant hydrological events.
5. A study of void capability to support native flora and fauna.
6. A proposal/s for end of mine void rehabilitation success criteria and residual void areas and volumes.

In response to these requirements, Peabody has engaged Hatch to prepare this report to address items 3 and 5 for the final voids remaining within Millennium, Mavis D and Mavis E Pits. The scope of work is in accordance with Hatch proposal 17-3710 (dated 6th September 2017) and includes:

- Review of the final landform to define physical characteristics including catchment area and stage storage characteristics for the final voids of Millennium, Mavis D and Mavis E Pits.
- Determine appropriate hydrological inputs to be used for modelling, including rainfall, evaporation, catchment yield and potential impacts of climate change.
- Determine appropriate hydrogeological inputs to be used for modelling, including groundwater interactions and associated inflow rates and spoil aquifer storage within each final void.

- Development of an OPSIM[1] water balance model (WBM) which encompasses each final void.
- Undertake predictive modelling for each final void to estimate the following:
  - Time taken to reach equilibrium.
  - Climate driven pit lake[2] water level variations once equilibrium[3] conditions have been achieved.
  - Likely salinity conditions (i.e. total salt load) within the voids over time.
  - Risk of discharging to surface waters either via overtopping the void crest.
  - Sensitivity analysis to quantify uncertainty associated with predictive model results.

The assessment has primarily focused on the fluctuations of the water levels within the pit lakes to understand the likelihood that water will release to the downstream receiving waterways via overtopping. The fluctuation of salinity, assessed as electrical conductivity (EC), has been a secondary assessment criterion and has focused on the bulk salt mass when the void reaches equilibrium water levels and the fluctuation of EC as the pit lake volume changes due to climatic cycles.

Key personnel involved with the investigations to date have included:

Peabody

- Daryn Railey, Senior Environmental Advisor

Hatch

- Kirsty Bethune, Senior Water Engineer
- Jim Heaslop, Lead Water Resource Management – Australia

JBT Consulting (JBT)

- John Bradley, Principal Hydrogeologist

GAUGE Industrial & Environmental Pty Ltd (GAUGE)

- Mike Ferguson, Principal Ecologist

[1] The OPSIM software is a general purpose simulation model for water resource systems. It is industry accepted and primarily used for mine site water management applications throughout Australia.
[2] For the purpose of this report, final void refers to the last remaining pit and associated ramps, while the formation of a water body within the final void is referred to as a pit lake.
[3] Equilibrium condition is the term used to describe the conditions in the void when a stable range in the water level is reached. At this time, the water level within the void may fluctuate due to season changes, however, the long term water level trend will not continue to accumulate or deplete over time.

1.1 Project Data

Relevant project data provided by Peabody and sourced from Hatch and publicly available sources has been summarised in Table 1-1.

Table 1-1: Project Data

Type	Item (Reference / Filename)	Description
Climate Data	Data Drill long term climate data	• Daily rainfall and evaporation data sourced from the online SILO Data Drill database (Data Drill) for MCM (22°00' S; 148°15' E). • Data downloaded from January 1889 to 2017
Survey Data	e_pit_final_shell.dxf	• Final landform topographic data for Mavis D and E Pits. • Dated 10 November 2017.
	mill_shell_v9_dump.dxf	• Final landform topographic data for Millennium Pit. • Dated 9 November 2017.
	a_lc_floor.dxf a_vc_floor.dxf a-vc-fl.dxf b_lc_floor.dxf b_vc_floor.dxf b-vc_fl.dxf	• Deepest mined surface data for Millennium Pit.
	c-vc_fl.dxf d_lc_fllor.dxf e_lc_floor.dxf s_lc_floor.dxf	• Deepest mined surface data for Mavis D and E Pits.
	vu1_sf_flts.dxf	• Fault line data for Millennium Pit.
GIS	Millennium_Sept17_25cm_AMG84.ecw	• Latest MCM aerial photography encompassing Millennium and Mavis Pits. • Assumed current as at September 2017.
Reference Material	Mine Void Water report-Millennium Mine-Hatch-Dec 2017-V0-1 DRAFT.pdf	• *"Assessment of Residual Void Water Capability to Support Native Flora and Fauna – Millennium Mine"* report prepared by GAUGE. • Dated January 2018 • Refer to Appendix B.
	Spoil Water Volumes – Millennium Mine.xlsx	• Exchangeable water volumes at various void water levels prepared by JBT. • Dated 15 January 2018.
	JBT01-062-0001-Millennium Final Voids.docx	• *"Spoil Water Contribution to Millennium and Mavis Pit Final Voids"* report prepared by JBT. • Dated 17 January 2018. • Refer to Appendix C.
	H353740-00000-228-202-0001_0.xlsx	• Preliminary final void modelling outcomes by Hatch. • Dated May 2017.

2. Final Void Model

2.1 Conceptual Model

A representative schematisation of a conceptual final void water balance has been presented in Figure 2-1. Review of this figure shows that key water inputs to the MCM final voids will include rainfall on the pit lake water surfaces, runoff from the pit faces and rehabilitated upstream catchment areas and groundwater interception. Outflows are expected to be limited to groundwater seepage and evaporation only. Under certain circumstances (i.e. if the final void water level exceeds the level of a neighbouring aquifer), outflows may also include seepage losses to surrounding aquifers. Sources of salt include salts dissolved in groundwater and catchment runoff. In the absence of any seepage or surface outflows to the environment, there is generally no removal of salt from the system, and thus, salt accumulate over time.

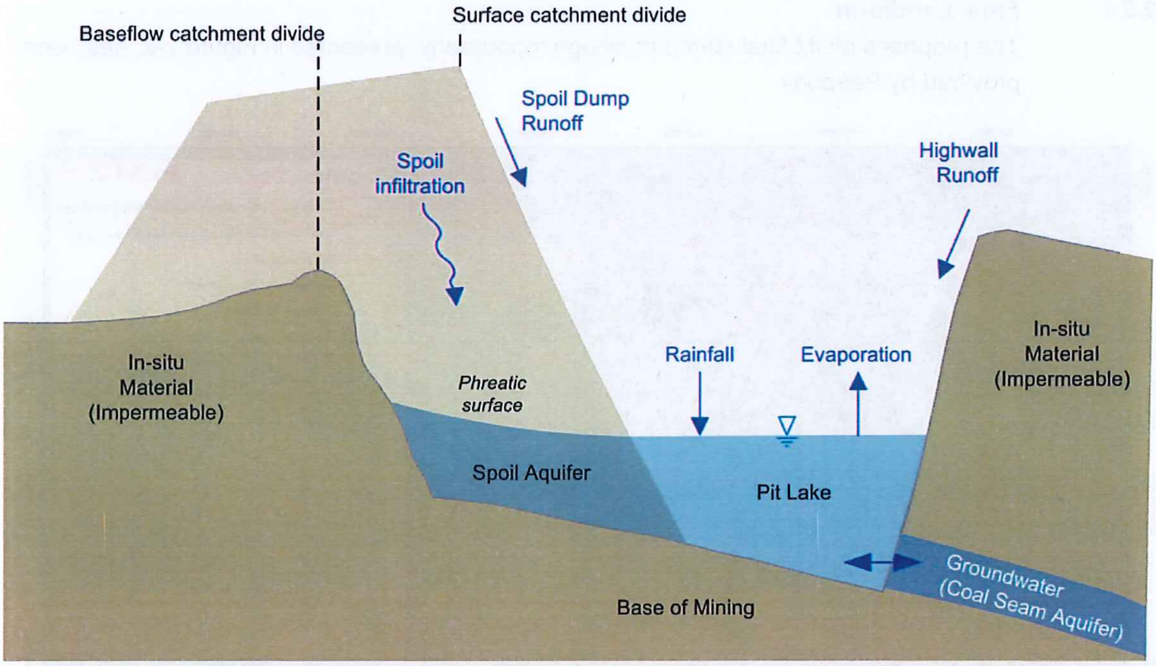

Figure 2-1: Final Void Conceptual Water Balance

In principal, for an initially empty void, water is expected to accumulate within the final voids until evaporative losses from the wetted surface areas offset catchment runoffs, rainfall and groundwater interceptions. Over a sufficiently long time scale, the water levels within the pit lakes are expected to reach a nominal steady state, with some variation about the steady state level during prolonged periods of wet and dry climate bias.

2.2 OPSIM Model

A numerical WBM has been developed using the OPSIM software platform to simulate the processes described in Figure 2-1. The model simulates the generation, movement and loss of water on a daily time-step within each final void, over a 1,000 year period. The model also tracks the bulk volume of mixed salt captured and stored within the system.

The final void OPSIM model has been built upon an existing model that was developed as part of a study recently completed by Hatch in 2017[4] (referred to herein as the 2017 WBM study). As part of this study, selected model parameters where calibrated to historical water level and water quality data collected between 2015 and 2017. Calibrated catchment yield and pit evaporation adjustment factors defined as part of the 2017 WBM study have been taken into consideration when selecting parameters for use in the final void WBM.

Key components of the final void WBM are summarised in the following sub-sections, including descriptions of key model assumptions, inputs, parameters and sensitivity analysis.

2.3 Physical Characteristics

2.3.1 Final Landform

The proposed MCM final landform design topography, presented in Figure 2-2, has been provided by Peabody.

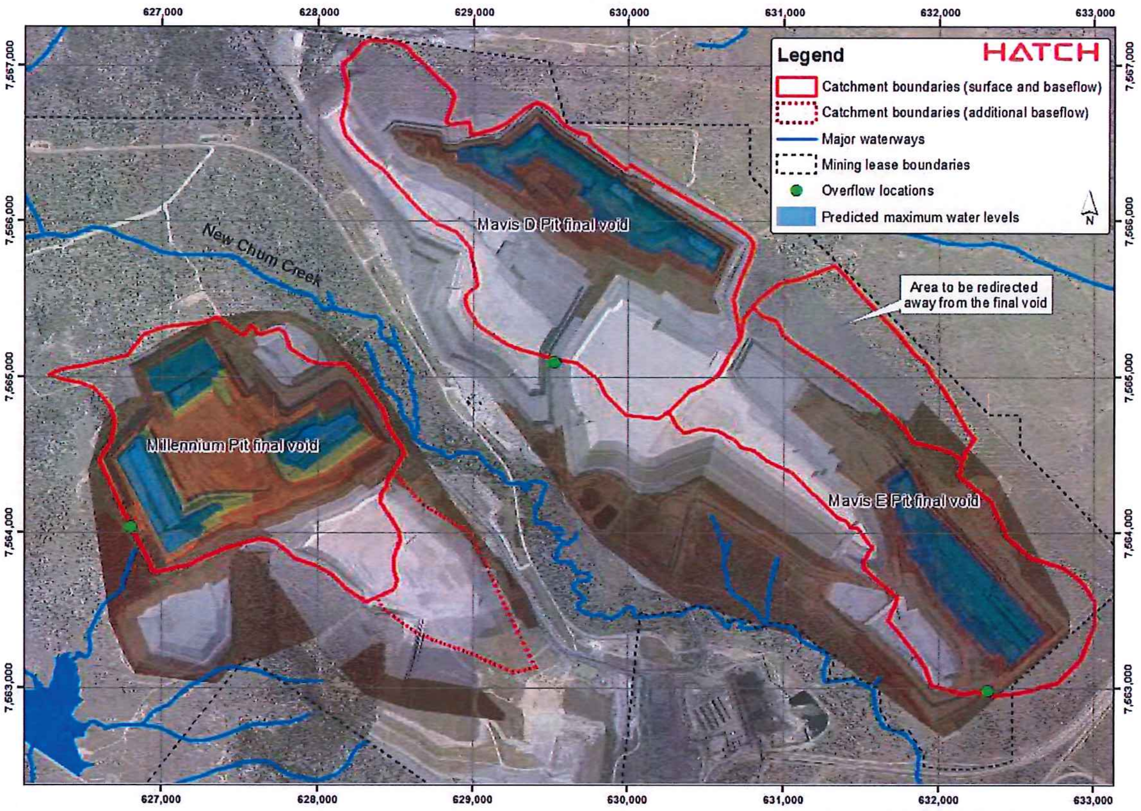

Figure 2-2: Final Landform and Void Catchment Areas

[4] Hatch, 2017. Millennium Coal Mine – Water Balance Model Update and Daunia Millennium Water Transfer Study. H353740-0000-228-054-0001 Rev 3 (dated 24 August 2017).

Review of Figure 2-2 shows the following:

- Three final voids are expected to remain following the completion of open cut mining operations at MCM (i.e. Millennium Pit, Mavis D Pit and Mavis E Pit).
- Three separate pit lakes are expected to form within the Millennium Pit final void. If water levels increase above an elevation of 214 mRL, all three pit lakes would combine to form one large pit lake surface.
- A separate pit lake is expected to form within both Mavis D Pit and Mavis E Pit final voids. However, review of the deepest mined surface has indicated that the Mavis Pit finals voids are connected above an elevation of 200 mRL. Review of the final void landform has also indicated that a spoil bridge has been placed between the two final voids. The spoil has been assumed to be porous and as such, over the long term and when the water levels are above 200 mRL, both pit lakes should reach the same equilibrium water level.
- The catchment area for each final void, as delineated using final landform contour information.
- The low point where water would spill if the voids where completely full.

It is noted that no manipulation or re-modelling of the final landform has been undertaken.

2.3.2 *Stage Storage Characteristics*

Stage storage curves for free water within the Millennium and Mavis Pits final voids have been presented in Appendix A. They have been based upon the free water volume derived from computer analysis of the proposed final landform design topography.

Volume versus depth relationships for spoil aquifers have been calculated by JBT based on review of deepest mined topography and an assumed spoil porosity of 20% (refer to Section 2.5.2).

2.3.3 *Overflow Levels*

Overflow levels for the final voids have been determined based on review of the proposed final landform design topography. Overflow levels have been defined as the minimum elevation at which water would flow from the final void to the environment via a surface pathway. Overflow levels have been summarised in Table 2-2 (on Page 8).

Outflows from final voids via subsurface pathways (e.g. seepage) have not been considered as part of the surface water balance analysis (this report).

2.3.4 *Catchments Areas*

Surface catchment areas reporting to the final voids have been determined based on review of the proposed final landform design topography. Surface catchment areas have been determined based on the following assumptions:

- That suitable flood protection works currently exist or will be included in the final landform design to prevent ingress of flood water from adjacent waterways of New Chum Creek.

- Natural catchment located to the north of the Mavis E Pit will be directed away from the final void as part of the mine closure planning.

The final void WBM also simulates infiltration of water into the rehabilitated spoil dump catchments and sub-surface drainage of the infiltration water to the downstream pit lake. Baseflow catchment areas reporting to each final void have been determined based on review of the deepest mined survey data. Any mined areas not covered by the surface catchment extents are assumed to be baseflow catchment (note that baseflow catchment runoff is equivalent to approximately 50% of surface catchment runoff[5]).

Surface and baseflow catchment areas have been presented in Figure 2-2 and summarised in Table 2-1 and Table 2-2.

2.3.5 *Land Use Breakdowns*

Land use breakdowns for the final voids of Millennium, Mavis D and Mavis E Pits were provided by Peabody as part of the 2017 WBM study. Land use classifications consisted of natural, cleared, industrial and roads, mining pit, stockpiles, unrehabilitated spoil and rehabilitated spoil.

For the final void modelling, the following land use assumptions have been made:

- All stockpile dumps, cleared, pit low walls and unrehabilitated spoil areas within the final void catchments will be rehabilitated and revegetated during the rehabilitation and closure phase at MCM.
- Rehabilitated areas will naturally revert to pre-disturbed or natural conditions over time, as vegetation matures and top soil weathering and consolidation takes place.
- Pit highwalls, endwalls and ramps are expected to produce higher runoff than rehabilitated spoil areas due to relative differences in slope and cover.

It is expected that long term steady state conditions will settle somewhere between rehabilitated and natural catchments. To account for the change in the catchment land use over time, the following final void land use breakdowns have been adopted:

- Natural case:
  - All cleared, industrial and road, stockpiles, pit low walls, unrehabilitated spoil and rehabilitated spoil areas have reverted to natural.
  - Existing natural and mining pit (i.e. highwalls, endwalls and ramps) areas remain unchanged.
- Rehabilitated case:
  - All cleared, industrial and road, stockpiles, pit low walls and unrehabilitated spoil areas have reverted to rehabilitated.
  - Existing rehabilitated, natural and mining pit (i.e. highwalls, endwalls and ramps) areas remain unchanged.

[5] Determined by the AWBM model parameter BFI (base flow index).

Final void land use breakdowns for Millennium, Mavis D, Mavis E Pits have been presented in Table 2-1. Note that surface runoff and baseflow and any additional baseflow areas have been detailed.

Table 2-1: Catchment Area and Land Use Breakdowns

Final Void	Surface Catchment (ha)				Additional Baseflow Catchment (ha)
	Natural	Mining pits	Rehabilitetd	Total area	
Millennium Pit					
Natural Case	220	33	-	253	61
Rehabilitated Case	15	33	205	253	61
Mavis D Pit					
Natural Case	284	25	-	309	-
Rehabilitated Case	4	25	280	309	-
Mavis E Pit					
Natural Case	228	19	-	247	-
Rehabilitated Case	49	19	179	247	-

Note: Baseflow is only associated with the natural and rehabilitated catchments only. Mining pit areas have no baseflow.

2.3.6 *Summary*

A summary of the final void physical characteristics as detailed in Section 2.3.1 to Section 2.3.5 have been presented in Table 2-2.

Table 2-2: Final Void Physical Characteristics

Final Void	Catchment Area (ha)	Overflow Level (mRL)	Storage characteristics at overflow level		
			Volume (GL)	Surface Area (ha)	Max Depth (m)
Millennium Pit	253	244	71	154	133
Mavis D Pit	309	256	52	130	126
Mavis E Pit	247	238	28	70	78

Note: Catchment area is the surface runoff catchment only with no additional baseflow.
Water within Mavis D and Mavis E Pits would overflow to the environment prior to joining as one large visible pit lake.

2.4 Hydrological Inputs

2.4.1 *Climate Data*

Climatic influence on the final voids is via direct rainfall, catchment runoff, evaporation from the pit lake water surfaces and evapotranspiration from their catchments. Historical data has been used to model rainfall, evaporation and evapotranspiration, based on the assumption that climatic conditions observed in the past are indicative of persistent local climatic trends. Historical data is therefore assumed to represent a range of potential conditions likely to be observed in the future. The potential effects of climate change have been addressed in Section 2.4.1.4.

Climatic data for MCM has been sourced from the SILO Data Drill service. The Data Drill service accesses grids of climate data interpolated from point observations by the Bureau of Meteorology (BoM) for any point in Australia. Sourced information includes daily resolution rainfall and evaporation data from 1889 to present day.

The Data Drill rainfall and evaporation data sets for the complete years from 1889 up to 2016 inclusive (128-year period) have been used to develop long term data sets. This has been done by repeating the 128 years of data eight times to create long term rainfall and evaporation data sets of 1,024 years duration. The developed long-term rainfall and evaporation data sets have been adopted as input to the final void WBM.

Consistent with the 2017 WBM work package, Data Drill climate data was sourced for MCM (22°00'S 148°15'E). This climate data set has been used for the final void modelling, processed and summarised in the following sub-sections of this report.

2.4.1.1 *Rainfall*

As part of the 2017 WBM study, a review and comparison of Data Drill rainfall against site collected rainfall data was undertaken and the Data Drill rainfall set was found to be relatively consistent with available site daily rainfall.

Annual Data Drill rainfall totals on a linear and percentile basis have been presented in Figure 2-3.

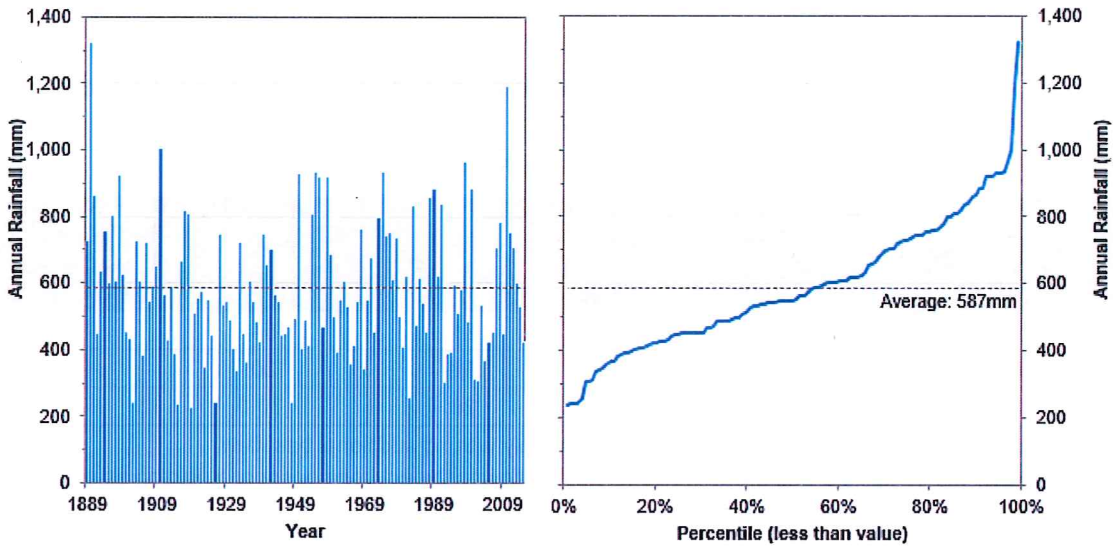

Figure 2-3: Historical Annual Rainfall Totals - Time Series and Percentiles

Review of Figure 2-3 leads to the following:

- Average annual rainfall of 587 mm.
- Maximum and minimum annual totals of 1,320 mm and 225 mm, respectively (1,095 mm historical range).

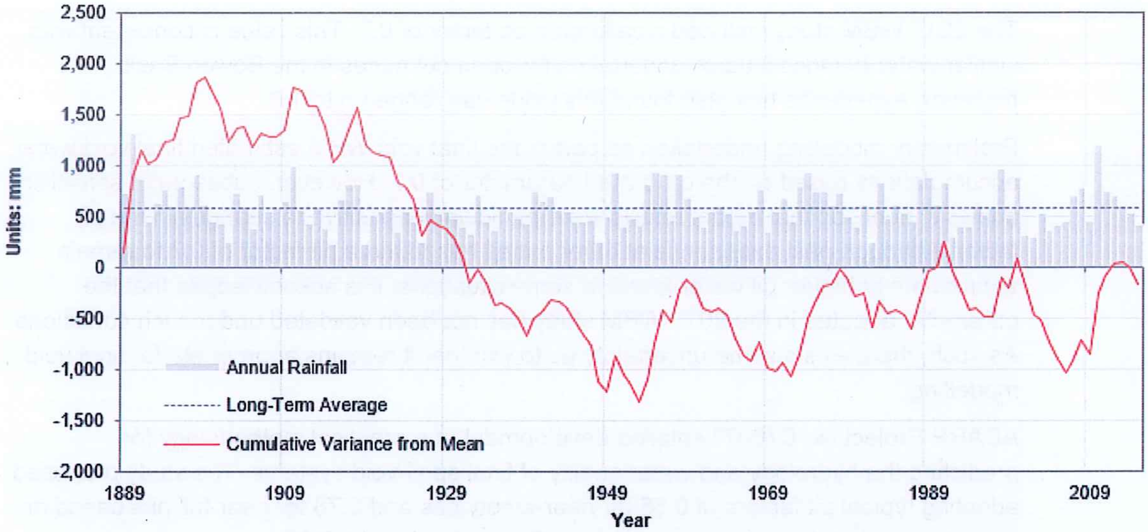

Figure 2-4: Rainfall Residual Mass Curve and Seasonality Analysis

Figure 2-4 shows a rainfall residual mass curve, which is derived as the cumulative sum of the difference between each year's annual rainfall from the mean annual rainfall. Downward trends indicate periods of persistent rainfall drought and upward trends indicate periods of persistent wet-bias (e.g. flood). Review of this figure shows the historical climate sequence features several periods of persistent flood and drought.

2.4.1.2 *Evaporation*

Data Drill daily evaporation data for the final voids includes:

- Morton lake (M_{lake}) evaporation that is used to estimate evaporation from the wet surface areas of the final voids
- Morton wet (M_{wet}) evaporation that is used to model evapotranspiration losses from catchment areas.

The final void WBM uses M_{lake} evaporation as the primary data input, with evapotranspiration calculated by factoring the M_{lake} daily values by the average ratio of M_{lake} to M_{wet}, which was calculated at 0.97.

Annual Data Drill evaporation totals have been summarised as follows:

- Average annual evaporation of 1,825 mm.
- Maximum and minimum totals of 1,990 mm and 1,540 mm, respectively (450 mm historical range).

Review of the Data Drill rainfall and evaporation data, shows that the average annual rainfall is approximately a third of the average annual evaporation.

2.4.1.3 *Pit Evaporation Adjustment Factor*

It is common practice to account for reduced evaporation from excavated voids due to shading and wind shielding provided by the pit walls. The pit evaporation adjustment factor is referred to herein as the pit factor.

The 2017 WBM study included a calibrated pit factor of 0.7. This value is consistent with similar water balance studies undertaken for open cut mines in the Bowen Basin, however, experience has also found this value can range up to 1.0.

Preliminary modelling undertaken as part of the final void WBM estimated final void water accumulations based on the calibrated parameter of 0.7. However, subsequent sensitivity analysis identified that model results were particularly sensitive to changes in the pit factor. Although past experience at other mines has found a pit factor of 0.7 to remain appropriate at higher pit water levels in some situations, it is acknowledged that the parameter adopted in the 2017 WBM study has not been validated under such conditions. As such, there exists some uncertainty as to whether it remains appropriate for final void modelling.

ACARP Project No C7007[6] entailed development of a practical methodology for predicting the hydrology and water quality of final spoil-void systems. The study proposed adopting typical pit factors of 0.56 for near-empty pits and 0.78 for near-full pits based on modelling undertaken at several mines in Queensland and NSW[7].

The final void WBM all included sensitivity scenarios testing pit factors of ±0.1 (i.e. 0.6 and 0.8) to better understand the uncertainty inherent with this parameter.

2.4.1.4 *Climate Change*

Given the final voids are proposed to be retained following mine closure, the effect of climate change on final void water levels has been considered.

The Australia Rainfall and Runoff: A Guide to Flood Estimation has been recently updated in 2016 and is referred to herein as ARR 2016. Review of the ARR 2016 found that the effect of climate change on the continuous future climatic simulation required for final void modelling was outside the scope of the document (refer to Chapter 7.5 of Book 2: Rainfall Estimation).

As no additional guidance was provided in ARR 2016, the potential changes to Queensland's climate has been based on extracts of the climate change paper written by the Queensland Government in 2011.

> *'Current projections indicate that rainfall is expected to decrease across most of Queensland, except for Cape York, the Gulf Region and Far North Queensland. Depending on the region, modelling indicates that this decrease could range between 1-7 per cent, by 2050.'*
>
> *'Climate change will also influence the seasonal and daily patterns of rainfall intensity, increasing flood risk. Projections indicate an increase in 2-hour, 24-hour and 72-hour extreme rainfall events for large areas of south east Queensland.'*

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[6] ACARP, 2001. *ACARP Project No C7007 – Water Quality and Discharge Predictions for Final Void and Spoil Catchments.* Document 86PP081-PR001Bab Rev B (May 2002).
[7] Note: adjustment factors published in ACARP assume pan evaporation input. Adjustment factors listed in this report have been scaled so that they may be applied in conjunction with lake evaporation rates used in the MCM final void WBM.

'By 2050, Queensland is expected to face an increase in annual mean evaporation of 5-7 per cent.'

Review of the extracts show that although the intensity of daily rainfall events may increase, overall, it is expected that the annual volume of rainfall will decrease. This will result in a reduction in the volume of water captured in the final voids due to rainfall-runoff. The net effect of this when coupled with an increased evaporation rate will be a reduction in the expected water levels within the final voids compared with the water levels associated with current day climate conditions.

As the final void modelling is primarily focused on establishing the maximum water level, climate change impacts have not been modelled. This approach will result in a conservative estimate of the final void water levels.

2.4.2 Catchment Yield

Catchment yield (rainfall-runoff) within the final void WBM has been simulated using the Australian Water Balance Model (AWBM). The AWBM is a saturation overland flow model which uses daily rainfalls and estimates of catchment evapotranspiration to calculate daily values of runoff using a water balance approach. The AWBM is widely accepted and commonly used within Australia[8].

The AWBM parameters used in the final void WBM were adopted from the 2017 WBM study. These parameters were calibrated and used to reproduce the observed site water inventory over the period January 2015 to January 2017.

As detailed in Section 2.3.5, the natural and rehabilitated land use classifications are expected to best represent long-term catchment conditions. As both these land classifications have only been calibrated to a limited extent, it was considered appropriate to compare performance of both natural and rehabilitated cases as detailed in Table 2-3. Note the final void WBM has also allowed for higher runoff from pit highwalls, endwalls and ramps (refer to Section 2.3.5).

Runoff from mining pit, natural and rehabilitated areas have been modelled using AWBM parameter sets used in the 2017 WBM study and have been presented in Table 2-3. Long term average catchment yields estimated using AWBM parameters have also been presented in Table 2-3.

