BHP

South Walker Creek Mulgrave Resource Access: Stage 2C (MRA2C)

EPBC 2017-7957

Appendix F: Residual Void Management Report

South Walker Creek Mine

Residual Void Study

June 2008

Version 1

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

LINKAGE BETWEEN EA REQUIREMENTS & REPORT CONTENT

EA CONDITION F7	REPORT
a) A study of options available for minimising final void area and volume; and	Sect 5
b) 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; and	Sect 6
c) 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; and	Sect 8
d) A hydrological study into the long-term risk of the Walker Creek / final void interaction, including erosion of the banks and spoil and extreme hydrological events, and the consequences of such interaction to the long-term stability of the final voids;	Sect 7
e) A study of void capability to support native flora and fauna; and	Sect 9
f) A proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes	Sect 9 Sect 5
g) The recommendations of this these studies are to be followed during the life of the mine, and will include detailed research and modelling.	Sect 1, Sect 6, Sect 7, Sect 8.

Glossary of Terms

BMC	BHP Mitsui Coal Pty Ltd The owner of the Mine.
BMA	BHP Mitsubishi Alliance (BMA).The Mine Manager
Domains	The overriding post mine land use concept for particular areas. Three domains are described at South Walker Creek: Grazing, Bushland and ECA's.
EA	Environmental Authority
ECA's	Environmental Control Areas – A domain type which defines post mine lands with a primary aim to prevent downstream impacts. Includes voids and ramps.
Final Void	The last mining pit.
EPA	Environmental Protection Agency
EP Act	Environmental Protection Act 1994
EMOS	Environmental Management Overview Strategy
EMP	Environmental Management Plan
EMS	Environmental Management System
Endwall	The lengthwise extremities of the pit. (As opposed to the side extremities which are the high and lowwalls).
FRR	Final Rehabilitation Report
Highwall	The pit wall of un-mined land
Lowwall	The spoil placed immediately adjacent to the pit in the previously mined strip.
MCA	Minerals Council of Australia
Partings	Overburden strata between coal seams
Prestripping	The operation to remove overburden with truck and shovel
QMC	Queensland Mining Council
RLT	Reserved Long Term
Rejects	Coarse coal washery waste stream (non-coal material).
Salinity	Generally refers to the concentration of sodium chloride either in soil or water
Spoil	Overburden after removal to expose the coal seam
Tailings	Fine coal washery waste.
Topsoil	The upper layer of the soil profile removed for reuse in rehabilitation.

1 EXECUTIVE SUMMARY

This study aims to meet the requirements of EA MIN 100552107 No (F7) item (a) of the South Walker Creek Mine Environmental Authority - that is complete a study of options available for minimising final void area and volume. It should be noted that at this stage there are no residual voids within areas covered by this Environmental Authority. The actual mining areas in which residual voids are expected to occur will be well to the west of the current pit areas.

The treatment of final voids and the final configuration of lowwalls, highwalls and endwalls is an area of considerable interest and at the time of this report preparation largely remains unresolved from an industry viewpoint. Many mines have adopted a fence and bund scenario and the Environmental Protection Agency (EPA) has provisionally approved this treatment via Environmental and Integrated Environmental Authorities. Notwithstanding this, EPA Guideline 18 indicates that the Regulator will be reluctant to accept relinquishment of mine leases if remaining voids are left in an unsafe, unstable or unsustainable configuration

South Walker Creek Mine also recognises that community and regulatory pressures may eventually require significantly greater attention to the rehabilitation of such areas. Thus the objective of this Study is to propose strategies for the rehabilitation of residual voids and highlight areas of further research and investigation which will improve the outcomes for final void stability and potential uses.

The mine will remain an operational project into the foreseeable future and the final configuration of the mine will ultimately depend on demand for coal and other factors. Long term mine planning seeks to infill voids with spoil, reject and tailings waste to the maximum extent practicable, but nonetheless several voids will remain at end of mine life. Preliminary studies conducted in early 2007 by SMG Consultants concluded that prior to mine closure, all ramps could be backfilled and 50% of all final mined pits may be partially backfilled or regraded during mine operations. Major mine planning revisions are still underway and it is possible that the current round of more intensive mine planning will result in a different backfill/regrade percentage.

There are no final voids as yet, thus provision of detailed specific geotechnical assessment and hydrological performance of “residual voids” is not feasible until one or more final voids are available for investigation. Thus much of this investigation is necessarily conceptually based, although wherever possible pertinent site data and projected void dimensions have been used. This investigation has included use of SEEP and GoldSim modelling methodology for examining water storage behaviour in voids of various configurations.

The GoldSim modelling predicts that salinity in many instances may eventually rise to extremely high levels unless linkage with the groundwater table is available and or the residual void is allowed to spill from time to time. However for the extensive regrade treatment (10% slopes) the modelling predicts that water quality may be much improved compared to the deeper 1:4 and angle of repose void scenarios. This is due to a predicted net downwards migration of water and salts into the water table well below the regraded void base. Thus it may be possible for rehabilitated voids which have been substantially regraded or backfilled to provide a viable water storage for livestock or fauna.

Overall this study concludes that there is very little potential for final voids to fill and spill, unless unusually large spoil areas report to the void. Nonetheless, with a regraded void situation the void itself becomes a considerable catchment with the potential to store large quantities of water. This is particularly the case for the deeper voids that are currently planned for the later stage of the South Walker Creek mine life.

However given that the mine is located for a large part in the floodplains of Walker and Carborough Creeks, the potential for void interaction with flood situations can not be discounted. Thus final landform design will take this potential into account with an aim of either eliminating interaction potential or by enabling some limited potential depending on which scenario offers the most environmental advantages. Discussions with DRNW will be required well in advance of finalising the designs for the spoil placement and void treatments for areas susceptible to flooding.

Further investigation in support of firming up the likely residual void stability, hydrological performance and rehabilitation concepts identified by this overview study includes:

1. More quantitative hydrological and geochemical research is warranted when the mine life and landform planning program further clarifies the likely configuration, size and position of the final voids. The research would be aimed at providing more reliable predictions of long term void water levels and mechanisms that may be used to enable the void to self regulate its salinity.

2. Groundwater investigation aimed primarily at understanding the behaviour of the regime in particular reference to the likely final position and configuration of the final void so that the void's potential to depress or recharge groundwater is understood and that the refined hydrological model accounts for groundwater realistically in determining long term storage levels.

3. Durable rock identification to ensure that sufficient material is available for rock mulching steep long slopes into voids if that treatment strategy is to be applied.

4. Further investigation into erosion mitigation on long slopes which will be formed when highwalls and lowwalls are subjected to substantial regrade treatments.

5. Active liaison with the EPA so that the Regulator can understand the complex nature of the final void issues and provide more strategic advice on its requirements for the rehabilitation outcome for large residual voids in Central Queensland. This will assist South Walker Creek Mine as it refines and also develops strategies for mine closure which are consistent with the Regulators long term view and requirements.

The process of refining rehabilitation methods for spoil areas, including residual voids and developing appropriate land use goals for land disturbed by mining is an ongoing one as mining technology develops and mine plans change. Accordingly, in the future, the treatments proposed for residual voids may change.

In addressing the void investigation issues a number of consultancies have made contributions including:

- PW Baker & Assoc. Pty Ltd – Project scoping, coordination, management and report preparation.
- Gilbert & Assoc Pty Ltd – Void hydrology and creek interactions.

- John Simmons Pty Ltd – Geotechnical Stability issues.
- SMGC Consultants – Estimated final void dimensions.

Other information and contributions have been made by various BMA South Walker Creek long term mine planners, environmental staff and BMA corporate environmental management personnel.

Overall, the desired outcome for residual voids is that a stable landform eventuates and that costs/liabilities to the owners are tolerable at closure. Thus the development of an agreed mine plan and final landform design is critical to the successful and cost effective treatment of residual voids at closure of the South Walker Creek Mine operation. This is essentially a mine planning and engineering task for which South Walker Creek Mine and all other BMA owned or managed operations are now actively engaged.

2 BACKGROUND

2.1 PROJECT DESCRIPTION

South Walker Creek Mine was developed by BMA on behalf of the owners BHP Mitsui Coal (BMC) to extract coal from these reserves on mining lease ML4750. ML70131 is primarily for the purpose of locating infrastructure and supporting activities, however, in the future this mine lease may also support mining activities. South Walker Creek Mine is currently assessing the feasibility of mining on mining lease ML4751 (Bee Creek) and MDL235 (Nebo West), which both currently have separate EM Plans and standard environmental authorities covering exploration activities. Should mining prove viable on these leases, then BMA on behalf of BMC may make application to include both or one of the abovementioned leases in the South Walker Creek Mine project and the associated Environmental Authority.

2.2 MINING SEQUENCE

Generally first disturbance of mining areas occurs through exploration drilling, seismic and other geological techniques which are conducted ahead of the mining operation for the purposes of coal resource estimation, mine planning and economic assessment.

Mining at South Walker Creek Mine is conducted by open cut strip mining with progressive backfilling of the pit. The main features of the mining sequence are

- vegetation is cleared and burned, or if appropriate stockpiled for use in rehabilitation;
- topsoil that is suitable for future use in rehabilitation is strategically recovered and either directly spread on regraded areas or placed in topsoil stockpiles;
- the strata overlying the coal seams (overburden) is drilled, loaded with explosives and blasted to enable removal;
- overburden is removed using a combination of dragline, dozers (ripping and pushing), hydraulic excavators and loaders and trucks. The overburden is generally placed in previously mined out areas in a geometry that ensures rehabilitation slope and drainage criteria can readily be met. Out of pit dumps are utilised from time to time when there is insufficient room for overburden to be cost effectively placed in previously mined out areas in accordance with the rehabilitation criteria.
- the coal seam is ripped to enable removal;
- coal is removed by excavator and taken to the Coal Processing Plant (CPP) using large capacity diesel trucks.

2.3 MINE REHABILITATION

The overriding post-mining land use goal is to reinstate disturbed areas to self sustaining vegetation communities which include tree and shrub communities (bushland), 'wetland' areas and open grasslands. Tree and shrub communities will be developed in association with grassland areas established to provide initial protection in areas of higher erosion risk. Rehabilitation methods reflect current technology and commitment to sustainable development.

As mining progresses, the stockpiles of excavated overburden (spoil) are rehabilitated in accordance with the rehabilitation schedule, to a stable land form. The rehabilitation process is in two parts. Initially the spoil is either placed to the planned final land form or is dumped and regraded to the planned land form. This land form is designed to be self-draining or in some locations, internally ponding. The second part of the rehabilitation process involves the establishment of vegetation. This may be assisted by strategic use of topsoil which has been stripped ahead of the overburden removal.

The main features of the rehabilitated landform are:

- spoil dump plateaus and infrastructure areas with slopes < 5%;
- truck dump margin areas with slopes up to 15%;
- dragline spoil dump margins with slopes up to 20%;
- bushland areas will be seeded to a mix of tree and shrub species which are suited to the spoil and preferably native to the area;
- grasslands areas will generally be topsoiled and seeded to a pasture mix of native and exotic species, often with a rapid growth forage crop. Straw mulching may also be employed in certain areas if deemed necessary. While trees and shrubs may encroach, grassland areas may persist in that form into the longer term;
- erosion and drainage controls from rehabilitation may include such measures as construction of permanent or temporary contour banks, rock lined waterways, drop structures, use of forage cover crops, straw mulching and contour furrows;
- final voids will remain with accumulated water likely to have varying salinity levels dependant on the dilution /evaporation rate of the void system. Depending on outcomes of current research programs (as discussed further in this document), the final void may be backfilled from the low wall to cover the upper most coal seam exposed in the pit to protect the resource and minimise coal aquifer inflows; or regraded more extensively to improve outcomes for a sustainable use.

Current mine planning indicates that the site can be fully rehabilitated within 5 years of the cessation of the mining of coal.

2.4 PROJECT LIFE

The ultimate life of the mine will be determined by a number of factors that are influenced both internally and externally. Current mine planning is at least to the year 2031 but operations may extend well past this point. In the future, additional coal may be extracted from seams exposed in the mine pit by techniques such as punch mining, highwall mining or auger mining. Also in the future, underground mining may be employed to extract more of the reserves from these mining leases. The market economics for the coal produced will also strongly influence the life of the mine.

The current long term mine plan is shown as ATTACHMENT 1 LONG TERM MINE PLAN.

3 REGULATORY ASPECTS

3.1 OVERVIEW

The Queensland Environmental Protection Agency (EPA) is the lead organisation in overall environmental regulation for South Walker Creek Mine. The major functional component in the mine-site regulation of the EP Act is the Environmental Authority (EA). The EA is essentially the 'licence to mine' and includes a comprehensive range of conditions to minimise impacts from mining activities on the environment. EA conditions may change over time in line with evolving technology, standards, industry experience, knowledge, research and other factors.

3.2 ENVIRONMENTAL AUTHORITY MIN100552107

This Residual Void Investigation has been carried out as per the requirements set out in Environmental Authority MIN100552107 which requires that a study dealing with residual voids be undertaken. In particular, Condition F7 states:

> *(F7) Complete an investigation into residual voids and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in F6 and landform design criteria by 30 June 2008. The investigation must at a minimum include the following:*
>
> *a) A study of options available for minimising final void area and volume; and*
> *b) 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; and*
> *c) 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; and*
> *d) A hydrological study into the long-term risk of the Walker Creek / final void interaction, including erosion of the banks and spoil and extreme hydrological events, and the consequences of such interaction to the long-term stability of the final voids;*
> *e) A study of void capability to support native flora and fauna; and*
> *f) A proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes*
> *g) The recommendations of this these studies are to be followed during the life of the mine, and will include detailed research and modelling.*

It should be noted that although void backfill/regrade at South Walker Creek Mine is now the preferred treatment when this can be undertaken cost effectively, the site is legally entitled to decommission the site with residual voids provided that the EA condition (F6) is met, that is:

> *"Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority"*

Such an approval is also dependent on the following slope limitations not being exceeded as outlined in the site's Rehabilitation Management Plan.

Rehabilitation Design Criteria

Rehabilitation area	Design Criteria	Qualifications
Final Highwalls: competent rock incompetent rock	<65° slope <30° slope	Competency certified by an appropriately qualified professional accredited by a credible third party.
Lowwalls and Ramp Batters	<17° slope	Angle of repose / benched / graded
Spoil emplacement areas	No less than 75% of area <11° slope Up to 25% of area >11° slope	Erosion control structures are to be installed at vertical intervals not to exceed 10m

Thus notionally at least EPA agrees to the concept that Residual Voids can remain at South Walker Mine, provided the void does not constitute a significant threat to the environment beyond the void.

3.3 EPA GUIDELINE 18

In 2006 EPA published Guideline 18: Rehabilitation Requirements for Mining Projects. This guideline provides further clarification on what the Government expects as outcomes for mine site rehabilitation. Overall, the general performance goals in Guideline 18 appear to be more stringent than earlier guidelines.

Guideline 18 specifies that there are four general rehabilitation goals required for rehabilitation of areas disturbed by mining including:

- Safe to humans and wildlife.
- Non-polluting.
- Stable.
- Able to sustain an agreed post-mining land use.

The regulator has also provided some clarification on its preferred position for acceptance of final voids (including voids, shafts, adits and subsidence areas) in the guideline. The guideline refers to three basic levels of acceptance:

- Generally acceptable - requires extensive void treatment including the possibility of backfill or considerable regrading,
- May be acceptable - a minimalist treatment is imposed such as sealing coal seams and hazardous material, allowing the void to fill with water, building a safety bund, battering unstable slopes to ensuring minor risk to fauna or stock. Overall the regulator may consider a land use situation of “unused void with low risk”.
- Rarely acceptable - leaving a void that has or accumulates hazardous material, poor quality water and is in a structurally unsound condition.

It appears that there is a stability requirement for final voids and it now appears that very limited treatment scenarios such as fence and bund strategies are unlikely to be accepted by the regulator – except in situations where the final void is stable and the interaction with the groundwater table is not adverse. Thus unless voids can be left in a stable configuration, it is unlikely that mine leases will be able to be relinquished.

As discussed in Section 5 South Walker Creek Mine is now planning to use more conservative treatments for its residual voids which aim to reduce the risk of potential instability as well as to greatly improve safety outcomes for stock, fauna and the community. A greater level of regrade treatment is now being proposed for residual void areas which do not meet stability and sustainability requirements. These treatments aim to meet BMA goals for safe, stable and sustainable landforms.

4 ENVIRONMENTAL CHARACTERISATION

4.1 PRE-MINING LAND SUITABILITY AND USE

South Walker Creek Mine Lease areas contain a range of land types historically utilised for low to moderate intensity grazing of native and improved pastures. The system of Rosser et al. (1974) was used in the allocation of pre-mining agricultural capability of the project area and a range of lands from Class V to VII were identified. Major limiting factors for grazing include potential for water erosion, restricted moisture holding capacity, effective soil depth and variable rainfall. Other significant factors are fertility restrictions and susceptibility to flooding. The distribution of pre-mining land capability has been assessed by Emmerton (1998), Global Soil Systems (1999), Groundwork (2002) and GTES (2006).

The area was previously mapped by Gunn et al (1967) in the Isaac - Comet reports at a scale of 1: 250,000 which described existing land types, many of which are productive grazing lands. The open eucalypt woodland did not require extensive clearing for cattle so much of the area has retained its original basic tree and shrub composition. Accordingly, the area has retained a significant emphasis on natural bushland values in association with grazing.

4.2 POST MINING LANDUSE

The rehabilitation is designed for grazing on selected areas especially the internal spoil dump areas. The grazing suitability will depend on the particular slope gradient and the soil type. Trials and monitoring of grazing will be undertaken similar to other BMA sites.

The removal of overburden results in the material swelling in volume by up to 25% and even though overburden is replaced in mined out pits, in most situations post mine landforms are more elevated than existed pre-mining. Slope gradients of post mine land will be generally greater than that existing prior to mining, which is a contributing factor to reduction in pre-mining land agricultural capability due to increased susceptibility to erode and reduced infiltration capacity. Some voids will also remain after mining and rehabilitation is complete.

The current Mine Life Plan indicates that all voids not utilised for placement of tailings or rejects will remain as a repository for water which accumulates from the combined effects of spoil percolation, exposed aquifers and precipitation. The Mine Life Plan strategy is that catchment areas of the final voids will be restricted to areas of mine disturbance and available monitoring data indicates that water quality may range from significantly saline through to that suitable for stock water. A three metre high safety berm and a stock proof fence will be constructed around all highwall and endwall areas. The berm has the added function of redirecting drainage away from the void.

4.3 CLIMATE

The Commonwealth Bureau of Meteorology has maintained a weather station at Moranbah Water Treatment Plant. A summary of long-term meteorological monitoring data for Moranbah is provided in Table 1. Moranbah (and Nebo) has a sub-tropical continental climate. In general winter days are warm and sunny and nights are cool. During summer, days tend to be hot and nights warm. Summer weather is influenced by a semi-permanent trough that lies roughly north-south through the interior of the state. The trough is normally the boundary between relatively moist air to the east and dry air to the west. It is best developed during spring and summer months when it triggers convection with showers and thunderstorms on its eastern side. Extreme variability in annual rainfall has been occurring for many years, with a tendency to drier conditions for the last several years (mid 1990's to 2007) with a wetter year in 2008.