[8] Refer to '*A Hydrograph-based Model for Estimating the Water Yield of Ungauged Catchments*' (Boughton, 1993) for further information.

Table 2-3: AWBM Catchment Yield Parameters

Item		Mining Pit[A]	Rehabilitated	Natural
Partial area (mm)	A_1	1.0	0.134	0.134
	A_2	0	0.433	0.433
	A_3	0	0.433	0.433
Surface storage capacity (mm)	S_1	10	20	30
	S_2	0	70	45
	S_3	0	150	123
Average surface storage capacity (mm)	$S_{average}$	10	97.9	76.8
Base flow index	BFI	0.0	0.50	0.50
Recession constant	K_{base}	-	0.95	0.95
	$K_{surface}$	0	0.85	0.40
Long term yield	%	39.2	12.5	12.3

Note: [A] Parameter set used to model runoff from highwalls, endwalls and ramps (i.e. high runoff areas)

2.4.3 *Salinity*

The final void WBM has been configured to track the net accumulation of salt mass within each final void. Salt is modelled as a mixed mass and generally reported in terms of total dissolved solids (TDS) or EC calculated assuming a conversion factor of 0.67 (EC x 0.67 = TDS).

Salt inflows to the system include salts dissolved with groundwater and in catchment runoff. Salt inflows are calculated by assuming a nominal EC concentration associated with each inflow stream. Water quality sampling data collected as part of the 2016 and 2017 Water Management Plan Reviews for MCM and RMJV (Hatch 2017)[9] has been reviewed in combination with salinity generation rates adopted for the 2017 WBM study to select an appropriate range of salt inflows for groundwater and catchment runoff.

The adopted salinity generation rates for the natural, rehabilitated and mining pit AWBM parameters along with the salt inflows from the groundwater have been presented in Table 2-4.

Table 2-4: Catchment Runoff and Groundwater Salinity Generation

Land Use	Salinity generation (µS/cm)
Natural	300
Mining pit	5,000
Rehabilitated	1,500
Groundwater	12,000

[9] Hatch Pty Ltd, 2017. *Review of Millennium Water Management Plan.* Document H356028-00000-230-228-0001 (Rev A) dated December 2017. *Review of Red Mountain Joint Venture Water Management Plan.* Document H356030-00000-230-228-0001 (Rev A) dated December 2017.

2.5 Hydrogeological Inputs

Hydrogeological aspects of the final void WBM have been defined/modelled based on specialist advice provided by JBT. Relevant information, as it pertains to the WBM, has been summarised in the following sub-sections. Detailed descriptions, analysis and basis are documented in the Groundwater Assessment Report prepared by JBT[10] presented in Appendix C.

2.5.1 Groundwater Inflows

No groundwater inflow rates have been modelled into any open cut pits. However, modelling has included a groundwater sensitivity scenario testing constant inflow rates as detailed in Table 2-5. These groundwater inflow rates have been adopted from the 2016 Integrated Water Management System and Water Balance Review[11].

Table 2-5: Groundwater Inflows

Final Void	Groundwater inflow (L/s)
Millennium Pit	0.8
Mavis D Pit	0.5
Mavis E Pit	0.8

2.5.2 Spoil Aquifer Storage

Spoil dump volumes have been estimated by comparing the deepest mined topography against the proposed final landform design topography. Water storage within the spoil dumps (spoil aquifers) has been modelled with an assumed 20% spoil porosity which corresponds to a 15% drainable porosity (please refer to accompanying JBT groundwater report for basis).

Modelling has included a sensitivity scenario testing for an assumed 25% spoil porosity (i.e. 20% drainable porosity) for all final voids.

2.5.3 Hydraulic Connectivity between Pits

Saturated spoils are assumed to function as a continuous porous median aquifer and water is assumed to equalise between the final voids via spoil aquifer connections. Hydraulic connections assumed to be established as follows:

- Between the pit lakes within Mavis D Pit and Mavis E Pit final voids (above a level of 200 mRL).
- Between the three pit lakes within the Millennium Pit final void.

Given the extended simulation time-scale and large expected variability in spoil hydraulic conductivity, modelling has assumed that sub-surface balancing flows between final void pit lakes occur at an unrestricted rate. On this basis, interconnected pit lakes within the Millennium Pit final void have been modelled and presented in the report as if it was a one pit lake. Mavis D and E Pits have been modelled as separate voids with connectivity above a level of 200 mRL (i.e. the deepest mined surface between the two pits).

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[10] JBT Consulting, 2017. *Spoil Water Contribution to Millennium and Mavis Pit Final Voids.* Document JBT01-062-004 (Draft 1) dated January 2018.
[11] WRM Water and Environment. *2016 Integrated Water Management System and Water Balance Review – Millennium Coal Mine/RMJV.* Document 0570-22-C dated January 2016.

2.5.4 *Seepage to Environment*

Modelling has not included allowance for any seepage losses from any of the final voids to the receiving environment.

2.6 Initial Conditions

Adopted initial water levels and salinities have been presented in Table 2-6. Water levels have been set based on recorded data received as part of the 2016 and 2017 Water Management Plan Reviews for MCM and RMJV (Hatch 2017)[12].

Table 2-6: Adopted Initial Conditions

Final Void	Water Level (mRL)	Starting EC (µS/cm)
Millennium Pit	159.5	2,500
Mavis D Pit	Empty	-
Mavis E Pit	Empty	-

Initial condition sensitivity scenarios have not been tested. Starting conditions will have no impact on long-term equilibrium water level outcomes. Filling timeframes will be influenced, as will water quality results to an extent. Sensitivity analysis regarding water levels should be undertaken as part of future studies, as closure plans progress, and/or for any voids where filling timeframes or water quality results are critical.

[12] Hatch Pty Ltd, 2017. *Review of Millennium Water Management Plan.* Document H356028-00000-230-228-0001 (Rev A) dated December 2017. *Review of Red Mountain Joint Venture Water Management Plan.* Document H356030-00000-230-228-0001 (Rev A) dated December 2017.

3. Modelling Outcomes

The primary focus of this assessment has been the fluctuation of the water levels within the pit lakes to determine the potential risk of voids filling and releasing water. As such, the assessment has been undertaken using a daily time step to estimate the following:

- Time taken to reach equilibrium within the pit lakes.
- Water level within the pit lakes once equilibrium conditions have been reached.

For each final void, long term water levels for both the natural and rehabilitated cases have been presented. For the final void water levels, a maximum and minimum envelope which encompasses the outcomes for both the natural and rehabilitated cases have been presented.

The secondary focus of this assessment has been the fluctuation of salinity, assessed as EC, within the pit lakes. Climate driven fluctuations of salinity of the bulk water volume have been estimated for the period when equilibrium pit lake water levels have been reached. An EC range has been established using the total salt mass in each final void along with the long term maximum and minimum volumes in each void.

While an EC range of the water within pit lakes has been estimated, it is acknowledged that EC values should be used as a guide to indicate the upper limit of EC within the voids. It is highlighted that estimates do not allow for:

- Reduced generation rates over time as salts are leached from the spoil material. It is noted that there is currently an ACARP study (ACARP C250039) underway to try and qualify the response of salt generation in spoil material over time.
- Detailed assessment of the fluctuation of salinity due to stratification within the void water bodies.
- Any loss of salt mass from the voids via potential seepage into the surrounding aquifers.

It is understood that establishment of permanent works will be designed to provide flood immunity and as such, flood ingress from adjacent waterways (i.e. New Chum Creek) has not been considered as part of this final void modelling assessment.

3.1 Mavis D Pit

The estimated Mavis D Pit final void modelling outcomes have been presented in Figure 3-1 in terms of final void water levels and associated envelope.

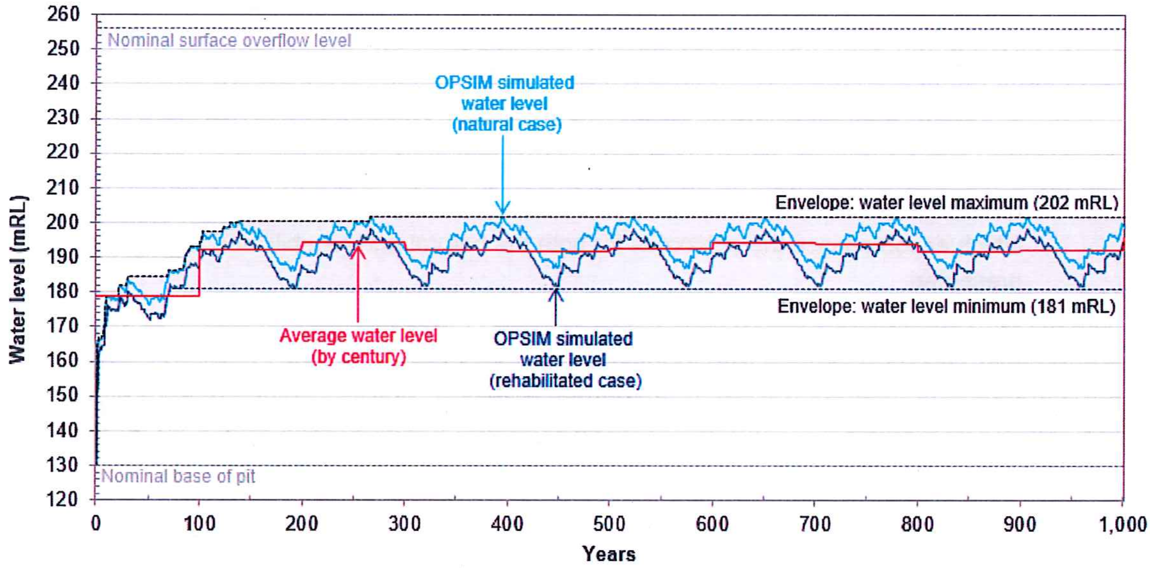

Figure 3-1: Mavis D Pit Final Void Water Levels

Review of Figure 3-1 leads to the following:

- The volume of water in Mavis D Pit reaches equilibrium after approximately 100 to 50 years.
- Once equilibrium conditions are reached, the water level fluctuates with seasonal variance within an envelope defined as follows:
  - Maximum water level of 202 mRL. Note this is above 200 mRL and as such, connectivity between Mavis D and E Pits exists.
  - Minimum water level of 181 mRL.
- Predicted pit lake water levels are well below the surface overflow level for Mavis D Pit and as such, release of water via overtopping is not predicted.

Although not shown in the figure, once equilibrium conditions are reached (i.e. after 150 years), the EC level fluctuates with seasonal variance and ranges from:

- 4,000 µS/cm after periods of above average wet conditions,
- 9,900 µS/cm after prolonged dry periods (i.e. droughts) which may extend for a number of years.

3.2 Mavis E Pit

The estimated Mavis E Pit final void modelling outcomes have been present in Figure 3-2 in terms of final void water levels and the associated envelope.

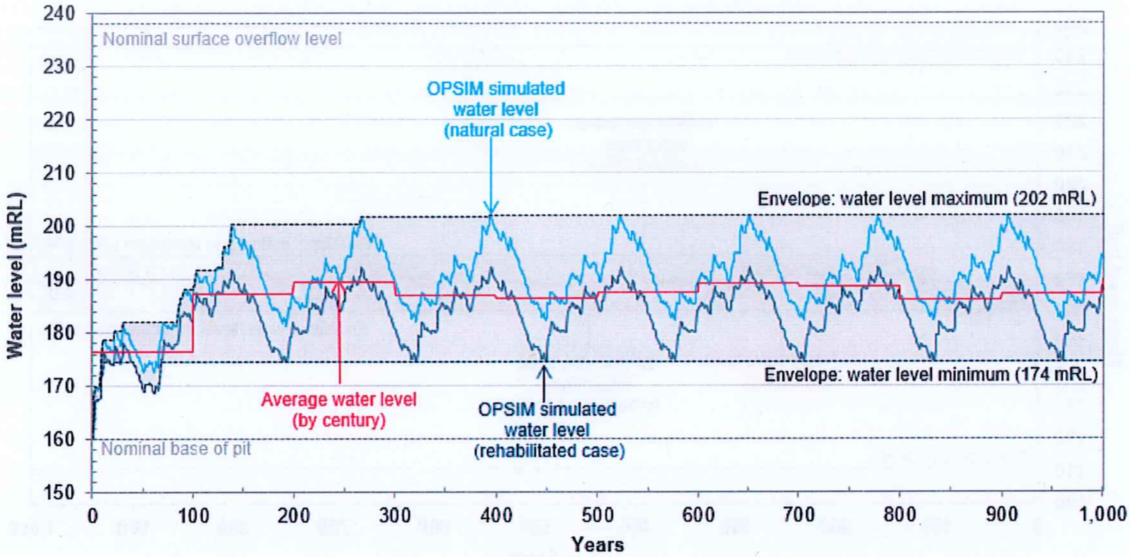

Figure 3-2: Mavis E Pit Final Void Water Levels

Review of Figure 3-2 leads to the following:

- The volume of water in Mavis E Pit reaches equilibrium after approximately 100 to 150 years.
- Once equilibrium conditions are reached, the water level fluctuates with seasonal variance within an envelope defined as follows:
  - Maximum water level of 202 mRL. As noted in Section 3.1, this level is above 200 mRL and is consistent with the predicted water level within Mavis D/E Pit.
  - Minimum water level of 174 mRL.
- Predicted pit lake water levels are below the surface overflow level for Mavis E Pit and as such, release of water via overtopping is not predicted.

Although not shown in the figure, once equilibrium conditions are reached (i.e. after 150 years), the EC level fluctuates with seasonal variance and ranges from:

- 4,100 µS/cm after periods of above average wet conditions.
- 14,300 µS/cm after prolonged dry periods (i.e. droughts) which may extend for a number of years. It is noted that this level is higher than the Mavis D Pit solely due to the reduced volume of water stored with Mavis E Pit.

3.3 Millennium Pit

The estimated Millennium Pit final void modelling outcomes have been present in Figure 3-2 in terms of final void water levels and the associated envelope.

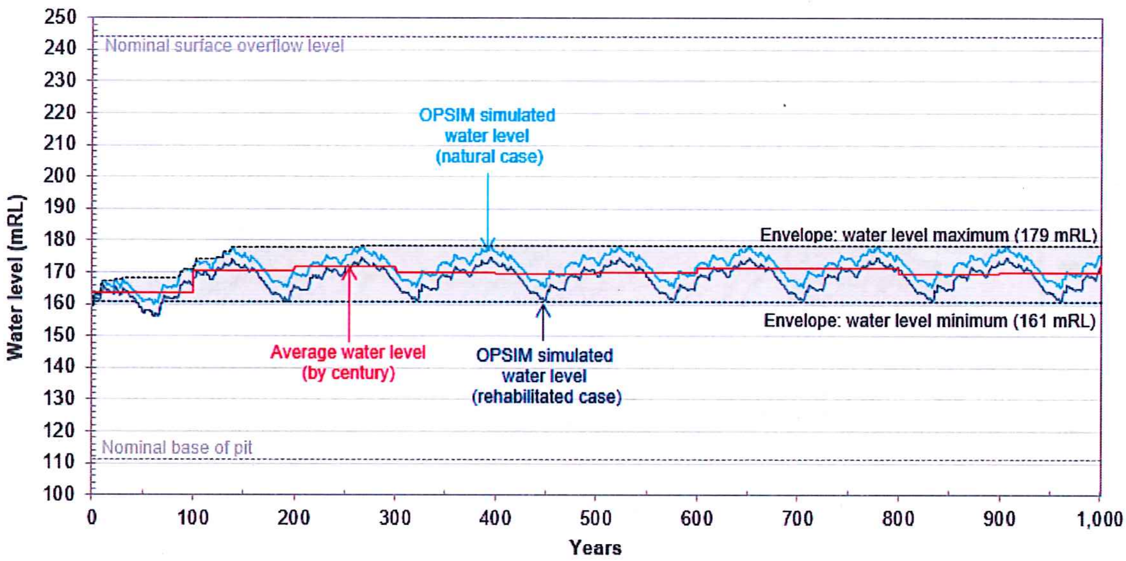

Figure 3-3: Millennium Pit Final Void Water Levels

Review of Figure 3-3 leads to the following:

- The volume of water in Millennium Pit reaches equilibrium after approximately 100 years.
- Once equilibrium conditions are reached, the water level fluctuates with seasonal variance within an envelope defined as follows:
  - Maximum water level of 179 mRL.
  - Minimum water level of 161 mRL.
- Predicted pit lake water levels are below the surface overflow level for Millennium Pit and as such, release of water via overtopping is not predicted.

Although not shown in the figure, once equilibrium conditions are reached (i.e. after 100 years), the EC level fluctuates with seasonal variance and ranges from:

- 5,200 µS/cm after periods of above average wet conditions.
- 13,200 µS/cm after prolonged dry periods (i.e. droughts) which may extend for a number of years.

3.4 Ecology

From a regional context, MCM is located in a zone of Australia that experiences extended periods of wet and dry, that may last in one cycle for years to decades. The region is characterized by having ephemeral watercourses (i.e. only experience flows for short periods following rainfall) and limited naturally occurring permanent water bodies. In response to these conditions, the ecology of the region has developed the ability to establish opportunistic populations that are salt-tolerant and thrive under a cycle of boom and bust conditions.

The pit lakes within the voids represent a novel long term habitat in an area characterised by ephemeral creek systems and floodplains. Site personnel have noted that currently the water bodies on the MCM site support a range of fauna species.

GAUGE has prepared a high level discussion on the capability of the MCM final voids to support flora and fauna. A copy of the discussion is presented in Appendix B, with the key outcomes of the discussion presented below:

- The pit lakes are likely to support opportunistic native flora and fauna species, including fish, invertebrates, macrophytes, algae, amphibians, fringing vegetation and birdlife as they provide a water body through wet and dry periods.
- It is expected that the EC levels within the voids will gradually increase over a long period of time. As the level increase, the diversity within the aquatic community may be limited to those species with at least moderate salt tolerance.
- The variety of species and the number of individuals present with be cyclical in nature with species rapidly colonising during wetter years (fresher waters) and diminishing during prolonged dry periods (i.e. droughts) which may extend for a number of years.

4. Sensitivity Analysis

To better understand the uncertainty and impact of a number of key final void WBM inputs and parameters, the following sensitivity cases have been modelled for the MCM final voids:

- Catchment yield
  - Natural case (plus existing mining pit)
  - Rehabilitated spoil (plus existing natural areas and mining pit)
- Spoil aquifer storage
  - 20% porosity (15% drainable)
  - 25% porosity (20% drainable)
- Pit evaporation adjustment factor
  - 0.6
  - 0.8
- Groundwater
  - No net groundwater inflow
  - Groundwater inflows as detailed in Table 2-5.

The base case has been taken as a natural catchment (except for the mining pit) with a 20% spoil porosity and a 0.7 pit evaporation adjustment factor.

Outcomes of the sensitivity cases modelled have been presented for the forecast water level within each final void once equilibrium has been reached. Results have been presented in Figure 4-1 to Figure 4-3 and have been compressed into a single column of data, to represent the mean and uncertainty range associated with each case.

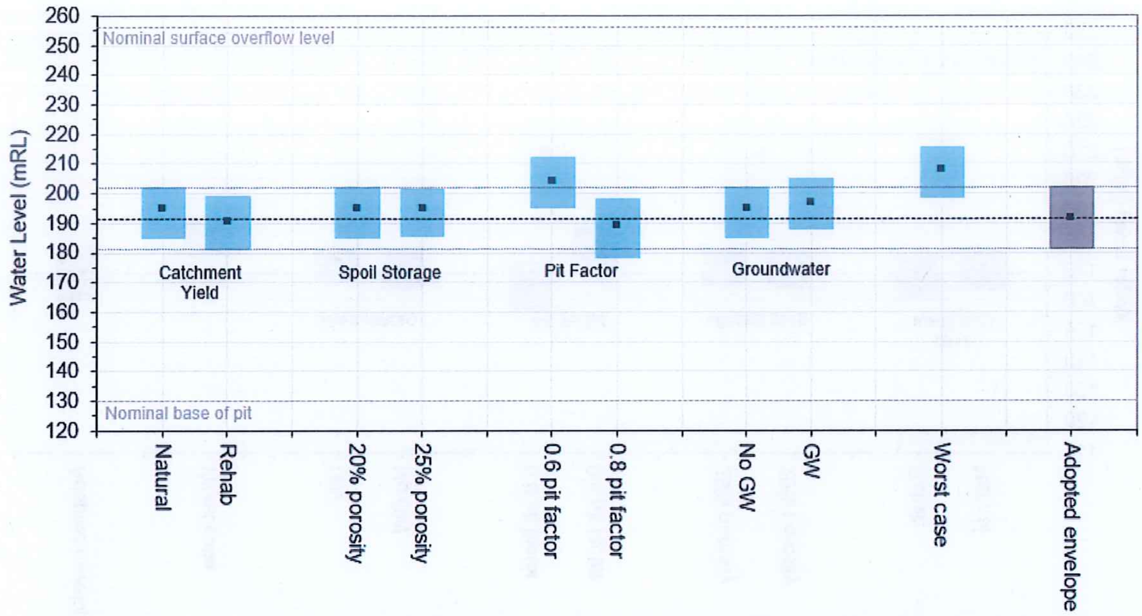

Figure 4-1: Sensitivity Case Outcomes - Mavis D Pit Final Void Water Levels

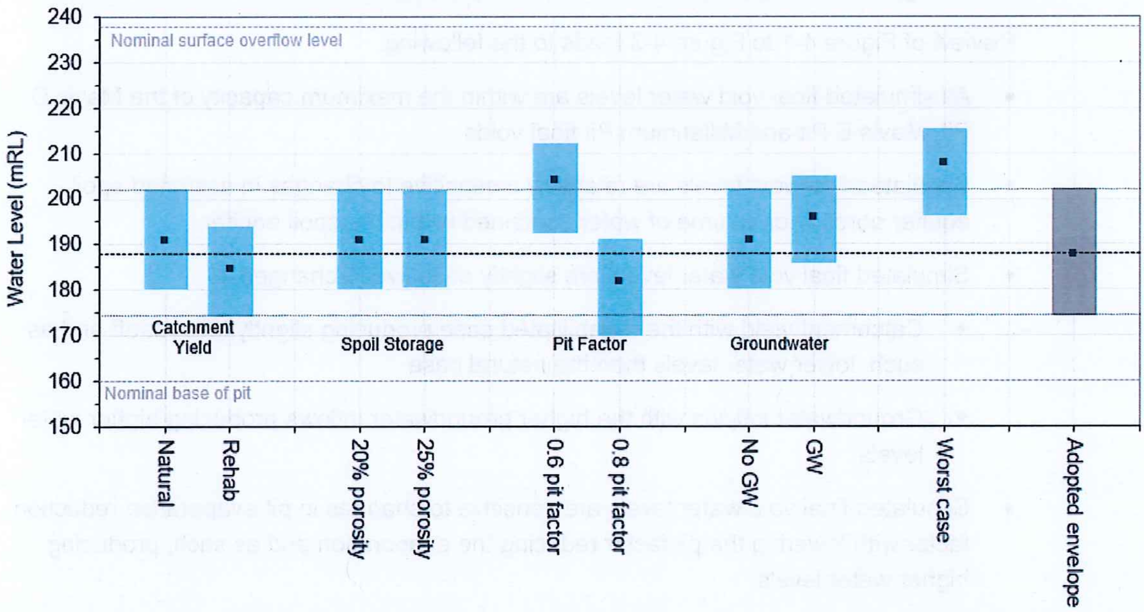

Figure 4-2: Sensitivity Case Outcomes - Mavis E Pit Final Void Water Levels

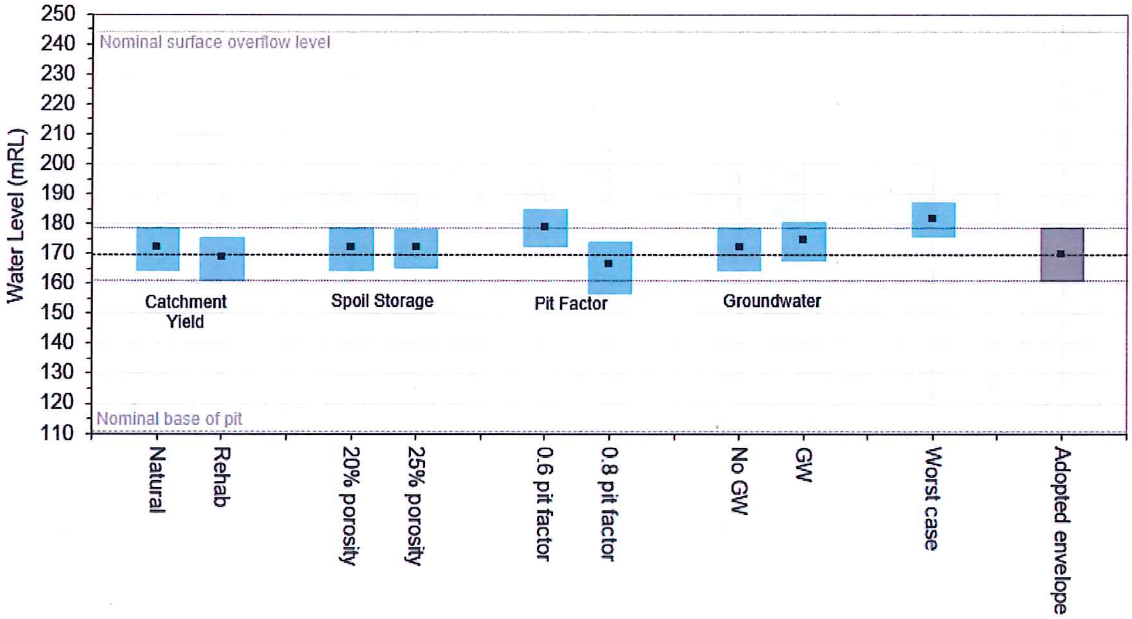

Figure 4-3: Sensitivity Case Outcomes - Millennium Pit Final Void Water Levels

Review of Figure 4-1 to Figure 4-3 leads to the following:

- All simulated final void water levels are within the maximum capacity of the Mavis D Pit, Mavis E Pit and Millennium Pit final voids.
- Simulated final void levels are relatively insensitive to changes in assumed spoil aquifer porosity or volume of water contained within the spoil aquifer.
- Simulated final void water levels are slightly sensitive to changes in:
  - Catchment yield with the rehabilitated case producing slightly less runoff and as such, lower water levels than the natural case.
  - Groundwater inflows with the higher groundwater inflows producing higher water levels.
- Simulated final void water levels are sensitive to changes in pit evaporation reduction factor with lowering the pit factor reducing the evaporation and as such, producing higher water levels.
- The adopted envelopes encompassed the majority of variability with all maximum expected water levels within the envelope with the exception of the groundwater and pit factor.

Sensitivity cases have also been modelled to simulate the impact of multiple parameter changes to produce pronounced dry and wet conditions. Under worst case dry conditions, pit lakes were not predicted to completely dry out during drought periods and under worst case wet conditions there were still no predicted instances of voids overflowing. It is noted that the likelihood of the worst-case scenario eventuating is considered to be very low, due to the compounding probabilities.

5. Conclusions and Recommendations

The MCM final void study has been undertaken in accordance with the scope of work outlined in Hatch proposal 17-3710-BP-AU01-1001 (dated 6th September 2017). This report documents aspects of the study relating surface water including:

- Review of topographic data to define physical characteristics of the proposed final landform design including topography, drainage, catchment areas and stage storage characteristics associated with the final voids.
- Definition of hydrological characteristics of the MCM site (i.e. rainfall, evaporation and catchment yield etc.) based on review of available reports and data.
- Definition of hydrogeological characteristics of the MCM site (i.e. groundwater interactions and associated inflow rates and spoil aquifer storages) based on review of available reports and data.
- Development of final void WBM (OPSIM) and predictive modelling to estimate hydrological characteristics of final voids.

Key outcomes of the current assessment include:

- All three final voids proposed to remain as part of the final landform are expected to maintain permanent pit lakes and to reach equilibrium approximately 100 to 150 years after the cessation of mining.
- Once equilibrium has been reached, the pit lakes within the final voids are expected to fluctuate around a steady-state equilibrium level in response to periods of flood and drought. No voids are expected to reach levels that would result in overflow into downstream watercourse via surface pathways.
- Fluctuations in the pit lake water quality (i.e. EC levels) will continue to occur and be driven by climatic variability as cycles of above and below average rainfall result in rapid water quality fluctuations (i.e. timeframe of years to tens of years) when compared with long term trends of gradual accumulation metals and metalloids (i.e. timeframes of hundreds of years).
- Sensitivity analysis has been undertaken to determine how final void hydrological characteristics vary in response to changes in model parameters. Changes to parameters in isolation generally produce changes in outcomes that fell within the range of results predicted by the base case envelope (which was designed to include some variability in selected parameters). Testing the impact of multiple parameter changes in combination produced more pronounced results; under worst case conditions, there were no predicted instances of voids overflowing. It is noted that the likelihood of the worst-case scenario eventuating is considered to be very low, due to the compounding probabilities and conservative nature of modelled groundwater inflow.