Table 1 Climate Averages, Moranbah Water Treatment Plant (BoM 2004)

MONTH	TEMPERATURE OC		RELATIVE HUMIDITY %		EVAP (mm)	WIND SPEED km/hr	RAINFALL (mm)		
	Average Min	Average Max	9am	3pm	DAILY	3pm	Median	Highest Daily	Highest Monthly
Jan	22.0	34.2	69	41	8.5	8.5	66.6	120.4	315.0
Feb	21.8	33.2	73	46	7.7	9.6	85.8	150.8	316.2
Mar	20.1	32.3	70	41	7.2	9.5	34.6	164.8	268.0
Apr	17.6	29.5	73	44	5.8	8.8	25.2	143.8	271.0
May	14.4	26.4	73	45	4.3	6.8	27.6	58.0	196.6
Jun	11.0	23.7	72	43	3.6	6.3	9.4	38.8	55.3
Jul	9.7	23.6	69	39	3.8	6.8	5.9	60.0	103.6
Aug	11.1	25.2	66	36	4.9	7.7	12.5	150.8	247.3
Sep	13.9	29.4	57	28	6.7	9.0	3.8	20.4	39.4
Oct	17.6	32.2	59	31	8.0	8.6	15.8	73.8	146.6
Nov	19.5	33.0	61	35	8.6	8.8	69.4	85.6	220.3
Dec	21.1	33.8	65	40	8.7	8.5	82.6	116.6	318.2
Annual Av.	**16.7**	**29.7**	**67**	**39**	**2,366**	**8.2**	**583.6**	**164.8**	

4.3.1 Temperature

Average maximum temperatures are 23-25°C during winter and 33-34°C during summer. A highest maximum temperature of 45°C has been recorded (BoM, 2004). Minimum overnight temperatures are 9-11°C during winter and 21-22°C during the summer months. A lowest minimum temperature of 0.2°C has been recorded in July.

4.3.2 Humidity

Relative humidity is fairly constant throughout the year, ranging from 73% in the summer to 28% in the winter and is generally highest during the early morning hours.

4.3.3 Rainfall

Rainfall in the area is seasonal, highly variable and unreliable, with the majority falling during the summer months. The average monthly rainfall varies from around 9 mm/month in winter months to over 80 mm/month during summer months. Annual Median rainfall is 583.6 mm, falling on an average of 55 rain days. The mean annual evaporation in the

Moranbah area is 2372.5 mm. Evaporation greatly exceeds precipitation, hence water stress is expected to be significant factor in the performance of future rehabilitation of disturbed land, particularly on slopes and or where topsoil thickness is limited and the under lying spoil may be compacted.

4.3.4 Flood, Drought and Climatic Extremes

The Bowen Basin area within which the mine is located has experienced relatively few cyclones in the past 100 years. The most intense cyclone, which occurred in January 1918, was classified as a Category 2 cyclone. The cyclone caused most damage on the coast near Mackay, although severe damage was also reported in the northern Bowen Basin. No other Category 2 cyclones have occurred in the past 100 years but some Category 1 cyclones have been reported. Category 1 cyclones are the weakest cyclones with wind speeds of between 63 km/hr and 125 km/hr.

Prolonged drought is the principal factor that may adversely impact on the rehabilitated landform. Steep slopes shed more water than shallow slopes; hence vegetation established on steep slopes is far more susceptible to droughting than flatter slopes. Slopes with vegetation denuded by drought or bushfire can be damaged by high intensity rainfall. In recent times the area has also been affected by summer monsoonal troughs which have caused large and prolonged rainfall events.

4.4 GEOLOGICAL SETTING

Details of the resource have been described by Gutteridge Haskins and Davy (1975). In summary, the lease areas are comprised of four separate geological units; namely Cainozoic Deposits, Rewan Group, Rangal Coal Measures and Fort Cooper Coal Measures. These have been delineated from 1:250,000 Geological Series (Bureau Mineral Resources, 1968) as well as extensive exploration drilling on the lease. The in situ open cut resources for the South Walker Creek project have been estimated at 58.1 million tonnes at the measured confidence level and 78.6 million tonnes at the indicated confidence level. The coal deposit extends over a strike length of 40 km with dips of 8°-16° to the west.

4.5 SPOIL CHARACTERISTICS

4.5.1 Introduction

The mine waste stream at the Project includes the following material types: Weathered and unweathered Tertiary and Quaternary sediments as well as unweathered overburden - Permian comprising of inter-bedded sandstone, siltstone and claystone. Carbonaceous zones occur near the base of overburden and interburden between coal seams comprises sandstones, siltstones and claystones with carbonaceous zones.

Management of inhospitable Tertiary spoil is required to ensure that erosion impacts are tolerable. This requires a conservative approach to rehabilitation and generally involves moderate slopes less than 10%. Encapsulation of Tertiary surfaces on steeper slopes is desirable and even more conservative practices again where steeper slopes are involved (such as 2 m durable rock mulching). Ongoing spoil characterisation will be required as the mine develops. Key assessment criteria include: pH, EC, ESP and PSA. Overall the chemical and physical characterisation of spoil surrounding the residual void will have a marked influence on residual void stability and water quality.

4.5.2 Overburden

The chemical characteristics including potential for acid generation from tailings, rejects and inter-burden spoil has been assessed in studies by Land Reclamation Services (1998 and 1999) See Table 2 and ELP (1996).

The Tertiary (generally a shallow weathered overburden) is considered to present negligible risk in terms of acid formation. Land Reclamation Services found that the Tertiary material has an ANC ranging from 35 to 135 kg H2SO4. The Tertiary spoil is alkaline and has a significant potential to mitigate acidity if that potential existed. This potential is not considered significant, particularly in view of acid neutralising capacity of spoil and soil in the immediate area. Nevertheless, monthly water monitoring programs include checks for acid effects.

Land Reclamation Services also noted that the Tertiary materials have high pH and higher salinity than Permian materials. ESP was reported as high in range 20 - 36%, whilst calcium to magnesium ratios were unbalanced. A high clay activity ratio was also recorded indicating potential for shrink and swell and possibly a risk of piping/tunnel erosion.

The weathered Permian material was also determined as having a moderate to high Acid Neutralizing Capacity between 9 and 97 kg H2SO4/t whilst fresh Permian also has a low to moderate ANC of 6-85 kg H2SO4/t. However lower ANC and sporadic occurrence of pyrite immediately above and below the coal seam can occasionally result in low acid production potential.

Overall the LRS study demonstrates that the overburden at South Walker Creek is non acid forming and has moderate acid neutralizing capacity. Minor areas of AMD potential do exist immediately above and below the coal seam. Thus placement of this material as overburden at or near final surface of the rehabilitation should be avoided.

Chemical characterisation of the weathered Permian indicated generally unfavourable characteristics such as high ESP and Ca Mg imbalance. Nonetheless a slightly better material when compared to Tertiary spoil.

Table 2 Typical Borehole Overburden Characteristics*

OB TYPE	Tertiary		Weathered Permian		Fresh Permian	Interburden
DEPTH	2-10m	6-14m	21-36	14-21	35-43	31.6 – 62.6
pH	9	9.7	9.6	9.8	9.7	9.7
EC	600	610	310	310	150	330
Cl	596	463	141	78	54	128
ESP	20	36	20	24	18	23
Ca/Mg	0.24	0.42	0.58	0.59	0.54	0.65
R1	0.8	0.87	0.57	0.57	0.54	0.6
%Clay	40	29	22	26	15	30

* from LRS 1998.

Table 2 indicates that Permian material is likely to be a more stable material with greater capacity to sustain vegetation. This is not an unusual situation. Overall Permian materials are often superior to Tertiary materials in the Bowen Basis. Sodicity is an issue with all spoils.

Spoil quality is also being measured as part of rehabilitation monitoring at South Walker Mine. A summary of spoil quality from rehabilitation monitoring follows as Table 3. The results from borehole data (Emmerton 1999) are also consistent with this summary.

Table 3 Summary of Spoil Quality – South Walker Creek Mine

Attribute	Site 1	Site 2	Site 5	Site 7	Comment
slope %	11	17	< 2	14	good range of site slope gradients
Ca:Mg	0.7	0.4	0.6	0.8	A Ca:Mg <1.0 indicates physical problems from sealing & hardsetting. All sites are <1.0
pH	9.1	9.4	8.4	9.1	All highly alkaline. Good acid neutralising capacity but possible phosphorus insolubility (restricts availability to plants)
EC us/cm	480	500	851	294	>600 is considered saline. No significant salinity issue indicated Site 5 higher EC is not related to chloride (see below).
chlorides ug/g	353	397	42	190	All low
CEC meq/100g	25	22	21	12	generally adequate. Site 7 is getting low. Major cations are generally adequate
ESP	17	17	21	23	All sites are dispersive. Erosion problems indicated
R1 dispersion	0.81	0.79	0.88	0.79	All sites high and prone to dispersion and tunnel erosion.
Particle size distribution	>50% fine sand and silt	54% fine sand and silt	>50% fine sand and silt	>50% fine sand and silt	Prone to surface sealing restricting infiltration, excessive runoff & erosion.
Sulphates	17	15	570	16	No problems indicated
organic carbon	2.1	0.6	1.6	1.0	Variable but generally low
Total N	0.05	<0.01	<0.01	<0.01	Very low.
Effective rooting depth range and average (from EC profiles)	40-100 (65)	40-100+ (70)	15-100+ (55)	100	Good rooting depth indicated.
Vegetation trends	2400kg dry matter/ha. low protein, Most elements adequate	5000kg dry matter/ha. very similar nutrition to site 1.	3600kg dry matter/h very similar nutrition to site 1.	new rehab	Dry matter / ha are well above natural sites which ranged from 500 – 4000 (average 1300) in the same period

Table 3 also indicates that overall the surface spoils are infertile, hardsetting and dispersive, but can generally sustain vegetation. Nonetheless, given the relatively high sodicity of the overburden it is likely that the material will be dispersive. Erosion and sedimentation controls will therefore be an important management tool. Landform design based on low slopes and or rock cladding will be required for long term stability outcomes in most situations.

4.5.3 Coal Rejects (carbonaceous interburden)

Coal rejects at South Walker Creek Mine are largely comprised of residual contact strata which have been identified as having potential for acid production. Land Reclamation Services found that total sulphur ranged from 0.5 to 2% with acid potentials ranging from 4 to 42 kg H_2SO_4/t. Not all samples were acid forming with one sample having considerable excess in ANC. Nonetheless, disposal of this material at depth in spoil or with at least 2m of benign spoil is warranted.

4.5.4 Trace Element Analysis and Sodicity

The minor element concentrations are very similar to those typical of shales, which dominate the geology in the region. The spoil material composition (based on minor element composition) will therefore be typical of the natural background erosional products. Land Reclamation Services reported that some enrichment of elements was detected when compared to "average" crustal abundance. However the metals did breach known DME investigation limits.

Overall, the most significant adverse characteristics of South Walker Creek spoil material as are pertinent to rehabilitation outcomes include:

- High Exchangeable Sodium Percentage (ESP > 15%) is common, thus dispersion is an issue.
- Low to moderate Cation Exchange Capacity (CEC < 10 -15 meq/100 grams), thus low fertility.
- pH is mostly quite Alkaline to pH 9 plus.
- Salinity with EC often > 1,500S/cm.
- High erodibility as well as hard setting and surface sealing tendency.

4.6 BACKGROUND SURFACE WATER QUALITY

The major surface drainage pathway on the South Walker Creek Mine is Walker Creek which is within the upper catchment of Bee Creek. Carborough and other small, un-named creeks also flow through the mining area. Streams in the area are ephemeral in nature with the major use, apart from aquatic ecosystem values, being stock watering and associated agricultural uses. Local drainage pathways, creek and the mine drainage system are depicted in ATTACHMENT 3 SWC MINE CREEKS & DRAINAGE. Background water quality data is included in the Water Management Plan and summarised in Table 4.

Table 4 Background Water Quality for Bee Creek

Analyte	90th percentile	Range	No readings
TSS (mg/L)	756	1 – 1460	17
TDS (mg/L)	277	74 – 466	17
pH	8.1	6.3 – 8.2	19
Sulphate (mg/L)	4.7	0 – 5.5	19
Conductivity (uS/cm)	455	93 – 840	18
Cl (mg/L)	56	6 – 145	19
Na (mg/L)	27	9 – 69	19

Source – Dept Natural Resources

4.7 GROUNDWATER REGIME AND QUALITY

Most groundwater in the mine area is associated with low yielding aquifers in the sediments of the coal seams and with the sandy channels of the local streams. Coal seam aquifers have medium to high transmissivity but low storativity. Open hole water levels were measured at the completion of an exploration program in 1986. The water levels show a consistent trend from RL 186 m in the north to RL 180 in the south east, indicating a north to south sub-regional groundwater flow. The ground water level below the surface in the mining pit varies from 21m in the south to 32m in the north. The unconsolidated Quaternary sediments, which overlie the Permian coal measures, are generally located above the water table and are unsaturated. The primary aquifer is the Main Seam which has a low to moderate permeability. Groundwater inflows to the pit are low and readily handled by pumping from in-pit sumps to the return water dam.

The groundwater associated with the coal seams is generally saline and not used while the shallow aquifers associated with the stream channels is generally of good quality but of limited quantity. Some of the shallow aquifers are used for stock watering. It would be prudent to carry out additional groundwater investigations when final landform and mine closure planning is more advanced, specifically for final void location sites sufficient to project potential inflows – and outflows from the future final voids. This will be necessary in order to design the final void configuration and reliably model the hydrological performance of the final void.

4.8 PIT AND SPOIL WATER QUALITY

Water accumulating in pits following rainfall is pumped to storage dams and released if quality criteria are met. Direct water quality in pits is not available; however these pit water dams are routinely monitored and are considered reflective of typical pit water quality. Examination of the data indicates that on occasions the water is quite saline. See Following Table 5.

Table 5 South Walker Creek Storage Dam Max Salinity

Dam	Electrical Conductivity uS/cm	pH	Date
Ramp F Dam	4,850	8.73	27/7/2005
Ramp C Dam	4,860	9.7	30/3/2006
East Sediment Dam	2,910	8.5	25/07/2005

4.9 TOPSOIL RESOURCES

All future topsoil resources have been assessed for soil type, pre-mining land suitability and stripping depths formulated. All topsoil in advance of mining is stripped to recommended depths and either stockpiled or replaced over rehabilitation.

Soils within the lease area comprise a range of media with variable suitability for placement on the rehabilitated landform. Soils range from shallow lithosols on relict lateritic mesa's, shallow sandy loams, thicker sandy loams through to well structured scrub soils and a range of brigalow clay soils. All soils have potential for use in rehabilitation; however each should be placed on the landform according to careful consideration of slope (erosion risk) and vegetation type. Available soil types for rehabilitation on the lease areas including final voids include:

- Poplar Box Sandy Duplex Alluvial Plain (A2)
- Sandy Duplex Plains with Poplar Box (E1)
- Thin Duplex Soil With Poplar Box and Brigalow (E3)
- Forest Red Gum on Deep Alluvial Uniform Loamy Coarse Sands (A1)
- Uniform Clay Drainage Lines With Mixed Brigalow Scrub (A3)
- Uniform Non Cracking Clay (B1)
- Shallow, Gravel, Thin Duplex, Gradational Or Uniform Non Cracking Clay (B2)
- Deep, Uniform Grey / Brown Clays (B3)
- Melanhole Lowlands (B3V)
- Well Structured Scrub Soils (B4)
- Linear Gilgai (B5)
- Relic Surface Mesas (E2)

4.10 REHABILITATION

The main features of progressive rehabilitation process are outlined in the EM Plan as:

4.10.1 Overburden Placement Areas

These areas will generally be regraded to 10%, then topsoiled with suitable soil, then ripped and seeded with a variety of native species. Note that on outer batters introduced pasture species may be necessary to stabilize the slopes. Native species will however be sown in alternating bands along the contour. On level or very gentle slopes native species will be sown on a broad acre basis.

Drainage on slopes greater than 100m long will be implemented with imbedded contour drains or preferably even larger structures known as swales. Drainage works will be constructed prior to topsoil application. Drainage structures will be constructed according to contemporary designs outlined in the BMA Draft Guideline for the Design of Sustainable Mine Landforms.

4.10.2 Residual Ramps

Whilst most ramps can be backfilled during operations, it is possible that one or more ramps may remain at mine closure. Treatment proposed for Ramps is identical to that of all other overburden placement areas.

4.10.3 Residual Voids & Highwalls

A good part of the final void can be backfilled with prestrip spoil during operations. However, at this stage mine planning indicates that about 8km of residual void will remain. The actual treatment prescription of this final void has not been determined. Nonetheless one or more of the following treatments options have been identified.

- Grade Control – BMA Sustainable Landform Guideline but generally grades less than 10% are preferred unless durable rock is available to sheet steeper slopes. Shorter slopes are preferred to longer slopes.
- Water Storage – if useful water can be stored in the void for stock and wildlife, the landscape plan of the area will ensure that access for livestock and fauna is available.
- Vegetation Establishment – native vegetation will be the primary focus on steeper (<25%) rock mulched slopes. Pastures with scattered trees and shrubs will be established on 10% regraded areas. Topsoil and continuous contour ripping and seeding will be applied to all areas not under durable rock mulch.

South Walker Creek Mine has conducted programs to monitor rehabilitation performance since the late 1990's.These programs concentrate mainly on surface erosion, soil profile and vegetative development.

5 FINAL LANDFORM PLANNING PROGRAM

5.1 FINAL VOID DEFINITION

The mining void for an operational mine comprises two distinct elements, the open pit from which coal has been extracted and the ramps which allow access to the pit for coal and overburden removal. These two features are transitional; the ramp becomes progressively longer as the pit progresses down dip, hence through time the area of the void expands.

Continued open cut strip mining results in the mine void and access ramps progressively moving down dip until a limit is reached. Limits include economic limit, resource limit, tenure limit, infrastructure or possibly environmental limit.

5.2 EXISTING VOID EXTENT

Ramps and pits form a substantial percentage of the major disturbance at South Walker Creek Mine. In 2008 pit areas totalled approximately 221 ha and ramps 45 ha. Overall at South Walker Creek Mine, operational "voids" (ramps and pits) currently make up approximately 266ha which represents approximately 32% of the 821 hectares of gross mining area disturbance. The location of current mine disturbance including active pits, ramps, spoil and infrastructure areas is shown in ATTACHMENT 2 DISTURBANCE AREAS 2008.

5.3 LONG TERM PLANNING & SPOIL FIT INVESTIGATIONS

5.3.1 Introduction

The greatest single challenge for provision of progressive rehabilitation into the future involves effective planning of dragline and truck and shovel operations and resultant spoil placement. This is well recognised by BMA and all of its operations are conducting substantial investigations involving spoil fit, final landform and residual void treatment. This will help meet the requirements of the South Walker Creek Mine Environmental Authority - that is complete a study of options available for minimising final void area and volume. The preliminary results of spoil fit investigations are discussed in following sections.

Long term mine planning suggests that dragline as well as truck and shovel operations will continue to be the primary methods for creating the final rehabilitation surface. A major aspect of the mine planning process now being undertaken is the long term planning which will highlight locations of future overburden removal, volumes (swelled) and timing. South Walker Creek Mine is developing a Spoil Placement Strategy which not only meets mining objectives but also develops preferred final landform configurations which maximise the proportion of better quality post-mine land.

Preliminary studies conducted in early 2007 by MB Mining Consultants Pty Ltd completed a preliminary final landform design and investigation including costing. (South Walker Creek Final Landform Design and Total Closure Costing – Final report March 2007). Assumptions used by the consultant included:

- All calculations are based on the Base Case Schedule from The Resource Development Plan.
- Final landform profile is based on Schedule F – Table 2 (Rehabilitation Design Criteria) from the Plan of Operations SWC FY07.
- The final dragline highwall is left intact after mining and it is assumed that the final prestrip highwall will be cut at 30 degrees in the weathered rock so no additional regrade work will be required.
- The final void will be filled with water to maximum level.
- The spoil emplacement areas are regraded to 20% (11 degrees) down to the final void maximum water line. Below the water line the lowwall is left intact.
- Regrading is carried out with CAT D11R dozer with universal blade.
- After regrading contour drains will be established at 10m vertical intervals typically directing water to the regarded ramp areas and into the final void.
- Rock lined drains will be established at 500m intervals down the regraded dump faces and down the ramps.

This landform concept developed by MB Mining was a first attempt at devising the final landform based on meeting grade and drainage requirements of the existing Environmental Authority. However the long term planning work is now being reviewed with respect to both improving the mine economics and as well improving the sustainability of the final landform.

5.4 LOA RESIDUAL VOID PLANNING SCENARIOS

Current LOA (Life of Asset) planning investigations indicate that the potential for the ramps and pits to continue to develop out to the lease boundary more or less as a continuation of excavation and spoil placement scenario at South Walker Creek Mine is not feasible given three significant recognized constraints – Physical, Economic and Environmental.

1. Physical – Volumes of prestrip material which will be generated from westwards pit progression are substantial and spoil fit within the disturbed / mined out areas is constrained, thus backfill of existing ramps and some pits should improve spoil fit in some areas.
2. Economic – If lowwall ramps are kept open, spoil elevation between ramps can become excessive and haulage costs increase. Thus backfill of some ramps and some pits is planned to enable cost effective placement of prestrip overburden. Whilst this may be an operational benefit, it also reduces the rehabilitation liabilities of the operation.

3. Environmental – Voids will form a very considerable area of the final landform. Erosion and stability risks are significant for these topographic features without considerable intervention. Thus BMA is investigating scheduling backfilling or regrading of the final void to reduce these risks.

Given that these limitations are now better understood, mine planning at South Walker Creek Mine is being changed to accommodate these constraints to ensure that the operation remains profitable for a very considerable time as well as enable it to conduct its mining operations in alignment with sustainable landform outcomes.

South Walker Creek Mine planning has developed a number of potential scenarios aimed at initially improving profitably of the operation in alignment with the sustainable landform concepts and further, it is currently developing a remediation case in which additional void backfill/regrading is undertaken during mining activities to limit the extent of the final void at cessation of operations. This activity is termed <u>reclamation</u>. Following cessation of mining operations, final rehabilitation of all remaining angle of repose voids/pits will be undertaken.

Void and ramp infilling is necessary to improve spoil fit, reduce haul costs and reduce rehabilitation costs on closure. Thus there will be a need to revise the Mine Life Plan strategies for void treatment when these void issues have been resolved. A considerable effort in mine planning and scheduling optimization has been undertaken to date. The work is of a very complex nature. Three main scenarios have been investigated including:

Fence & Bund

At mine closure most or all of the final strips remain as open voids with at least one ramp. This has limited potential at South Walker Creek given the requirement for prestrip spoil disposal plus problems with permanently stabilizing deep open pits.

Progressive Backfill or Regrade

By mine closure, most or all of the ramps have been backfilled and most or all of the last mined strips have been regraded or backfilled by progressive backfilling.

Final Rehabilitation

Isolation (fence and bund) of remaining stable voids or extensive regrading of the remaining lowwalls and highwalls.

SMG Consultants have provided the following estimates of final voids sizes and configurations according to the above treatments. The following Table 6 shows that at cessation of mining unless voids are progressively regraded or backfilled, the length of open pit would be approximately 13.4 km. However, provided pits and ramps are progressively backfilled during operations (reclamation) as is currently being considered, the total length of standing highwall is reduced to 2.9 kilometres by cessation of mining. This represents approximately a 78% reduction in the overall liability for final void rehabilitation by that time

Table 6 Base & Remediation Cases – South Walker Creek

	OPTION 1	OPTION 2	OPTION 3	
PIT ID	BASE CASE (Pit Length m)	Backfill during operations (Pit Length m)	Already regraded by cessation of mining (Pit length m)	Remaining voids at closure requiring Reclamation (Pit Length m)
Kemmis Pit	2930	430	2000	500
Northern Mulgrave	5060	2180	2200	680
Carborough	1190	1190	0	0
Walker	4240	1580	900	1760
TOTALS	**13 420**	**5 380**	**5 100**	**2 940**

Table 6 also projects that at closure there will be approximately 10.5 kilometres of final void which have been rehabilitated by complete backfill or regrading to 25% or 10% slopes. The residual 3 kilometres of void will then be regraded to make safe, stable and sustainable.

The following three tables are presented to indicate the results of recent conceptual mine planning to show how operational activities can be undertaken to reduce the extent of the final voids at South Walker Creek Mine. Dimensional results are shown for three scenarios which address a minimal treatment e.g. a fence and bund scenario assuming that all voids are open at end of mine life; a 25 % highwall/lowwall regrade scenario which assumes that a thick application of rock mulch will be applied to the regraded surfaces and a 10% regrade scenario which assumes that the conventional topsoil treatment will be utilized. For both regrade scenarios, considerable void backfill and or regrade takes place during operations, thus significantly reducing the length of open pit requiring rehabilitation at closure.

Table 7 Final Void – Mining Configuration, Fence and Bund Treatment

Pit Name	Width of floor (m)	Depth below natural RL (m)	Spoil Height above natural RL (m)	Highwall Batter Width (m)	Total Low-wall Height above base of pit (m)	Total L'wall Batter Width (m) 1V:3.1H	Total width across pit at natural ground level	Total catchment width – h'wall crest to crest of L'wall.	Pit Area at crest of h'wall (ha)	Immed. catchment Area of pit inc. all L'wall face (ha)
Kemmis Pit	60	50	25	50	75	233	265	341	78	100
Northern	60	71	36	71	107	330	351	459	178	232
Carborough	60	98	49	98	147	456	462	610	55	73
Walker	60	130	65	130	195	605	593	790	251	335
								TOTAL AREAS (ha)	**562**	**740**

Table 7 shows the extent of voids at mine closure if no backfill or regrading activities were to occur. This is the least preferred scenario; however it provides an insight to the potential size and scale of mining voids in the very late stage of the mine operation. Because the coal seams generally dips downwards, most of the pits become progressively deeper. For example Walker Pit is expected to reach over 100 m depth in its final mining configuration.

Table 8 Residual Void after Regrade 25:25 Treatment

Pit Name	Strip length at pit closure(m)	Depth to base of reshaped void (m below natural RL)	Catchment to low-wall crest (m)	Catchment length highwall batter (m)	Approx Area (ha)
Kemmis Pit	2500	34	236	136	93
Northern	2880	50	342	200	156
Carborough	0	0	0	0	0
Walker	2660	93	632	372	267
TOTAL	**8 040**			**TOTAL AREA**	**516**

In Table 8 residual void configurations are provided assuming that all voids not backfilled are regraded during operations or post closure to 25% on the highwall and lowwall sides. Thus the depth of the rehabilitated void reduces considerably to the mining configuration.

Table 9 Residual Void after Regrade 10:10 Treatment

Pit Name	Strip length at pit closure(m)	Depth to base of reshaped void (m below natural RL)	Catchment to low-wall crest (m)	Catchment Length highwall batter (m)	Approx Area (ha)
Kemmis Pit	2500	20	450	200	163
Northern Mulgrave	2880	29	645	290	269
Carborough	0	0	0	0	0
Walker	2660	53	1180	530	455
TOTAL LENGTH	**8 040**			**TOTAL AREA**	**887**

Table 9 provides an estimate of residual void configuration and assumes that all voids not backfilled during operations are regraded to a 10% slope on the highwall and the lowwall. The above tables also show that the area of the residual void increases most under the under the 10% regrade scenario even though considerable backfill has been undertaken, thus emphasising the need for careful consideration of the impacts of the final catchment area on the hydrological performance of the final void.

Note for both regrade scenarios, it has been assumed that the lowwall crest was more or less level at the time the reclamation has been undertaken. However, it is noted that the configuration of the lowwall spoil including its crest area may reduce or increase the effective catchment length of the low-wall spoil. Further spoil fit modelling will need to be undertaken to refine this concept.

Ramps

By cessation of operations it is expected that all but five of the conventional low-wall ramps would have been backfilled. It is expected that the remaining five ramps will be reshaped to ensure run-off is diverted to appropriately designed water management systems.

Ramps most likely still open at closure include:

- Ramp F
- Ramp I
- Ramp J
- Ramp K
- Ramp L

The final configuration of the ramps has not yet been determined; however regrading of the residual ramps to ensure safety, stability and sustainability objectives are met has been proposed.

5.5 PROPOSED RESIDUAL VOID DESIGN CRITERIA

South Walker Creek Mine is committed to undertaking substantial treatments of residual voids in order to ensure that such areas are safe, stable and sustainable after cessation of operations.

In 2007 BMA Coal and its consultants commenced development of a set of generic design criteria to assist its sites with the development of stable landforms “Guideline for the Design of Sustainable Mine Landforms”. This landform guideline has been developed to help BMA mines implement closure planning processes aimed at the achievement of sustainable rehabilitated landforms on a cost effective basis.

The guideline acknowledges that rehabilitation of mine disturbed land is not simply an environmental task. The work is of a complex and expensive nature and satisfactory outcomes can only be achieved if closure planning is embraced at the corporate, site management and operational levels.

There has been recognition for some time that spoil placement programs have largely been formed on the basis of minimising haul distance and not necessarily in alignment with the construction of a sustainable final landform. The BMA Sustainable Landform Guideline requires that planning, design and scheduling of excavation and spoil placement should be aligned with a mine closure plan so that cost effective practices can be implemented during the operational phase of mining with a goal of substantially reduced rehabilitation expenditures at closure. This is the essential basis of BMA closure / rehabilitation requirements.

These guidelines provide a framework for implementation of the closure process based on:

- Embedding closure / landform requirements into the responsibilities and accountabilities of all senior personnel. This is necessary as the ability of mines to implement satisfactory closure planning and implementation processes will necessarily impact on the business and its long term viability.

- Outlining preferred strategies / practices for improved spoil placement and reduction of void volume by closure, hence progressive backfill when practicable is encouraged.

- Describing various treatments which could be used to better stabilize spoil placement and in particular recognition that steep long Tertiary spoil slopes are exceedingly difficult to stabilize without rock mulching.

- The guideline also discusses rehabilitation resource inventory programs given that rock mulching is seen to be an important aspect of stabilizing steep slopes. Knowledge of the available resource and routine salvage during stripping / excavation operations will be necessary.

The BMA “Guideline for the Design of Sustainable Mine Landforms” is currently subject to site and corporate review. The Guideline encourages progressive backfilling of ramps and final voids during operations to improve spoil fit and reduce haul costs; and minimise the amount of open void at cessation of mining. The Guideline requires periodic updating to ensure that improved outcomes from operational experiences and learning's are retained.

The Guideline provides for a range of conservative treatments aimed at making residual voids safe and stable once rehabilitation of the site has been completed. Treatments for residual (remaining voids at cessation of mining) include:

Ramp:

- Backfilling sequentially with mine spoil and or CPP waste.
- Regraded to <10% and capped with Permian spoil as required.
- Steeper slope options should not normally exceed 25% slope and be capped with at least two meters of durable rock and soil matrix.
- Drainage off adjacent prestrip dumps should be integrated into the ramp backfill design.

Lowwall:

- Backfilled sequentially with mine spoil or CPP waste.
- Regraded to <10% and capped with Permian spoil as required.
- Steeper slope options should not exceed 25% slope and be capped with at least two metres of durable rock and soil matrix as described for the highwall.
- Drainage off adjacent prestrip dumps should be integrated into the lowwall treatment design.

Highwall:

- Sequential backfilling of final voids with prestrip spoil or CPP waste is preferred.
- Regrading to <10% slope, covering with approximately 1m benign rocky Permian spoil before topsoil application.
- Alternatively, a steeper slope up to 25% can be formed and clad with durable rock mulch to at least 2 m deep. If rocky hospitable Permian spoil is placed at least 1m depth first, the thickness of the durable rock mulch cover may be reduced to 1 m. Note that the lowwall should be regraded first to minimize the amount of natural ground that will be disturbed by regrading the highwall.

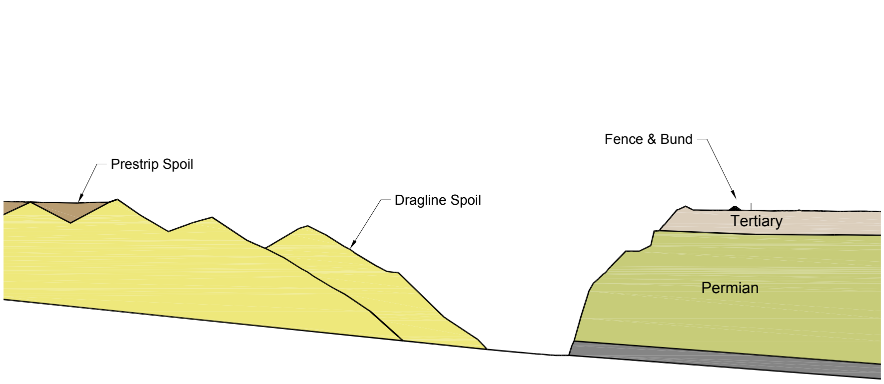
Mine planners will develop mine schedules showing how the mining operation can optimize the backfill of final voids, minimizing lengths of residual highwalls, during operations and satisfy progressive rehabilitation requirements.

It should be noted that the guidelines is evolutionary and improvements will be made from time to time. Currently the guideline is focussed more at placement of spoil materials, but in the future may address surface finish and drainage issues.

Further information on the above provisional reclamation strategies follow:

5.5.1 Fence & Bund

The fence and bund treatment is reserved for those instances where safe, stable and sustainable highwall and lowwall situations are possible. This is legally allowed under the current environmental authority. However, this scenario may have limited application for the South Walker Creek Mine final highwall treatment given the frequent occurrence of weak poorly consolidated, sodic, erodable Tertiary material overlaying generally incompetent deeper Permian Strata.

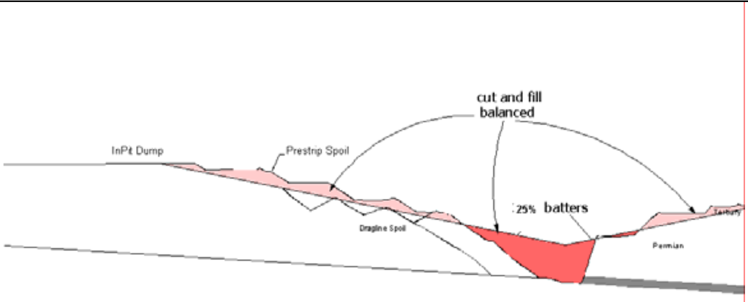


Large open mine void representative of a fence and bund scenario **assuming** competent high and lowwalls.

Figure 1 Fence & Bund Scenario

5.5.2 25% Regrade

The 25:25 regrade concept as per the BMA Sustainable Landform Guideline which recognises that steep long slopes into the final void will require the application of a durable rock mulch.

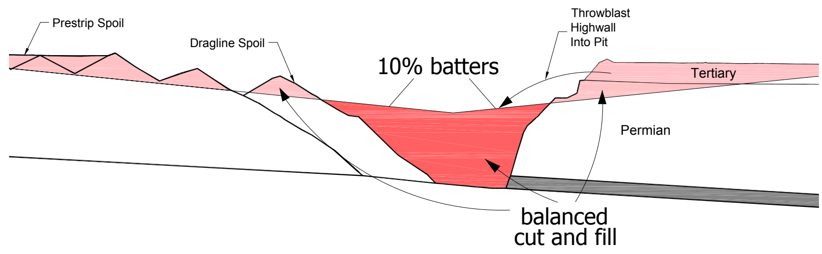


25% Regrade with Rock Mulch Treatment Scenario

Figure 2 - 25% Regrade of high & Lowwalls

5.5.3 10% Regrade

The 10:10 regrade concept as per the BMA Sustainable Landform Guideline recognises that without an extensive application of thick durable rock mulch, long slopes such as occurring on regraded lowwalls and highwalls should be no steeper than 10%.



10% Regrade on Highwall and Lowwall

Figure 3 - 10% Regrade of high & Lowwalls

Drainage control will be an important element of the final design for regraded voids given that the final slopes leading into the voids may range from several hundred metres to a kilometre or more depending on the amount of backfill that is undertaken prior to final regrading. Thus in the future, mine planning and rehabilitation investigations and resultant trials aimed at identifying mitigating strategies to limit erosion on long regraded slopes are warranted.

Strategies which could be covered by this further research include mine planning studies aimed at reducing relative elevations such as:

- not mining the deeper coal seam in the last one or two mining strips, hence stepping the final void up to shallower levels;
- backfilling to shallow depth before regrading;
- forming a lower elevation prestrip dump above the void by backfilling adjacent voids.

Also, investigation of ameliorative treatments is warranted such as:

- application of extensive or localised use of durable rock mulch;
- incorporation of large drainage swales to pass water across the regraded face of the lowwall spoil to deposit water on natural ground or into a ramp entry; and,
- more conventional rock lined and graded bank drainage scenarios may have application in some circumstances.

6 LONG TERM VOID WATER STORAGE AND QUALITY

6.1 INTRODUCTION

The long term quality and quantity of water stored in residual voids is dependent on a number of variables including:

1. Climate – particularly rainfall and evaporation.
2. Catchment areas reporting to the void
3. Extent of void regrade – regrading voids can substantially increase catchment area.
4. Catchment areas and topographical configuration of the final void and surrounding spoil.
5. Effectiveness of rehabilitation in reducing surface and subsurface runoff into the voids.
6. Rapidity of solubilisation of salts being transported by both surface and subsurface drainage to the voids. Water quality tests confirm that water collecting in voids will almost certainly be alkaline and saline.
7. Remaining amount of process and other water affected by the mine workings pumped into the voids.
8. The salinity and potentials of the void floor material.
9. Presence of groundwater inflows and outflows from the voids.

Thus predicting final water quality performance is a complex matter and given that South Walker Creek long term final mining and landform planning is undergoing a major revision, final void location and extent is entirely provisional until this comprehensive planning process is more advanced. However, some generalisations regarding void water quality can be made, based on the existing site information:

- Groundwater flows into voids are known to be very limited. Ground water monitoring from coal aquifers confirms that the water is quite saline in the area. However, small aquifers in shallow Tertiary and Quaternary paleo channels might contribute significant amounts of groundwater in wetter years.
- The spoil mass surrounding voids is known to be moderately to highly saline and highly alkaline. Catchment dams below spoil areas are invariably saline and alkaline.
- Solubility of salts in spoil is high, given very high electrical conductivities that have been recorded after rainfall.
- Monitoring quality of the pit water collected in highwall dams confirms the expectation that water is saline and alkaline, indicating salt and other analyte transfers between spoil and water.
- Strata in close contact with coal e.g. coal basement strata are known to be saline.

A long-term concern for residual voids in arid areas is the potential for water to become hyper-saline and perhaps seep into surrounding water tables. This has been recognised for many years. For example: ACARP Project No. C7007 (Water Quality and Discharge Predictions for Final Void and Spoil Catchments) made a number of general / primary findings following completion of their field studies and void water quality modelling. In particular (S7.3 conceptual model of mine water flow) notes the following:

1. There is a correlation between TSS and TDS thus water quality in final void will be reflective to some extent of the TSS of surface runoff.
2. In many situations most of the void water is derived by surface runoff.
3. The influence of subsurface flow through spoils might be limited because of low flow volumes moving thru the spoil.
4. Preferred pathways may exist which may cause rapid movement of seepage water – eg along the base of the spoil piles. But preferred pathways may block over time.
5. Direct rainfall to the void introduces low concentration water.
6. Evaporation has the opposite effect.
7. A stable system with no salt build up will occur if groundwater flows are greater than evaporation.
8. In a closed system, the water accumulating in the void could come from any of the sources or paths described (groundwater/seepage/preferred pathways/incident rain/surface runoff) but can only leave by evaporation. The water level is maintained by evaporation and evaporation causes continuous deterioration of water quality due to salinity build up.

South Walker Creek Mine is located in a semi-arid climatic zone where the long term average annual rainfall and evaporation are 584mm and 2,366 mm respectively and evaporation exceeds average rainfall 12 months of the year.

Salt levels in South Walker Creek operational pits are generally borderline of that which can be tolerated for long times by beef cattle. This is evidenced in dams used for storing water pumped from pits where the overall average salinity is generally between 2000 and 3000uS/cm and the alkalinity at pH 8.5 to 9.0 and sometimes above.

ANZECC salinity tolerance levels for beef cattle are shown in the following Table 10.

Table 10 ANZECC Guideline* for Beef Cattle Tolerance to Salinity

Salinity ppm and (EC uS/cm)	ANZECC GUIDELINE
0 – 4000 (0-6,000)	No adverse effects on animals expected
4,000 – 5,000 (6,000 – 7,500)	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production
5,000 – 10,000 (7,500 -15,000)	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually to Beef cattle
>10,000 (15,000)	Totally unfit for stock.