- Net effects of climate change are expected to increase the annual evaporation and reduce the annual rainfall totals in fewer more intense rainfall events (refer Section 2.4.1.4). As the pit lake assessment is primarily focused on establishing the maximum water level, climate change impacts have not been modelled as part of this assessment. This approach will result in a conservative estimate of the pit lake water levels.
- All the pit lakes within the three final voids are expected to provide a relatively stable habitat in an area characterised by ephemeral creek systems and floodplains. The pit lakes should provide a continualy water source that will support opportunistic species that are able to respond to changes in salinity over the long term. These species are likely to thrive and flourish during the wet periods and diminish during the prolonged dry periods (i.e. droughts that may continue for a number of years).

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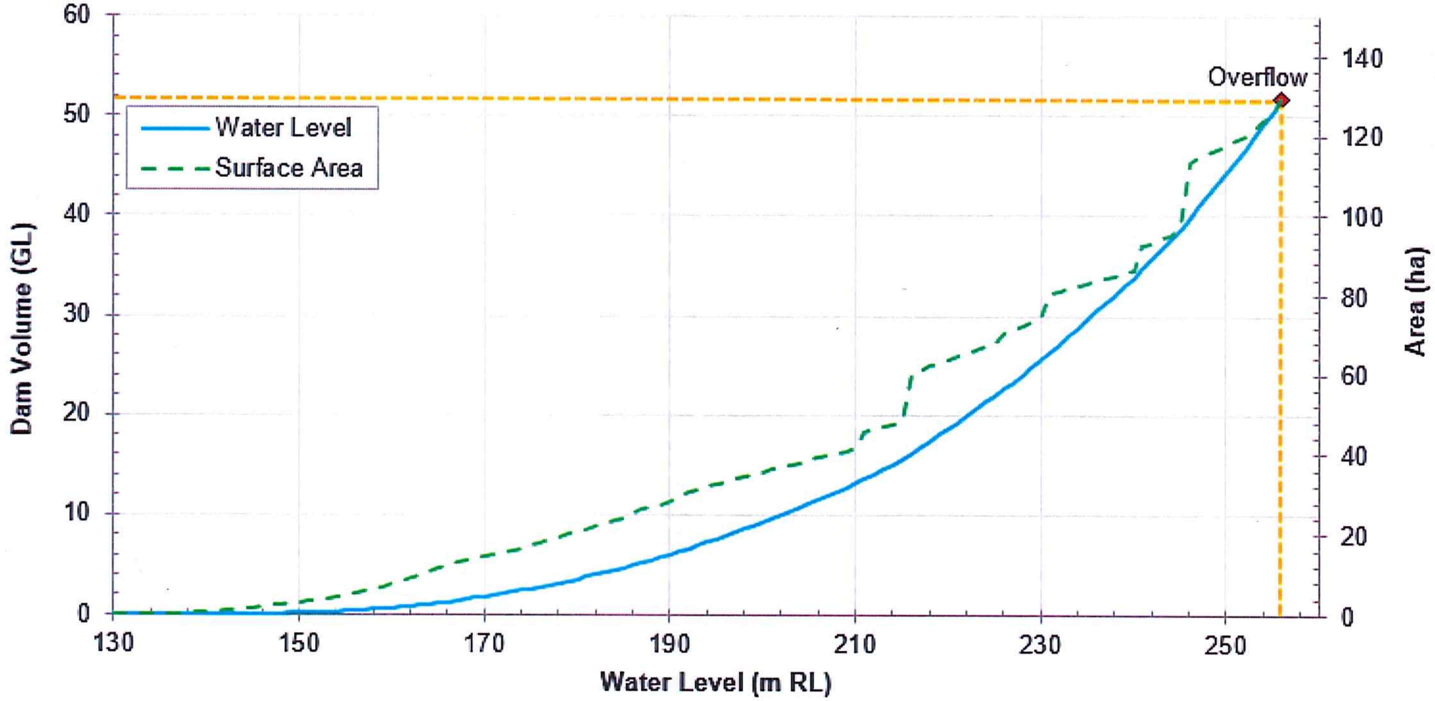
Appendix A
Final Void Stage Storage Curves

(Free Water Volume ONLY)

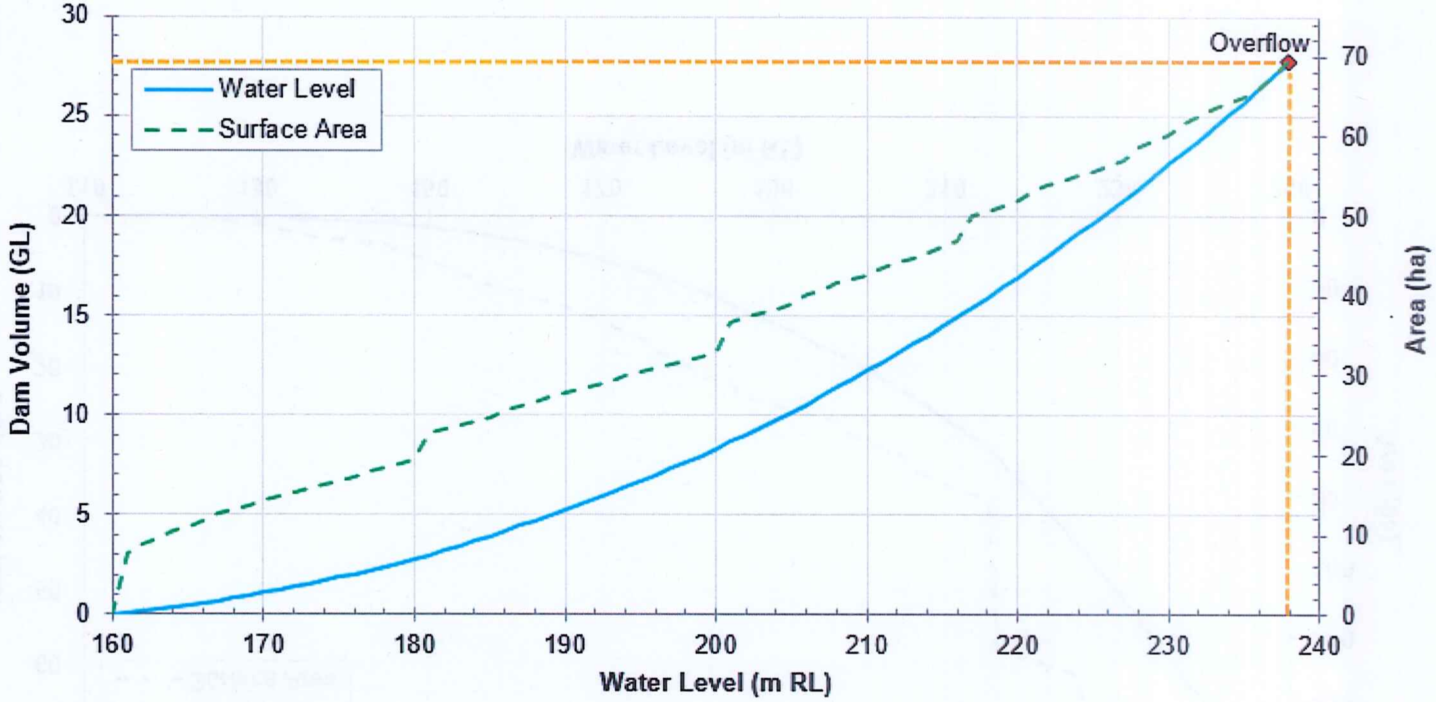
Mavis D Pit

Level (m RL)	Area (ha)	Volume (GL)
130.0	0.0	0.0
140.0	0.7	0.02
150.0	3.2	0.20
160.0	7.8	0.71
170.0	14.6	1.9
180.0	20.8	3.6
190.0	28.4	6.1
200.0	35.9	9.3
210.0	41.8	13.2
220.0	64.0	18.7
230.0	74.4	25.6
240.0	86.5	33.9
250.0	117.6	44.4
260.0	132.4	52.5



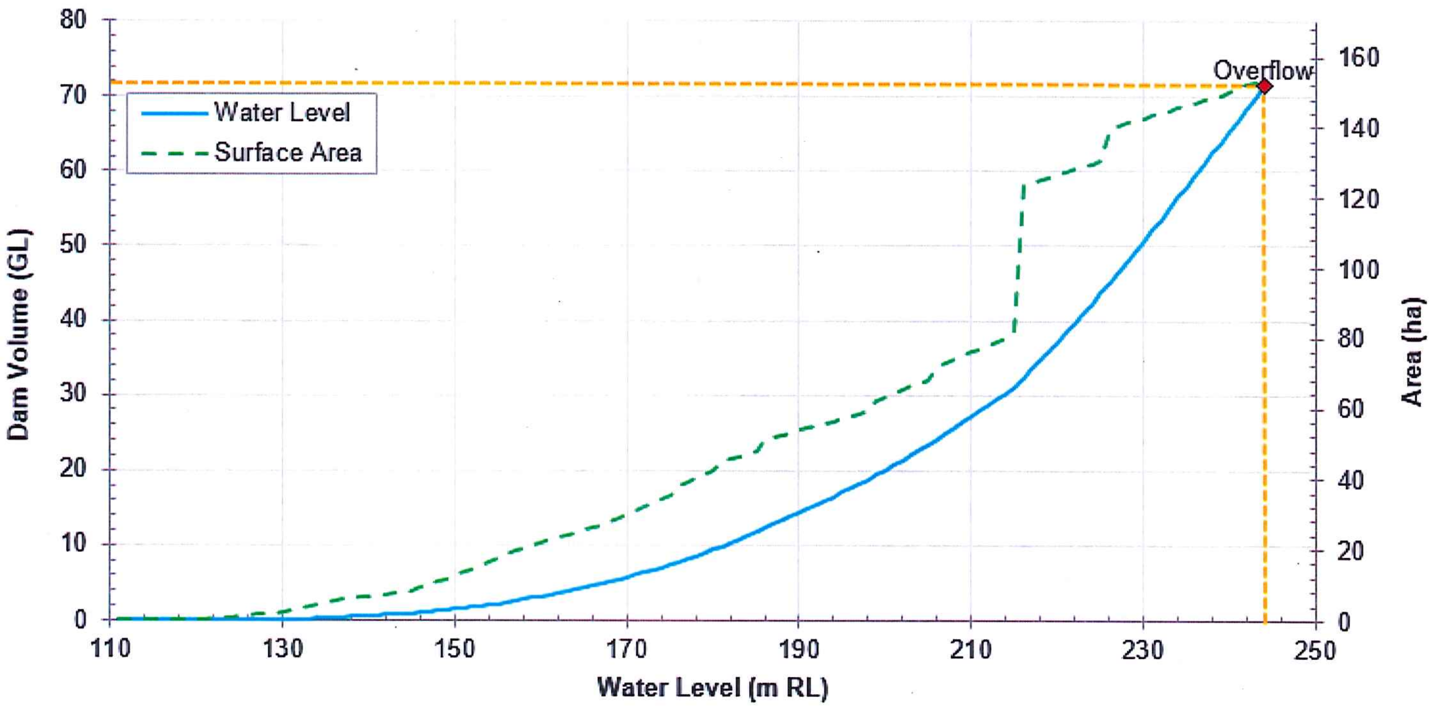
Mavis E Pit

Level (m RL)	Area (ha)	Volume (GL)
160.0	0.0	0.0
170.0	14.3	1.1
180.0	19.5	2.8
190.0	27.7	5.3
200.0	33.0	8.3
210.0	42.7	12.3
220.0	52.0	17.0
230.0	60.2	22.6
238.0	69.5	27.7



Millennium Pit

Level (m RL)	Area (ha)	Volume (GL)
111.0	0.0	0.00
120.0	0.4	0.01
130.0	2.3	0.13
140.0	6.7	0.61
150.0	12.5	1.5
160.0	22.1	3.3
170.0	29.9	5.8
180.0	42.7	9.5
190.0	53.8	14.4
200.0	63.3	20.1
210.0	76.1	27.1
220.0	126.7	37.3
230.0	142.8	50.8
240.0	150.0	65.4
244.0	154.0	71.5



Appendix B – Spoil Water Contribution to Millennium and Mavis Pit Final Voids

Hatch Pty Ltd

Millennium Mine

SPOIL WATER CONTRIBUTION TO MILLENNIUM AND MAVIS PIT FINAL VOIDS

February 2018

JBT consulting

JBT01-062-004

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JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

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APPENDICES

1.0 INTRODUCTION

1.1 Project Description

Millennium Coal owns and operates the Millennium Mine, an open-cut coal mine located approximately 160 km south-west of Mackay and 20 km east of Moranbah. Millennium Coal have commissioned Hatch Pty Ltd (Hatch) to undertake a water balance analysis as part of the closure studies for the Millennium Mine, which includes the Mavis and Millennium pits (pit locations are shown below on Figure 1-1). Hatch have engaged JBT Consulting (JBT) to undertake a groundwater analysis to quantify groundwater inputs to the water balance model.

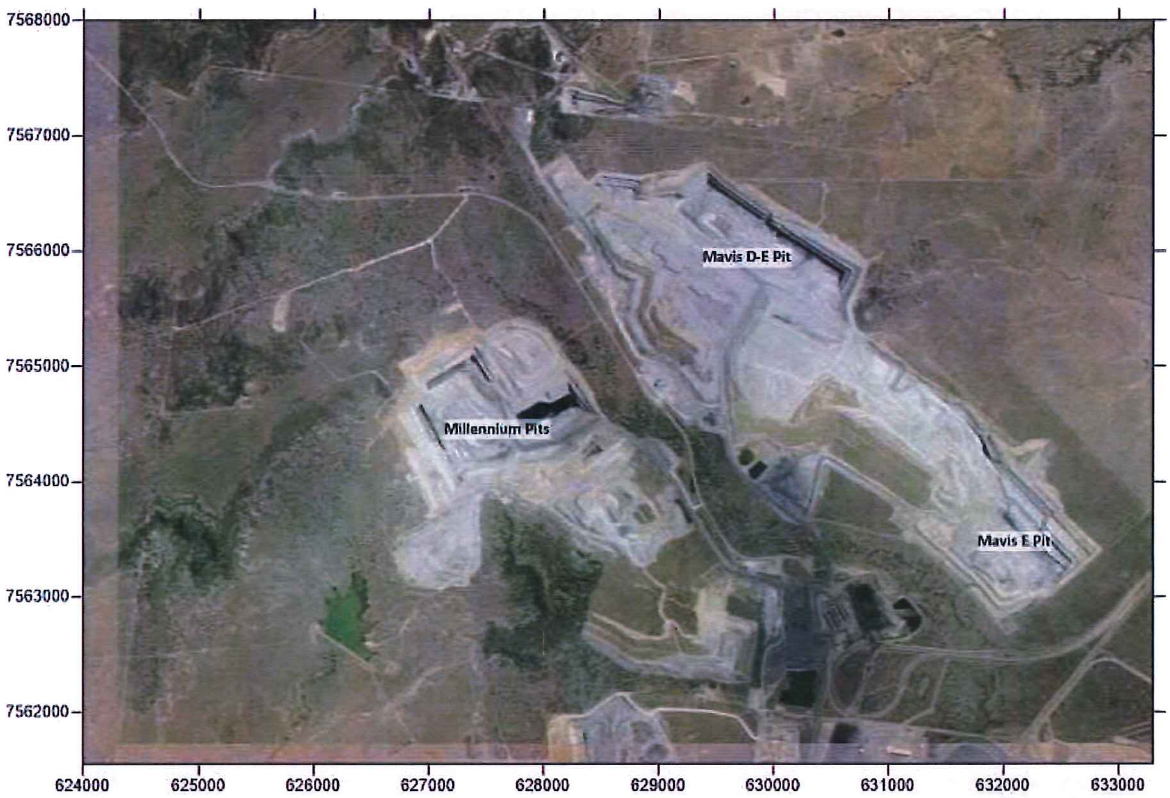

Figure 1-1: Location of Millennium and Mavis Pits at Millennium Mine

1.2 Scope of Work

The scope of work includes the following:

- Review available groundwater data to establish the likely groundwater contribution to the voids;
- Analyse and review available surfaces including deepest mined void and current topography to establish spoil volumes;
- Review the available data to calculate the groundwater storage volume within spoil;
- Prepare stage storage data for groundwater inflow to the final voids at various void water RLs, in a format suitable for Hatch to include in the Opsim water balance model.
- Provide input to the Hatch final report, including development of a technical memorandum (this report) that describes the groundwater assumptions and inputs to the final void modelling, suitable to be included as an appendix to the Hatch final report.

1.3 Available Data

The following data was considered for the groundwater assessment discussed in this report:

- 3-dimensional dxf files of the following surfaces:
  - Current topographic surface over all mining areas;
  - The final landform surface for both the Millennium and Mavis Pit areas;
  - The base of the mined coal seam in each mine, which was used to establish the deepest mined surface for each mining area. For each mine area the deepest mined coal seam is understood to be as follows:
    - Mavis Pit - the Leichhardt Seam; and,
    - Millennium Pit - the Vermont Seam.
- An outline (as dxf file) of the total area mined for each operation;
- A geo-registered aerial photo over the Millennium mining area;

1.4 Assumptions

The following assumptions were made by JBT to allow completion of the scope of works:

- Storage properties (porosity, specific (drainable) yield) are unknown for the spoil at Millennium Mine. Assumptions relating to spoil storage properties are discussed in Section 2 of this report;
- The water level within the spoil is unknown. The assumptions relating to spoil water level are outlined and discussed in Section 2.4 of this report.

2.0 GROUNDWATER STORAGE WITHIN SPOIL

2.1 Introduction

An assessment of the volume of mined spoil that could contribute water to the final void has been calculated for each open cut pit, to allow inclusion of the spoil water volume within the final void water modelling that has been undertaken by Hatch. Mined spoil tends to become a distinct groundwater unit and can have a significant impact on final void hydrology, for the following reasons (refer to Figure 2-1 for a schematic diagram that illustrates the concepts discussed below):

- The final void is the visible expression of a much larger mined area, with the previously mined area generally backfilled with spoil. In some cases, the total volume of water stored within the pore spaces of the spoil may be significantly greater than the volume of water that is contained within the final void;
- The catchment area for the final void will include some or all of the spoil area. In cases where the totality of the mined area drains towards the final void, the catchment area for the void may include all of the spoil area, even though the surface topography may suggest that the catchment area of the final void is smaller, based on the location of the surface water catchment divide (Figure 2-1);
- The final void is generally present at the deepest point in the excavation, as mining generally extends down-dip. Therefore, a significant volume of water that recharges the spoil can report to the final void via gravity drainage or, as the final void fills, a component of water can enter into storage within the spoil. The volumes of water that can be stored within the spoil, and which can impact on final void hydrology, are potentially significant; and,
- Water that recharges the spoil will have its chemistry altered to some degree by interaction with the spoil, which can impact the chemistry of the void lake as groundwater from the spoil aquifer seeps into the void.

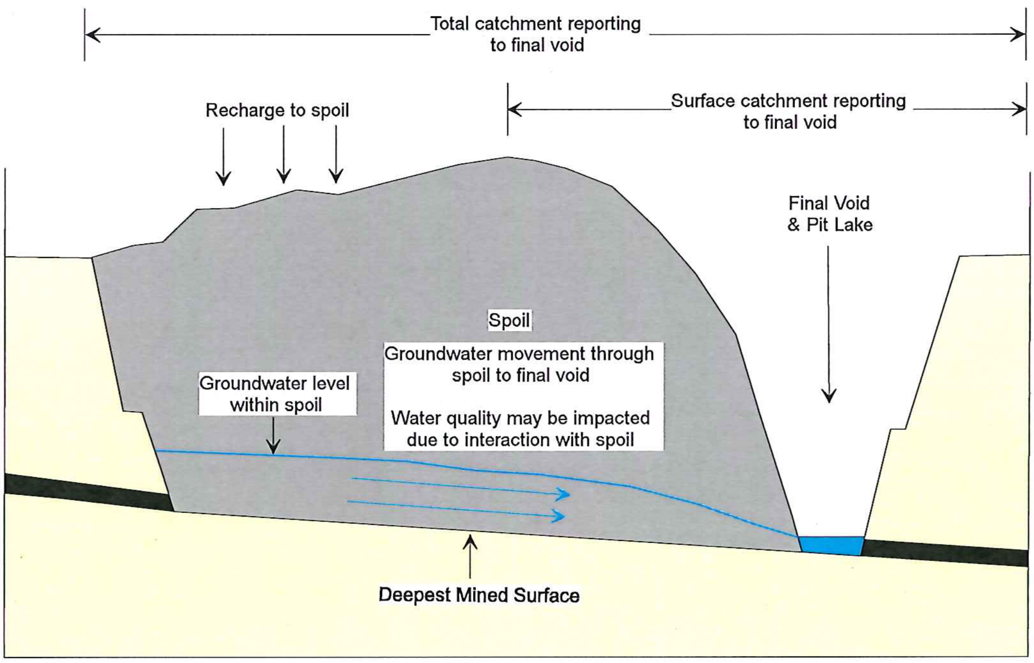

Figure 2-1: Schematic Representation of Spoil Aquifer/ Final Void Relationship

2.2 Groundwater Characteristics of Mined Spoil

Mined spoil has unique characteristics compared to other groundwater units, as summarised below:

- Spoil tends to be extremely heterogeneous (the aquifer properties differ at different locations within the spoil pile) and anisotropic (the hydraulic properties at one location may differ in the x, y and z directions) relative to naturally formed hydrogeological units;
- The hydraulic conductivity of spoil can vary significantly both spatially (i.e. at different places within the spoil pile) and temporally (i.e. the hydraulic conductivity may change over time as the spoil settles and becomes more compacted). One study of surface coal mines from five separate mining areas of the northern Great Plains area of the United States reported a six order of magnitude range in hydraulic conductivity values for spoil, with a range between 10^{-3} and 10^{-9} m/s, a mean of 8×10^{-7} m/s and a 1.5 order of magnitude standard deviation (Rehm et al. 1980). It was concluded that the variability in hydraulic conductivity was due to factors such as:
  - The original lithology and the variability in the material being dumped (i.e. sandstone vs siltstone vs mudstone vs coal etc.);
  - Variability in grain size (with spoil tending to be a poorly-sorted assemblage with a grain size varying from clay/silt to cobble/boulder fractions);
  - The method of spoil handling and re-shaping; and,
  - The time of year during which spoil is handled (e.g. whether the spoil was wet or dry when being reshaped and compacted by dozers).
- When spoil is dumped by truck or dragline and regraded by bulldozers, larger spoil particles tend to roll downwards towards the valley created between adjacent spoil ridges. This can result in the presence of higher permeability conduits at the base of spoil piles relative to the permeability of the finer-grained sediments at the crest (i.e. preferred pathways for groundwater flow). The pattern of dumping may also create a strong directional anisotropy within the spoil pile;
- The characteristics of groundwater flow may change when the groundwater system is being stressed (e.g. during pumping or recharge events). Under relatively steady-state conditions (e.g. between recharge events, or when no groundwater pumping is occurring), spoil may act as a porous medium aquifer, where groundwater flow occurs through a series of inter-connected pores. However, when subjected to transient conditions (e.g. during aquifer stressors such as recharge events, the onset of pumping etc.), double-porosity conditions may apply for some period (i.e., the spoil responds to aquifer stressors in a similar manner to a fractured rock aquifer where flow occurs primarily through preferred pathways (analogous to fractures), while groundwater in the material between the preferred pathways is released (or recharged) more slowly (Hawkins and Aljoe 1992);
- Multiple water tables (i.e. perched aquifer systems) may exist in the short-term when the spoil aquifer system is placed under stress (due to recharge, pumping etc.). However, spoil tends to be relatively free-draining and under relatively steady-state conditions the spoil generally contains only one water table (Hawkins 1998);
- The dip of the pit floor is a significant determining factor in the direction of groundwater flow (Hawkins 1998).

2.3 Volume of Spoil Within Each Mining Area

An assessment has been undertaken for the Millennium and Mavis Pit mining areas of the area and volume of spoil that could contribute to the final void (i.e. either providing water to the void or providing additional storage of void water, depending on the RL of the void lake). The assessment of each final void was undertaken as follows:

- For each mining area, a surface was produced of the lowest mined coal seam over the area of mining. Data for the lowest mined coal seam was supplied for this study by Peabody. The deepest mined surface, as well as the assumed extent of mining, is shown as the upper right figure in Figure 2-2 for the Mavis Pit and Figure 2-3 for the Millennium Pit. Note that for the Mavis pit, the contours of the deepest mined surface are skewed at the location of mapped faults, which are also shown on Figure 2-2;
- Contours for the final landform were generated over the area of each mine, based on data from dxf files provided by Hatch (lower left figure on Figures 2-2 and 2-3);
- For each pit, the area of the final void lake was determined, in conjunction with Hatch personnel (shown on lower left and lower right figures on Figures 2-2 and 2-3);
- The total volume of spoil within the mining area was determined via grid-to grid subtraction, i.e. the grid for the deepest mined surface (described in (2) above) was subtracted from the final landform surface (described in (3) above) to produce a grid file of the total thickness of mined spoil. Because the surface described in (2) above includes the deepest mined surface within the final void area, the final void area has a zero thickness of spoil. The calculated thickness of spoil is shown as the lower right plot in Figure 2-2 (Mavis pits) and Figure 2-3 (Millennium pits)

The total volume of spoil water storage was then determined, via the process outlined below in Section 2-5.