* Salt limits to 10,000ppm derived from Table 4.1.3 in National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000

ANZECC 2000 also states that if water has a purgative or toxic effect (especially if the TDS concentration is above 2,400 mg/L), the water should be analysed to determine the concentrations of specific ions. Thus the guideline levels reported above may represent higher than tolerable levels if synergistic ion involvement occurs.

Use of the pit water for agronomic use is very limited due to high salinity levels. The average reported salinity of most of the pits would be tolerable for cattle and sheep for a limited period only, if no other source of water were available.

Evaporation exceeds rainfall by a factor well over 3, thus it is likely that pit water salinity will increase and not decrease through time for any void which does not occasionally spill or can not shed salts through groundwater discharge, nor receive fresher water via a groundwater seepage mechanism. The extent of the salinity increase could be considerable.

Unless void water can transfer to the groundwater table, the water in the residual voids will probably not be suitable for sustained stock water supply, thus the principal beneficial use of voids might be their role as collection sumps to prevent outflow of saline water. Infilling to make all the pits to be self draining would be costly unless undertaken as part of an operational spoil backfill. However, this may be a useful remedy to maintain the salinity of residual voids at a suitable quality for livestock. Further investigation of this strategy is warranted if use of void water for a productive purpose is anticipated.

6.2 VOID STORAGE BEHAVIOUR

Modelling post mining void storage and water quality behaviour to examine the potential for the void to overtop in extreme events depends on an ability to determine key characteristics including surface flow, incident rainfall contributions and groundwater recharge rates to the spoil aquifer and void. Also, prediction of water quality requires characterising the spoil mass as well as predicting the effects of preferred flow paths and geochemical processes within the spoil body that drains to the void.

An investigation was undertaken on predictive modelling of void hydrology for open-cut coal mines in the BHP Coal Pty Ltd sponsored Spoil Hydrology Research. As part of this work, PPK consultants prepared a Spoil Hydrology Lumped Parameter Model (SHLPM) for voids at the BMA Peak Downs Mine in May 1997. A daily water balance model was developed in an attempt to assess the long-term hydrological responses of final spoil-void systems in the Bowen Basin. The SHLPM is designed for situations where containment of water reporting to the final void is required. The model assumed a Runoff coefficient 0.6 above water level. This is an extremely high surface runoff – but reasonable for spoil batters and steeper areas reporting surface runoff directly to the void. PPK used Pan factors 0.7 for low water level to 1.0 for high-water level.

For the typical void scenario, the PPK modelling indicated that idealised voids would reach a steady state depth in about 40 years post closure. Work using OPSIM modelling at Oaky Creek in 2003 Mine also demonstrated that voids have no potential to spill and are effectively dry most of the time when the catchment area to void area is typically 4:1 or less and where groundwater ingress ins minimal. Much greater ratios are required to cause a void spill situation. (Pers com P. Baker. May 2008)

Void storage behaviour at South Walker Creek Mine has been further investigated by Gilbert and Associates Pty Ltd using SEEP and GoldSim modelling.

6.2.1 SEEP & GOLDSIM Modelling

Understanding of residual void behaviour is an important aspect of planning for mine closure, given that there is an expectation that the void characteristics such as size and depth of the void, contributing catchment areas, groundwater regime and spoil and soil characteristics will ultimately dictate whether water can be fully contained within the void and at what the long term salinity may be.

From a purely water balance viewpoint, there is a reasonably high degree of confidence that water level behaviour for regraded voids in particular, can be predicted using water balance models. Gilbert and Assoc Pty Ltd have used GOLDSIM and SEEP modelling software to examine void hydrological and salinity behaviour of a typical final void. The groundwater aspects were modelled using the SEEP/W® software package. SEEP/W is a finite element software product for analysing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock. It allows analyses ranging from simple, saturated steady-state problems to sophisticated, saturated-unsaturated time-dependent problems.

The water and salt balance model was developed using the Goldsim® modelling package. It simulates rainfall runoff inflows to the void from its catchment, evaporative losses from the void and groundwater inflows and outflows derived from the generic groundwater flow modelling discussed above. Runoff from the void catchment was simulated using the AWBM (Australian Water Balance Model) which was incorporated (coded) into the water and salt balance model.

The void water and salt balance modelling has been undertaken in a number of possible void configurations to provide an indication of the likely behaviour of residual voids at South Walker Creek Mine. See ATTACHMENT 5 VOID HYDROLOGICAL MODELLING**.** The study has involved:

- a hydrological assessment of the salt and water balance of a typical final void at South Walker Mine – based on the Walker Pit void;
- an assessment of the long term behaviour of the void and its interaction with local and regional surface and groundwater resources (excluding flood events in nearby creeks flushing the voids) as well as the sensitivity of predicted behaviour to current unknowns;
- identification and assessment of mechanisms by which the Walker/South Walker Creek could interact with final voids at South Walker Mine and the controls which might be employed to achieve a desired outcome, and
- formulation of recommendations for future investigations and research aimed ultimately at developing an acceptable, low risk plan for the final void(s) at South Walker Mine.

Results of this modelling were used to generate generalised relationships linking groundwater inflow/outflow functions to void water level. These relationships were then incorporated into the overall surface water balance model of the void. See Section 5.4 for the Walker Pit void dimensions.

Modelling has been restricted to one future residual void (the Walker final void) and a range of void configuration options including leaving the void in its mined configuration i.e. **Fence and Bund**, regrading the void to 25% highwall and low-wall slopes and regrading to 10% for both highwall and low-wall respectively. Key findings from the preliminary modelling indicate:

> **Fence and Bund.** The simulated water levels in the void reached equilibrium levels after a period of approximately 10 years and then fluctuated in response to climatic variability. Long term model predictions were for ongoing net groundwater inflows and, as a consequence, salt concentrations as measured by electrical conductivity (EC) units continued to increase slowly throughout the simulation to eventually reach hypersaline levels e.g. projected level of 300,000uS/cm by 150 years.
>
> The highest salt concentrations occur in the **End of Mining** configuration. For this option salt concentrations are predicted to continue rising as salt accumulates from ongoing net inflows of saline and highly saline groundwater. The void in this situation acts as a groundwater sink. Water is removed due to evaporation and the water level does not reach a level sufficient to flush dissolved salt back to the aquifer. Also water levels are deeper for this scenario than for the regrade treatments.
>
> **25% Regrade Option**. The simulated final water levels in the void stabilise to equilibrium very quickly (within 2 years) and fluctuate about the equilibrium from then on. Net exchange of salt to and from the void stabilised but salt concentrations in the void fluctuated due to changes in water volume over time The simulated salt concentrations reached for the 25% regraded void configuration option are very high (25,000 to 160,000 µS/cm) and often exceed those for the Fence and Bund situation, however, salt concentration in void water does stabilise over time as salt eventually enters and leaves the void at similar rates. Also, as water levels are deeper for the Fence and Bund option than for the 25% regrade option, the total amount of salt contained in the Fence and Bund option though similar salt concentrations are predicted.
>
> **10% Regrade Option.** The simulated final water levels in the void stabilise to equilibrium very quickly (within 2 to 3 years). Net exchange of salt to and from the void stabilised but salt concentrations in the void fluctuated due to changes in water volume over time. However salt concentrations under this scenario are significantly lower than either the Fence and Bund or 25% Regrade options due to transfer of water from the void to the groundwater table. The simulated salt concentration in the 10% option void varies between 1,000 and 3,000 µS/cm once an equilibrium level is reached.

The 10% Regrade option clearly has marked salinity improvement to both the Fence and Bund treatment and 25% Regrade option. This phenomenon is due to the 10% regrade void base being elevated well above the re-established groundwater table. Thus there is a gradual transfer of water and salt simulated between the pond and the underlying groundwater. In this instance the modelling demonstrates that under the assumed conditions sufficient water exchange occurs from the void pond to the underlying groundwater stores to prevent progressive salinisation of the void's water.

However, the consultants also modelled a limiting case of no transfers between the void and groundwater sources for the 10% regrade situation. This model allows only surface water runoff from the connected catchment (including spoil) and direct rainfall to enter the pit. Water leaves only through evaporation and spills. Simulation results from the model indicated no spill events occurred and, as expected, salt concentrations in the void continued to increase throughout the simulations.

The conclusion drawn by Gilbert and Assoc Pty Ltd is that complete isolation of the void from groundwater transfer would likely produce an "evaporation pan" where salt levels continue to increase at a consistent rate until real world physical constrains limit the process.

6.3 OVERALL FINDINGS

It is clear for South Walker Creek Mine and much of the Bowen Basin where average evaporation far exceeds average rainfall (and extreme rainfall as well), that in the absence of significant groundwater contributions, overflow from deep pits including regraded pits is most unlikely. This situation could change if the catchment area above the void is sufficiently large to cause water levels to rise on an annual basis. Even though a spill is unlikely, it is acknowledged that regraded voids (e.g. to 10% slopes) have sufficient insitu catchment to form a substantial body of water from time to time.

Although spill levels are very unlikely to be encountered, the existence of a large saline water body needs further consideration. The limited fence and bund treatment indicates that salinity will rise to 300,000uS/cm or greater, where as the 25% regrade scenario simulated salt concentrations reached are a little lower at 25,000 to 160,000 µS/cm. Interestingly, the more conservative 10% regrade treatment has potential to offer a higher water quality outcome than the steeper treatment scenarios. The simulated salt concentrations reached in the case of the 10% regrade option are much lower than for the other two treatment scenarios and varies between 1,000 and 3,000 µS/cm once an equilibrium level is reached. Thus indicating potentially at least a useful source of water for livestock and some native fauna.

The important aspect of the above preliminary SEEP and GOLDSIM modelling exercises is that it enables South Walker Creek to conceptualise various combinations of spoil topography and size around designated residual voids to determine what the storage behaviour of a particular residual void might be. Then via a design process if necessary, it may increase or decrease contributing catchment areas to reduce annualised stored water levels or perhaps increase annualised levels. Improved understanding of potential groundwater behaviour and the permeability of regraded spoil in pits will enable South Walker Creek to further understand the hydrology of deep voids.

This investigation provides South Walker Creek with a broad understanding of the issues and a range of residual void scenarios and related storage and salinity behaviour. More modelling and investigation may be undertaken as the final landform planning becomes firmer and as more comprehensive environmental monitoring data becomes available in the immediate vicinity of the final location of the final void

Ultimately the hydrological and chemical dynamics of a regraded void will have to be confirmed by trialling various treatments on one or more voids. This trial need not be site specific, provided close comparisons can be drawn between the characteristics of the trial site and those measured for the particular mine void location. It is further recommended that research be extended to provide more specific information (including the physical and geochemical characteristics of spoil). These actions would enable model inputs to be refined.

7 WALKER CREEK - VOID INTERACTION

7.1 INTRODUCTION

The following discussion on the potential for interaction between mine residual voids and Walker Creek has been prepared by Gilbert and Assoc. Pty Ltd. Clearly as the long term mine plan is revised and final landform scenarios are further developed, the void creek interaction can be examined more closely. Nonetheless on a preliminary basis a number of issues and potential remedies are discussed. The overall aim of flood mitigation is that South Walker Creek operations do not cause significant impacts on local creek systems as a result of the potential ingress of Walker Creek with the residual voids post closure.

7.2 LOCATIONAL ASPECTS

Much of the South Walker Mine is located within the flood plains of Walker and Carborough Creek. These creeks are ephemeral tributaries of Bee Creek which is a tributary of the Connors – Isaac River.

Recent flood estimates confirm that flooding from Walker Creek is a natural occurrence. See ATTACHMENT 4 SWC MINE FLOOD INUNDATION AREAS**.** Thus landform design and final void treatment is an important element for closure and operational considerations.

At present the final location and configuration of the voids is not known with certainty. The intention of this review undertaken by Gilbert and Assoc. Pty Ltd has been to identify the issues associated with final void location with respect to these watercourses, then to identify possible outcomes and controls that might be employed to produce the most desirable outcomes.

The most significant potential event identified by the consultants centred on the possibility that high floods in Walker and Carborough Creeks could overflow and fill one or more of the voids and potentially drain back into Walker and/or Carborough Creek during the flood's recession. The potential issues associated with these occurrences include:

- Loss of flow in the creeks due to flow diversion/capture in the voids;
- Damage and erosion on the flood plain in the vicinity of the voids;
- Damage to rehabilitated spoil areas within the voids and structural damage to the voids;
- Contamination of downstream watercourses due to creek water mixing with void water and then flowing back out of affected voids and into the creek.

The Walker and Carborough Creeks are alluvial systems and there is potential for channel migration across the flood plain over time. Some, if not all of the South Walker Creek Mine voids will inevitably be in the flood plain of one or both of these watercourses and the potential for the creek channel to re-align itself such that it connects directly with the void is at least a possible outcome. The potential issues associated with a watercourse connecting with a void are:

- Damage and instability to the rehabilitated mine area surrounding the voids;
- Capture of water and sediment flows in the voids leading to reduced flow and erosion downstream;
- Deterioration of water quality downstream of the voids due to mobilisation of contaminants in the voids and from the larger mine area.

7.3 MITIGATION STRATEGIES

Controls for limiting or preventing damage to riparian areas include construction of isolation bunds to provide immunity against all conceivable flood events up to the "Probable Maximum Flood". However as noted by the consultant, such restriction of the flood plain could affect flood patterns possibly resulting in erosion and channelisation in the surrounding floodplain.

Other remedies which could be effective in minimizing or eliminating adverse impacts caused by creek and void interaction include:

- configuring the final void areas such that inundation events do not pose significant threats to the capture and retention of very large amounts of what would be otherwise be uncontaminated flood water; and, ensuring that if discharges from voids in this circumstance were to occur, that engineered discharge channels capable of withstanding extreme events are provided.
- also backfill of those residual voids which have the most significant potential for interaction with local creeks may also be considered.

Final landform design will take this potential interaction into account with an aim of either eliminating interaction potential or by enabling some limited involvement. Discussions with DRNW will be required well in advance of finalising the designs for the spoil placement and void treatments for areas susceptible to flooding.

8 PIT WALL STABILITY

8.1 INTRODUCTION

Highwall stability investigations are routinely carried out on an operational basis as part of mine planning to ensure the safety of personnel and the security of the exposed coal. However, from a closure perspective, it is recognised that further specific investigation will be required in to better define highwall stability aspects, particularly for future final highwalls which will be well down dip of the current workings and necessarily significantly deeper than the current situation.

Highwall and endwalls of the South Walker Creek Mine pits are comprised of generally highly dispersible, unconsolidated Tertiary material sitting above firmer consolidated Permian sediments. Endwalls usually exhibit greater instability than highwalls due to the exposed alignment of bedding and faulting planes. Studies by ACARP researchers (Rehabilitation of Highwalls - ACARP Project C14048 - Final Report) based on inspections of several mines across the Bowen Basin concluded that most of the highwalls in Tertiary and weathered overburden would not be geomechanically stable in the long term. These sedimentary materials are simply not strong enough for the main to resist failures due to water incursion and failures due to physical erosion damage.

The lowwall spoil can be a dispersive and fine grained sodic clayey media in which pH and salinity may be beyond the limits for satisfactory sustainable vegetation cover. Hence substantial regrade may be required to render a stable outcome. Capping with more durable Permian rocky spoil is also proposed for steeper situations. Considerable treatment to highwalls is also anticipated to achieve a stable safe outcome. This may include throw blasting of the highwalls and endwalls, use of more durable Permian rocky spoil to cap steeper areas of residual Tertiary material as well as more conventional topsoiling treatments on flatter situations.

At South Walker Creek Mine there are no voids available for rehabilitation. All existing voids are considered to be operational and will be progressively backfilled as the next strip of coal resource is excavated. The final voids at South Walker Creek will be located well to the west of the existing open pits. Thus an investigation based on physical measurement and inspection can not be undertaken until a final void becomes available at some time in the future. However an insight into the probable geotechnical performance of residual voids is provided. The following section of this report has been prepared by John Simmons Pty Ltd (Sherwood Geotechnical and Research Services) and draws on their considerable experience in evaluation of geotechnical conditions in Bowen Basin mining over many years.

8.2 SUMMARY OF GEOTECHNICAL ASPECTS

8.2.1 Context

Pit slopes at South Walker Creek mine are formed by excavation of insitu materials and dumping of spoil materials generated by excavation activity. In addition, waste materials generated by coal processing, consisting of rejects and tailings, may be dumped and/or deposited in storage facilities which may incorporate elements of pit slopes. Landforms generated by excavation, dumping, and waste storage are typically designed to minimise cost criteria while satisfying risk criteria relating to hazards arising from the physical aspects of slopes and activities associated with slopes. Cost and risk criteria relating to landforms based on final void treatments are typically considered separately from mining operations as part of whole-of-business activities.

Consideration of sustainable end-of-mine landform scenarios is very different from operational conditions because very different cost and risk management criteria apply. Slope stability for operational conditions is considered over a short-term timescale relative to that applying to end-of-mine considerations, and has relatively simple objectives in terms of human activities. The technical framework of geomorphology is more relevant for sustainable end-of-mine scenarios, and is very different to the technical framework of slope geotechnology (Ward, 1945). In a paper that could still be regarded as a state-of-the-art in terms of long-term versus short-term considerations, Ward stated that in terms of geological time "no slope is perfectly stable". The timeframe for the geotechnical engineering of pit slopes is the life of the engineered facility, while the timeframe of current geomorphological processes extends from the immediate to the indefinite future, and the effects of geological time can be measured from a period of at best a few years to millions of years. It is therefore important to have a clear understanding of what is meant by "sustainable".

For the context of this review a "sustainable" landscape refers to the effects of natural processes similar to those of the present-day and expected to occur over a period of at least several human generations, that is 60 to 200 years and projectable indefinitely into the future. "Sustainable" means that such a landscape is intended to display similar attributes over such a time period without reliance on human-based interventions.

8.2.2 Geological and Geotechnical Conditions

Summaries of geological conditions at South Walker Creek mine is provided in O'Reilly (1993) and BHP Australia Coal (1995). Originally the Walker Pit area was developed by strike-advance truck/shovel methods, and then the Mulgrave Pit area was developed as a dragline operation. Production was supplemented by dip advance truck/shovel mining of the Walker Pit and then the development of the Carborough Pit, between Walker and Mulgrave Pits.

All pits mine the Main Seam plies of the late Permian Rangal Coal Measures, which are subdivided by ply splitting. The Main Seam is underlain at depth by plies of the Hynds Seam and the Fort Cooper Coal Measures. The mine is located within the fault-disturbed eastern side of the Nebo Synclinorium, which is also mined at the Coppabella Mine to the southwest and Hail Creek Mine to the northwest. Seam structure dip is generally towards the southwest. In most areas the pit floor is formed by thin-bedded carbonaceous siltstones and sandstones with bedding-parallel shears and occasional thin sheared clay bands. Seam roofs in some areas include thin sheared clays. Boxcut and in-pit dump lowwall development has required stabilisation in many sections of the mine using various techniques ranging from blasting to trenching and buttressing. Overburden materials vary widely, including deep Quaternary or Tertiary sands in the proximity of Walker Creek and a general thickening of Tertiary clay and sand sediments towards the southwest. The coal measures overburden materials typically comprised siltstones and interbedded sandstone-siltstone units. There are also some local intrusions generally in the form of dykes and sills.

In some areas of the mine are thick sequences of Tertiary and Quaternary sand sediments. The pre-mining land surface has been subjected to cycles of intense weathering which caused laterisation, indurated zones, and deeply fissured clay-rich rocks of extremely low to low strength. The Tertiary deposits typically infilled drainage channels in the former land surface, and are therefore water-bearing in the deepest sections.

Within the Rangal Coal Measures significant groundwater is found within the coal seams, which are typically of relatively high Transmissivity and low Storativity which means that water within the seams can flow relatively easily but in small quantities with relatively rapid depressurisation. Within the Tertiary and Quaternary sequences groundwater tends to be more localised into pods or zones associated with sands and gravels or fractured basaltic layers. Yields within the Tertiary and Quaternary are highly variable and unpredictable over relatively short distances. Cutoffs and diversions have been constructed where the mine path has crossed Walker Creek and tributary drainages.