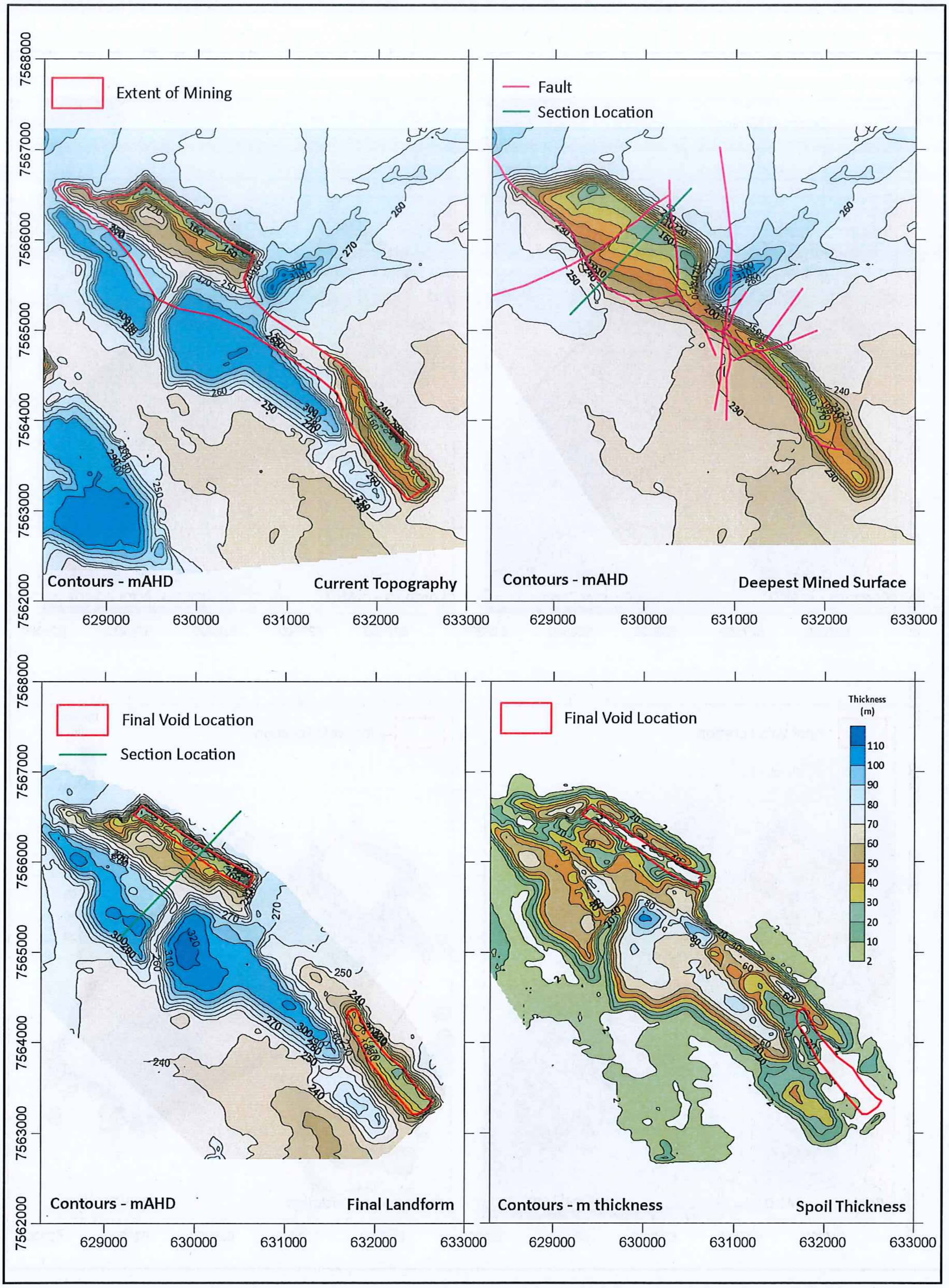

Figure 2-2: Mavis Pit – Current topography, deepest mined surface, final landform and spoil thickness

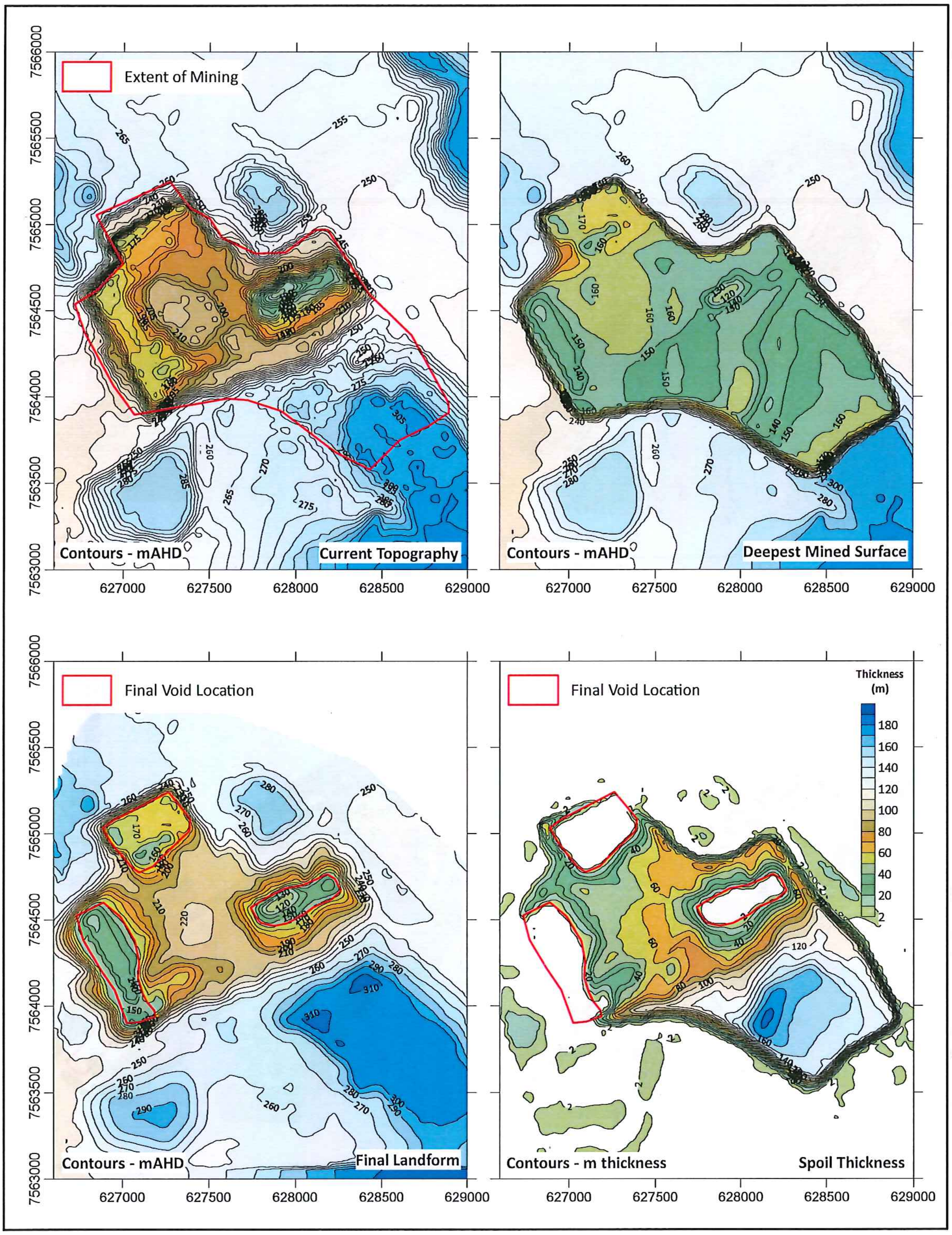

Figure 2-3: Mavis Pit – Current topography, deepest mined surface, final landform and spoil thickness

2.4 Groundwater Level within Spoil

The location of the water table within spoil is generally poorly known, due to the practical and operational difficulties of installing and maintaining monitoring bores within spoil. However, a 2004 study of coal mine spoil from mines in the Appalachian Plateau of the U.S. (Hawkins 2004) concluded that the predicted saturated interval of spoil (i.e. the interval between the water table and the base of spoil) averages 19% of the spoil thickness (i.e. nearly 1 m of saturated zone for every 5 m of spoil thickness) and is related to factors such as:

- The overall thickness of the spoil;
- The lithology of the spoil (the ratio of sandstone to shale);
- The dip of the pit floor;
- The age of the spoil; and,
- The distance to the highwall

There are no groundwater bores within the spoil at Millennium Mine, therefore it was necessary to predict the groundwater level via some other means (as the current water level in the spoil would have an impact on the available additional water storage area within the spoil when the water level in the final voids is increased). The predicted current water surface within the spoil was generated as follows (refer also Figure 2-4, which shows a cross section through the Mavis Pit (refer Figure 2-2 for Section location) and describes the inputs to the spoil water assessment

- It was assumed for each assessment that the final void is initially dry (i.e. that there is no existing pit void lake);
- The thickness of saturated spoil was calculated, based on an assumption that 19% of the total available spoil thickness at any given location was saturated (Hawkins 2004). The total thickness of saturated spoil was then added to the RL of the deepest mined surface to create a groundwater RL surface for water within the spoil. For the region west of the Mavis Pit final void on Figure 2-4, the dark blue line represents a groundwater surface that is based on being 19% of the thickness of the interval between the red line (deepest mined surface) and the brown line (final landform, i.e. top of spoil).

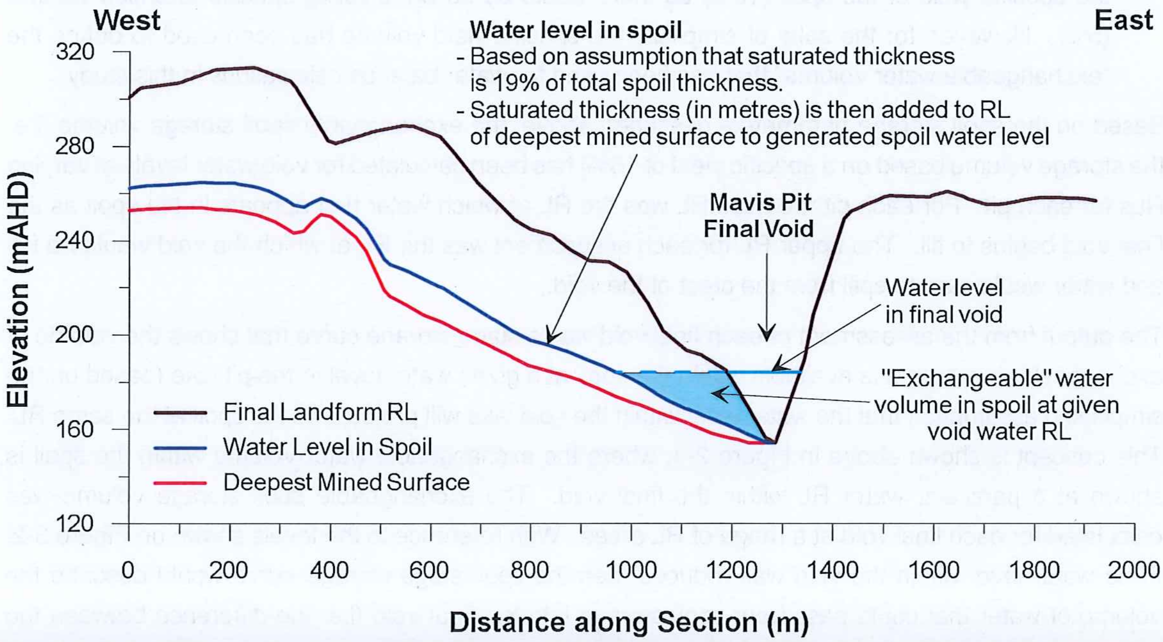

Figure 2-4: Schematic Cross Section Showing Components of Spoil Water Assessment

2.5 Spoil Storage Volume

The spoil has a capacity to store and exchange significant volumes of water with the final voids. Without consideration of water storage in the spoil, the void water level would rise more quickly in response to rainfall and fall more quickly in response to evaporation and pumping. Consideration of the storage capacity of the spoil will mean that the void water level will rise less quickly in response to rainfall (as additional water will be stored within the spoil) and fall less quickly in response to evaporation or pumping (as a reduction in void water level will release additional water from storage within the spoil).

The volume of water stored within and released from spoil will be dictated by the following parameters:

- The porosity of the spoil, which will dictate the maximum volume of water that can be stored within the spoil. The porosity of the spoil for the Millennium Mine is unknown. A review of a number of papers from studies of U.S. coal mines (e.g. Hawkins 2004, Rehm et al. 1980) present significantly different porosity values for spoil, though the higher values (which tend to be derived from laboratory tests) tend to be rejected by the authors as being unrepresentative of field conditions. In-situ spoil porosity values were reported to range from around 15 to 25%. A spoil porosity value of 20% has been assumed for this study;
- The specific yield of the spoil, which dictates the volume of water than can drain from the spoil under gravity drainage conditions. The specific yield of the spoil at the Millennium Mine is unknown. A specific yield value of 15% has been assumed for this study;
- The specific retention is the volume of water that is retained by the spoil (e.g. water adhered to grains or trapped within small pores or hydraulically disconnected pore spaces) once gravity drainage has occurred. For a spoil porosity of 20% and a specific yield of 15%, the specific retention will be 5%.
- The specific yield value represents the exchangeable yield of the spoil, i.e. the specific yield is the value that is used to calculate the volume of water that will drain from a given spoil volume as the water level in the void lake is lowered as well as the volume of water that can fill the spoil if the water level in the void lake is increased. It is noted that, for completely unsaturated spoil, an initial increase in the water level of the void lake would fill the total porosity of the spoil (20%) rather than the specific yield of the spoil (15%) as there would be no pre-existing specific retention volume (5%). However, for the sake of simplicity the specific yield volume has been used to define the "exchangeable water volume" that has been used for water balance calculations in this study.

Based on the spoil storage parameters described above, the exchangeable spoil storage volume (i.e. the storage volume based on a specific yield of 15%) has been calculated for void water levels at varying RLs for each pit. For each pit the base RL was the RL at which water first appears in the spoil as the final void begins to fill. The upper RL for each assessment was the RL at which the void would be full and water would start to spill from the crest of the void.

The output from the assessment of each final void was a stage storage curve that shows the volume of exchangeable water that is available within the spoil at a given water level in the pit lake (based on the simplifying assumption that the water level within the void lake will project into the spoil at the same RL. This concept is shown above in Figure 2-4, where the exchangeable water volume within the spoil is shown at a particular water RL within the final void. The exchangeable spoil storage volume was calculated for each final void at a range of RL slices. With reference to the levels shown on Figure 3-2, if the water level within the void was reduced then the spoil stage storage curve would describe the volume of water that could pass from spoil storage into the final void (i.e. the difference between the storage volumes between the starting RL and new RL of water within the void). Similarly, if the water level in the void were to increase, then the spoil stage storage curve would describe the additional volume of water that could be stored within the spoil at the new final void water level.

The drainable yield calculations and stage storage curves have been provided to Hatch for inclusion in the Opsim water balance model and are included in this report as Appendix A-1 (Mavis pits) and Appendix A-2 (Millennium pits). Note that the data in Appendices A-1 and A-2 include the calculation of drainable storage volumes for a specific yield of 15% (the value assumed for this study) as well as for a 5% higher specific yield of 20%. This assessment is included to highlight the change that a relatively small increase in specific yield can have on the calculated drainable yield value of the spoil.

3.0 CONCLUSIONS

- An assessment has been undertaken of the volume of water that is contained with the open cut spoil in the Millennium and Mavis mining areas that could interact with the final voids. This data is presented in Section 2 and Appendix A and has been provided to Hatch Pty Ltd for inclusion in final void water balance modelling;
- The calculations of spoil storage volumes are sensitive to a number of parameters that are either unknown or poorly known at Millennium Mine (consistent with the majority of Australian coal operations), including:
  - The porosity and specific yield (drainable yield) of the spoil, which will dictate the volume of water that can be stored and/or released from spoil);
  - The recharge characteristics of the spoil; and,
  - The current water level within the spoil;
- The calculations of spoil drainable yield are included in Appendix A for specific yield (drainable yield) values of 15% and 20%. The relatively large change in storage for a relatively small change in specific yield highlights the sensitivity of calculations to changes in storage volumes; and,
- An improved understanding of the factors outlined above (i.e. spoil storage properties) would improve the predictions of drainable yield volumes that have been presented for use in final void water balance models.

4.0 REFERENCES

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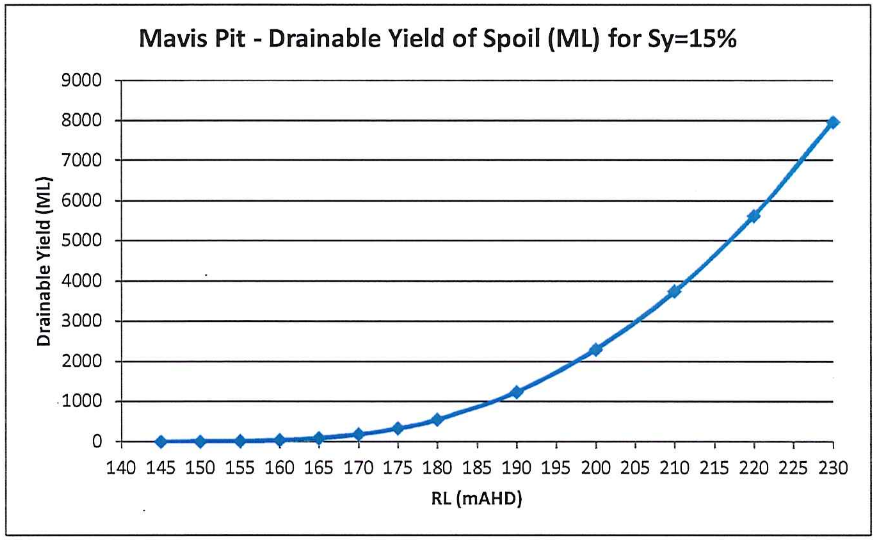
APPENDIX A

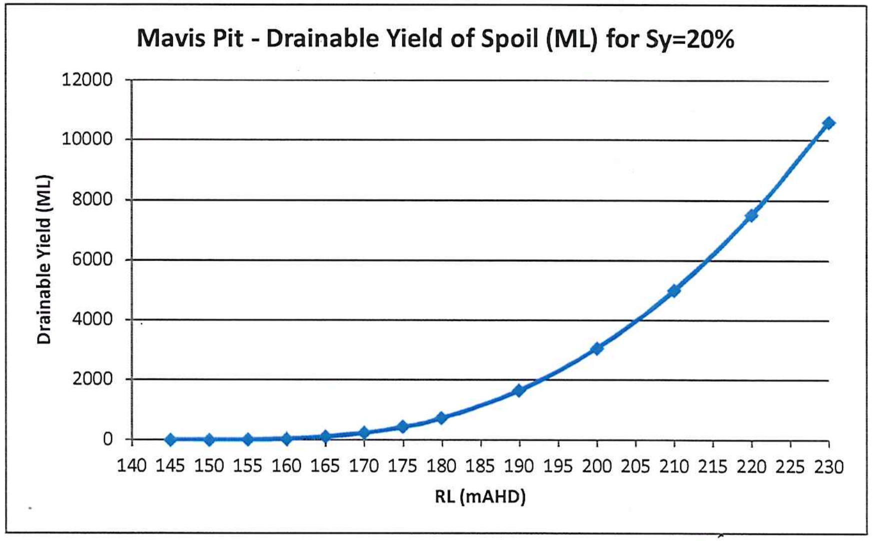
DRAINABLE YIELD CALCULATIONS FOR FINAL VOIDS

Appendix A-1 - Drainable Yield Calculations for Spoil at Mavis Pit

RL	Saturated Spoil Volume (m3)	Porosity (%)	Volume of Contained Water (ML)	Specific Yield (Sy) (%)	Drainable Yield (ML)
143	257	20	0.05	15	0.04
145	2195	20	0.44	15	0.33
150	22354	20	4	15	3
155	85594	20	17	15	13
160	228195	20	46	15	34
165	567381	20	113	15	85
170	1194600	20	239	15	179
175	2180217	20	436	15	327
180	3644901	20	729	15	547
190	8222811	20	1645	15	1233
200	15353480	20	3071	15	2303
210	24994864	20	4999	15	3749
220	37585325	20	7517	15	5638
230	53085381	20	10617	15	7963

RL	Saturated Spoil Volume (m3)	Porosity (%)	Volume of Contained Water (ML)	Specific Yield (Sy) (%)	Drainable Yield (ML)
143	257	25	0.06	20	0.05
145	2195	25	0.55	20	0.44
150	22354	25	6	20	4.5
155	85594	25	21	20	17
160	228195	25	57	20	46
165	567381	25	142	20	113
170	1194600	25	299	20	239
175	2180217	25	545	20	436
180	3644901	25	911	20	729
190	8222811	25	2056	20	1645
200	15353480	25	3838	20	3071
210	24994864	25	6249	20	4999
220	37585325	25	9396	20	7517
230	53085381	25	13271	20	10617

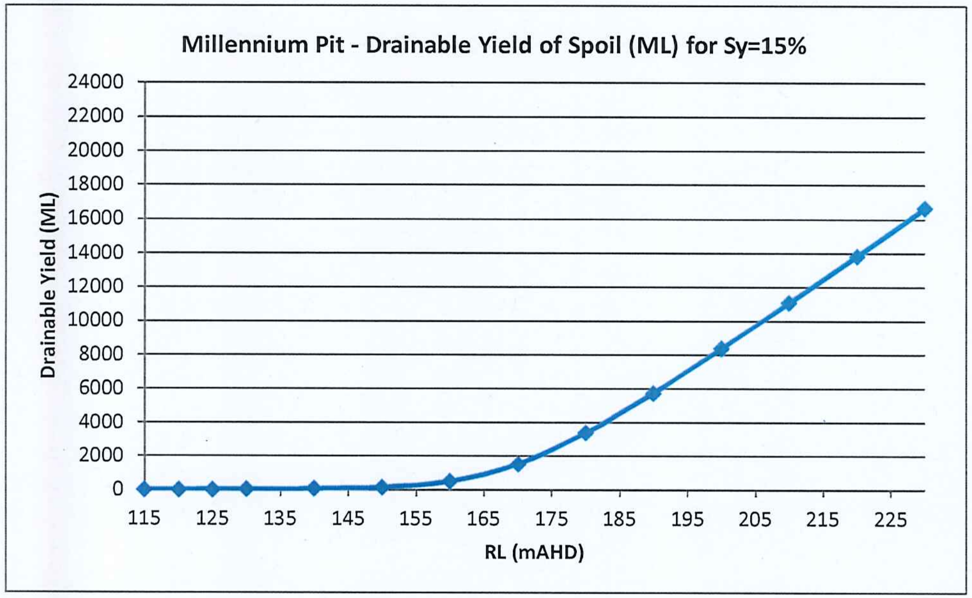


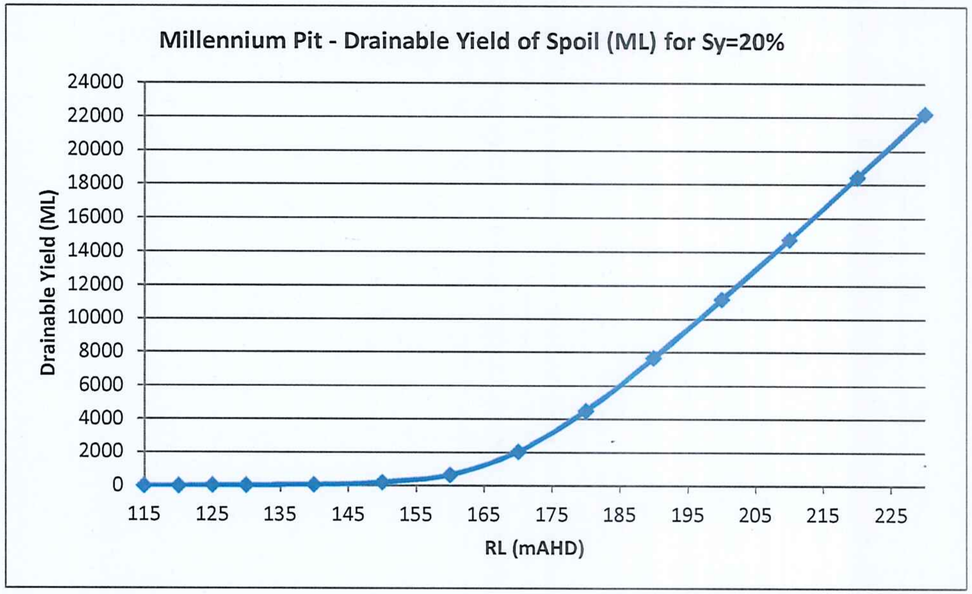


Appendix A-2 - Drainable Yield Calculations for Spoil at Millennium Pit

RL	Saturated Spoil Volume (m3)	Porosity (%)	Volume of Contained Water (ML)	Specific Yield (Sy) (%)	Drainable Yield (ML)
115	0	20	0	15	0
120	19972	20	4	15	3
125	66863	20	13	15	10
130	139073	20	28	15	21
140	387285	20	77	15	58
150	1006060	20	201	15	151
160	3256253	20	651	15	488
170	10169818	20	2034	15	1525
180	22506330	20	4501	15	3376
190	38355187	20	7671	15	5753
200	55795403	20	11159	15	8369
210	73788037	20	14758	15	11068
220	92172736	20	18435	15	13826
230	110921710	20	22184	15	16638

RL	Saturated Spoil Volume (m3)	Porosity (%)	Volume of Contained Water (ML)	Specific Yield (Sy) (%)	Drainable Yield (ML)
115	0	25	0	20	0
120	19972	25	5	20	4
125	66863	25	17	20	13
130	139073	25	35	20	28
140	387285	25	97	20	77
150	1006060	25	252	20	201
160	3256253	25	814	20	651
170	10169818	25	2542	20	2034
180	22506330	25	5627	20	4501
190	38355187	25	9589	20	7671
200	55795403	25	13949	20	11159
210	73788037	25	18447	20	14758
220	92172736	25	23043	20	18435
230	110921710	25	27730	20	22184





Appendix C – Residual Void Slope Stability Study

GCS GEOTECHNICAL CONSULTING SERVICES

MILLENNIUM MINE

RESIDUAL VOID SLOPE STABILITY STUDY

For

MILLENNIUM COAL PTY LTD

Report No. 170
August 2017

MILLENNIUM MINE

RESIDUAL VOID SLOPE STABILITY STUDY

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MILLENNIUM MINE

RESIDUAL VOID SLOPE STABILITY STUDY

Geotechnical Consulting Services Pty Ltd — Barry Ward
Report No. 170 — August 2017

1. INTRODUCTION

Mining commenced at the Millennium Mine complex in 2005, with a current projected finish to opencut truck and shovel mining in late 2018, after which it is proposed to conduct highwall scavenging using highwall augering or highwall mining methods.

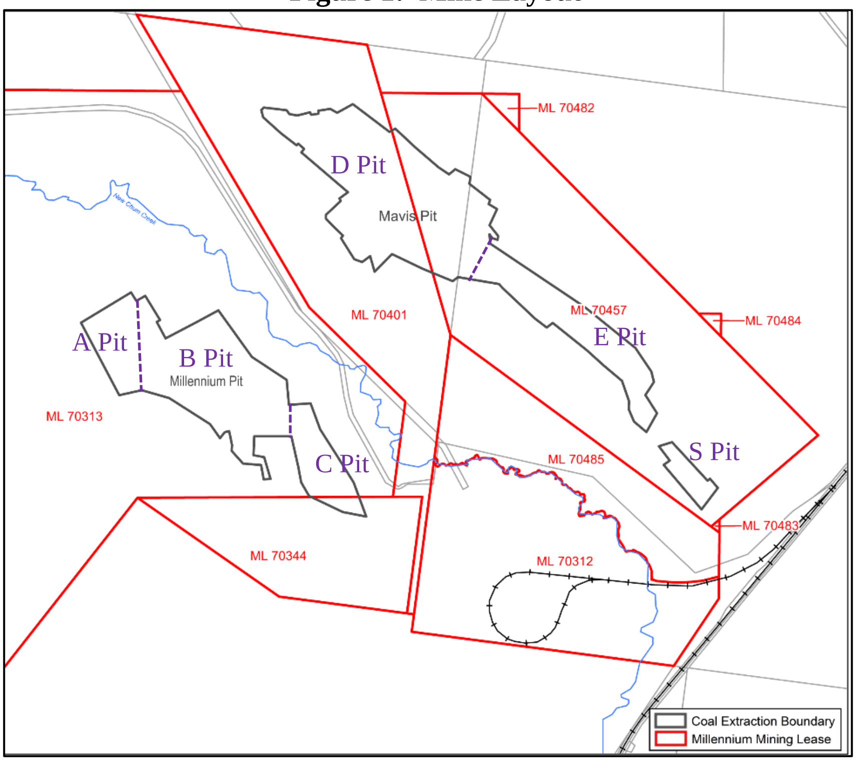
Under the conditions of Environmental Authority Permit No.EPML00819213, Clause F7 (d), a pit wall stability study must be undertaken with proposals for meeting the residual void design. A geotechnical site inspection was accordingly undertaken during the period 8 to 12 May 2017 to assess the stability of the pit walls and dumps with respect to final void conditions.

This report presents an assessment of the geotechnical stability of highwall and low wall slopes and provides an indication of the remedial measures needed to achieve geotechnical stability. It is based on the site inspection, discussions on site and slope stability calculations where appropriate.

2. MINE LAYOUT

Figure 1 shows the general layout of the Millennium Mine complex, with mining leases and opencut pit areas. The mine site comprises two opencut mining areas, Millennium Pit and Mavis Pit, which are separated by a major fault system. Mining is by truck and shovel in both cases. New Chum Creek runs between the two mining areas.

Figure 1: Mine Layout



Millennium Pit was originally developed as three conjoined pits, A Pit, B Pit and C Pit, the mining areas being separated by major fault systems. B Pit and C Pit have been mined out with current mining confined to A Pit. Mining is on a block basis against advancing highwalls on two sides with an advancing in-pit spoil dump on the south-east side.

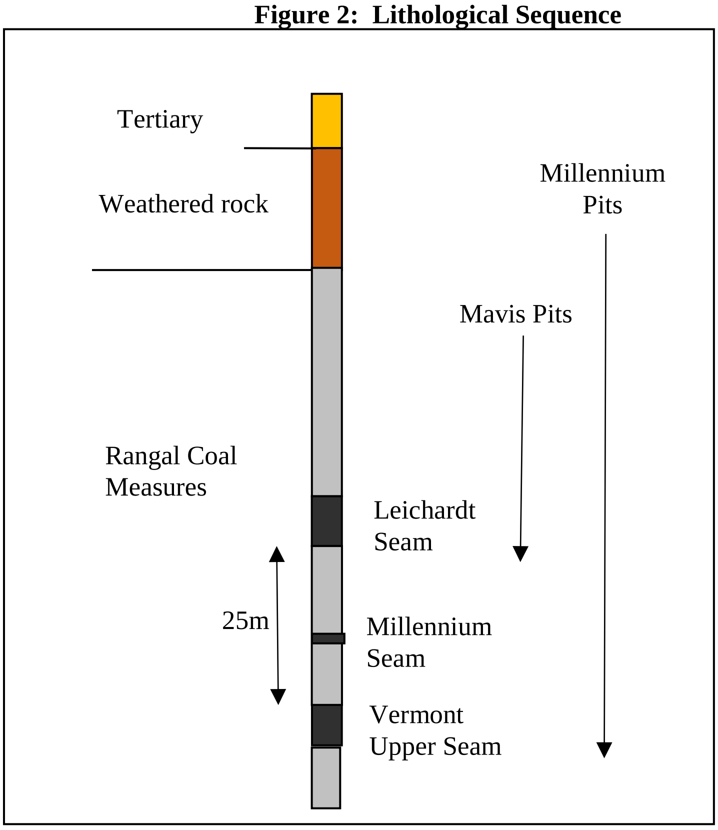
Mavis Pit comprises the conjoined D Pit and E Pit, with the small S Pit at the southern end of the strip, now combined with E Pit. Mining is in down-dip strips with a highwall advancing towards the north-east and with spoil dumping on the low wall side and externally out-of-pit. S Pit was excavated as a boxcut which was then used for water storage between 2013 and 2017. It has since been dewatered with another two strips currently being excavated. Opencut mining has ceased in E Pit, except for the southern end which is being linked up to S pit. D Pit has reached its down-dip limit but there is a possibility of extending the pit to the north depending on arrangements with the adjacent leaseholder (Carborough Downs Mine).

Highwall augering has been undertaken at Millennium Mine on three occasions in 2008, 2011 and 2015/6, and is currently underway in D/E Pits. Further augering or highwall mining is under consideration for remaining exposed highwalls in both Millennium and Mavis Pits as a post opencut mining operation.

3. GEOLOGY

Millennium coal mine is situated in the Rangal Coal Measures in the northern part of the Bowen basin. A generalised succession of strata is illustrated in Figure 2 below.

Figure 2: Lithological Sequence



The main units forming the overburden are:

Tertiary/residual soil: mostly sand and silt, with some clay
Weathered rock: weak to moderately strong brown sandstone, siltstone
Coal Measures: moderately strong to strong grey siltstone and sandstone

The sandy superficial deposits are generally between 2m and 10m thick, beneath which is weathered rock to a depth (base of weathering) of between 20m and 30m. These layers are generally mined as free-dig benches.

Fresh rock comprises thinly interbedded sandstone and siltstone typical of Rangal coal measures overburden. The main overburden down to the Leichardt Seam contains thicker beds of stronger sandstone, with finer grained laminite forming the interburden between the seams. The rock overburden is up to 70m in the highwalls.

The main target seam for both mining areas is the Leichardt Seam, which is typically about 4.5m thick. The 2.0m thick Vermont Upper Seam occurs 20m to 30m below the Leichardt Seam and is mined in Millennium Pit only. The lesser 0.7m thick Millennium Seam, which occurs at a variable location within the interburden, is also a possible target seam but is not normally taken during mining operations.

The seams generally dip at less than 10^0 (between 3^0 and 10^0) within the pits in a direction generally between south-west and north-northwest but the strata are interrupted by large scale reverse faults with local steepening of the dip. The main structural disturbance at Millennium is the A/B Fault which runs NNW-SSE and separates A Pit from B Pit. This fault dips at between 25^0 and 35^0 to the west and has a vertical displacement of about 80m. There are however numerous lesser faults at various orientations.

Mavis Pit is highly disturbed with a number of major faults intersecting the highwalls plus strike faults along the pit. Local steepening of the pit floor in association of these faults is not uncommon.

The groundwater table varies from 17m to 54m below ground level, with an average depth of 32m for the mining areas.

4. SLOPE DESIGN

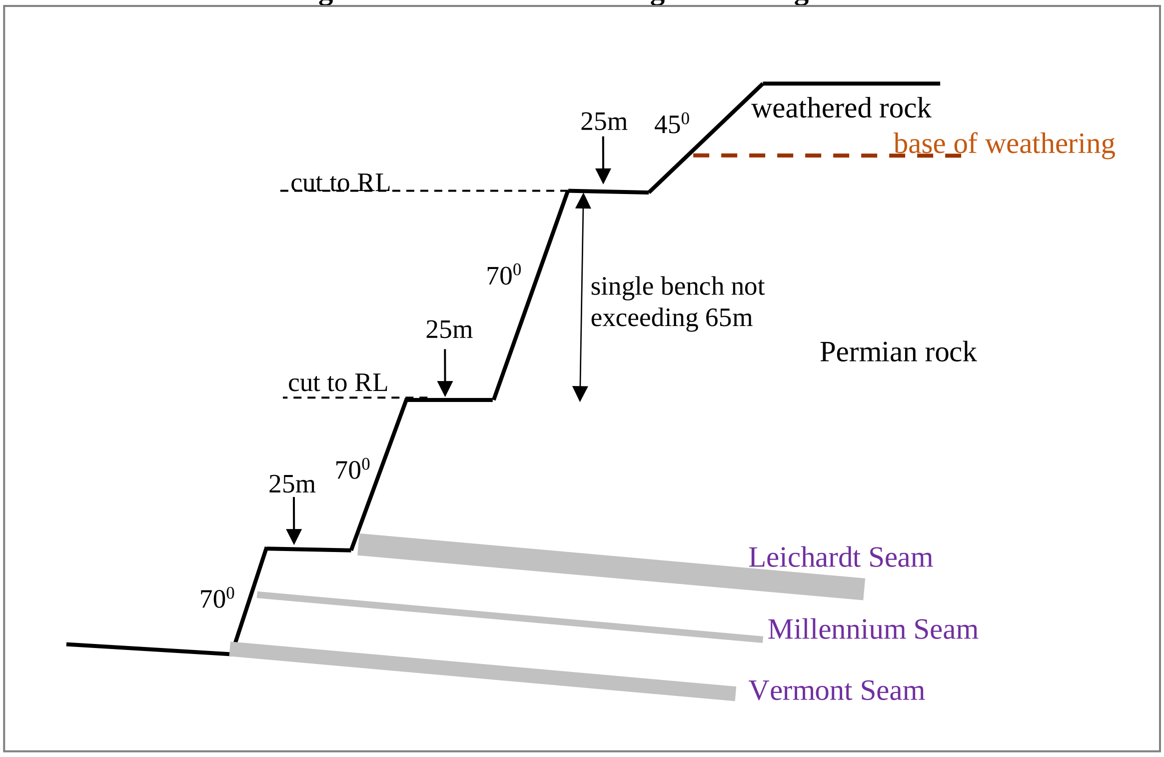
4.1 Highwalls and Endwalls

The standard slope design for insitu walls is illustrated in Figure 3 below. The main points are:

- Berms are designed to RL to ensure consistent drilling horizons, unless following a floor of coal;
- Batter angle in the superficials/weathered rock is 45^0;
- Rock benches are pre-split at 70^0;
- The maximum bench height in rock is 65m;

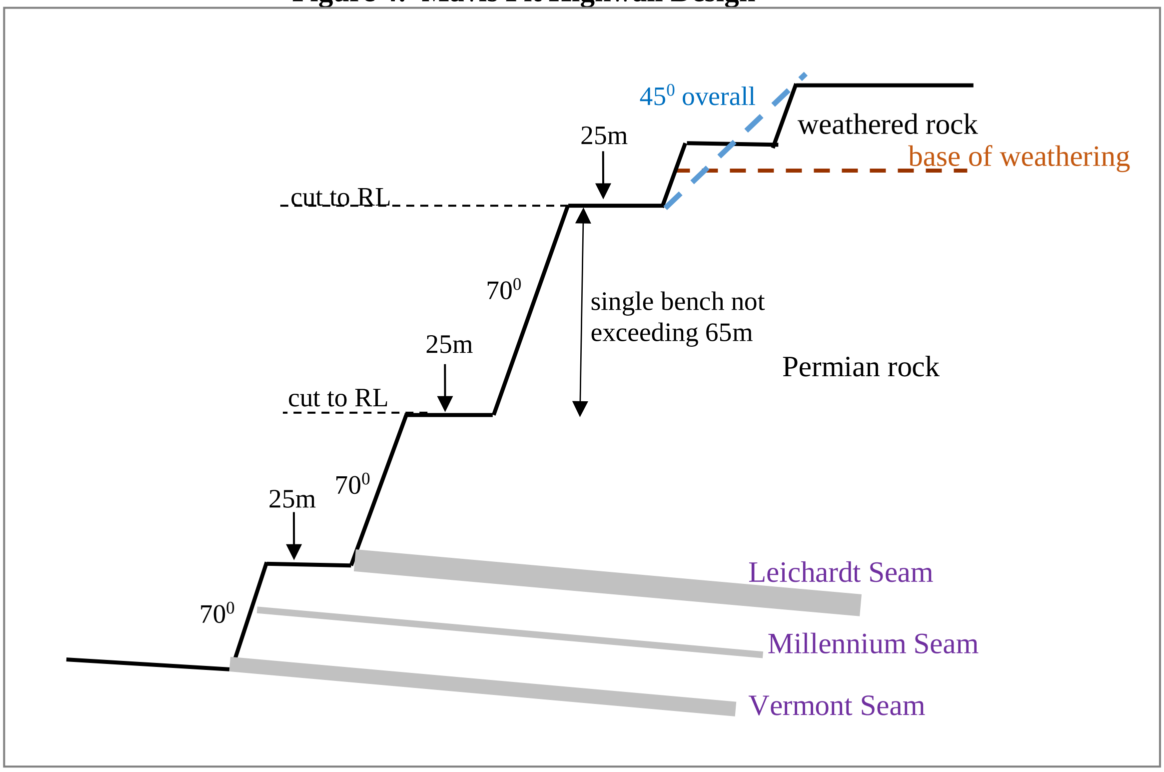
This design is used for all insitu side wall slopes in normal conditions; modifications may be made for local situations where fault zones intersecting the walls and could create conditions of instability.

Figure 3: Millennium Pit Highwall Design



A 'rough-cut' design variation is used in Mavis Pits where the soft overburden is dug by excavator. In this case the top bench through softer ground (soil/Tertiary/weathered Permian) is excavated as two individual benches cut to suit the excavator swing, with a berm of suitable width to ensure the overall slope angle of both benches does not exceed 45^0. This variation is shown in Figure 4 below.

Figure 4: Mavis Pit Highwall Design



The photo below shows a typical highwall representation.

E Pit Highwall

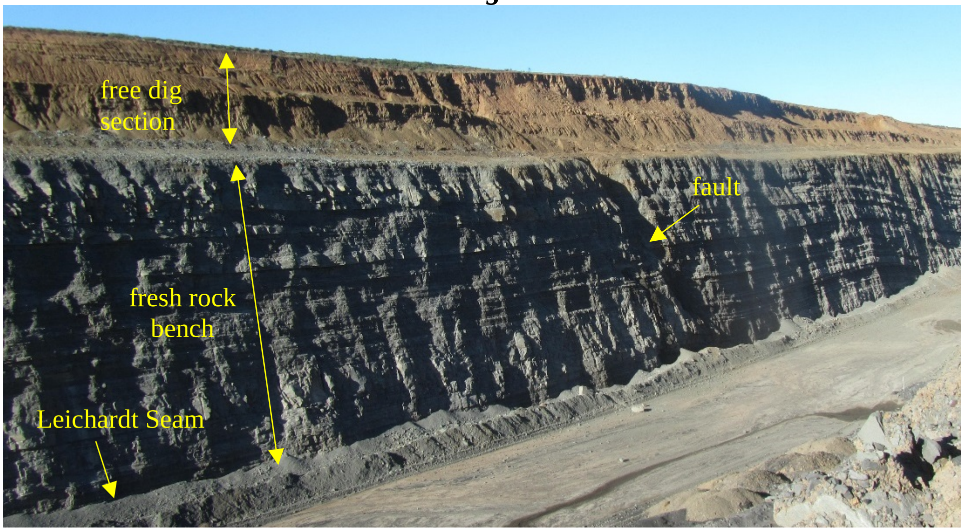


Photo taken 28/06/2016, looking ENE

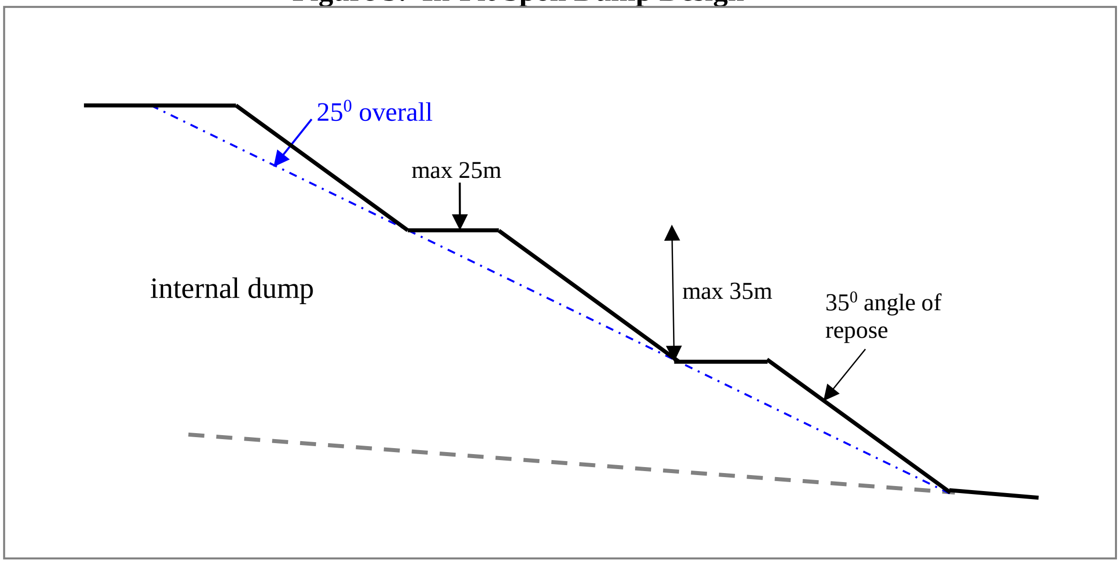
4.2 Spoil Dumps

In-pit spoil dumps are built up in lifts at angle of repose batters with berms. Angle of repose is 35^0 on average. The final profile may depend on operational factors but is within the following constraints:

- Maximum dump bench height 35m;
- Maximum berm width 25m;
- Maximum overall slope angle (toe to toe) not to exceed 25^0 (46%).

The design profile is illustrated in Figure 5 below.

Figure 5: In-Pit Spoil Dump Design



The general aspect of the in-pit dump is illustrated in the photo below, which shows the face of the advancing dump in B Pit.

B Pit in-pit dump

Photo taken 9/05/2017, looking SW

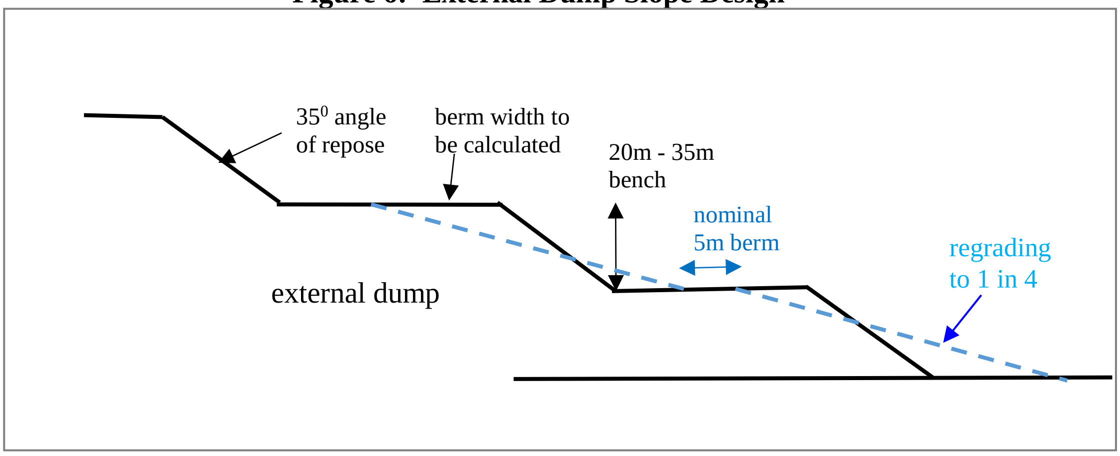
Floor treatment is used to disrupt bedding or slip planes prior to dumping or casting spoil on steeper floor dips to ensure the in-pit dump remains stable. This is only applicable to parts of Mavis Pit where the dip exceeds 12½^{0}.

External dump faces are formed to facilitate re-grading to 1 in 4 slopes for rehabilitation. The final dump profile will be depend on the circumstances and will be calculated to give a cut-and-fill balance for the re-grading push-down. Berm width varies according to the bench height and is designed to leave a nominal 5m residual berm after pushing down the batter. The overall guide is:

- Maximum bench height 35m;
- Nominal bench height 20m;
- Residual berm width nominally 5m;
- Final re-graded batter 1 in 4 (14^{0}).

The design profile is illustrated in Figure 6 below. For a 20m bench height, which is the usual design, the berm width would be 56m.

Figure 6: External Dump Slope Design



The photos below show as-constructed external slopes of the low wall spoil dump at D Pit and re-graded rehabilitated external slopes at E Pit.

Pit external low wall spoil dump face

Site photo 143458861 taken 18/07/2017, looking ENE

E Pit external low wall rehabilitated spoil dump face

Photo taken 9/05/2017, looking NE

4.3 Compliance

The Environmental Authority (EA) specifies that highwall slopes in competent rock can remain as constructed if they are geotechnically stable or otherwise benched with 15m berms at 20m intervals. This would be equivalent to a maximum overall slope angle of 63^0 for benched slopes. Low wall spoil dumps are to be benched or reshaped accordingly to ensure geotechnical stability. External spoil slopes (landform) must not exceed 1 vertical to 3 horizontal (18^0). The specified and as-formed slope angles are tabulated below.

Slope Type	EA requirement	As constructed
Highwall – competent rock	geotechnically stable	70^0 benches; 15m berms
Low wall – void side	geotechnically stable	benched, 25^0 overall
Landform – external dump side	max 1 v : 3 h	re-graded to 1 in 4 (14^0)

The EA requirements for pit slopes are not specific in terms of design parameters, the criterion being that they should be geotechnically stable. The as constructed highwall slope profiles are typical opencut coal industry designs that have proven adequate for general application.

Normal coal measures rock is too strong to undergo shear failure under gravitational loading and requires the presence of pre-existing separation planes, such as pervasive joint planes, faults or dykes to create conditions of potential instability. So that in the absence of adverse structure, 70^0

or vertical highwalls can be expected to stand indefinitely without risk of major collapse. The Millennium Mine design is thus compliant in providing geotechnically stable highwalls.

Instances of where faults intercept or occur close to pit walls are treated on an individual basis with the standard design modified as necessary to ensure any instability can be managed.

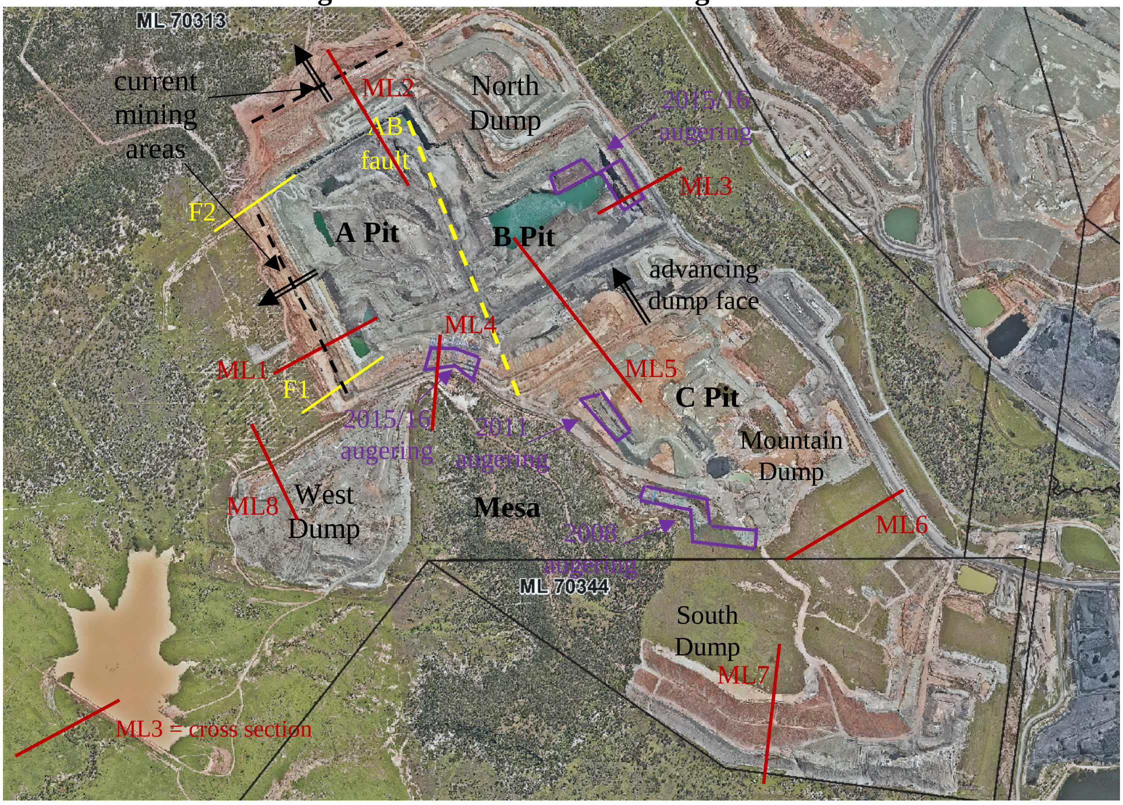
Low wall dumps are built up in benches at angle of repose to a maximum lift height of 35m between berms, which is a typical well-proven industry design for rockfill dumps on flat or gently dipping ground, and thus complies with the EA requirement for geotechnical stability. In-pit dumps are generally susceptible to mass failure if the floor is sloping, particularly if there are weaknesses in the floor. Steeper dips are a feature of some parts of Mavis Pit but there are design variations involving floor treatment or re-assessment of the design if the dip exceeds a threshold value of 12½^0.

External dumps have been re-graded to 1 in 4 which is flatter than the EA requirement.

5. MILLENNIUM PITS

The aerial photo below (Figure 7) shows the salient features of the Millennium Pit mining area. These include the designated pit areas A Pit, B Pit and C Pit and the out-of-pit dumps which are built above ground level. Also shown are the highwall augering blocks, the lease boundaries and the locations of cross sections (ML1 etc) referred to in the text.

Figure 7: Millennium Pit Mining Area



Mining commenced in C Pit which is now mined out and completely infilled with spoil and built up to RL305, some 50m above ground level. This referred to as Mountain Dump. The initial boxcut spoil for C Pit was dumped to the south as the South Dump; this old dump has been regraded and largely rehabilitated. Other out-of-pit spoil was placed in the North and West Dumps. The main in-pit dump is advancing north across B Pit and a new dump is being established in A Pit.

A mesa forms high ground between the south and west dumps which constrained mining on the south side. This feature contains cultural heritage sites. As the insitu low wall was exposed along the mesa on the south side, successive periods of auger mining were undertaken, extending under the low wall. The east highwall and north wall of B Pit was also subject to highwall augering after they had been established as final wall locations.

Current opencut mining is restricted to the north and west walls of A Pit, where one or two strips are planned. The eastern half of the north highwall was not visible at the time of the inspection as it had been blasted and was obscured by cast blast material. There could be a potential for highwall mining in the final north and west highwalls.

The final plan will leave a void against the north and west walls in the current mining areas in A Pit. It is intended to infill B Pit to ground level, at least for the most part, with a possible spoil-bounded void in the middle. B Pit is currently occupied by a pond that can be seen in Figure 7. Preliminary modelling results of maximum long term void inundation levels by Hatch indicates the water level in Millennium Pit would rise to a maximum of RL164 after 10 years and would fluctuate around RL160 thereafter.

5.1 Highwall Stability

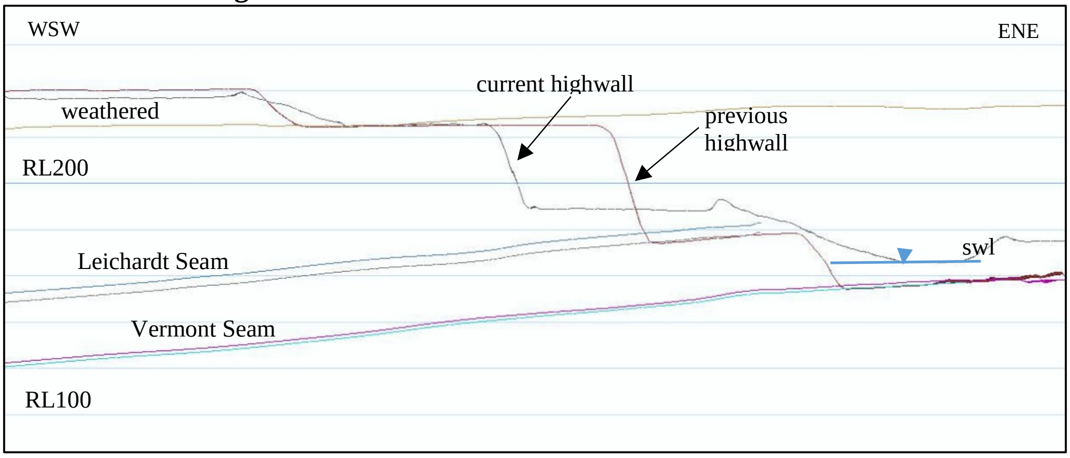
In normal conditions the pre-split rock benches are clean and stable. In some cases the walls have not been pre-split but have been scaled to present a reasonably clean face. In either case there will always be a background risk of small blocks becoming detached through weathering and falling out. The Rangal Coal Measures, particularly the finer grained rock, are susceptible to slaking and this allows the softer material to weather out and undercut the harder sandstone blocks. This has no impact on the overall geotechnical stability of the slope but represents a long term weathering effect. The photo below shows a typical scaled highwall bench with undercutting of the harder sandstone bands.

A Pit south highwall

Photo taken 4/12/2016, looking NE

Full height final highwall faces will be left along the west and north sides of A Pit. Cross Section ML1 in Figure 8 below shows the current configuration for the west wall, with the partially exposed highwall for the next strip. More strips may be mined but the final configuration should be the same, comprising a 45^0 upper bench up to 30m high through the weathered zone and a 70^0 pre-split main overburden bench up to 55m high. Also shown is the predicted long term void water level at RL164.

Figure 8: Cross Section ML1 - A Pit west wall



The highwalls are cut through material that is too strong to permit material failure by shearing and hence will stand indefinitely subject only to weathering degradation. The systematic risk of massive block slippage can also be discounted since the bedding dips back into the wall. However, rock failure conditions can be created by adverse pervasive discontinuities such as fault planes, joint planes or combinations of planes producing block or wedge configurations.

The main structural disturbance at Millennium Pit is the A/B Fault which runs NNW-SSE and separates A Pit from B Pit. This fault dips at between 25^0 and 35^0 to the west and has a vertical displacement of about 80m. Localised instability has occurred as a result of slippage down the fault plane but this was an interim mining issue that could be managed by judicious location of the temporary faces within the pit. No instability has been noted where this fault system intersects the north highwall, as the fault system is perpendicular to the wall, which tends to neutralise any potential instability from adversely dipping planes.

Several large steep reverse faults occur within the mining areas, but most of these are also more or less perpendicular to the wall and do not usually result in any significant instability. Where these faults are parallel to and just behind a face they can create a risk of large scale wall collapse. One of these was in the north wall of B Pit; this was remedied by cutting back the upper part and buttressing the affected part of the wall with spoil after mining the coal.

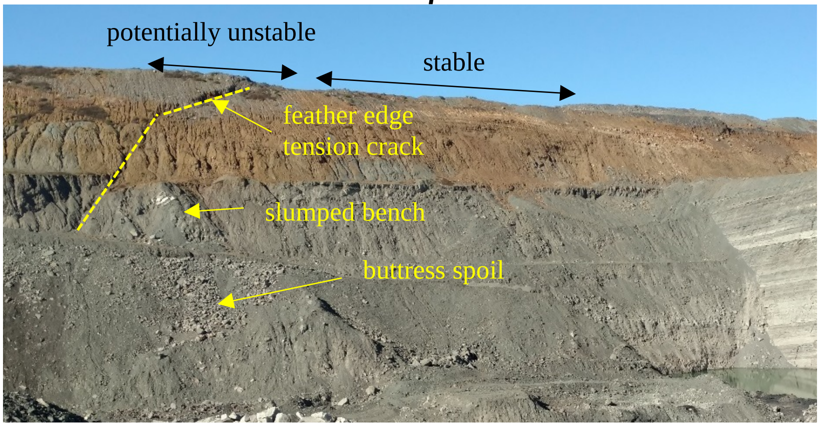
Two other instances of potential fault-induced instability occur at each end of the west wall, marked as F1 and F2 on Figure 7. F1 appears to be a high angle fault running behind and sub-parallel to the south wall, dipping out of the wall. It has incurred some movement, manifest as a tension crack along the edge of the haul road and slumping of the lower bench. The tension crack enlarged significantly following inflow from cyclone Debbie in March 2017 as shown in the photo below.

F1 tension crack

Site Photo taken 9/05/2017, looking NE

Inspection of the face reveals that the movement is due to a slumping collapse of the feather-edging fault intersection with the wall – too much weight on too narrow a base – and that the main section of wall in front of the crack appears to be intact. The feather-edging tension crack is shown in the photo below cutting down across the upper weathered benches. The lower rock batter has incurred slumping collapse.

South wall fault F1



Site Photo IMG_20170524_ 091625948 taken 24/05/2017, looking NE

A spoil buttress has been placed against the wall and this has effectively buttressed the lower bench against any further slumping. The residual risk would be shallow slip failure through the top of the weathered material and haul road spoil at the top.

In terms of remedial action for final void, because the failure is fault controlled it will not extend any further back than the fault itself marked by the tension crack, the recommended action would be to leave as is with a rock bund along the haul road 15m from the tension crack. As the fault trend is moving further away from the wall the potential for mass failure should be reduced and it is unlikely to have any impact on the stability of the next strip endwall.

The other fault (F2) is also projected to run almost parallel to the northern endwall of the next strip. This fault can be seen daylighting in the current north wall but with no indication of instability. The fault plane appears to be dipping back into the wall which would negate the potential to induce a similar collapse of strata off the fault plane. As the fault trend is also slightly oblique to the wall, it will be further back from the face on the next strip which would minimise the risk of fault-induced endwall failure in the next west wall strip.

In either case the consequences of wall failure would be material movement into the residual void, with a failure extend defined by the fault line, hence the recommendation to bund off behind the line of the fault or tension crack to prevent access into a potentially failing edge area. The alternative would be to buttress the wall to ground level with the in-pit spoil dump.