For mine planning geotechnical design purposes groundwater levels are typically taken to be at or near the base of weathering at some distance from coal faces, and drawn down to near seam roof level at newly-exposed faces. It is much more difficult to predict groundwater levels within the Tertiary materials for two reasons: there are few measurements and those measurements tend to be open slotted observation wells connected to underlying coal seams, which makes interpretation impossible.

For spoil dump lowwalls and ramp profiles, short-term geotechnical stability planning is based on reasonable assumptions about groundwater levels. In the longer-term, the groundwater levels within spoil profiles will adjust to long-term water levels in final voids. If these voids are regraded with the intention that no permanent pools of water may develop, it will be much more difficult to predict groundwater levels in spoil and no reliable basis for making decisions or judgements about groundwater regimes. Currently there are no known reliable groundwater measurements within rehabilitated areas of South Walker Creek Mine. In order to provide objective guidance for final void landform planning purposes it is therefore considered important to commence a program of groundwater monitoring within and adjacent to rehabilitated areas.

Geotechnical stability assessment for slope profiles in excavated rock involves consideration of potential mechanisms involving:

- defect-controlled ("structural") sliding;
- defect-controlled toppling of blocky masses;
- sliding involving composite rock mass strength including the effects of defect sliding strength and intact rock material strength.

Examples of highwall failures based on these mechanisms are described in Baker (2006). In practice, design of excavated rock walls is not as straightforward due to inability to acquire detailed foreknowledge concerning the exact distribution of rock mass defects and their associated strengths. Sliding involving composite strength also involves uncertainties regarding the spatial distribution of intact rock material strength. Reasonable working knowledge of rock mass strength and rock defect sliding strength has been accumulated over the operating life of the mine, but this knowledge applies for short-term purposes and does not normally extend to consideration of long-term loss of strength by weathering and erosion processes.

Geotechnical stability assessment for open pit coal mines in the Bowen Basin is based largely on precedent experience and judgement. BMA Coal maintains a geotechnical database that includes many test results, and from this basis a framework for assessment of shear strength for spoil materials was developed (Simmons and McManus, 2004). For excavated rock walls, rock mass shear strength is typically estimated from empirical evidence and also by using published procedures based on the Generalised Hoek-Brown criterion. Shear strength for specific defect surfaces is often estimated based on experience because of the difficulties and non-representative status of specific samples. The BMA Coal database and experience have provided adequate estimates of mass shear strength for Tertiary materials which fall somewhere between rock and soil in terms of behaviour and parameters.

Different slope stability analysis techniques are used depending on the nature of the materials and the likely type(s) of potential failure mechanism(s). The most common analyses are based on the Factor of Safety concept, which is easiest to understand as the ratio of forces resisting failure to the forces causing failure. Implicit in all shear strength parameters are their derivation based on short-term behaviour, and their varying levels of reliability (Duncan, 2000). There are no specific geotechnical procedures or guidelines for downgrading strength parameters to reflect long-term behaviour, other than to make judgements to allow for softening or for creep.

8.2.3 Geomorphological Processes and Long-Term Slope Stability

Observations of both excavated rock wall and spoil dump slopes that have been exposed for periods of between 6 months and 5 years indicate that slope profiles change over time predominantly in response to geomorphological processes rather than to development of geotechnical instability mechanisms. For coal measures rocks, whether weathered or fresh when originally exposed, different lithological units are observed to respond at different rates to weathering and erosion processes. In some cases, rocks of high strength may slake rapidly, losing clay binders and releasing sand and silt particles to erosion by water or wind. Most of the time, however, lower-strength fine-grained rocks typically slake more rapidly than higher-strength coarser-grained rocks.

Because of the layered nature of coal measures sedimentary environments, an initially uniform excavated rock batter will differentially slake and erode over time. The stronger rocks are also more likely to have well-developed joints at spacing's that are related to the thickness of the layer. When a stronger rock is sufficiently undermined by differential erosion of an underlying unit, it is likely to loosen and then fall under the action of gravity. Differential erosion also occurs along natural and blast-induced defects, forming lateral release surfaces that make it easier for the loosening and falling processes to proceed.

Various studies have identified and discussed general geomorphological processes which are commonly causal factors associated with time-dependent changes to a landform or landscape slopes (Kirkby, 1985; Bierman and Nichols, 2004; Brathen et al 2004). With respect to rehabilitated open pit coal mine landforms, these processes have also been linked to changes in runoff water quality (Carroll et al, 2004). Slope instability in a wide variety of forms may develop as a consequence of these geomorphological processes, depending on combinations of conditions that may vary with space and time (Cruden and Varnes, 1996). However even in the absence of geotechnical instability, these processes may cause landform changes that would be regarded as damage and non-sustainable performance. These geomorphological processes may be summarised as:

- Weathering – Either chemical alteration of minerals to form oxidation or reduction products, typically oxides or hydroxides, sulphates, and chlorides, or physical alteration due to temperature and/or humidity changes resulting in fracturing or swell-related disaggregation. Weathering may result in either loss or gain of cohesive strength of the materials. All of the overburden materials at South Walker Creek mine are subjected to weathering that continues at widely varying rates depending on minerals and exposure.
- Dispersion – Disaggregation of clay minerals in contact with water to suspension or solution. Dispersed clays are difficult to treat and settle unless the water is treated with introduced or naturally produced flocculants such as acids. Much of the spoil formed by weathered Permian and Tertiary materials at South Walker Creek mine is highly dispersive, whereas fresh Permian materials do not generally release dispersive clays.
- Erosion – Includes physical dislodgement by rain-splash and surface movement of water, as well as transportation by water flow. Also includes dislodgement and transportation by wind action. While most of the South Walker Creek mine spoils are clay-rich, sharp-sided features formed by water erosion and flat surfaces without vegetation cover may experience plucking and winnowing. Dispersive spoil materials are particularly prone to erosion.

The Illawarra escarpment is an example of a high-relief natural rock slope formed in sedimentary rocks very similar to those of the Bowen Basin, where there is some indication of the overall rate of profile modification. Moon (2005, pers.comm) described geomorphological studies in connection with rock fall risk assessment and remediation along Lawrence Hargreave Drive near Stanwell Park. Moon's indicated best estimates of profile change were a general rate of 1 – 2m per century for a truly "long-term" landform, and a local rate of 1 – 5m per century for specific cliff-forming blocky sandstone units. Casual observations of natural rock fall scars on the Burton and Kerlong Ranges and around Springsure suggest rainfall-induced erosion events causing profile changes similar to the rates indicated by Moon. In the absence of better and more specific geomorphological data for excavated rock slopes at South Walker Creek mine, a general scarp retreat rate of 1-2m per century may be a useful starting-point for discussion of long-term performance.

Based on such considerations, an appropriate definition of long-term stability for rehabilitated landforms would be "geomorphological slope profile processes for the foreseeable future in which vegetation cover is not diminished notably by erosive processes". From this, it would follow that an appropriate definition of profile failure would be "when rehabilitated land becomes unstable due to geotechnical or geomorphological processes as evidenced by loss of vegetation cover, expanding areas of sheet wash, rill and gully erosion".

In addition to geotechnical stability considerations, what factors need to be considered for long-term stability of rehabilitated landforms? Application of geomorphological techniques to existing non-treated and rehabilitated landforms would provide useful guidelines, in much the same way as current guidelines for limiting slope grade and height to minimise surface erosion from rainfall and runoff. Clearly there is potential for applying these techniques to highwall rehabilitation treatments but it will require targeted research.

8.2.4 Specific Landforms to be Evaluated

Final void landforms could range from the "minimal treatment" scenario to an engineered surface where all slopes were regraded and re-surfaced as appropriate to achieve erosion control and water management criteria. The natural landscape also provides some insights into the dominant geomorphological processes that have formed regional land surfaces over the past few million years, at least. In Central Queensland elevated areas such as residual mesas and relict ranges and ridges are underpinned by resistant strata and rock scree such as ironstones, sandstones, silcretes and to some extent old volcanic intrusions. Over the millennia softer sedimentary areas have largely been rendered to gently undulating plains. Thus from a long term geomorphological perspective unless elevated unconsolidated spoil materials are well vegetated and or protected by competent rock scree, these processes will attempt to revert these areas to a similar configuration.

8.2.4.1 "Minimal Treatment" Scenario

In the Bowen Basin there are several mine sites where strips have been left in the as-mined condition for extended periods for various business reasons, and these provide some insights into natural geomorphological processes. Some mine sites have utilised pits for tailings and/or water storage, and such situations provide similar insights.

Slope designs based on shear strength parameters and analysis methods have been proven to be effective in practice, but are not immune from failures. There are techniques for estimating likelihood of failure using geotechnical parameters but the required additional information on parameter variability is rudimentary and actual likelihoods, in quantitative terms, appear to be much less than predicted likelihoods. The simplest geotechnical approach for estimating long-term stability would be to reduce the shear strength parameters and adjust the groundwater pressures for expected long-term conditions. Unfortunately there is no method for reliably estimating the reduction in strength over time, and the most important reason for this is that long-term performance has more to do with geomorphological processes than strength.

Characteristics of geotechnical instability in untreated excavated rock profiles have already been documented (Baker, 2006) in the context of highwall rehabilitation requirements. It is difficult to apply geotechnical stability concepts to long-term performance of such slopes because of lack of credibility of strength reduction guesstimates and also because geomorphological processes are not represented by geotechnical models.

During mining operations, excavated highwalls and endwalls and lowwall spoil dumps are configured to provide an adequate Factor of Safety for managing specific hazards over a relatively limited time frame. On a more permanent basis however there are a number of mechanisms which will interplay and cause geotechnical failures to varying extents over an indeterminate time frame. These factors include:

- Structure and strength of the highwall and endwalls

- Resistance of the insitu sedimentary rock to rainfall-induced weathering processes – some of which may be very rapid for poorly consolidated softer sediments such as shales and mudstones through to very slow weathering of less common sandstone strata. Often the two are present in highwall formations, hence weathering of less competent material below more competent material has the potential to effectively destabilise, higher strength strata lying above.
- Highwall and endwall drainage – isolated preferential drainage may cause excessive water to seep/flow into preferential pathways / fractures and cause hydraulic displacement of both small and large sections of standing rock faces.
- Ponding of water in final void might cause rapid breakdown of sediments in contact with water and progressive back-cutting of the inundated strata. This has potential to cause major wall failure.
- Saturation of the base of the lowwall has the potential to cause major failure.

Overall, except in unusual conditions involving highwalls and endwalls comprising material with high strength and high resistance to weathering, there is little likelihood that a final void could be left in its mined configuration and demonstrate sustainably stable behaviour over an extended time, which in practical terms would be beyond say 20-50 years.

It may be possible to construct a bund and safety fence arrangement offset sufficiently from the highwall to reduce risks for an extended period. The highwall and endwalls would be allowed to weather and erode progressively through time and not present undue risk to the community, stock or fauna provided that the bund and fencing were maintained. Unfortunately at this time it is not possible to predict the rate of highwall deterioration and its long-term "stable" profile dictated by regional and local geomorphological processes.

8.2.4.2 Regraded Slope Profiles

Proposed regraded slopes for final voids in the range of 10% - 25% are inherently "stable" overall but consist of made ground with natural voids of various scales where weathering processes will continue and produce geomorphological change generally in the form of hardening of exposed surfaces and development of sinkholes or small collapse features when internal void edges soften and merge. Providing that flatter surfaces are topsoiled and a reasonably good cover of vegetation is established, the potential for development of sinkholes and settlement irregularities might be avoided in practical terms. Particular efforts would be required in order to effectively treat dispersive spoil materials (Henderson, 2004). This may involve isolation of Tertiary spoil, in particular, below a blanket of less dispersive media such as rocky fresh Permian spoil.

Based on typical short-term shear strengths and likely surface and groundwater scenarios, regrading to 25% would produce geotechnically stable landforms for lowwall spoil highwalls and endwalls with an outer surfacing of primarily Permian materials. The intervening final void might have a seasonally variable water ponding function, and this would be extremely unlikely to create conditions where geotechnical instability could develop. Further treatments may be required in order to achieve a stable landform in terms of long-term geomorphological processes, based on improved future understanding of how these might operate on a regraded landform profile. However, for outer surfacings of predominantly Tertiary materials, 25% is likely to become geotechnically unstable under long-term groundwater regimes, and a 10% regrade is likely to be more sustainable in practice. The same comments would apply to further treatments to achieve stable landforms over the long-term.

8.2.5 Stability Risk Assessment

A comprehensive framework exists for risk assessment for geotechnical instability as it relates to slope hazards (Picarelli et al, 2005). These concepts cannot be extended to include landform stability as defined in Section 3 above, because at present the lack of information on geomorphological processes would result in risk assessments being subject to large uncertainties and assumptions that have no scientific basis.

Based on present knowledge, it may be concluded that excavated rock wall (highwall and endwall) deterioration is likely to be characterised by occasional rock falls, with a possibility of massive profile instability which in the short-term is relatively unlikely but which cannot be more reliably predicted in terms of time or future location. More certain is that profile change will take place over time under the influences of weathering, dispersion, and erosion. If highwalls are to be left in a state of minimal treatment, the stratigraphy and geotechnical stability of the final void location will require detailed investigation, and the hydrological behaviour of the final void will need to be clarified. Further studies will be required before reliable predictions of profile change can be made.

Regrading or backfilling of mine voids largely eliminates geotechnical stability issues aside from localised settlement and potential sinkholes. Further research is still required, particularly in relation to:

- Prediction of very long term settlement effects.
- Development of profile changes by weathering dispersion and erosion processes,
- Investigations of surface and subsurface drainage and groundwater profiles, given that some of South Walker Creek mine's large elevated spoil dumps include primarily Tertiary and Quaternary materials where drainage system failure due to potential localised settlement may create failure of the landform as defined in Section 3 above.

8.2.6 Identified Requirements for Ongoing Research

There is a clear need for further research to characterise the geomorphological and geotechnical processes that would act on rehabilitated landforms, covering the range from minimal treatment to regraded slopes ranging from 10% to 25%. The aim of the research would be to identify the processes and measure their effects, to the extent that reliable information would be provided regarding the following issues:

- Definitions of stability and sustainability in terms of geomorphological processes and slope profiles
- Long-term geotechnical strength information based on existing natural analogues, including rates of recession, profile change mechanisms and sequences, etc
- Linkage between surface and groundwater hydrology in the post-mining environment.

There is also a need for groundwater monitoring within dumped spoil in and adjacent to rehabilitated landforms in order to provide information on the existence and development of groundwater profiles. Without such information there is no scientific basis for predicting long-term groundwater profile development for sustainable rehabilitated landforms. This would link to further studies which should also be undertaken on linkages between surface and groundwater hydrology for the proposed range of rehabilitated landforms.

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9 VOID CAPABILITY TO SUPPORT NATIVE FLORA & FAUNA

9.1 REHABILITATION PERFORMANCE

South Walker Creek has been conducting rehabilitation monitoring programs for several years. These programs concentrate mainly on surface erosion and vegetative development.

The South Walker Creek Monitoring program also covers vegetation cover and erosion monitoring. The former is subject to large changes due to seasonal influences and the method used for the erosion monitoring will require several more monitoring rounds at least before any meaningful indication of trends towards or away from a stable situation can be identified. The monitoring primarily considers three aspects as prime indicators of the likelihood of a system to improve or decline over time.

The indicators are;

- aspects of soil chemistry and profile development,
- vegetation changes, and
- gully or rill erosion and sheet erosion.

Methods used in assessing rehabilitation performance are described in the sites Rehabilitation Management Plan – a document also required as a condition of the sites Environmental Authority **MIN100552107** in which condition F5 states the operator must:

> *(F5) Complete an investigation into rehabilitation of disturbed areas and submit a report to the administering authority proposing acceptance criteria by June 2008. The Rehabilitation Management Plan must at a minimum*

9.2 SCENARIO DEPENDENCY

There are a number of scenarios that will cause marked differences in the capability of a residual void to support flora and fauna.

- Intensive treatment such as backfilling will yield a similar environment to the balance of the rehabilitated spoil areas. Fauna monitoring at South Walker Creek rehabilitation already demonstrates that a return of native fauna occurs, as would be expected, given a variety of shrubs and trees and pasture cover which can support avifauna and macropods.
- Regrading lowwalls will provide safe access for fauna to temporary water which may pond on the pit floor during rainfall. However, as discussed in earlier sections the usefulness of the temporary water storage may be limited due to increasing salinity due to evaporative effect.
- Comprehensive regrading of the final void such as a 25% rock mulched high and lowwall, will reduce exposure to high salinity mudstones and shales at the

base of the pit as well as possibly provide an opportunity for the residual void to store less saline water compared to water being stored on the saline strata forming the floor of the mined out pit. Native vegetation can be established readily in a rock mulch situation as evidenced at the nearby Goonyella Riverside Mine in which wattles and eucalypts have been established in rock spoil mulch on the reshaped batters of a large bucket wheel spoil dump.

- Major regrade / backfill to 10% or flatter slopes will provide an opportunity for the residual void to spill and maintain water of a suitable quality for fauna and livestock. In this instance, rehabilitation of the slopes leading to the residual void based on native vegetation and pasture establishment will provide habitat for avifauna and macropods in very close proximity to a water source. Erosion potential on long slopes is recognised as a potential issue for which further investigation and trialling is warranted.
- Provided the catchment area of the residual void exceeds a specified ratio it is possible that the water may be available on a permanent basis. More advanced hydrological and geochemical modelling will be required in the future to support this strategy. Use of void to support specific uses such as aquatic fauna for aquaculture will require further investigation.

However, with deep, steeply sloping voids in Central Queensland (and also reported in Western Australia) the ability of voids as is to support significant life will depend on whether there is permanent water stored in the void and the ultimate salinity of the void water. Refer to **Section 6** which discusses levels and salinity projections for different void treatment scenarios.

The oxygen flux of the void may also have important implications for the ability of the water to sustain aquatic fauna. Measurements of some typical mine voids with standing highwalls in Central Queensland has shown that oxygen levels can diminish very rapidly as depth increases, thus limiting use of the voids for aquaculture without active and costly oxygenation. (Pers comm. – P. Baker, March 2008)

Decisions in the future will have to be made regarding mechanisms to maintain water quality in final voids at a useful level to support fauna or livestock. This may include a need to utilize more backfill to reduce storage capacity or open up greater areas of catchment to improve yield. Further the chemical and physical dynamics of the void water body require investigation. For example, the development of a thermoclines and chemoclines may be dependent on a host of topographic and hydrological variables such as void depth, batter length and slope, catchment area and yield, and perhaps groundwater incursion. Further studies to better understand these issues will need to be commissioned well before mine closure should fauna habitat be considered as a post-closure option.

9.3 RESIDUAL VOID REHABILITATION SUCCESS CRITERIA

The EPA has provided an indication of its acceptance criteria for residual voids in Guideline 18. The provisional performance criteria are based on design guidelines detailed in the BMA Sustainable Landform Guideline which provides for backfilling voids progressively during mine operations, then making the final void safe, sustainable and stable. Criteria for South Walker Creek residual voids include:

1. Safe: the potential for highwall collapse causing injury to persons, stock or fauna will be eliminated by substantial backfilling or regrading of the residual void.
2. Stable: no highwall or lowwall will be left unless it is geotechnically and erosionally stable and safe as described above.
3. Sustainable: the residual void will form part of the overall spoil rehabilitation of the minesite. Spoil may be subject to one or more treatments based on minimising erosion potential including: 10% slope or flatter regrade and conventional topsoiling, or steeper regrade e.g. 25% with durable rock and soil mulching.
4. A variety of native trees and shrubs and native and introduced grasses as are currently used at South Walker Creek Mine will be established.

These are the minimum level of performance that is indicative of a stable and sustainable outcome. Subsets of performance may need to be developed for various treatment alternatives depending on what specific landform treatment is imposed and what the characteristics of the residual void are in terms of water storage and salinity behavior. Further discussion on rehabilitation success which is applicable to regraded spoil in void situations is provided in South Walker Creek Mines report into the rehabilitation of disturbed lands as required under Environmental Authority condition (F7**)**. That report discusses rehabilitation methods, success criteria, monitoring and maintenance practices in some detail which are applicable to spoil areas, such as slopes leading into voids.