The top bench is cut through weathered rock for the most part. Circular slip type failure is theoretically possible but can be discounted given the absence of lower strength Tertiary clay or completely weathered mudstone (clay type material) in the batter and the inherently higher shear strength of weathered rock which tends to include some stronger sandstone bands.

Rockfall is more prevalent from the top bench however due to softer soil-like material eroding out from around the more resistant blocks, particularly if a steeper batter has been formed. The upper bench of B Pit north wall shown in the photo below is an example of a steep rough-cut batter.

B Pit north wall

Photo taken 9/05/2017, looking NW

In this instance a band of strong sandstone has prevented the formation of the normal 45^0 batter and although there is no risk of mass failure, there is a likelihood of large blocks weathering out. Any rockfall will report to the void and will in any case be contained on the wide rock berm.

B Pit north wall bund

Photo taken 9/05/2017, looking E

It is planned to leave an access road along the wall behind this bench as part of the final works. There should not be an issue with that provided the substantial rock bund already in place some 15m back from the crest to protect the current haul road, is left as a permanent exclusion against the edge area.

The upper bench east wall of A Pit is also likely to be left as a final wall off the void. This is shown in the photo below. In this instance the standard 45^0 batter has been cut through the weathered rock creating an intrinsically stable bench but still subject to minor rockfall from weathering effects. There is a 25m catch berm below for rockfall.

B Pit east wall

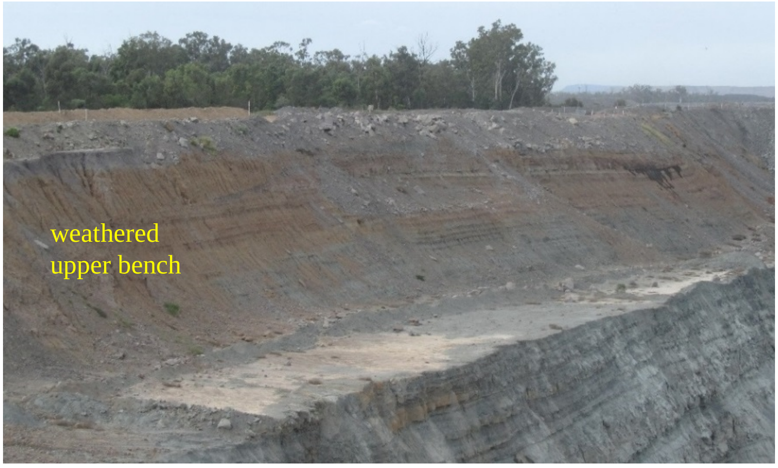


Photo taken 9/05/2017, looking SE

From experience to date and the current condition of the walls, it can be concluded that the highwall design is appropriate for producing a stable final wall, except for those areas where faults are present behind and parallel to the face as discussed above.

In terms of long term void water level, the predicted RL164 mark would result in inundation of the lower rock bench to a height of about 5m and 10m above the pit floor respectively for the north and west final highwalls. Submergence of fresh rock benches does not normally change the stability condition and hence would not be expected to trigger any failure.

Slopes in weathered rock would be susceptible to slaking and erosion and the batter could degrade due to slumping if the water level reached higher than the base of weathering. As the base of weathering is between RL225 to RL240, the top bench in weathered material would be well above the maximum predicted void inundation levels and this situation would not arise.

5.2 Dump Stability

There is no apparent history of low wall failures in Millennium Pit, other than localised slippage on steep dips associated with the AB Fault. Both the in-pit dump and the external dumps are clearly stable, nevertheless slope stability analyses were carried out to confirm the Factor of Stability (FoS). Shear strength parameters used for analyses, based on the foregoing, were as follows.

Shear Strength Parameters

Material	Density (kN/m^3)	c (kPa)	ø	Reference
Fresh spoil	20.0	50	30^0	Category 3 dry
Aged spoil	20.0	30	28^0	Category 2 dry
Basal spoil (submerged)	20.0	15	23^0	Category 2 saturated
Weathered rock	22.0	25	35^0	estimate

Rock spoil is blocky when fresh and appears to be mostly BMA Category 3[1] (blocky spoil with fines) with a reasonably high shear strength. Over time the spoil will undergo slaking with breakdown of the lumps so that the spoil has more fines than blocks. Testing of spoil from the nearby Moorvale Mine[2] shows predominantly low plasticity for the fines which would tend towards a Category 2 spoil type (fines with blocks). Spoil from the weathered zone already can be assumed to be similar to the same material at Moorvale Mine, which testing showed to be low to intermediate plasticity with high dispersivity, that is equivalent to Category 2.

Analyses were made for specific as constructed profiles represented by the selected cross sections, together with the standard design in the case of the in-pit dump profile. The analyses were made using the Galena code for circular failure for external dumps and bi-planar slippage for the in-pit dump. The results are summarised below. The inundated case is for the void flooded to the maximum 10 year level at RL164.

[1] Simmons J V & McManus D A ‘Shear Strength Framework for Design of Dumped Spoil Slopes for Opencut Mines’ Advances in Geo Engineering, The Skempton Conference, Thomas Telford, London, pp981-991

[2] Ward B ‘Moorvale Mine Residual Void Slope Stability Study’ Geotechnical Consulting Services Pty Ltd, Report No.158 November 2014

Analysis Results (FoS)

Section	Dip	Current	Inundated
West Dump (Section ML8)	flat	2.44	-
In-pit standard	6^0	1.61	1.40
West wall void (Section ML1)	6^0	1.68	1.58
North wall void (Section ML2)	1.5^0	1.72	1.67

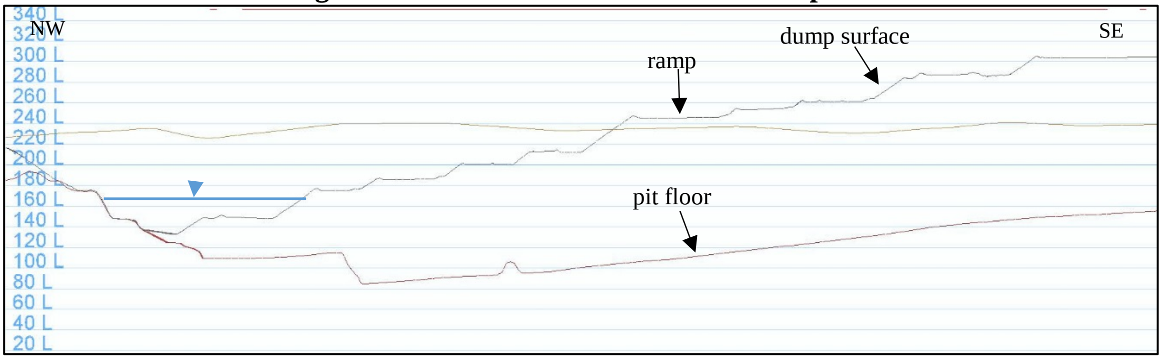
The FoS criteria in common use in the coal mining industry are:

FoS $\geq$ 1.2 short term run-of-mine slopes
FoS $\geq$ 1.5 long term slopes or where slope failure could impact on infrastructure etc

Figure 9 shows the profile along Cross Section ML5 through the advancing in-pit dump face from pit bottom to the top of the Mountain Dump. This is as per the standard design although the overall slope is flatter due to the insertion of ramps at various levels across the dump face.

The in-pit standard analysis was based on this cross section from pit bottom to the elevated top height at RL305 on the 6^0 dipping floor but without the ramps. In practice there are ramps crossing the face of the dump which would reduce the overall slope angle so that the profile without ramps represents the worst case. The results indicate stable conditions for this hypothetical case with the inundated condition having a slightly less than desirable FoS for long term stability, noting however that the FoS for the as-constructed low wall would be higher with the inclusion of the ramps in the profile.

Figure 9: Cross Section ML5 - B Pit dump

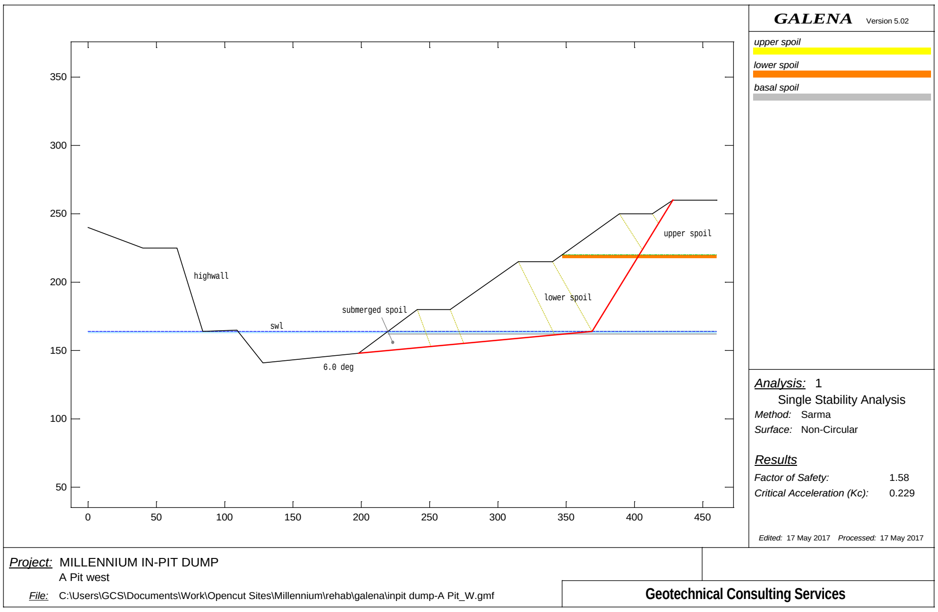


Irrespective of the analysis results however, Cross Section ML5 shows that the spoil dump extends to the opposite highwall and is buttressed against that and the Vermont Seam bench. This would preclude the possibility of mass failure for the current in-pit dump.

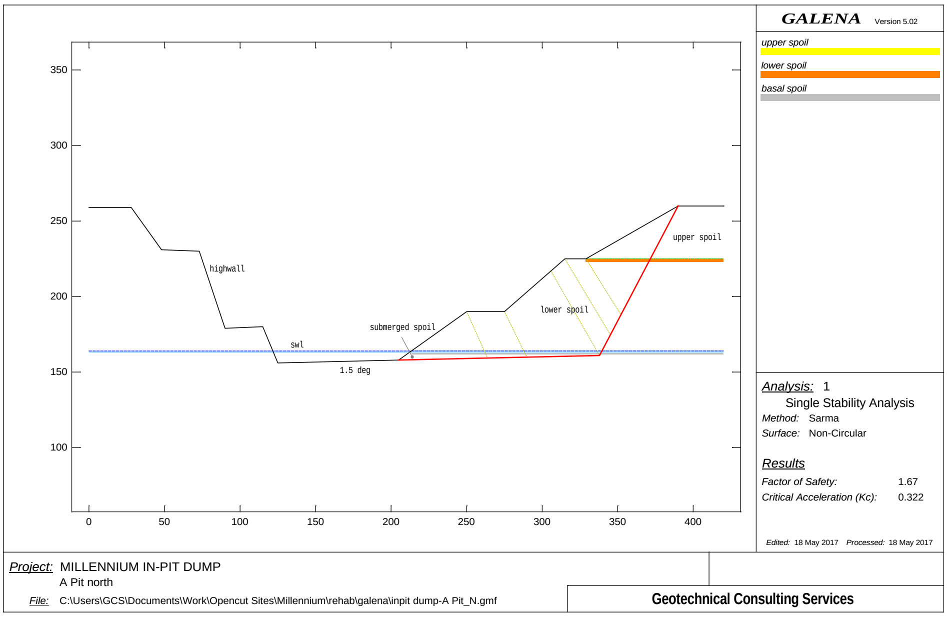
Unbuttressed in-pit dump faces would be formed at the completion of mining in A Pit opposite the west and north walls. For these cases the standard dump design was applied to Cross Sections ML1 and ML2, assuming the A Pit dump is raised to ground level at RL260. Analyses were made for a presumed final void profile, allowing for inundation to RL164. The upper spoil forming the top bench may include some weathered material and has thus been treated as Category 2, with submerged spoil as Category 2 saturated. Failure mode is bi-planar with slippage on the pit floor and shearing back up through the spoil dump.

The results tabulated above show FoS in excess of the long term design value for both as constructed (drained) and inundated conditions. This would indicate that internal dump failure would be highly unlikely. Note that displaced material from failing slopes would in any case be contained within the pit void. The outputs from the Galena program are presented below. The FoS for the north facing dump are higher because of the shallower dip in that direction.

A Pit west wall void



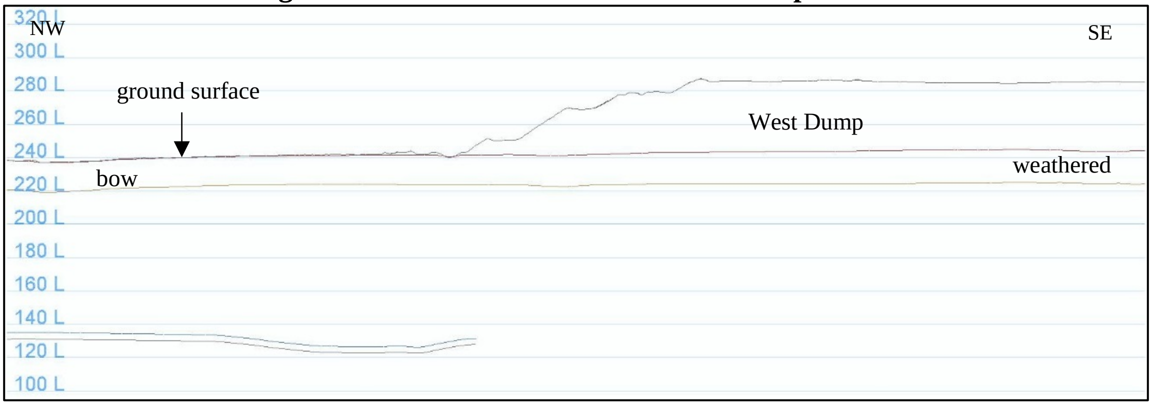
A Pit north wall void



External dump profiles are currently determined from a calculator designed to balance the cut and fill to allow for pushing down the batters to an overall 1 in 4 rehabilitation slope. In theory they would normally be 20m benches at angle of repose with 56m wide berms. With a wide-bermed profile like this the possibility of mass failure is eliminated. Slumping of individual benches is possible under extreme conditions of saturation but is highly unlikely.

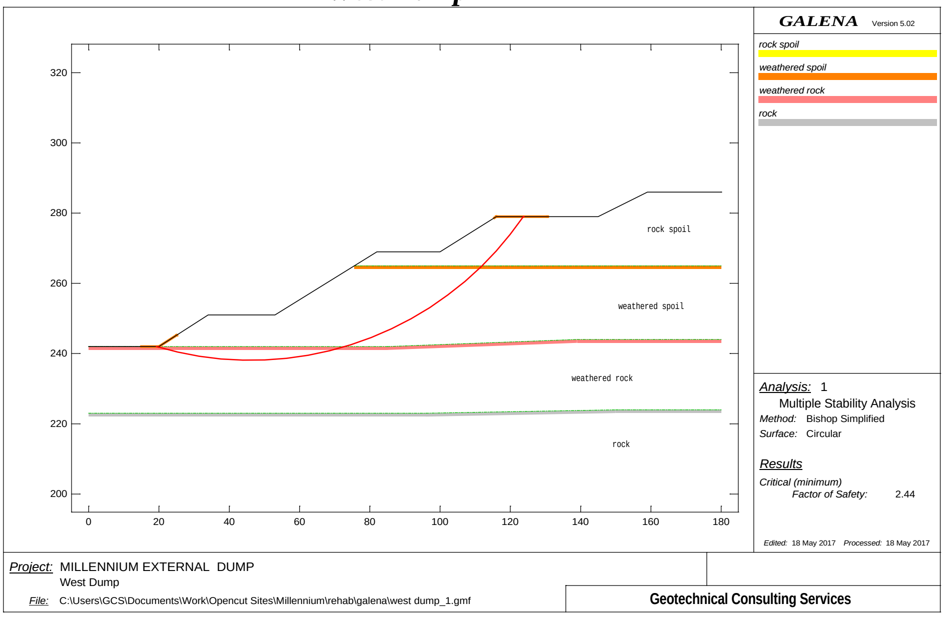
Earlier out-of-pit dumps were steeper with narrower berms and this includes the North and West Dumps. Both of these have an as-constructed profile as they have not yet been re-graded, although technically they are in compliance with the EA requirements. Figure 10 below shows the profile for Cross Section ML8 through the northern side of the West Dump.

Figure 10: Cross Section ML8 - West Dump



Analysis of this profile shows a high FoS of 2.44 for circular slip failure, with the most critical failure surface through to the third bench as illustrated on the Galena model below.

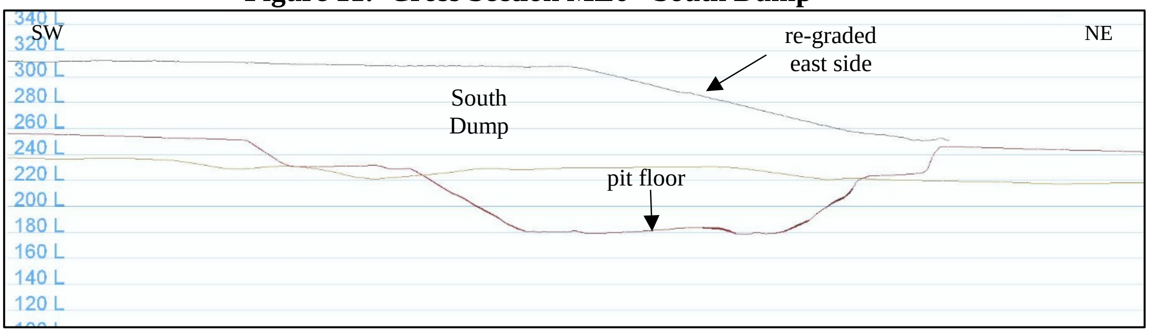
West Dump



It can be concluded that the external dump faces with as-constructed profiles are geotechnically stable.

Final external dump faces are re-graded to 1 in 4, covered in rock mulch and grassed for rehabilitation status (see Section 4.2). Cross Section ML6 below shows the profile through the east side of the old south dump. This is an example of early re-grading without any berms.

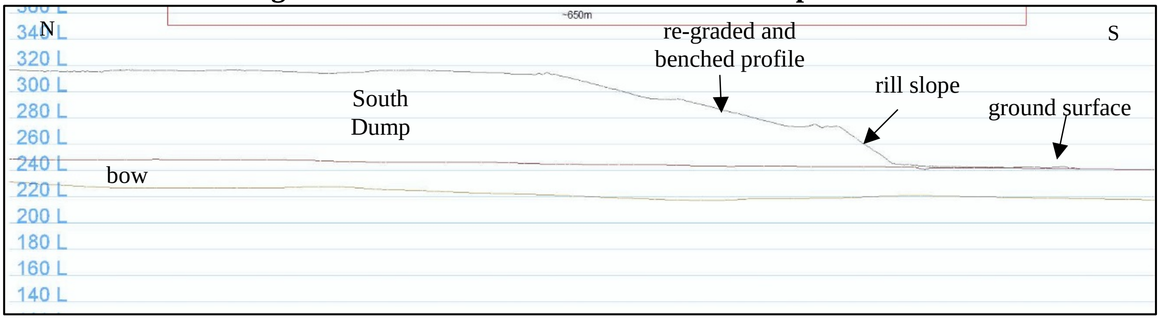
Figure 11: Cross Section ML6 - South Dump



The top of the dump is flat to reduce run-off as per the requirements of the EA. In this respect it has been the practice to bury tailings in cells in the spoil – this causes differential compaction which tends to create temporary ponding on the surface over the cells.

The south side of the South Dump has also been re-graded as shown in Cross Section ML7 below. In this case however, final works have not been completed pending agreement to push material over onto the adjacent lease. As a consequence the bottom batter is still as-dumped at angle of repose.

Figure 12: Cross Section ML7 - South Dump



Due to the shallow slope profile created by the re-grading, there is no risk of mass slope failure and rehabilitated slopes can be considered geotechnically stable over the long term.

5.3 Highwall Augering

Highwall augering has been undertaken at Millennium on three occasions in 2008, 2011 and 2015/6. The locations of the auger mining are shown on Figure 7. The 2008 augering was in C Pit low wall at the southern end of the mine area, with single row panels in both the Leichardt and Vermont Upper Seams. Subsequent augering was in the Leichardt Seam only with a double row of holes wherever possible.

The next section of B Pit low wall was mined in 2011, together with an internal panel along a north wall in B Pit. These entries, and the earlier ones, have all been buried under the in-pit dump.

B Pit Highwall Augering

In 2015/16 augering was undertaken in the next section of low wall in A Pit together with east and north walls in B Pit. The photo shows auger holes in the north wall of B Pit.

Photo taken 12/04/2016, looking E

Auger designs are based on a Factor of Stability (FoS) of not less than 1.2 for the coal pillars under maximum overburden loading and not less than 1.5 at the portal under the highwall face[3].

[3] Ward B 'Millennium Mine Highwall Augering' Geotechnical Consulting Services Pty Ltd, Report No.165, September 2015

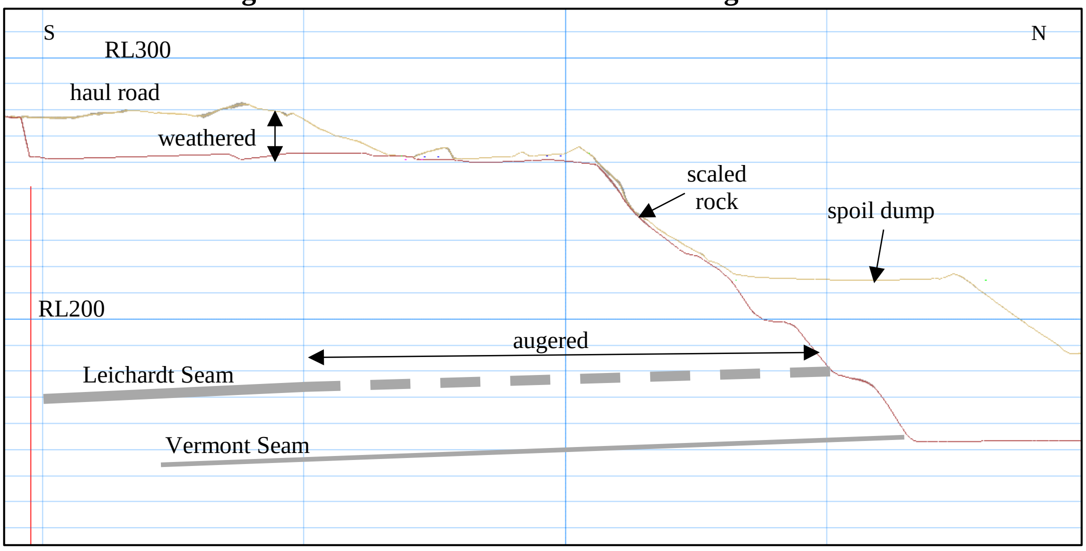
These general design FoS values are for run-of-mine extraction and are not adequate for ensuring long term stability, and although there has not been any indication of distress in any of the auger entries or pillars to date at Millennium, there will be a possibility of long term deterioration (creep) of the coal pillars over time, allowing the pillars to eventually fail and crush down. The consequences of a long term deterioration and collapse would be subsidence at the surface but this would not be expected to exceed about 0.75m.

Pillar failure at the portal would undermine the highwall and could result in a collapse of the highwall face. Slope failures from this cause tend to be relatively shallow, more of a collapse type slump than a deep seated slope failure, and do not extend far behind the highwall. The use of the higher long term stability FoS value under the highwall should reduce the risk of highwall collapse in isolation, although a widespread collapse of pillars inbye could run forward under the highwall.

The 2008 and 2011 auger blocks are now buried under spoil such that highwall instability is now irrelevant and any subsidence reporting to ground level through the spoil would not be of any consequence.

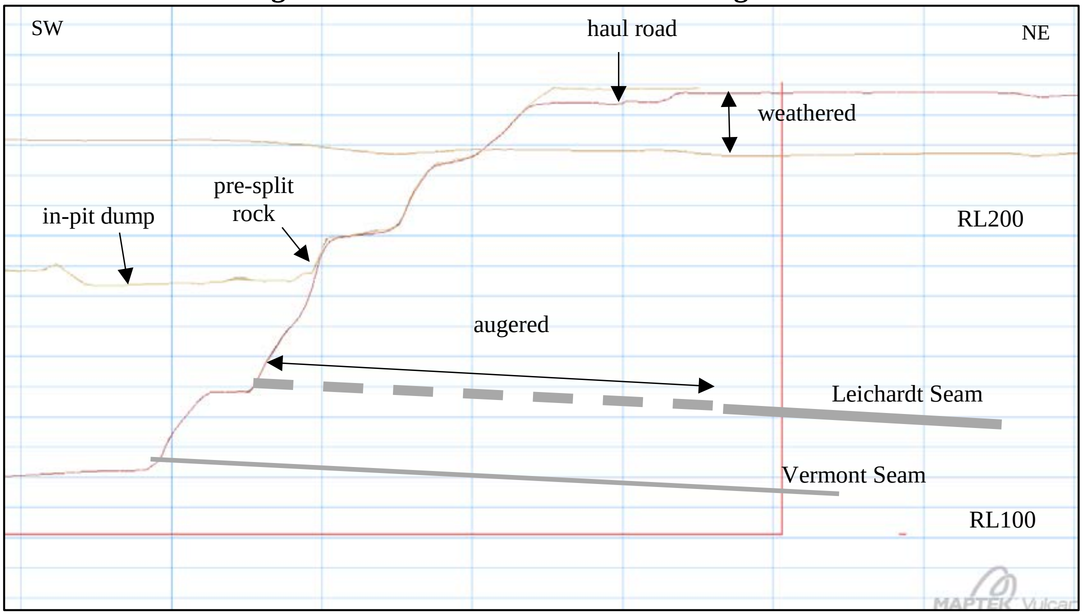
A cross section through the south wall is shown in Figure 13 below. The auger holes generally penetrated between 80m and 160m, with a maximum of 200m in places, so did not penetrate further in than the haul road, which would not therefore be affected by any long term subsidence. The stability of the scaled 50^0 upper batters would not be affected by any subsequent pillar crushing and only the bottom rock bench would be at risk of face collapse. However the holes are now buried under a buttressing spoil dump which would offer greater confinement to the pillars under the face and reduce the opportunity for pillar failure.

Figure 13: Cross Section ML4 - south highwall



A similar case applies to the east wall auger holes, as illustrated in Figure 14 below. The auger holes penetrated some 140m to 155m and passed beneath the haul road but were stopped well short of the New Chum Creek levee. As the pit is already partially backfilled there is no residual risk of face collapse from long term pillar deterioration but a possibility of some small amount of easily remedied subsidence under the haul road if this is to be left as an access road.

Figure 14: Cross Section ML3 - east highwall



The other 2016 holes in the internal north wall are limited to the lower rock bench which will be buried beneath the in-pit spoil dump.

Consideration is being given to post opencut scavenging of the current highwalls (north and west) using highwall mining. Unlike augering which produces round holes, mining is carried by a continuous mining machine which cuts a rectangular section typically 3.5m wide. Nevertheless the same comments in regard to long term stability and the possibility of pillar creep apply. Full penetration is 300m, geological structure permitting, which may result in undermining a greater area of the crest.

6. MAVIS PITS

The aerial photo overleaf (Figure 15) shows the salient features of the Mavis Pit mining area. These include the designated pit areas D Pit, E Pit and S Pit together with dump areas and the highwall augering block. Also shown are the locations of cross sections (MV1 etc) supplied for analytical purposes.

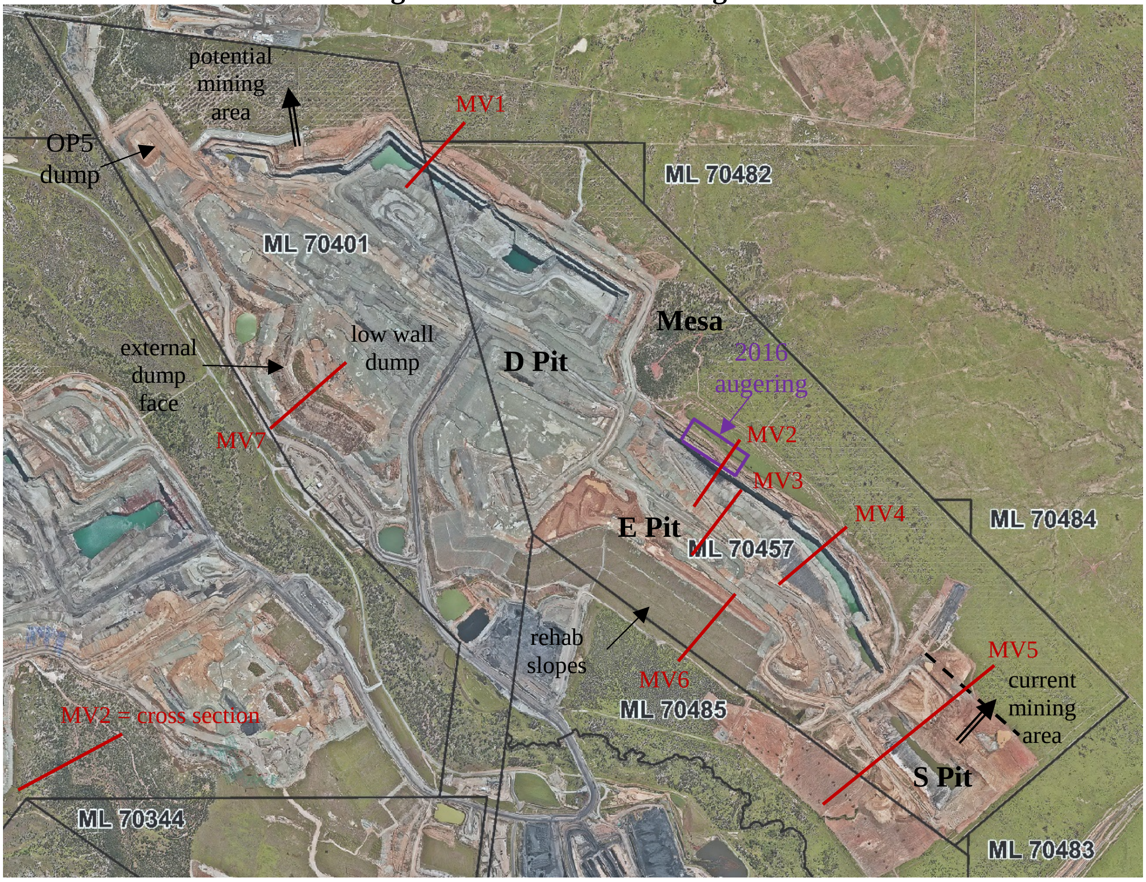
Mavis Pit is a strip mine, with successive strips being mined down-dip against an advancing highwall on the north-east side and spoil dumped behind each strip on the south-west side. The initial boxcut spoil was dumped west of the low wall on natural ground and the dump raised and advanced by spoil from subsequent strips. A small out-of-pit dump (OP5) was formed at the northern end of the strip.

S Pit was developed as a boxcut with spoil dumped externally on the low wall side. It was then used for water storage but is now currently being mined with one or more strips towards the north-east where it will terminate against a major fault.

Spoil is dumped in lifts on the up-dip side to form an advancing low wall dump leaving an external face on the south-west side. Re-grading and rehabilitation has been undertaken on the E Pit external face.

Current opencut mining operations are restricted to D Pit and S Pit, with a potential to extend the pit to the north (D Pit North) towards the lease boundary. A small mesa forms high ground behind the D Pit southern endwall. Highwall augering is underway in the final E Pit highwall, as indicated in Figure 15 below, with plans to extend over the rest of the northern half of the pit. The seam dip in the southern half is too steep for auger mining.

Figure 15: Mavis Pit Mining Area



Current final void planning is for partial infilling of the northern end of E Pit with open voids against the remainder of the highwall and extending into S Pit and an open void against the whole of D Pit highwall, including the north wall where there is a potential extension into D North Pit. Preliminary modelling results of maximum long term void inundation levels by Hatch indicates the water level in D Pit would rise to a maximum of RL182 after 10 years and would fluctuate around RL180 thereafter, whilst in E Pit it would be at RL174 and vary between RL170 and RL175 over the longer term.

6.1 Highwall Stability

The highwall slopes are formed in moderately strong back-dipping bedded rock and are inherently stable for the most part. The walls are intersected by a number of large high angle faults but these have tended to be perpendicular to the face and thus do not create a potential for mass failure. In some cases there has been some spalling or shallow slumping to create a vee-shaped notch down the wall but this is a very local feature confined to the fault intersection and does not prejudice the stability of the rest of the face.

The photo below shows a typical highwall face, together with a fault intersection.

E Pit north highwall

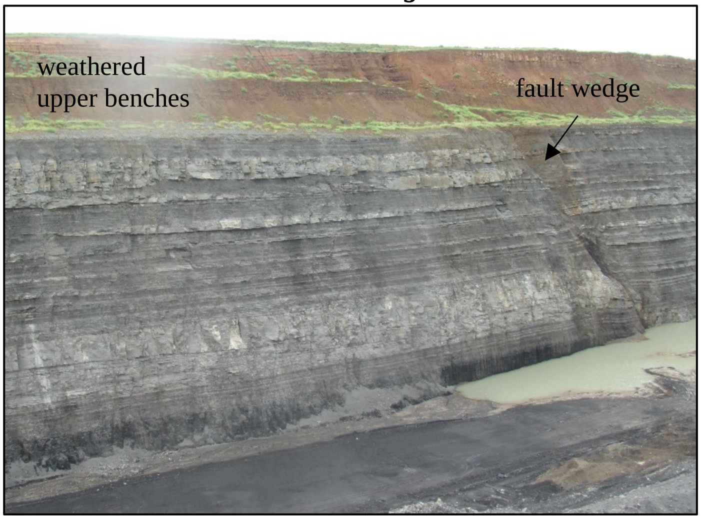


Photo taken 5/01/2017, looking E

A more substantial wedge failure has occurred in D Pit highwall due to a major joint plane intersecting a fault in the face. Material within the wedge has slipped down or been scaled back to the intersecting sliding planes. In terms of long term effect, the zone of instability is confined to within the triangle on the berm formed by the intersecting discontinuities. The failure cannot extend any further back into the highwall in the absence of any other contributing planes and any residual material left suspended will slide down into the void.

D Pit wedge failure

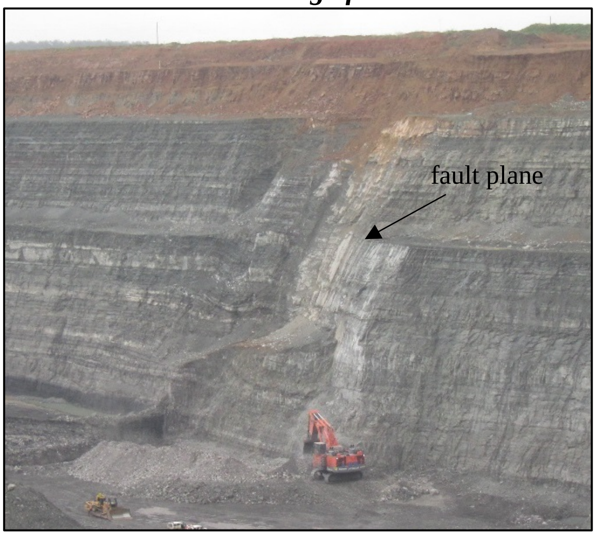
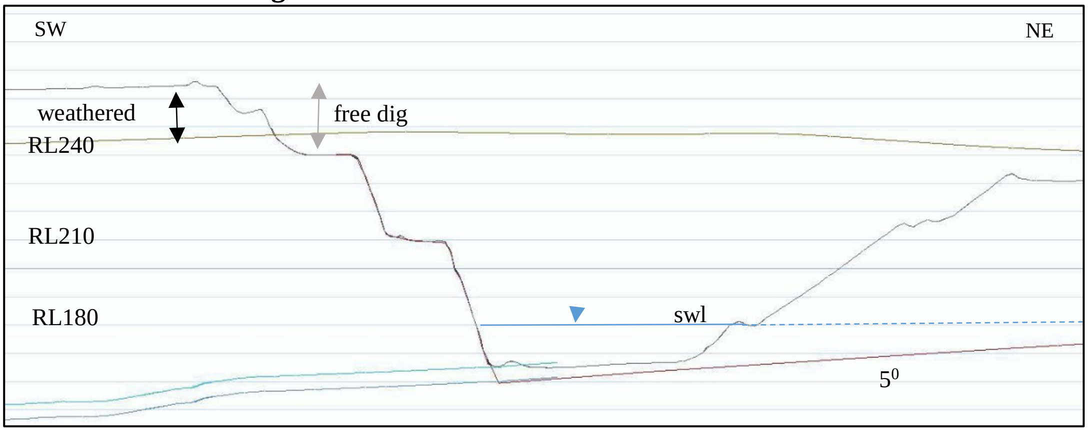


Photo taken 11/05/2017, looking N

The failure has cut back to and slightly undercut the weathered rock bench. This may cause some shallow slumping or erosion in the softer material but would not prejudice the geotechnical stability of the upper benches. No further action would be needed for residual void protection other than the standard exclusion bund at the crest.

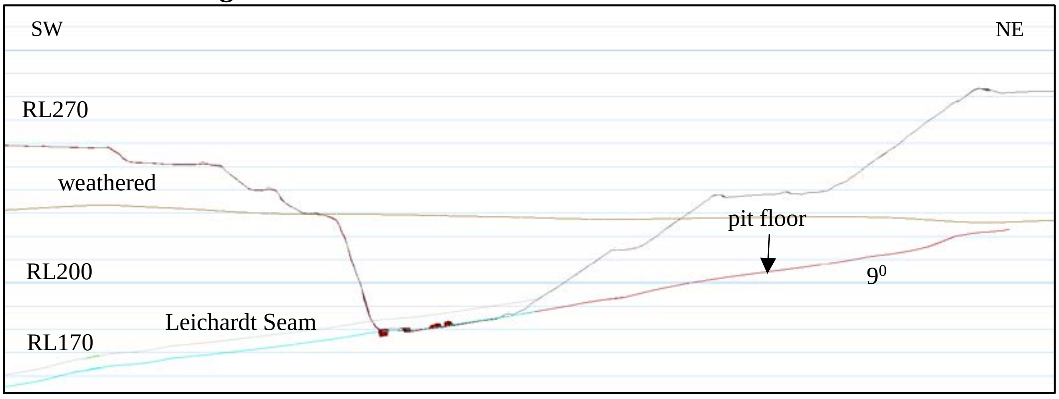
Cross Section MV1 at the northern end of D Pit is presented below. This shows the general configuration for an 80m high double bench highwall, with 70^0 pre-split benches and 15m berms at RL210 and RL240. It also illustrates the shape of the 'rough-cut' free-dig benches through the weathered material. The benched in-pit spoil dump is constructed on the pit floor up-dip of the mining void at angle of repose. The predicted long term water level is shown at RL180.

Figure 16: Cross Section MV1 - D Pit North



In E Pit the rock highwall is 50m to 60m high and has been cut as a single bench, as illustrated in Figure 17 below (Cross Section MV2). The pit floor in the northern part of E Pit is at RL180 or so and would be above the predicted long term water level.

Figure 17: Cross Section MV2 - E Pit North



In terms of long term void water level, the predicted RL180 mark in D Pit would result in inundation of the lower rock benches to a height of about 20m above the Leichardt Seam. In E Pit only the southern part would accumulate water for a predicted long term level of RL175, again indicating a maximum submergence depth of 20m at the highwall. In each case only the lower part of the fresh rock bench would be impacted, and this would not be expected to induce any instability in the rock face.

The northern limit of mining in S Pit is apparently a fault running parallel to the pit. Faults parallel to the highwall present a significant risk to wall stability, as discussed in Section 5.1, however it is understood that the current plan is mine out to the other side of the fault plane such that the fault would not be left behind the highwall thus removing the risk of instability.

As per Millennium Pit, the walls slake readily, leading to undercutting of the harder sandstone blocks and a creating a background risk of small blocks becoming detached through weathering and falling out.

Upper spoil benches are cut through weathered rock, which has a variable nature depending on the presence of more durable sandstone beds. In Mavis Pits the weathered zone appears to be more soil-like with less harder bands but still has a high enough strength to form stable batters. However, the silty and clayey fractions are dispersive and prone to erosion which can effect environmental stability without impacting on the geotechnical stability.

The condition of the upper batters is illustrated in the photo below. The batters were 'rough-cut' design and are individually too steep for long term environmental stability and, as a consequence, are gullying from run-off and eroding into lower angle rill slopes.

E Pit upper highwall benches

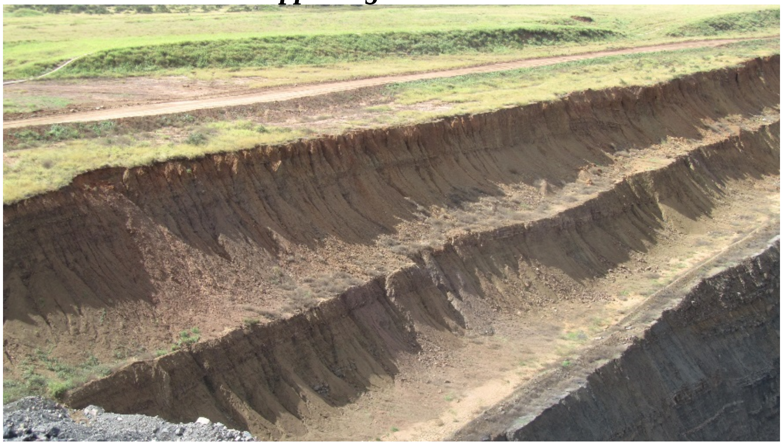


Photo taken 11/05/2017, looking ESE

There is no risk of mass failure but the degradation will continue to eventually create a 35^0 or so slope. There is adequate room on the rock berm to accommodate rilled material.

The upper benches at the northern end of D Pit are steeper with a greater proportion of harder material. This is resulting in a different weathering profile whereby the top section is failing by toppling collapse which thus creates and maintains a near-vertical top part, with a smaller rill slope.

D North Pit upper highwall benches

Photo taken 11/05/2017, looking E

The long term implication of this is that the toppling collapse could cause the shape to be retained and allow the crest to be eaten back further over time rather than degrading to a continuous rill slope. One option for remediating this would be to push down the batters to say 28^0 (typical angle for dozer-push) which would remove the toppling type degradation.

The overall conclusion is that the highwall design is appropriate for producing a stable final wall but with the likelihood of ongoing long term degradation of the over-steep 'rough-cut' batters through the weathered zone.

6.2 Dump Stability

Low wall dumps on a dipping floor are at risk of mass failure due to basal slippage, particularly if the floor contains weak or sheared horizons. In Mavis Pit the experience has been that dumps are stable on dips up to 8^0 in general, or $12½^0$ on sound floor. No dump instability was apparent from the site inspection. The photo below shows the stable low wall configuration with good quality spoil forming the base.

E Pit low wall spoil

Photo taken 11/05/2017, looking SE

The dip on the floor varies along Mavis Pit, increasing from north to south with the change commonly occurring across faults. The general situation is summarised in the following table.

Floor dip

Area	D pit	E North Pit	E South Pit	S Pit
Dip	4^0 to 5^0	9^0	16^0	20^0

In-pit spoil dumps have only been formed on the shallower dip areas of D Pit and E Pit North. The stability of the dumps in these two cases was examined by carrying out slope stability analyses for bi-planar slippage along the pit floor using the Galena code for Sarma's method. The shear strengths used were as per the Millennium Pit analyses (see table on page 13).

The results are summarised below. The inundated case is for the void flooded to the maximum 10 year level at RL180 in D Pit and RL175 in E Pit.

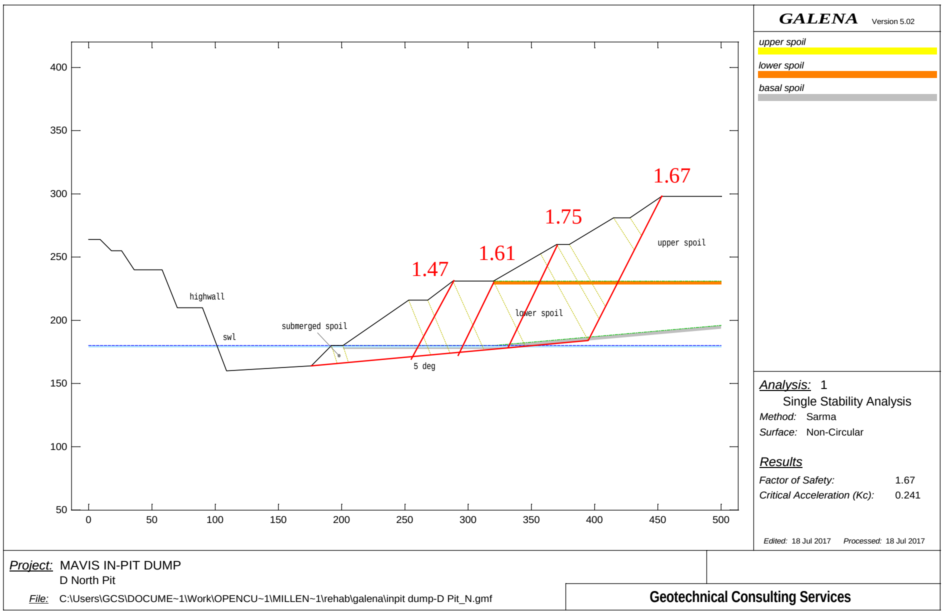
Analysis Results (FoS)

Section	**Dip**	**Current**	**Inundated**
D Pit (Section MV1)	5^0	1.73	1.47
E North Pit (Section MV2)	9^0	1.71	1.71

The analyses for D Pit North were based on Cross Section MV1 in Figure 16 **(**p.22), extended up to the full height of the dump at about RL300. The Galena analysis model showing the full profile is presented below.

Analyses were made failure configurations ranging from the RL230 crest up to the top of the dump at the RL300 crest as shown above. The results show FoS from 1.73 to 1.90 for the as-constructed dry conditions, well in excess of the long term design value. The FoS for the inundated condition are shown on the model section; these are lower but still more than adequate for the most part.

D Pit North void

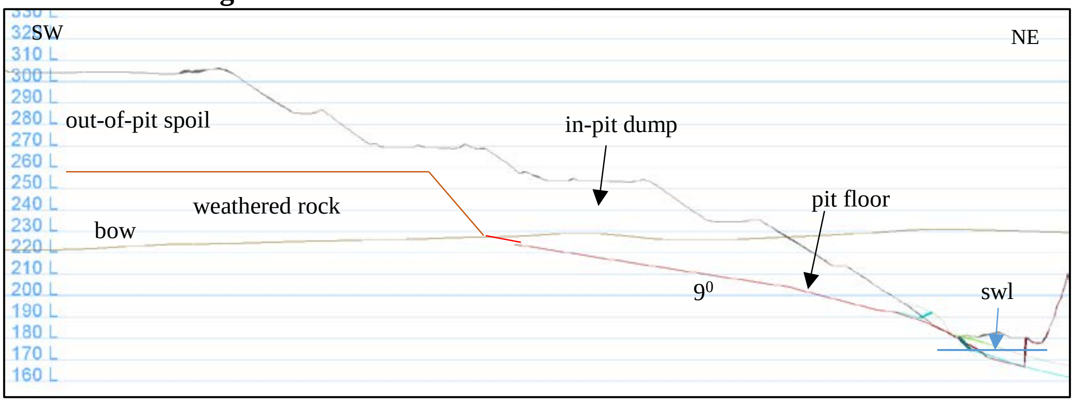


The influence of the submerged spoil becomes more apparent towards the toe of the dump causing a reduction in the FoS. A minimum FoS of 1.47 was noted at the RL230 crest as indicated on the plot above.

These results would indicate that mass failure of the internal dump would be highly unlikely, with the worst case FoS of partial failure under inundation still more or less acceptable for long term stability. Although inundation to the predicted level would not prejudice the dump in terms of mass instability, it could possibly cause some shallow slumping if the slope was undercut by notching at the water line. The spoil is not dispersive but has a high potential for slaking from wetting and drying.

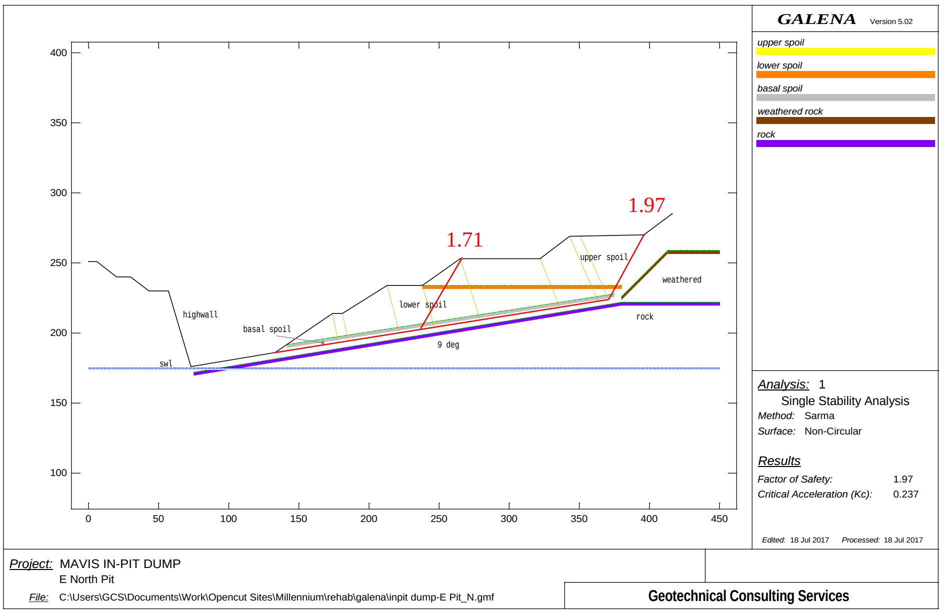
The analyses for E Pit North were based on the profile in Cross Section MV3, as illustrated in Figure 18 below, which extends to the full dump height but using the floor profile from Figure 17 (p.22).

Figure 18: Cross Section MV3 - E Pit North



The floor level in the void in this part of E Pit is generally above the predicted flood level so that inundation is not a factor in stability analysis. The other issue is the geometric constraint on failure due to the upper part of the dump being situated on insitu ground. This would preclude full height failure as bi-planar slippage would be limited to the front part only, where the spoil has been dumped on the pit floor. The farthest back for failure is thus on the RL270 bench. The Galena analysis model is presented below.

E Pit North void

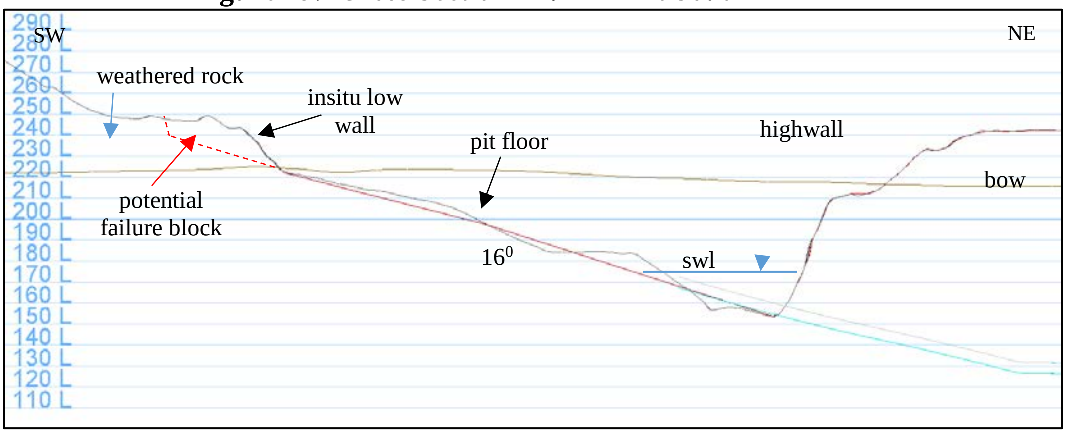


The FoS are high, despite the steeper dip, because of the lower dump height and the lack of submergence of the spoil. Mass failure of the in-pit spoil dump can be discounted in this instance. Notwithstanding the foregoing, the long term plan is to continue to infill E Pit North with spoil, which will mean that the low wall will be buttressed against the highwall. This will remove any possible risk of mass movement of the low wall.

In both D Pit and E Pit North there will be a residual risk of downwash and scouring of fines but any displaced material would be contained within the pit void.

Steep dips are a feature of E Pit South and S Pit and no spoil has been dumped on the pit floor in these areas because of the risk of slumping. Cross Section MV4 in Figure 19 below shows the configuration for E Pit South.

Figure 19: Cross Section MV4 - E Pit South

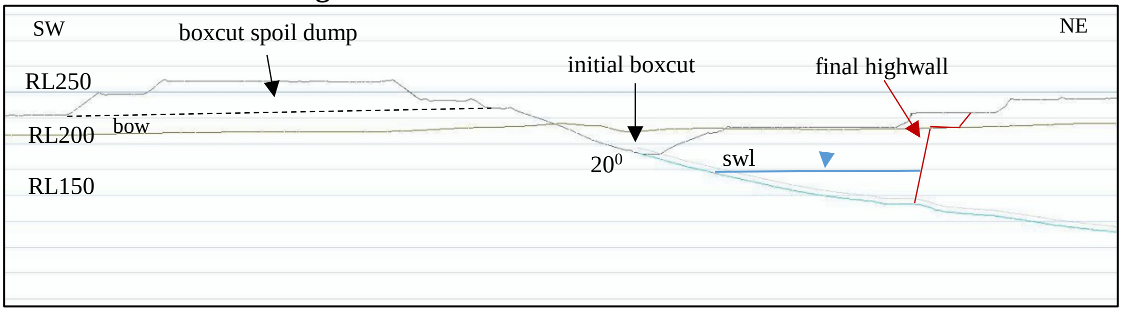


In this case however an insitu low wall has been cut down to the base of weathering, which leaves a residual risk of low wall failure due to slippage along the relict coal horizon extending up through the weathered zone. The potential failure configuration is shown above. The FoS is obviously more than 1.00 but as the dip angle is at least as much as the expected friction angle on the relict slip plane, the FoS can be presumed to be close to 1.00. This means there will be a high probability of failure in the insitu low wall at some stage, as consequence of softening of the shear strength and increased pore pressure from ingress of water, particularly during storm events.

In terms of long term exposure, the low wall would not have an acceptable margin of stability and failure can be expected. This condition could be alleviated by pushing down the low wall bench in front of the out-of-pit dump to match the pit floor. Alternatively it could be left to fail as any displaced material would migrate down the pit floor towards the highwall and would be contained within the void.

S Pit was developed as a boxcut with all the spoil being dumped out-of-pit away from the low wall because of the high dip. After being used for water storage, mining has now been resumed. The cross section through S Pit and the boxcut spoil dump is shown below.

Figure 20: Cross Section MV5 - S Pit

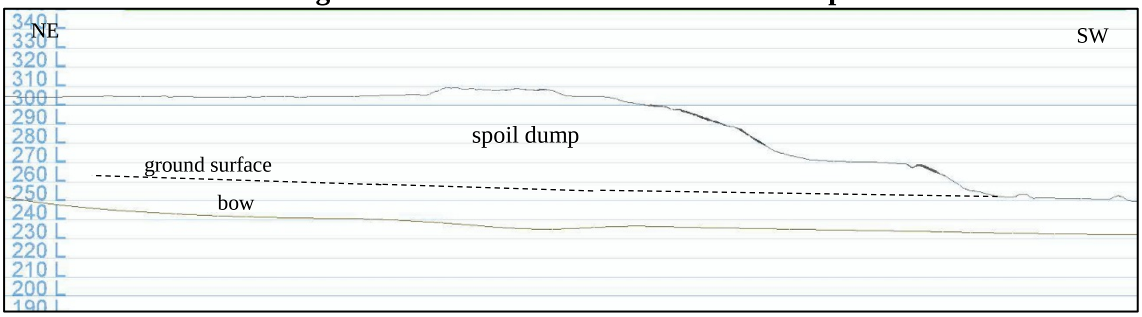


The initial insitu low wall was cut down at the dip angle so there is no material resting on the potential relict coal slip plane and the pit floor, which is effectively a footwall, is not steep enough to present any risk of slab failure. As a result the pit configuration is stable with no kinematic condition conducive to failure.

The outer face of the D Pit spoil, the small out-of-pit OP5 dump and the S Pit dump are as-constructed following the standard design. These slopes are clearly stable having been there for some time. Out-of-pit dump stability was discussed in Section 5.2 with analysis of the standard profile showing FoS of over 2.40 for circular slip failure.

Figure 21 below shows a cross section through the outer part of the D Pit dump, illustrating the shape of the benches and the flat top.

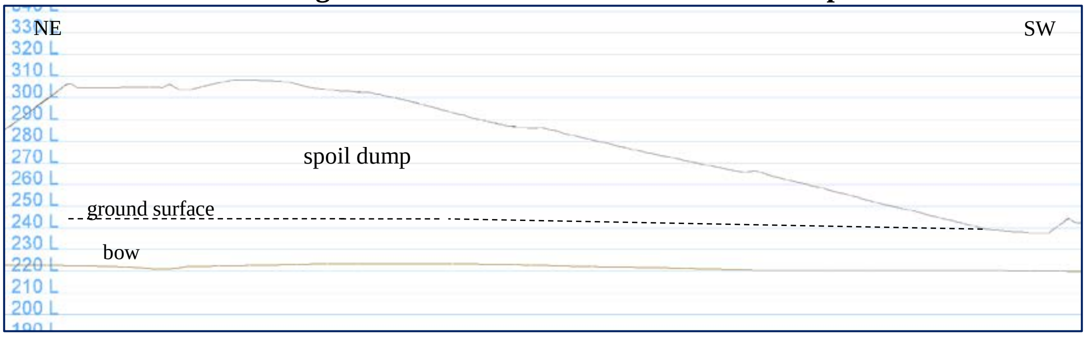
Figure 21: Cross Section MV7 - D Pit dump



These slopes formed as per the standard design can be considered to be inherently stable for the long term in regard to potential mass failure. In terms of environmental stability they will be subject to ongoing surface erosion which will gradually over millennia flatten the batter angle of the faces.