As indicated in the previous Sections 6 and 8, further investigation on specific void design and rehabilitation treatment is required before the capability of the residual void to support viable sustainable native fauna can be predicted on a more confident basis.

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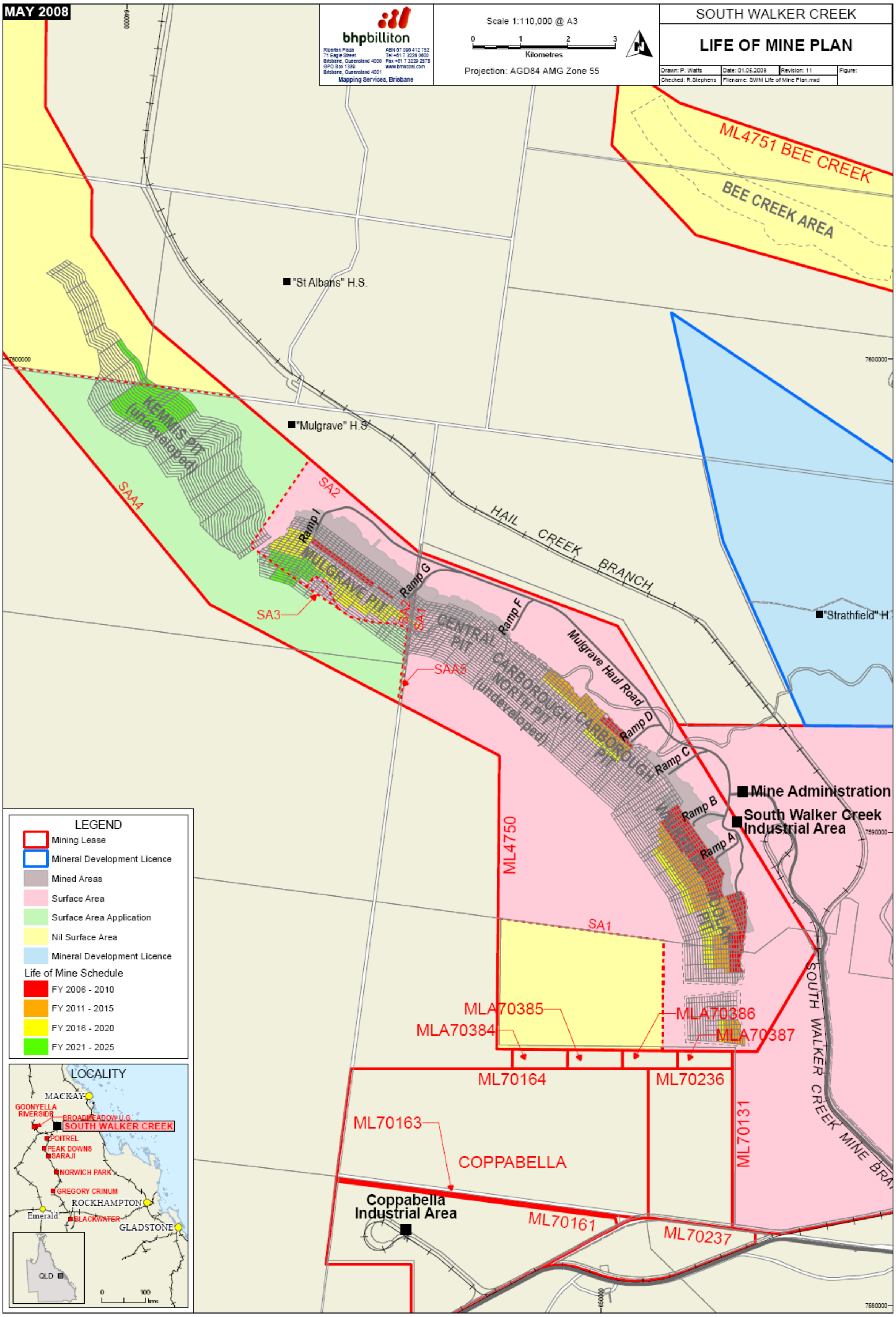
ATTACHMENT 1 LONG TERM MINE PLAN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bhpbilliton
Mapping Services, Brisbane
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Kilometres
Projection: AGD84 AMG Zone 55
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LIFE OF MINE PLAN
ML4751 BEE CREEK
BEE CREEK AREA
"St Albans" H.S.
"Mulgrave" H.S.
"Strathfield" H.
HAIL CREEK BRANCH
KEMMIS PIT (undeveloped)
MULGRAVE PIT
CENTRAL PIT
CARBOROUGH NORTH PIT (undeveloped)
CARBOROUGH PIT
Mulgrave Haul Road
Ramp I
Ramp G
Ramp F
Ramp D
Ramp C
Ramp B
Ramp A
SAA4
SA2
SA3
SA1
SAA5
Mine Administration
South Walker Creek Industrial Area
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COPPABELLA
ML70131
Coppabella Industrial Area
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ML70237
SOUTH WALKER CREEK MINE BRA
LEGEND
Mining Lease
Mineral Development Licence
Mined Areas
Surface Area
Surface Area Application
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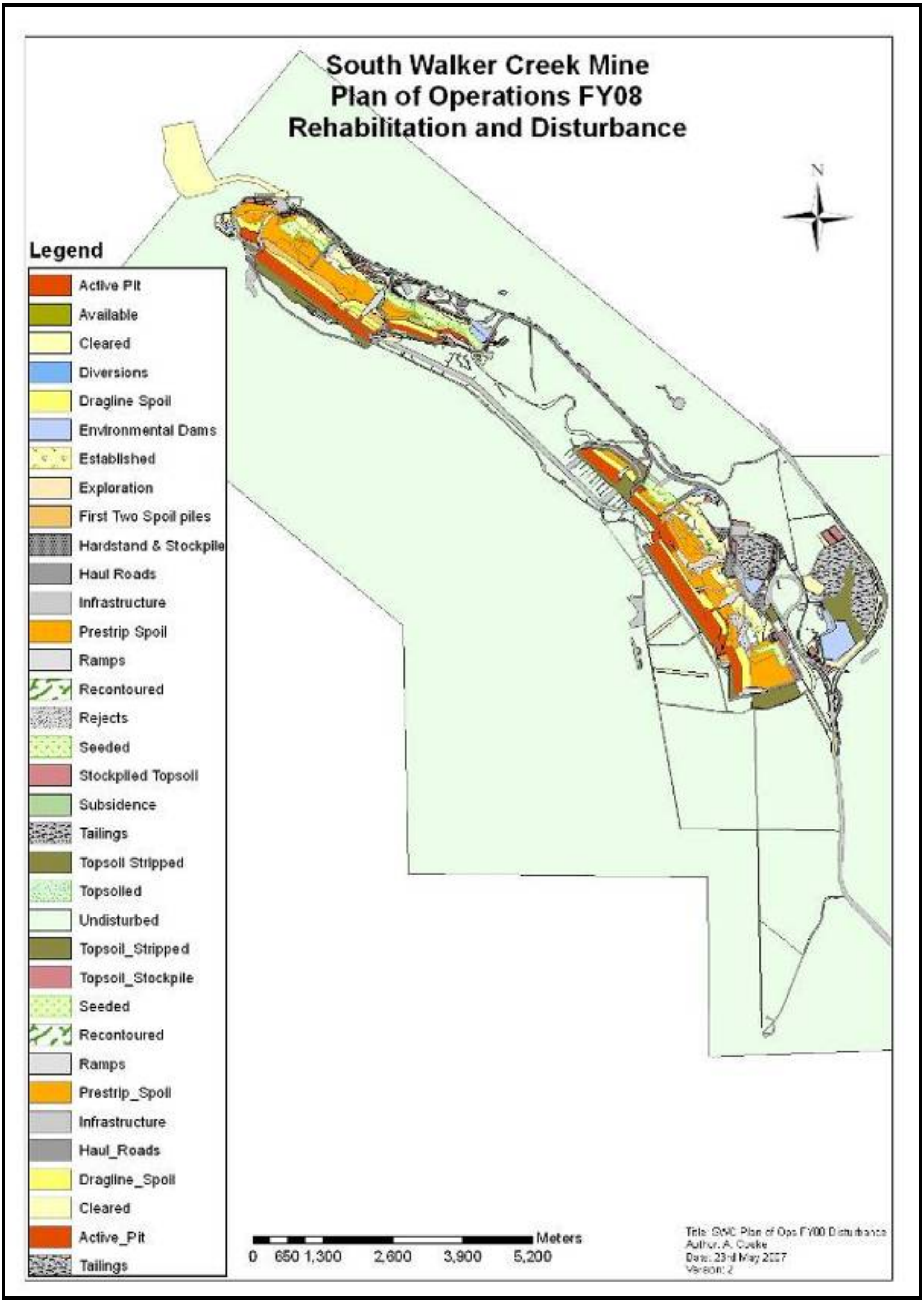
Mineral Development Licence
Life of Mine Schedule
FY 2006 - 2010
FY 2011 - 2015
FY 2016 - 2020
FY 2021 - 2025
LOCALITY
MACKAY
GOONYELLA RIVERSIDE
BROADMEADOW U.G.
SOUTH WALKER CREEK
POITREL
PEAK DOWNS
SARAJI
NORWICH PARK
GREGORY CRINUM
ROCKHAMPTON
Emerald
BLACKWATER
GLADSTONE
QLD

ATTACHMENT 2 DISTURBANCE AREAS 2008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Plan of Operations FY08
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Cleared
Diversions
Dragline Spoil
Environmental Dams
Established
Exploration
First Two Spoil piles
Hardstand & Stockpile
Haul Roads
Infrastructure
Prestrip Spoil
Ramps
Recontoured
Rejects
Seeded
Stockpiled Topsoil
Subsidence
Tailings
Topsoil Stripped
Topsoiled
Undisturbed
Topsoil_Stripped
Topsoil_Stockpile
Seeded
Recontoured
Ramps
Prestrip_Spoil
Infrastructure
Haul_Roads
Dragline_Spoil
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Active_Pit
Tailings
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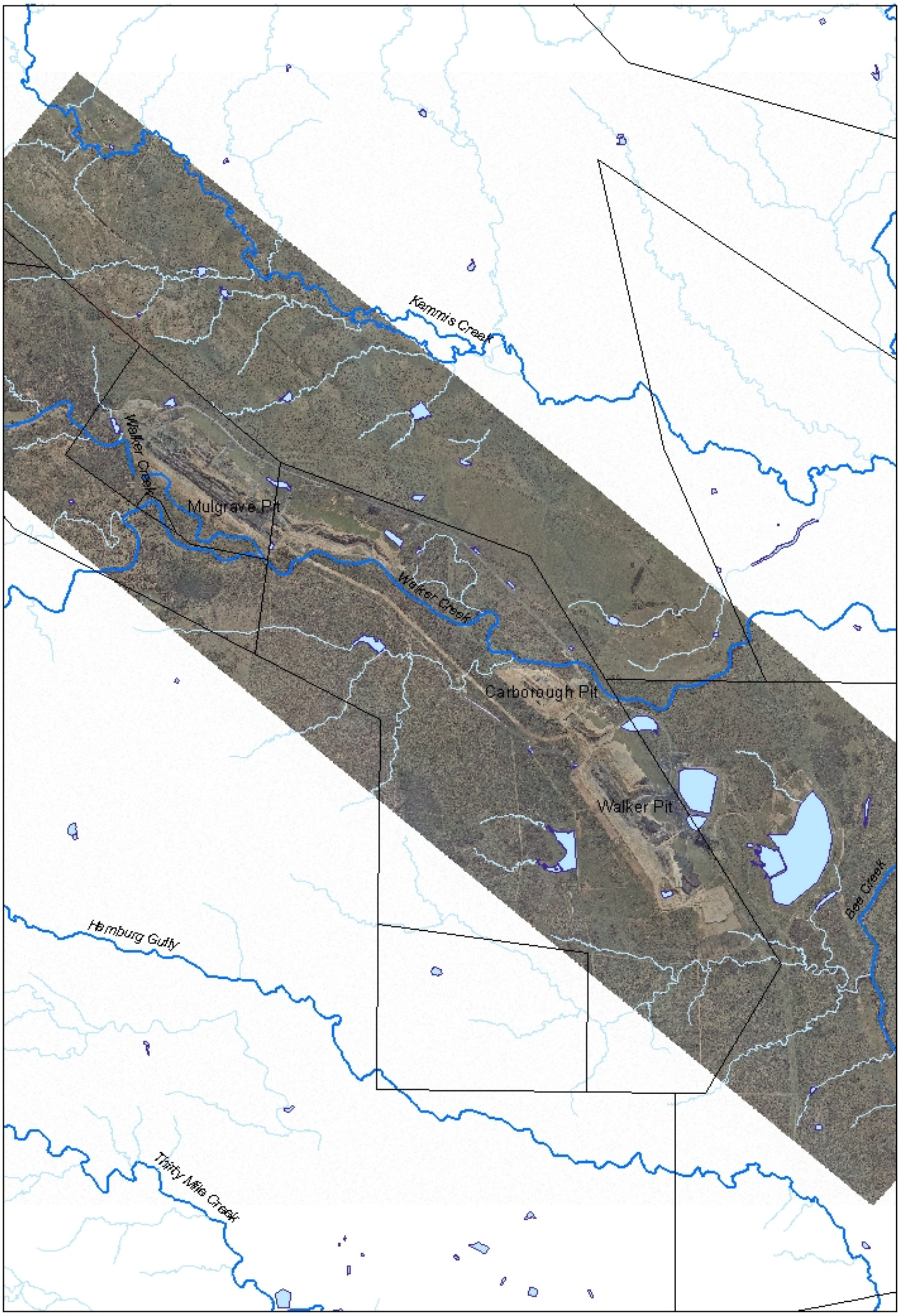
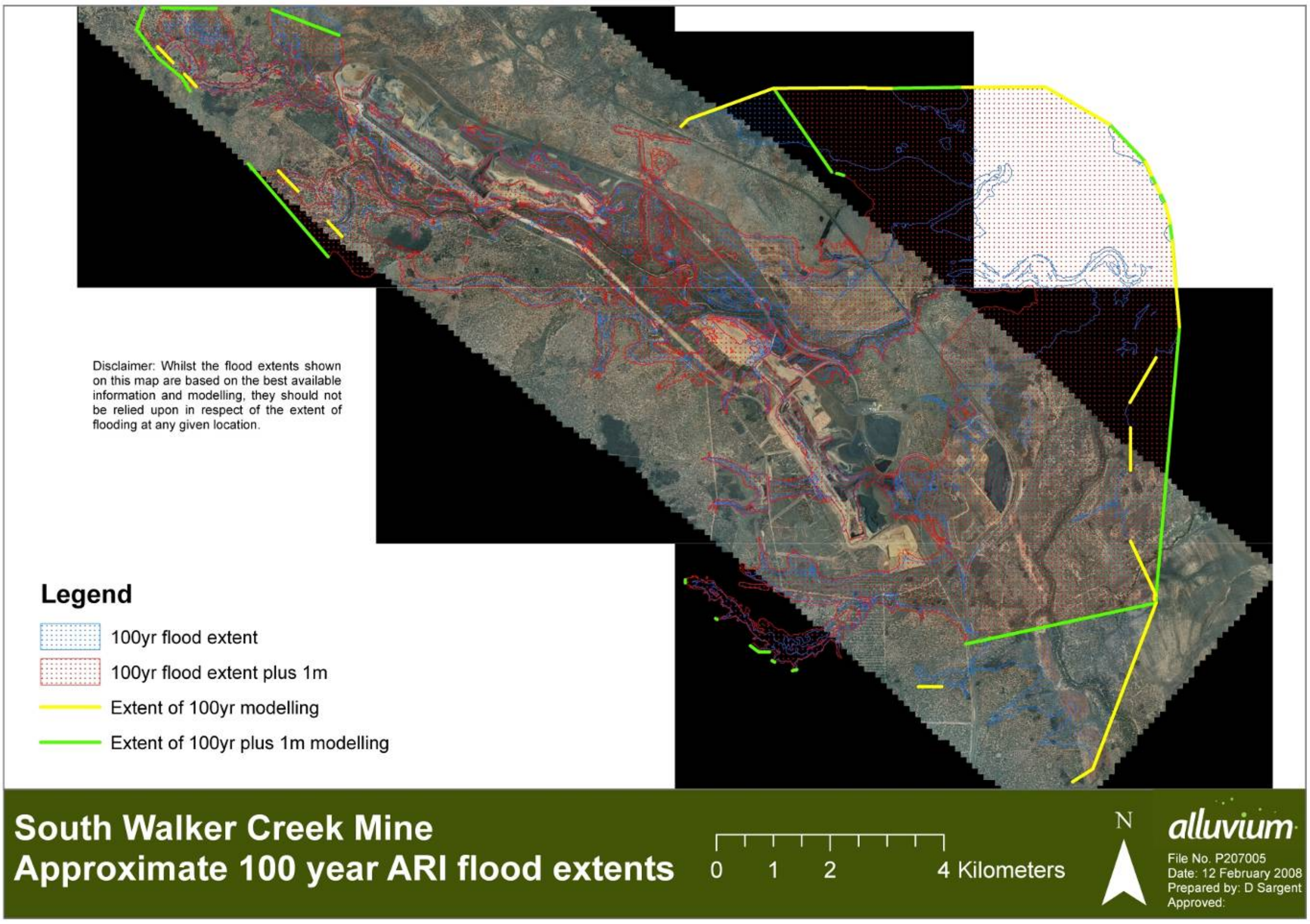
ATTACHMENT 3 SWC MINE CREEKS & DRAINAGE


Kemmis Creek
Walker Creek
Mulgrave Pit
Walker Creek
Carborough Pit
Walker Pit
Bee Creek
Hamburg Gully
Thirty Mile Creek

ATTACHMENT 4 SWC MINE FLOOD INUNDATION AREAS



ATTACHMENT 5 VOID HYDROLOGICAL MODELLING

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

Gilbert and Associates Pty Ltd

REPORT

South Walker Creek Coal Mine: Final Void Hydrological Assessment

Prepared for: **BHP Billiton Mitsubishi Alliance (BMA)**

Project Facilitator: **PW Baker & Assoc. Pty Ltd**

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PO Box 2057
Milton, Qld. 4064

Tel: (07) 3367 2388
Fax: (07) 3367 2833

A.C.N 085 419 852
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EXECUTIVE SUMMARY

An understanding of residual void behaviour is an important aspect of planning for mine closure, given that there is an expectation that the void characteristics such as size and depth of the void, contributing catchment areas, groundwater regime and spoil and soil characteristics will ultimately dictate whether water can be fully contained within the void and what the long term salinity level may be.

Final void water and salt balance modelling has been used to investigate a range of final void configuration options and to provide an indication of the likely behaviour of residual voids at South Walker Creek Coal Mine. Modelling has been restricted to one future residual void (the Walker final void) and a range of void configuration options including leaving the void in its mined configuration (**End of Mining**), regrading the void to 25% highwall and low-wall slopes (**1v in 4h**) and regrading to 10% for both highwall and low-wall respectively (**1v in 10h**). Key findings from the preliminary modelling indicate:

> **End of Mining** - The simulated water levels in the void reached equilibrium levels after a period of approximately 10 years and then fluctuated in response to climatic variability. Long term model predictions were for ongoing net groundwater inflows and, as a consequence, salt concentrations as measured by electrical conductivity (EC) units continued to increase slowly throughout the simulation to eventually reach hypersaline levels.
>
> **1v to 4h** - The simulated final water levels in the void stabilise to equilibrium very quickly (within 2 years) and fluctuate about the equilibrium from then on. Net exchange of salt to and from the void stabilised but salt concentrations in the void fluctuated due to changes in water volume over time
>
> **1v to 10h** - The simulated final water levels in the void stabilise to equilibrium very quickly (within 2 years). Net exchange of salt to and from the void stabilised but salt concentrations in the void fluctuated due to changes in water volume over time. However salt concentrations under this scenario are significantly lower than either the **End of Mining** or **1v to 4V** options due to transfer of water from the void to the groundwater table.

This investigation provides South Walker Creek Coal Mine with a broad understanding of the issues and a range of residual void scenarios and related storage and salinity behaviour. More modelling and investigation will be required as the final landform planning becomes firmer and as more comprehensive environmental monitoring data becomes available in the immediate vicinity of the final location of the final void. It is recommended that monitoring data include void and bore water levels and water quality. It is further recommended that research be extended to provide more specific information (including the physical and geochemical characteristics of spoil). These actions would enable model inputs to be refined.

In addition, the issues associated with possible interaction between final voids at South Walker Creek Coal Mine and the Walker and South Walker Creeks have been identified along with controls that might be employed to achieve desirable outcomes. Specific recommendations are made in regard to advancing a fuller understanding of this issue.

1.0 INTRODUCTION

Gilbert & Associates Pty Ltd was commissioned by PW Baker & Assoc. Pty Ltd to undertake a high level assessment of the hydrological issues associated with the Walker Pit final void at the South Walker Creek Coal Mine (South Walker Mine). South Walker Mine is one of a number of large open cut and underground coal mines operated by BHP Billiton Mitsubishi Alliance (BMA) in the Bowen Basin in central Queensland. The current study is one component of a final void planning study being undertaken by PW Baker & Assoc. on behalf of BMA.

The study has involved:

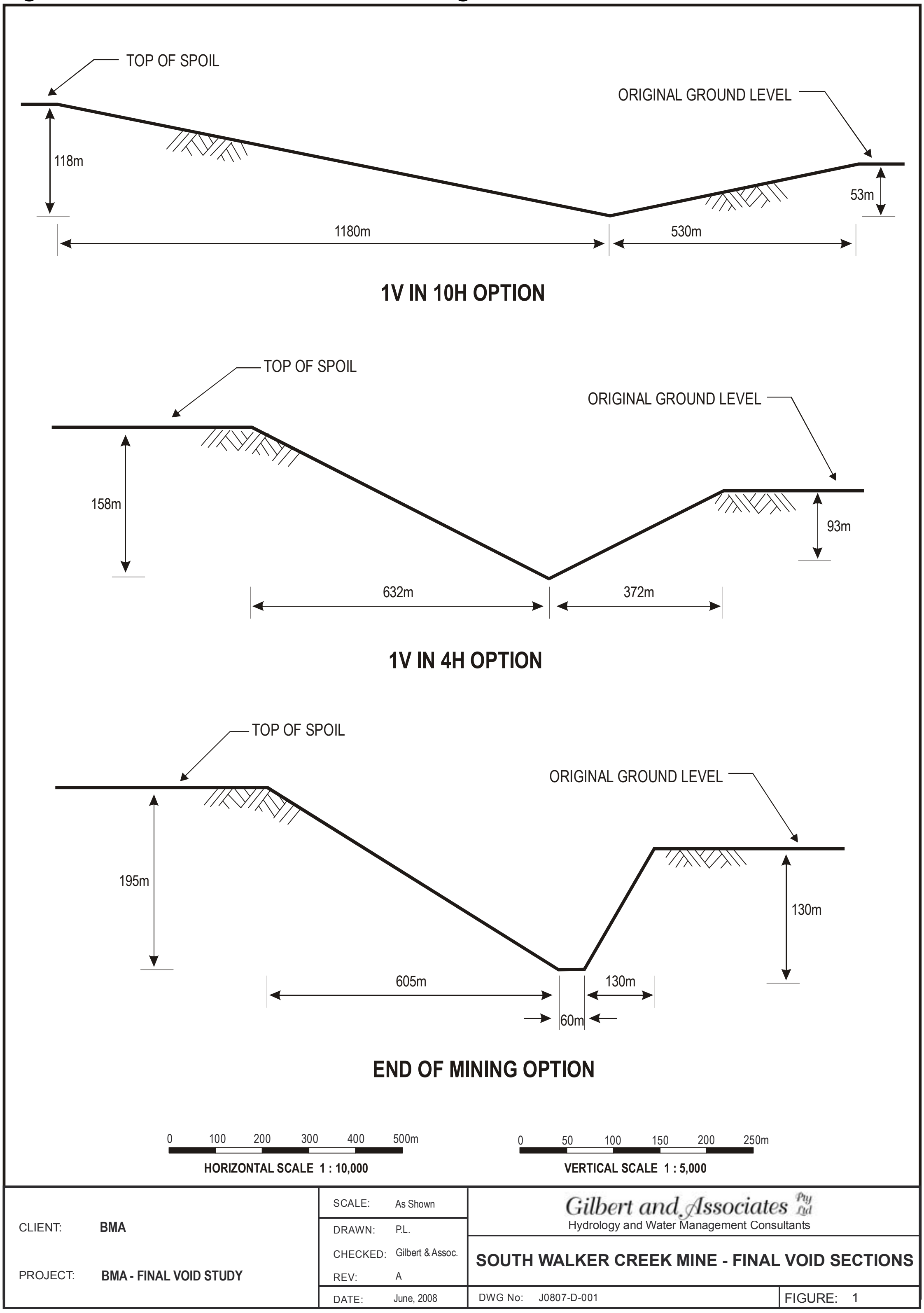
- a hydrological assessment of the salt[1] and water balance of a typical final void at South Walker Mine – based on the Walker Pit void;
- an assessment of the long term behaviour of the void and its interaction with local and regional surface and groundwater resources (excluding flood events in nearby creeks flushing the voids) as well as the sensitivity of predicted behaviour to current unknowns;
- identification and assessment of mechanisms by which the Walker/South Walker Creek could interact with final voids at South Walker Mine and the controls which might be employed to achieve a desired outcome, and
- formulation of recommendations for future investigations and research aimed ultimately at developing an acceptable, low risk plan for the final void(s) at South Walker Mine.

[1] Whilst there may be several different physiochemical parameters that will ultimately need to be considered in the final void assessment, total dissolved solutes, or salinity, are known to be a major issue and the current preliminary investigations have been limited to assessment of long term salt concentration in the final void.

2.0 BACKGROUND

The probable hydrological and water quality characteristics of the final void(s) which would be left at the completion of mining at the South Walker Mine have been assessed using the Walker Pit as a representative case. The geometry of the Walker final void was provided by BMA as three alternative cross-sectional profiles (i.e. cross sections perpendicular to the strike of the coal seam). The final void has been assumed to be uniform along the entire length of the void (i.e. along strike). Details of the three final void cross sectional profiles provided are shown in Figure 1.

Figure 1 Final Void Cross-sectional Diagrams



The three different void configurations represent:

1. the final void as it would be at the end of mining – representing the “do nothing once mining ceases” configuration (**End of Mining** case);
2. final void partially backfilled with spoil to form 1v in 4h surface slopes on both sides (**1v in 4h** case); and
3. a third configuration involving greater spoil back filling to form a shallower void and flatter surface slopes of 1v in 10h (**1v in 10 h** case).

The coal removed during mining was, from a groundwater perspective, a confined aquifer and the creation of a void below the original groundwater table means that the final void water and solute balance will reflect both groundwater and surface water processes. To investigate these processes, surface and groundwater modelling has been undertaken. A simplified generic 2D (cross sectional) groundwater flow model was developed to assess groundwater fluxes into and out of a void under a range of different conditions reflective of a typical open cut coal mine void in the Bowen Basin. The model was developed using the SEEP/W® software package. Results of this modelling were used to generate generalised relationships linking groundwater inflow/outflow functions to void water level. These relationships were then incorporated into the overall water and salt balance model of the void.

The water and salt balance model was developed using the Goldsim® modelling package. It simulates rainfall runoff inflows to the void from its catchment, evaporative losses from the void and groundwater inflows and outflows derived from the generic groundwater flow modelling discussed above. Runoff from the void catchment was simulated using the AWBM[2] which was incorporated (coded) into the water and salt balance model.

The salt balance component of the model incorporates sources and sinks of salt. Salt sources comprised salt contaminated inflows from surface water runoff, seepage through spoil and groundwater inflows from the adjacent aquifer formations. The salt sources were assumed to supply salt to the void at a constant concentration particular to each source. Losses of salt from the void were simulated allowing seepage outflow and spill[3]. The concentrations of salt in these loss components were assumed to be the same as the calculated salt concentration of the void. The void salt concentration varied as a result of different salt and water inflows and outflows over time.

The salt concentrations applicable to the different sources were based on site specific information provided by BMA, and where this was not available, from published information and our experience of other mines in the Bowen Basin. The source salt concentrations adopted in the modelling are summarised in Table 1.

[2] Boughton, W.C. (2004). *The Australian Water Balance Model.* Environmental Modelling & Software, Vol. 19, pp 943-956.

[3] Whilst spills and associated loss of salt from the void was allowed for in the model it did not occur in any of the simulation runs conducted.

Table 1 Adopted EC Values Used in Void Modelling

Salt Source	EC (μS/cm)	Source of Data
Void catchment runoff	385	Experience
Spoil seepage	2,300	Spoil leach test results and observations by PW Baker
Saline groundwater inflows from coal seams.	22,300	Information packages supplied by P.W. Baker.[4]

[4] Reports contained within these packages indicated this is a realistic value for use in modeling saline groundwater from coal seams in the Bowen Basin.

3.0 GENERIC GROUNDWATER MODELLING RESULTS

Details and results of the generic groundwater modelling are given in a separate attachment to this report. The key results of relevance to the overall hydrological assessment are summarised below.

For the **End of Mining** case the model results indicate that under equilibrium (eventual steady state conditions) there would be a net groundwater inflow – predominantly from the coal seam and to a lesser degree from the in-pit spoil. Model results for the **1v to 4h** case indicate that under equilibrium conditions there would be a relatively small net groundwater inflow – predominantly from the coal seam and to a lesser degree from the in-pit spoil. Model results for the **1v to 10h** case indicate that under equilibrium conditions there would likely be a negligible net inflow of groundwater originating from the coal seam and small transfers of water between the spoil and the void.

4.0 VOID WATER AND SOLUTE BALANCE MODELLING

4.1 General

In general the partial infilling of the void with spoil at relatively flat grades has the potential to significantly increase the minimum catchment that would report to the void – this being, in the most limited case, the lengths of battered slopes which are below the height of the surrounding ground surface and which must drain to the void. It is probable that additional catchment area outside this minimum would also drain to the void. Because the final catchment configuration is unknown, surface runoff generation was simulated for three different cases corresponding to:

(i) an absolute **minimum catchment case** dictated by the void configuration,

(ii) an **intermediate catchment case** where runoff from most of the in-pit spoil catchment would also drain to the void, and

(iii) a **large catchment case** where it was assumed that runoff from an additional 500m wide strip of undisturbed catchment adjacent to the void would also be captured.

Each water balance model simulation was undertaken over several repeated sequences of the available 116-year historical climatic record.

4.2 Model Sensitivity Runs

In addition, a series of sensitivity runs has been undertaken for each configuration for the **intermediate catchment case** to assess the importance of parameter uncertainty. This comprised re-running the water and salt balance model for expected maximum and minimum values of the following key components:

- Catchment runoff and spoil seepage set to base case + 50% (maximum) and -50% (minimum)
- Groundwater inflows/outflows set to 10 times less and 10 times more than initial model estimates.
- Salt concentrations set to 1/3 and three fold assumed levels

4.3 Approach to Assessment and Interpretation of Results

Results of the simulations have been used to semi-quantitatively classify the behaviour of the selected void configurations in terms of long term containment and salinity levels. The classification system used is based on three ordered containment groups and four ordered salinity groups as described below.

The three containment groups comprised:

<u>High Containment</u> used to describe voids where water levels reached steady state levels well below spill level and the bottom of the alluvial, near surface stratum which could interact with surface drainage features or affect surface vegetation. The limiting water level for this group was for all simulated water levels to be at least 40m below the natural surface.

Moderate Containment was used to describe voids where water levels reached steady state levels well below spill level but where they did, at least occasionally, reach the bottom of the alluvial, near surface stratum which could interact with surface drainage features or affect surface vegetation. The limiting water level was for all simulated water levels to be at least 15 m below the natural surface.

Low Containment was used to describe voids where water levels reached at least occasionally, a level equivalent to 5m from the spill level. This was taken to be indicative of voids that could or would spill to surface waters. This containment category was to apply to all voids which had simulated spills[5].

The four salinity groups comprised:

Low Salinity, which comprises water with EC less than 1,000 µS/cm. This would be high quality fresh water.

Moderate Salinity, which comprises water with EC from 1,000 to 10,000 µS/cm. Water at the high end of this EC range (greater than about 7,000 µS/cm) would cause animal health problems if used for stock watering.

High Salinity, which comprises water with EC from 10,000 to 58,000 µS/cm

Hyper-Salinity, which comprises water with EC greater than 58,000 µS/cm, i.e. greater than seawater.

Assignment within both containment and salinity groups has been used to differentiate the effect of different void configurations, catchment management assumptions and parameter sensitivity results on the key outcomes. The "position" of each void configuration within this two-way classification scheme is shown graphically along with the effects of sensitivity runs and catchment type variation in the results presented below.

4.4 Results for the End of Mining Option

Under this configuration the simulated water levels in the void reached equilibrium levels after a period of approximately 10 years and then fluctuated in response to climatic variability. Long term model predictions were for ongoing net groundwater inflows and as a consequence, EC continued to increase slowly throughout the simulation.

The key results of the simulations are summarised in Table 2.

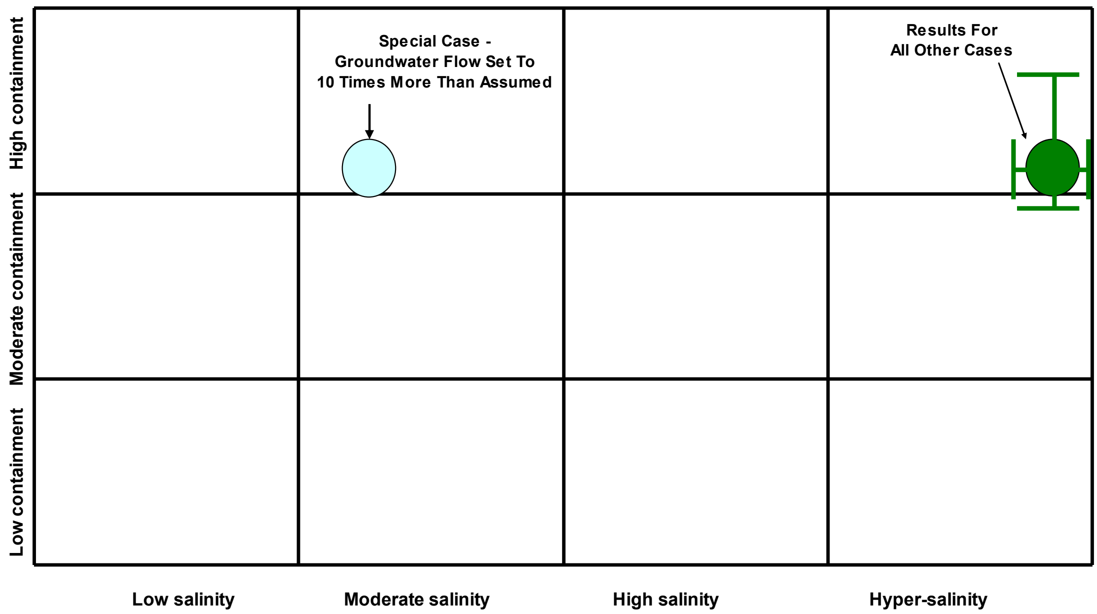
[5] Whilst this description has been included in the classification scheme there were no simulated spills in any model run.

Table 2 Summary of Containment and Salinity – End of Mining Void Option

Catchment Management Case	Containment Group	Salinity Group
Minimum catchment	High	Hyper-saline
Intermediate catchment	High	Hyper-saline
Large catchment	High	Hyper-saline

The location of the void within the classification scheme is shown on Figure 2. The green dot indicates the position of the void water condition observed in simulation under the **base case**, which was taken to be the **intermediate catchment case** with all other terms trialled in the sensitivity analysis set their estimated values. The green bars extending from this dot indicate bounds for a region containing the classifications observed for other results in the sensitivity analysis except where groundwater flow was set to 10 times more than was assumed for the base case. The position of this remaining case within the two-way classification is shown by the light blue dot. The results displayed in Figure 2 indicate very little variation occurred in the void classification for the **End of Mining** option in the sensitivity analysis unless groundwater flow is increased 10 fold. The behaviour observed for the high groundwater flow case was for salt concentration to initially increase with influx of water from the saline coal aquifer and then decrease over time as fresher water enters the void from spoil seepage and other above ground sources.

Figure 2 Classification for the End of Mining Void Option



4.5 Results for Void Backfilled to 1v in 4h Final Slope Option

Under this configuration the simulated final water levels in the void stabilise to equilibrium very quickly (within 2 years) and fluctuate about the equilibrium from then on. Net exchange of salt to and from the void stabilized but EC in the void fluctuated due to changes in water volume over time

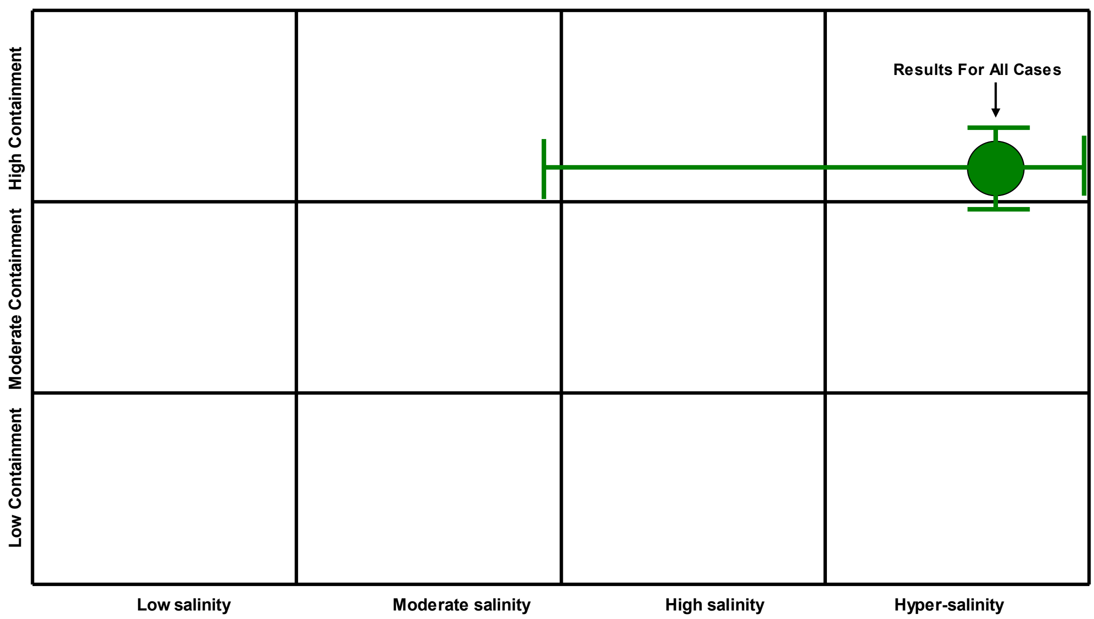
The key results of the simulations are summarised in Table 3.

Table 3 Summary of Containment and Salinity – 1v in 4h Void Option

Catchment Management Case	Containment Group	Salinity Group
Minimum catchment	High	Hyper-saline
Intermediate catchment	High	High to Hyper-saline
Large catchment	High	High to Hyper-saline

The location of the void within the classification scheme is shown on Figure 3. As above, the green dot in Figure 3 indicates the position of the void condition under the **base case** of the **1v in 4h** void option (taken to be the **intermediate catchment case** with estimated levels accepted for the other terms). The bars extending from the dot indicate a region containing the classifications observed for this void option throughout the rest of the sensitivity analysis.