The outer face of the E Pit dump has been re-graded and rehabilitated; Figure 22 below shows the final profile at 1 in 4 slopes with nominal 5m berm, giving an overall slope angle of 13^0. There is no risk of mass failure with re-graded slopes at this angle.

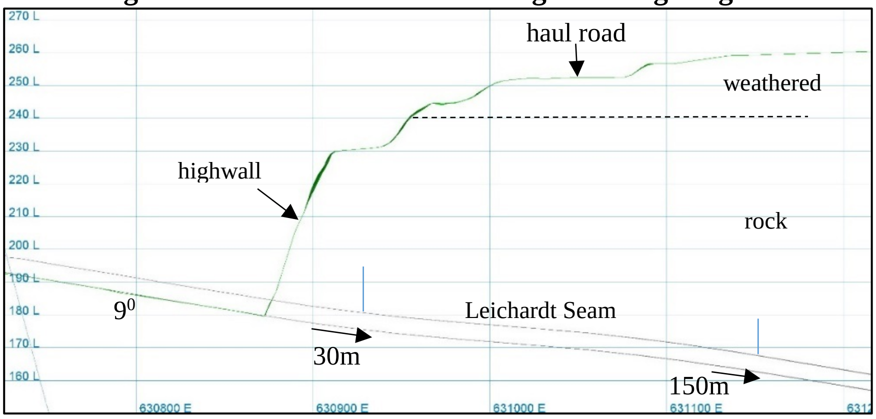
Figure 22: Cross Section MV6 - E Pit dump



6.3 Highwall Augering

Highwall augering has been carried in the northern half of E Pit North with a double row of holes in the Leichardt Seam. The location of the mined block, along a section of highwall between two faults, is shown in Figure 15. A cross section through the highwall is shown in Figure 23 below.

Figure 23: Cross Section MV2 - highwall augering



Full penetration of 200m was not achieved due to the presence of an unknown fault running at an angle behind the highwall, penetration depths being between 30m and 150m. Many of the holes would have extended under the haul road along the crest, but stopping a long way short of the perimeter drain and levee, which is approximately 200m back from the crest.

Augering is planned at other locations in D Pit highwall but these are of very limited lateral extent, being confined between faults, and would not be wide enough to present a risk of long term extensive pillar creep or subsidence.

The implications of augering with respect to the long term stability of Millennium Pit highwalls is discussed in Section 5.3 and the same comments apply to E Pit although the FoS are probably higher in E Pit since the web widths would have been conservative, being designed for full penetration.

Consideration is also being given to possible highwall mining in D Pit. There are no structures behind the highwall, other than access roads, that would be affected by any long term subsidence of pillars. Any pillar collapse at the portal should not result in deep-seated failure of the highwall, any slumping or collapse being most likely confined to the lower rock bench.

7. ENVIRONMENTAL STABILITY

The preceding section on geotechnical stability refers to the possibility of mass failure of the slope. However, regardless of the overall stability, there will be a residual effect of slope degradation due to weathering and erosion, referred to as environmental stability.

Differential weathering – E Pit

The Permian Rangal coal measures are prone to slaking, in particular the siltstone, which slakes and falls as fines continuously from the highwall. This action undercuts the harder more durable sandstone beds and leads to ongoing rockfall. Observations of highwalls at Burton Mine suggest a degradation rate of 40mm to 50mm per year on the highwall, equivalent to 1m after 20 years.

Photo taken 10/05/2017

In the long term the entire highwall face will move back, however it should still maintain its profile as the harder bands act as reinforcement within the slope. This process has no impact on the geotechnical stability of the highwall and as there are 25m berms at rockhead there is no risk of undercutting the upper weathered benches. The ongoing rockfall hazard means that people should not enter final voids.

The weathered rock and the thin cover of superficial deposits in the upper benches is likely to be slake susceptible and dispersive, and will gradually degrade to a flatter slope angle. There is ample room on the rockhead berm to allow this process without significant displacement of material into the void. The only exception is where fault wedge failures have occurred, for example D Pit South, where the wedge has cut back through the rock berm and is undercutting the weathered material above. In these cases rilling of weathered rock will run down the wedge into the void.

As the softer weathered rock and superficial deposits at the crest will degrade, especially if there is surface or concentrated run-off over the edge, allowance should be made with the placement of bunds or fences (see Section 9). Run-off over the rock edge is unlikely to have any detrimental impact of the rock face.

Fresh rock spoil is blocky with little fines but the rock slakes and breaks down so after 12 months or more the blocks are less apparent and there is a significant amount of fines. Aging spoil dump surfaces will be susceptible to erosion from surface run-off with a possibility of 10% loss of fines. This would apply to untreated low wall dump faces or other in-pit dumps. In these instances this would result in fines reporting to the enclosed void, which is inconsequential. Outer dump faces are to be re-graded and rehabilitated with rock mulch and grassed which will reduce the potential for downward migration of fines.

8. WATER MANAGEMENT

There is higher ground to the north of Millennium Pit with run-off mainly going into New Chum Creek which flows to the south between the Millennium Pit and Mavis Pit opencut areas. A levee runs along the B Pit eastern highwall to protect the opencut operations from flooding in New Chum Creek. This will not be needed for that purpose at the end of mining, however it may be advisable to retain it to prevent direct run-off over the highwall.

Run-off over the highwall should have no impact on the stability of the rock benches – no areas of potential mass instability have been identified – but concentrated run-off will erode and gully the upper free-dig benches in weathered rock. This should not result in slope failure but gullying will tend to eat back from the crest over time.

As discussed in Section 5.3 the highwall augering in the east wall stopped well short of the New Chum Creek levee and hence would not create any potential for subsidence issues.

Run-off towards the A Pit north wall is intercepted by a catch drain and directed round the pit towards the south-west. A permanent drain and bund will be needed to prevent uncontrolled erosive discharge over the highwall, or alternatively, a rock-lined discharge point could be cut into the crest to direct run-off into the pit at a given location. The potential for subsidence damage may need to be taken into account in the event that highwall mining of the north and west walls penetrates far enough to undermine any flood protection drains and bunds.

A drain runs along the south highwall at the base of the Mesa, directing run-off to the west via a vee-drain. As the top benches of the south highwall are to be left exposed, this drain will form part of long term water management.

The ground behind D Pit highwall slopes to the north-east or east-northeast, away from the highwall such that long term run-off would be limited to the immediate crest area and haul road. At the northern end of D Pit there is drainage towards the highwall and a discharge point would need to be considered to control the flow into the pit.

Water draining south off the small mesa is by a drain that runs south along E Pit highwall but well back from the edge. The E Pit highwall augering did not penetrate as far as this drain. The drain will eventually discharge into S Pit void, together with general run-off from behind the highwall. S Pit is a current mining area and the highwall was not exposed at the time of the slope assessment inspection. A review of the final highwall condition should be undertaken to check that there are no major instability issues with respect to discharging run-off over the highwall, given that there is a predicted major fault close to the proposed highwall location.

In general terms, water management is not seen as presenting a risk to geotechnical stability as run-off scouring would have only a limited impact on the stability of the highwall due to the lack of easily eroded unconsolidated material and the presence of hard rock layers in the weathered zone. No action would be needed with respect to the overall stability of the final void, other than a small bund, minimum height 1m (or 0.5m above the predicted 1 in 100 flood level if this is applicable) around the highwalls in order to limit the run-off area behind the crest. Exclusion bunds, as discussed in Section 9, may be used for this purpose.

Notwithstanding the low geotechnical risk, there is nevertheless a potential for concentrated run-off over highwalls in some places which is likely to cause erosion damage in the top benches in softer material without having any significant impact on the stability of the rock benches. Training run-off around the affected areas with bunds and drains is an option for limiting this but for long term effectiveness it is preferable to run with the flow as water will eventuate find the direct gravitational pathway.

In these cases where the general flow direction is towards the highwall, run-off could be directed into rock-lined discharge points over the highwall, or alternatively be allowed to drain freely over a wider area through gaps in a boulder-size rock exclusion bunds, as mentioned in Section 9.

Run-off pathways may develop over time in the internal spoil dump faces as water drains towards the pit and these would result in minor scouring of fines, as the spoil appears to be liable to dispersion, but would not prejudice the stability of the dump.

9. EXCLUSION

All abandoned pit walls contain some residual risk to people standing beneath or climbing on them. There is an obvious risk of rockfall with steep rock slopes as the faces weather and joint-bounded blocks can be released but there is also a risk of boulders on flatter or re-graded slopes weathering out or being washed out and rolling down the slope.

It is not practicable to treat slopes to entirely eliminate such hazards. The approach taken is minimize the likelihood of such hazards by re-grading slopes that present a significant risk, as described in the preceding sections, and then restrict access to the pit itself. This is achieved by bunding off the access ramps and placing exclusion bunds along final void highwalls.

It is understood that the entire mining area is fenced off to restrict access, however a more durable physical barrier is advisable around the voids to restrict access to the crest of pit walls as the edges will become eroded, crumbly and ill-defined over time. Limits of access should be marked by a bund wall and signs. Bund walls for this purpose should have a minimum height of 2m and should be constructed of non-dispersive material, or alternatively by placing large rocks which would prevent vehicular access without constricting run-off if water is being directed into the void.

Exclusion bunds need to be located at adequate distances from the highwall edge to avoid damage from slope failures or degradation, but from a psychological perspective should be close enough to allow the hazard to be seen or identified from the bund. There are no official guidelines in Queensland pertaining to the appropriate location of exclusion bunds, however the following generic guidelines have been developed, based on unpublished comprehensive studies of opencut voids at German Creek by Ward[4] and at Oaky Creek by Klenowski[5].

1. Highwalls that are geotechnically stable:

Inside edge of bund to be offset 10m from projected lines as illustrated below:

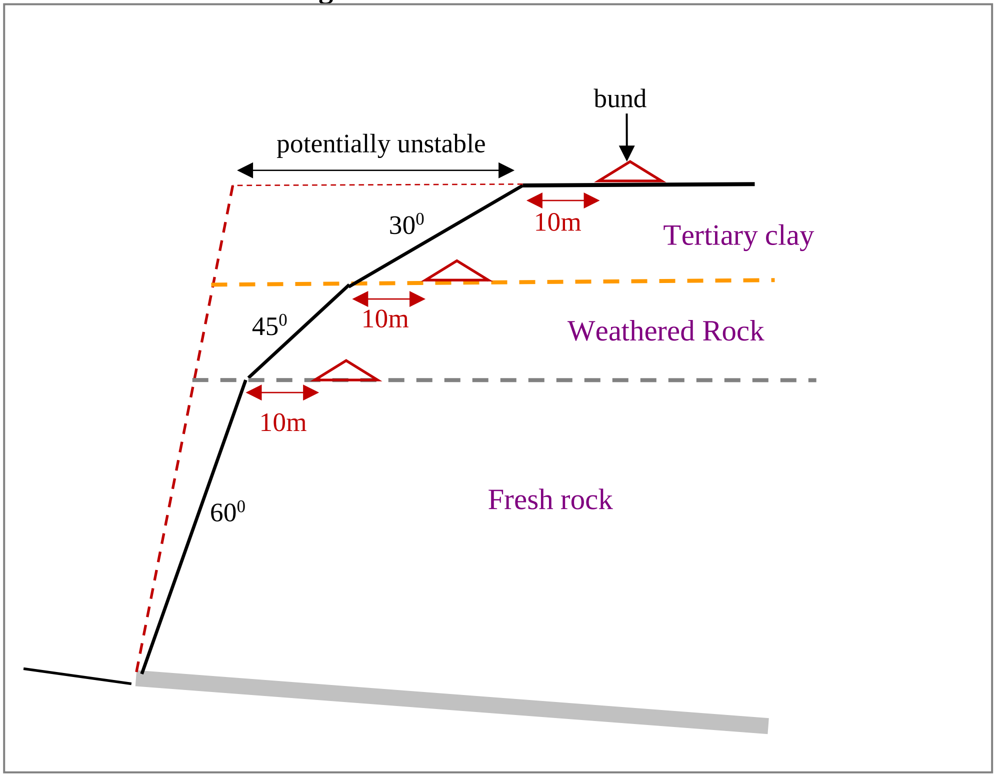
- 60^0 from toe for fresh rock;
- 45^0 from base of weathering through weathered rock;
- 30^0 from base of Tertiary to surface.

This is illustrated diagrammatically in Figure 24 below. Any part of the highwall profile steeper than the projected lines is deemed potentially unstable with regard to the possibility of failures cutting back into the crest and the bund is to be located 10m back as shown.

[4] Ward B 'Slope Design for Long Term Stability at German Creek Mine' Geotechnical Consulting Services Pty Ltd, Report No.109, Feb 1999 (Report for Capricorn Coal Management)

[5] Klenowski G 'Report on Highwall Safety Bunds for Final Voids at Oaky Creek Mines' Australian Mining Engineering Consultants, Mar 2017 (Report for Glencore Coal Queensland)

Figure 24: Bund Location Guide



The bund location relative to the actual crest is thus determined according to the thickness of the three material types present in the highwall, and the projected angles.

2. Highwalls with a history of slope failure or with a potential for slip failure:

Inside edge of bund to be offset as follows:

- existing failures - 5m back from the farthest tension crack;
- potential failures - 5m back from the location of the backscarp for the most critical slope failure path;
- rock slopes subject to structural disturbance with closely spaced discontinuities - at the point defined by where a line drawn at 50^0 from the toe of the slope meets the ground surface (that is 50^0 line instead of the 60^0 line in Figure 24).

These cases need to be assessed on an individual basis to check the failure geometry. Slopes where the dip is towards the face such that block slippage is possible have the potential to fail a long way back from the crest. Where failure is a result of movement on major discontinuities such as fault planes or combinations of faults and major joint planes, the distance back into the crest may be determined by the failure geometry.

There is very little if any Tertiary in the highwalls at the Millennium Mine complex, the only significant Tertiary thickness occurring under the mesas. The bund location will therefore be governed by the weathered rock profile. At Millennium Pit the standard design is for a 45^0 top bench so the bund would normally be located 10m back from the crest. In some cases, however the batter has been undercut to a steeper angle, for example B Pit north wall (see p.12) in which case the bund should be 10m back from a projected 45^0 line, or to make it simple 15m back from the crest.

In the case of Mavis Pit with a double undercut bench, the bund should be 10m back from a projected 45^0 line from the toe of the upper bench, again 15m back from the edge would provide a general approximation.

The only case of major instability is at the fault intersection in the south wall of A Pit (see **p.10**), where a large tension crack is visible in the access road. The criterion here would be 5m back from the tension crack or 10m back from a projected line from the base of weathering in the highwall face, whichever is the furthest back.

The foregoing is primarily directed at reducing the risk to people. At the Millennium opencut consideration is being given to post-operational use for agricultural purposes, specifically for running cattle. In this situation cattle could have free access to partially filled voids where grass is growing, and in particular, to within close proximity of abandoned highwall faces. Although over time it is likely that small scree slopes will form at the toe of exposed rock walls from weathering which will inhibit growth and thus discourage cows from foraging close to the wall.

Protection of personnel from rockfall hazards during mining operations is by means of a 10m wide exclusion zone at the toe of the wall which is normally marked by a small bund; cognisance of risk is obviously not an appropriate control for animals. Protection for animals (and landowners) could be addressed by a physical barrier along the exclusion zone such as an agricultural type wire fence. However, given the very low likelihood of occurrence and the low level of consequence, protective measures may not be justified and the decision to install fencing may be left to the landowner.

10. CONCLUSIONS

- The standard slope designs meet the EA requirements for as-constructed pit slopes to be geotechnically stable with regard to the ground conditions at the Millennium Mine complex;

- The highwalls are inherently stable against mass failure but local instability can occur where fault planes daylight in the wall and any new exposed final highwalls should be subject to geotechnical inspection to check for geological structure that could give rise to instability;

- Major wall failures due to faulted ground are present in the final south highwall in A Pit and at the wedge in D Pit but these failures are localised and fault-constrained and do not prejudice the overall long term stability of the highwall;

- The ‘rough-cut’ upper benches in Mavis pits are individually too steep for long term environmental stability and will degrade through gullying and erosion into lower angle rill slopes or in the case of the northern end of D Pit with the harder bands causing toppling failure,, could continue to eat back randomly into the crest;

- Pushing down the ‘rough-cut’ upper benches would be a means of preventing the continuous toppling cut-back effect on the crest;

- In-pit low wall dumps are stable with a more than adequate long term Factor of Stability, including a condition of partial submergence to the predicted 10 year water level;

- Historical instability in the low wall has been counter-acted by floor treatment and by avoiding dumping on the steeper floors, or by buttressing the spoil against the highwall;

- The external dump slope for E Pit and most of the south dump over the former C Pit have been regraded and rehabilitated in accordance with the EA specifications but the external slopes of other out-of-pit dumps are as-constructed with angle of repose batters and are not compliant with the final void requirements;

- The dump faces that require re-grading are the bottom bench of the south dump along the lease boundary, the West Dump, the small OP5 Dump and the whole of the external slopes at D Pit;

- There are no issues relating to potential risk of geotechnical instability due to run-off entering the void;

- The spoil has a susceptibility to slaking resulting in low plasticity fines which have a strong dispersive reaction which will wash down into the void;

- Highwall augering (and highwall mining if undertaken) has the potential to cause subsidence or collapse the highwall if the pillars fail due to long term creep;

- The highwall augering has not penetrated far enough back from the highwall to undermine any significant structures such as levees, so that any potential long term surface subsidence should not present any significant concern;

- Any subsidence induced face failure is only likely to impact on the lower rock bench, with material collapsing into the void, and should not extend back far enough to prejudice the upper benches through the weathered part or the crest.

11. RECOMMENDATIONS

The general findings of this study are that there are no significant issues in regard to mass slope instability and as a consequence there are no specific recommendations for remedial treatment. However mining is still underway in a number of places. A further review of highwall and ground stability is recommended for the following cases.

- The final A Pit north and A Pit west highwalls, and any new section of D Pit highwall, to be inspected and checked for any structural instability.

- Sections of highwall subject to highwall mining to be checked for potential damage from undermining and monitored (see below) with photographic recording immediately after mining and 12 months later.

The softer upper benches in weathered material will be subject to environmental instability with erosion from weathering and run-off. Consideration should be given to options for treatment of the following situations.

- Run-off management where the natural flow is towards the highwall at the northern end of D Pit and also A Pit north wall and A Pit south wall at the base of the Mesa where there are permanent drains. There may be a case for long term management by directing water flow over the highwall into the void by means of a rock-rubble drain or by diffusive flow through a permeable bund.

- Erosion of free-dig upper benches from weathering of over-steep batters. The slope will degrade over time to become self-stabilising or in the case of D Pit north, the crest may migrate back through toppling type degradation. There may be a case for pushing down the batters to a flatter angle which would reduce the potential for uncontrolled eating back into the crest. This would be recommended in any case if there was any a risk of animals or people using the surface area in front of the exclusion bund as otherwise the edges could be crumbly and unstable.

One means of monitoring the performance of the residual slopes over time is through photographic records. The recommendation would be to undertake drone surveys at say 5 year intervals (plus a survey after 12 months of completion of any highwall mining to check for pillar creep damage), with oblique shots of highwalls to show the overall aspect and condition. This would provide a means of monitoring areas of ongoing environmental degradation. Oblique shots of the dump faces and upper surfaces could be used to monitor the performance of rehabilitation practices and identify any unplanned areas of erosion.

MAusIMM CP (Geotech); RPEQ No.14047

Principal
Geotechnical Consulting Services Pty Ltd

Appendix D - Assessment of Residual Void Water Capability to Support Native Flora and Fauna

Assessment of Residual Void Water Capability to Support Native Flora and Fauna

Millennium Mine

December 2017

Prepared for:
Hatch/Peabody Energy

Version 1.1 FINAL

Prepared by:

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Executive Summary

This report assessed the capability of residual voids at Millennium Mine to support native flora and fauna, as required by the mine's Environmental Authority (EA).

Void water modelling by Hatch (2017) predicted the voids will reach a volume equilibrium after 100 years and acquire a salinity of between 4,000 – 5,200 µS/cm during above average wet conditions, and concentrate to 9,900 - 14,300 µS/cm in prolonged dry periods of typically 5 – 6 years of drought conditions.

This salinity is expected to support native flora and fauna, including fish, invertebrates, macrophytes, algae, amphibians, and birdlife, and not affect fringing vegetation. The voids will provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise highly ephemeral system. The aquatic community will be limited in diversity to those species with at least moderate salt tolerance.

The variety of species and the number of individuals present will be cyclical in nature. More diverse communities recruited during wet periods are expected to diminish to a less diverse, salt tolerant community during prolonged dry or drought periods, and with seasonal changes in salinity stratification. This assessment was limited to salinity influences on flora and fauna, as other water quality parameters were not included in the modelled conditions.

1. Scope

Gauge Industrial and Environmental Pty Ltd was engaged by Hatch to assess the capability of mine life residual void water to support native flora and fauna at Millennium Mine operated by Peabody Energy, as required by Condition F7(e) of the mine's Environmental Authority (EA) (EPML00819213).

2. Modelled Void Water Quality

Hatch (2017) assessed the final void water volume and salinity using a final void water balance model developed using OPSIM software. They determined the five voids on site would reach an equilibrium volume after approximately 100 years. The amount of water in each void is predicted to vary from 12% up to 32% of capacity.

The void water will contain analytes associated with coal mining, particularly salts from the Permian and Tertiary age strata and ongoing groundwater inflows. In addition to long term accumulative changes, seasonal variation in salinity will arise from brief rainfall inputs providing fresher water followed by evaporation during mainly dry periods. Salinity, measured as Electrical Conductivity (EC) is expected range between 4,000 – 5,200 µS/cm during above average wet conditions, and concentrate to 9,900 - 14,300 µS/cm after prolonged dry periods of typically 5-6 years (Table 1).

Salinity is expected to stratify in the significant void depths, and seasonal temperature fluctuations may also cause some inversion mixing of salinity within a void.

Table 1 – Predicted Void Volumes and Salinity

Void[3]	Max. Volume[3] (GL)	Volume as % of capacity	Modelled EC – Wet[1] (µS/cm)	Modelled EC – Drought or Prolonged Dry[2] (µS/cm)
Millennium	8.9	12	5,200	13,200
Mavis D	10.0	19	4,000	9,900
Mavis E	9.0	32	4,100	14,300

*Source: Hatch (2018). [1] Wet = above average wet conditions; [2] Drought or Prolonged Dry = typically 5-6 years; [3] Maximum volume is free water volume only and does not include any spoil volume.

Other water quality parameters, such as pH and heavy metals, were not modelled, and this assessment is limited to salinity measured as EC, and does not include chemical interactions or variations in ionic composition.

3. Capability to Support Flora and Fauna

3.1 General

Some species have a capacity to tolerate saline conditions, although increased salinity is generally associated with lower aquatic biodiversity (Dunlop, et al., 2005). Ecotoxicology studies found salinity levels up to EC 2,000-2,500 (as µS/cm) provide 95% protection for aquatic species in the Fitzroy Basin (Prasad, et al., 2012). Above these salinities, mildly to highly salt tolerant flora and fauna tend to dominate.

Variations in salinity caused by seasonal changes and droughts may have short to median term impacts on flora and fauna individuals and populations.

The streams in the area are highly ephemeral with species present before mining limited to those adapted to the seasonal and drought cycles whereby the available aquatic habitat is minimal and short-lived. The residual voids provide a permanent aquatic habitat which can potentially support native species in all seasons and during drought, and serve as an wildlife refuge that would otherwise not be available in the area.

3.2 Fish

Most native freshwater fish are derived from recent marine ancestors and are tolerant of salinities up to EC 14,000 – 19,000 or greater, although adverse effects on eggs can occur at EC 3,000-6,600 (Hart et al, 1991; Bacher and Garnham, 1992; Dunlop, et al, 2005; Nielsen, et al, 2003).

Native fish common to the area (DERM, 2010) include species tolerant of salinities greater than EC 15,000 and up to EC 40,000 (Pusey, et al, 2004). The voids are expected to support native fish following wet conditions, either as breeding populations or individuals introduced by natural recruitment (for example, by transfer by waterfowl). After prolonged dry periods (5-6 years), diminished fish breeding may reduce numbers, however the voids are expected to support a variety of native fish species.

3.3 Invertebrates

High salinities can be lethal to small, multicellular organisms (e.g. flatworms) and macroinvertebrates without impermeable exoskeletons (e.g. gastropods). A general threshold of EC3,000 produces lethal effects in microinvertebrates, and adverse effects on macroinvertebrates, particularly those without impermeable exoskeletons (Dunlop, et al., 2005). However, many native macroinvertebrate species are of marine ancestry, and relatively tolerant of elevated salinity (Dunlop, et al., 2005). Marshall and Bailey (2004) challenged numerous taxa in lowland streams to increased salt concentrations between approximately EC 1,500 and EC 5,000. They found most taxa (88%) were unaffected by salinity, and a minority (12%) were significantly reduced in numbers at EC 2,200. Although diversity decreases rapidly as salinity approaches EC 15,000, the rate of decrease slows above this level (Nielsen, et al, 2003).

The modelled salinities during wet periods (EC4,000 to 5,200) are expected to affect sensitive invertebrates, particularly microinvertebrates. As salinity increases (up to EC14,300) during dry periods, a shift to moderately to highly salt tolerant communities is likely, with a subsequent reduction in species diversity. As invertebrates have short lifecycles, and many macroinvertebrates are aerially mobile, a more diverse macroinvertebrate community is expected to re-establish following fresh water inputs.

3.4 Macrophytes and Algae

Freshwater algae are sensitive to increasing salinity although some have adopted life stages and undergo morphological and physiological changes to survive a broad range of salinities (Nielsen, et al, 2003). The majority of algae do not tolerate salinities above EC 15,000 (Bailey and James, 2000).

Aquatic macrophytes are susceptible to raised salinity, with sub-lethal effects (lethal to some species) occurring at salinities above EC 1,500-3,000; and the upper limit for most freshwater macrophytes being EC 6,000 (Nielsen, et al, 2003; Dunlop, et al, 2005). Salt tolerant native species such as *Ruppia* spp and *Lepilaena* spp species tend to dominate above EC 6,000 (Nielsen, et al, 2003).

3.5 Amphibians

Amphibians are particularly sensitive to salt, although the limited tolerance data available (for *Rana esculenta* and *Rana temporaria*) suggests salinities above EC 10,000 are tolerable (Dunlop, et al., 2005).

3.6 Fringing Vegetation

The Hart, et al (1991) review of salinity effects on riparian trees (limited to Eucalyptus, Melaleuca and Casuarina species) indicates salt-sensitivity starts around EC 3000, and with the majority of species (including *Eucalyptus tereticornis*) sensitive at approximately EC 9,000, and some species tolerating EC >22,000. A south-east Queensland study found many native trees were moderately to highly salt resistant, requiring root zone salinities of ECse[1] 6,000-14,000 to inhibit growth by 25% (Dunn, et al., 1994). *Eucalyptus tereticornis* and *Casuarina cunninghamiana* are considered tolerant of soil salinities up to EC 8,000-12,000 (QDPI, 1998; FAO, 2002; Anderson, 2003). Riparian species such as *Eucalyptus camaldulensis* and *Melaleuca halmaturorum*, with extensive root systems in contact with several sources of subterranean water of varying salt concentrations, have been observed to utilise the less saline microhabitats (James, et al., 2003).

During wetter conditions, the modelled void salinities are expected to provide a source of water tolerable to support salt tolerant fringing riparian vegetation with root systems deep enough to access the void. Under dry conditions, the void water may become too saline for all but the most salt tolerant species.

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[1] ECse is the electrical conductivity of a saturated soil extract. Using irrigation water conversions provided in ANZECC (2000 p 4.2-6), average root zone salinities (loam soil) of ECse 1,360 equate to EC1,000 in water.

The Brigalow (*Acacia harpophylla*) vegetation common to the area have relatively shallow, spreading roots (up to 4 metres) (CSIRO, 2003) and are unlikely to access the voids except possibly in low wall areas, and are therefore unlikely to be affected.

3.7 Birds

The mine voids are expected to support native bird life as a source of food (e.g. fish, algae and crustaceans), and if necessary, their mobility permits the use of alternative, fresher water sources for drinking such as Western Dam and the Sediment Dams that will be retained for stock watering dams. Mine staff have noted that the existing dams at the mine support ducks, pelicans, cormorants, brolgas, emus and black swans, which before mining, would otherwise not have access to water at the site.

4. Conclusion

The predicted salinity of the residual voids is expected to support native flora and fauna, including fish, invertebrates, macrophytes, algae, amphibians and birdlife, and not affect fringing vegetation. The voids will provide a permanent aquatic habitat to serve as a wildlife refuge in an otherwise highly ephemeral system.

The aquatic community will be limited in diversity to those species with at least moderate salt tolerance. The variety of species and the number of individuals present will be cyclical in nature. More diverse communities recruited during wet periods are expected to form a less diverse, salt tolerant community during extended dry periods (over 5-6 years) and with seasonal changes in salinity stratification.

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