Figure 3 Classification for the 1v in 4h Void Option



4.6 Results for Void Backfilled to 1v in 10h Final Slopes Option

Under this configuration the simulated final water levels in the void stabilise very quickly (within 2 years). However, EC in the void fluctuated due to changes in water volume over time

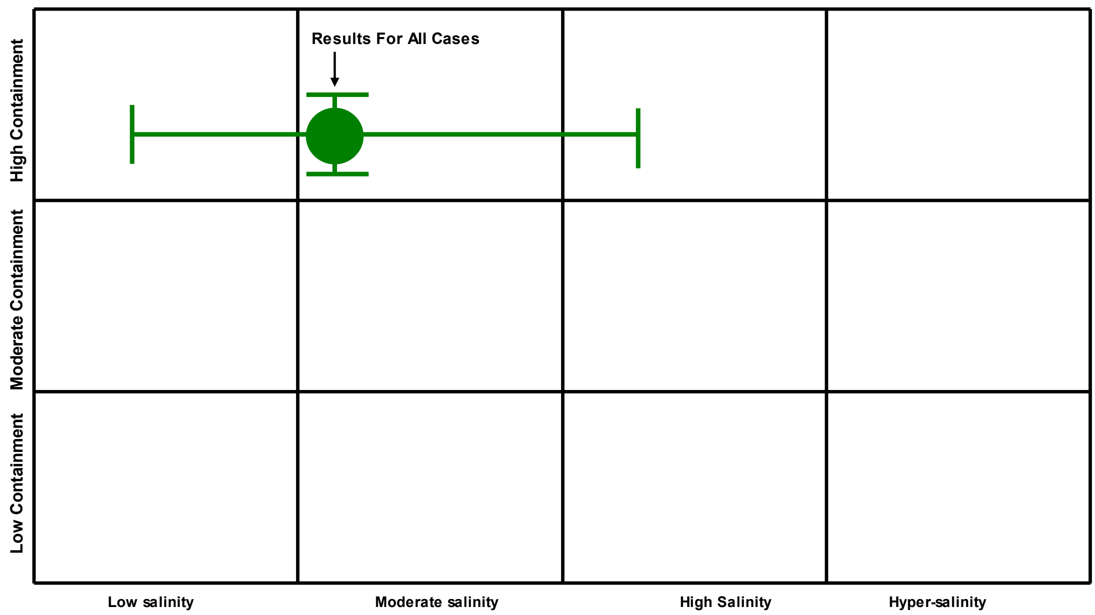
The key results of the simulations are summarised in Table 4.

Table 4 Summary of Containment and Salinity – 1v in 10h Void Option

Catchment Management Case	Containment Group	Salinity Group
Minimum catchment	High	Moderate
Intermediate catchment	High	Moderate
Large catchment	High	Low to Moderate

The location of the **1v in 10h** void within the classification scheme is shown on Figure 4. The green dot in Figure 4 indicates the position of the void condition under the **base case** of this option (taken to be the **intermediate catchment case** with estimated levels accepted for the other terms). Bars extending from the dot indicate a region containing the classifications observed for this void option throughout the sensitivity analysis.

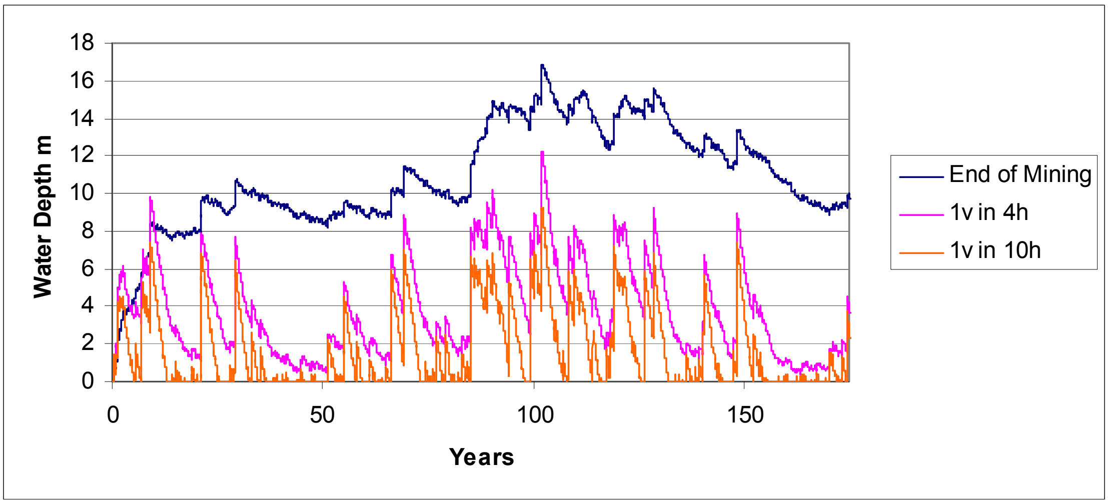
Figure 4 Classification for the 1v to 10h Void Option



4.7 Results for the Intermediate Level of Catchment Control

Graphs showing typical model output for all void configurations under an **intermediate catchment case** (minimum catchment plus spoil runoff) are shown in Figures 5 to 7. The results displayed in these graphs are qualitatively similar to those observed for the other simulated catchment cases. Figure 5 shows the simulated depth of water in the void under the three void configuration options studied.

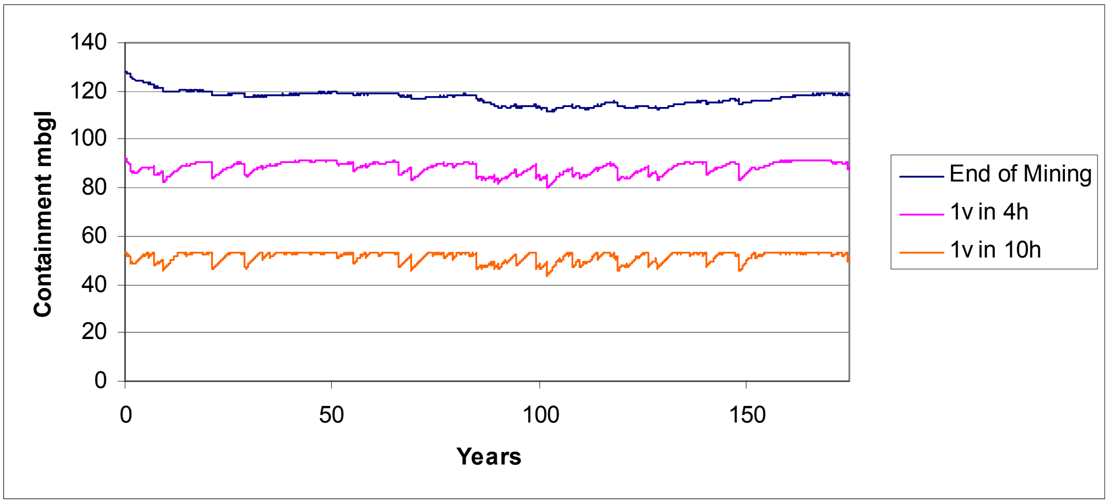
Figure 5 Simulated Void Water Depths



The water levels encountered in the **End of Mining** configuration option are significantly higher (8 to 16 metres after 10 years) compared to the **1v in 4h** and **1v in 10h** options (0 to 12 metres) due to the respective depth of each void configuration base below ground level and partial recovery of the local water table.

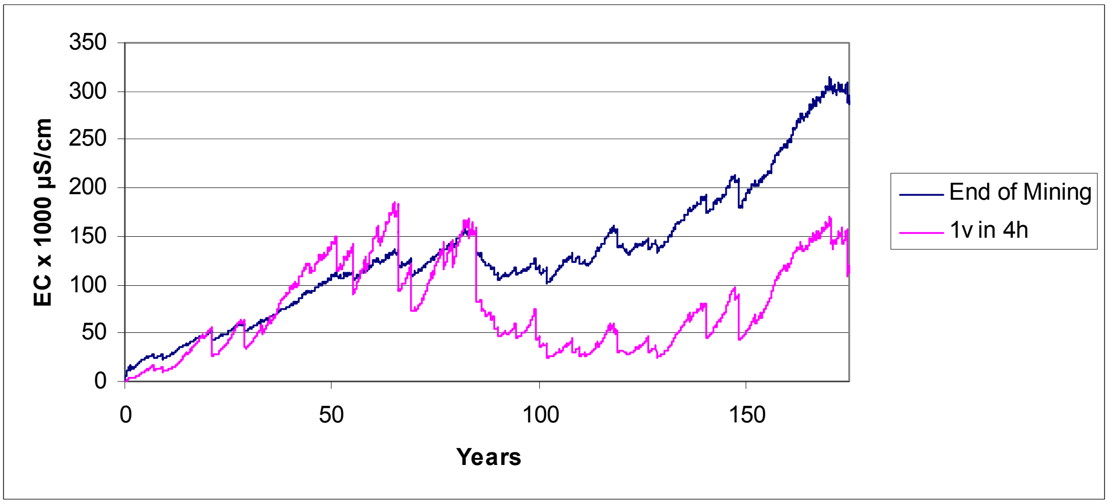
Figure 6 shows the level of water that collects in each pit void configuration in metres below ground level (freeboard) – as a measure of the degree of containment. This graph shows that the simulated water in the **End of Mining** void option is deeper below ground level, and therefore more distant from interaction with the surface than the other void options. Likewise the water surface in the **1v in 4h** void option is shown to be contained further below ground level than the water surface in the **1v in 10h** void option.

Figure 6 Simulated Freeboard Depth (mbgl)



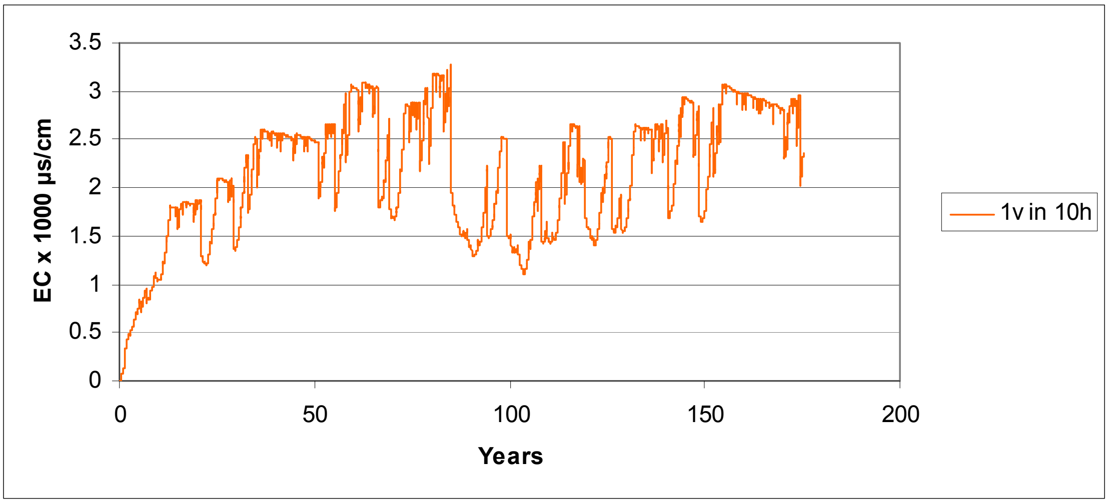
Figures 7 and 8 show the simulated salt concentrations in void water. The highest salt concentrations occur in the **End of Mining** configuration. For this option salt concentrations are predicted to continue rising as salt accumulates from ongoing net inflows of saline and highly saline groundwater. The void in this situation acts as a groundwater sink. Water is removed due to evaporation and the water level does not reach a level sufficient to flush dissolved salt back to the aquifer. The simulated salt concentrations reached for the **1v in 4h** void configuration option are very high (25,000 to 160,000 µS/cm) but do stabilise over time as salt eventually enters and leaves the void at similar rates (see Figure 7) and then fluctuates with pit water volume. Also, as water levels are deeper for the **End of Mining** option than for the **1v in 4h** option void, the total amount of salt contained in the **End of Mining** option void is much greater than in the **1v in 4h** option void even though similar salt concentrations are predicted.

Figure 7 Simulated Salinity (End of Mining and 1v in 4h Void Options)



The simulated salt concentrations reached in the case of the **1v in 10h** option void are much lower than for the other two configurations and have therefore been plotted in Figure 8 on a separate graph. The simulated salt concentration in the **1v in 10h** option void varies between 1,000 and 3,000 µS/cm once an equilibrium level is reached.

Figure 8 Simulated Salinity (1v in 10 h Void Options)



The **1v in 10h** option clearly has marked salinity improvement to both the **End of Mining** and **1v in 4h** options. This phenomenon is due to the **1v in 10h** void base being elevated well above the re-established groundwater table. Thus there is a gradual transfer of water and salt simulated between the pond and the underlying groundwater. In this instance the modelling demonstrates that under the assumed conditions sufficient water exchange occurs from the void pond to the underlaying groundwater stores to prevent progressive salinisation of the void's water.

4.8 1v in 10h Void with a Sealed Base

As well as the options required in the initial brief for this report, Gilbert & Associates has been asked to consider the consequences of adding a compacted clay rich layer of approximately 50m to the base of the **1v in 10h** void option. The purpose of this action would be to attempt to isolate the void from the underlaying saline groundwater.

A limiting case of no transfers between the void and groundwater sources was simulated. This model allows only surface water runoff from the connected catchment (including spoil) and direct rainfall to enter the pit. Water leaves only through evaporation and spills.

Simulation results from the model indicated no spill events occurred and, as expected, salt concentrations in the void continued to increase throughout the simulations. Table 5 shows the maximum depths of water reached in the void under the three catchment cases studied and the rates of increase observed in the minimum void salt concentration.

Table 5 Summary of Results for the 1v in 10h Void Option When Completely Isolated from Groundwater Transfers

Catchment Case	Maximum Water Depth (m)	Rate of Increase in Minimum Salt Concentration (µS/cm per year)
Minimum	4.2	64
Intermediate	9.2	104
Large	10.9	107

The conclusion drawn from these simulations is that complete isolation of the void from groundwater transfer would likely produce an “evaporation pan” where salt levels continue to increase at a consistent rate until real world physical constrains limit the process.

5.0 WALKER AND SOUTH WALKER CREEK - VOID INTERACTION

Significant parts of the South Walker Mine are located within the flood plains of Walker and South Walker Creeks which cross through the mine lease area. Walker and South Walker Creeks are ephemeral tributaries of Bee Creek which is in turn a tributary of the Connors – Isaac River.

A recent flood study by Alluvium Consultants[6] identified that sections of the mine are naturally prone to flooding (because of the mine's location within the flood plain of these creeks). It seems inevitable that the final voids at the South Walker Mine will be close to either or both Walker and South Walker Creeks and will remain within the original/natural flood plain of these watercourses. The potential for interaction between the final void(s) and Walker and/or South Walker Creeks ; either by way of flood waters entering them or as a result of the channel of one of these watercourses migrating into the void in the long term, is a key issue for any final void management and rehabilitation design.

At present the final location of the voids are unknown and there is insufficient information available to undertake any detailed assessment of the issue. The intention of this review is to identify the issues associated with final voids being close to these watercourses and to discuss possible outcomes and controls that might be employed to produce the most desirable outcomes. This is followed by a series of recommendations

5.1 Issues

Given their probable location it is considered there would be a high likelihood that floods in Walker and South Walker Creeks could overflow into one or more of the voids causing damage to their geotechnical integrity. Depending on the duration and magnitude of inflows, affected voids might fill with water and water might drain back out of the voids back into Walker and/or South Walker Creek during the flood's recession. The potential issues associated with these occurrences are:

- Loss of flow in the creeks due to flow diversion/capture in the voids;
- Damage and erosion on the flood plain in the vicinity of the voids;
- Damage to rehabilitated spoil areas within the voids and structural damage to the voids;
- Contamination of downstream watercourses due to creek water mixing with void water and then flowing back out of affected voids and into the creek.

The Walker and South Walker Creeks are alluvial systems and there is potential for channel migration across the flood plain over time. Some, if not all of the South Walker Mine voids will inevitably be in the flood plain of one or both of these watercourses and the potential for the creek channel to re-align itself such that it connects directly with the void is at least a possible outcome. The potential issues associated with a watercourse connecting with a void are:

[6] Alluvium "South Walker Creek Mine Flood Study" January 2008

- Damage and instability to the rehabilitated mine area surrounding the voids;
- Capture of water and sediment flows in the voids leading to reduced flow and erosion downstream;
- Deterioration of water quality downstream of the voids due to mobilisation of contaminants in the voids and from the larger mine area.

5.2 Controls

The voids could be physically isolated from flood waters by construction of isolation bunds around the void. If constructed high enough they would provide immunity against all conceivable flood events up to the "Probable Maximum Flood". Possible issues with this approach include the long term integrity of the bund system and the effect(s) it would have on flood flow patterns possibly resulting in erosion and channelisation in the surrounding floodplain.

Whilst the potential for the channel of one of the watercourses to migrate and link-up with a void would probably be reduced by the presence of a substantial isolation bund it may still remain a significant risk. The risk of one or both of the creek channels migrating and directly connecting with one or more voids will depend on a number of factors including:

- The presence and effectiveness of geological or man made controls between the voids and the existing channel and more generally the nature/stability/erosional resistance of the ground between the voids and the existing channel.
- The distance that the channel would have to move to intersect the voids and the likelihood, based on recent geological evidence, that the channel would move that far within a reasonable assessment period[7].

Based on soils mapping information provided for this study it appears there are significant alluvial deposits covering extensive areas within and surrounding the mine area. This suggests that local creek channels may have migrated in the past and may continue to move in the future.

[7] Any assessment of final void issues needs to be tied to some assessment period. Clearly periods covering geological time scales are inappropriate for obvious reasons and some shorter time period needs to be adopted.

6.0 RECOMMENDATIONS

The water and salt balance model developed for this study can be used to test the likely water and salinity balance for a wide range of different possible void configurations. By necessity the model is a simplification and some assumptions made in the modelling are somewhat arbitrary being, at present, based on our experience and somewhat limited information available on base conditions at the site.

More confidence in the validity of some of these assumptions and the model in general could be obtained by developing a greater understanding of the regional groundwater system and the effects that other mines in the area may also have on it. This would require further monitoring of the coal seam aquifer(s) down dip of the projected final void area in particular. Monitoring should include both bores which are close to and further away from mining activity near the limit of current drawdown effects. Similarly salinity and other key water quality indicators in the various coal seams will be important inputs. The current water quality information should be reviewed and supplemented where deficiencies are revealed. The focus should be on characterising the quality of water in down dip areas of the coal seam aquifers.

The hydrological and hydraulic characteristics of spoil material are not well known and this lack of knowledge is a potential limitation on future more detailed final void modelling. Moreover, final void position is usually quite remote from existing active mine pits, thus the availability of site specific environmental characterisation data in these future mining areas is limited. It is recommended that research be extended to provide more specific information (including the physical and geochemical characteristics of spoil).

It is also recommended that, when available, final voids be subject to specific investigation. The programme could be conducted at one or more BMA Coal Mines and involve the instrumentation of a final voids which have been regraded to the **1v in 4h** and **1v in 10h** options.

To advance resolution of issues associated with interaction between the final void and regional watercourses, it is recommended that a high level assessment be undertaken of the possible outcomes of different levels of interaction ranging from occasional overflows (during 1 in 100 year floods or larger) to the complete capture of Walker or South Walker Creek within a final void. Outcomes would be quantified/qualified in terms of their possible and probable effect on flow, geomorphic stability and water quality downstream. Such an assessment would provide information on which outcomes are more desirable in terms of all relevant attributes including cost, risk and environmental performance.

Depending on the outcomes of this initial, high level assessment, addition investigations will be required. To assess the possibility of the Walker and/or South Walker Creek channel migrating into a void, further geotechnical and geomorphic information will be required. As a first step it is recommended that baseline data on the nature of the Walker and South Walker Creek flood plain be collated and assessed. This would include geological mapping of the flood plain and documenting changes to the channel position over historical and recent geological times, identification of any geological controls within the floodplain and conduct of broad geotechnical investigations including the collation of available information on the depth to bedrock, extent of alluvium and the geotechnical properties of near surface material in the floodplain.