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Appendix C – Assessment of the Complete Backfill Options

Overburden Management Project

APPENDIX C – ASSESSMENT OF THE MRM OPEN CUT VOID BACKFILL CLOSURE ALTERNATIVE

Supplementary Environmental Impact Statement
February 2018

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Executive Summary

Although often prescriptively proposed as “best practice” by a number regulatory bodies and sustainability organisations, fully or partially backfilled pits may sometimes lead to poorer regional closure outcomes than retaining a pit lake of some form (McCullough, 2013). As a result, mine closure planning requires a case-by-case strategy considering all site-specific risks, known information and scientific data.

The option of either completely or partially backfilling the McArthur River Mine (MRM) open cut void with mine waste at the completion of mining has been raised several times during the MRM Overburden Management Project (OMP) Environmental Impact Statement (Draft EIS) process. For example, a mine closure option based on completely backfilling the open cut void with mine waste material was proposed in a report published by the Minerals Policy Institute in 2016 (“The McArthur River Project: The Environmental Case for Complete Pit Backfill”, Mudd 2016). In addition, a number of responses were received through the public and stakeholder consultation process following the submission of the Draft EIS regarding various options of either completely or partially backfilling the MRM open cut void.

This report has been prepared to address stakeholder comments by presenting McArthur River Mining’s assessment of a number of open cut void backfilling scenarios, including complete backfilling and a number of partial backfilling options. The scenario proposed by the Minerals Policy Institute is also specifically evaluated and discussed.

It should be noted that the Draft EIS included a partial backfill option as the proposed Project closure scenario. It included placing the entire approximately 100 Mt of tailings, plus 15 Mt of non-benign waste from the final six years of mining operations and 5 Mt of potentially acid forming (PAF) material with the greatest risk of acid generation into the base of the final open cut void. This equates to 120 Mt in total, or approximately 15% of the total waste streams, and results in some of the higher risk material on site being subaqueously disposed under a depth of more than 150 m of water, where it is completely isolated from the receiving environment.

The five classes of overburden at MRM are, in order of increasing potential for environmental impact:

- low salinity non-acid forming (high capacity) (LS-NAF(HC));
- metalliferous saline non-acid forming (high capacity) (MS-NAF(HC));
- metalliferous saline non-acid forming (low capacity) (MS-NAF(LC));
- potentially acid forming (high capacity) (PAF(HC)); and
- potentially acid forming (reactive) (PAF(RE)).

PAF(HW) is a subset of PAF(HC) located in the open cut hanging wall. It has been classified differently for operational purposes rather than significant geochemical differences.

<u>Complete Backfill option</u>

The primary objective of the complete backfill option would be to remove the North Overburden Emplacement Facility (NOEF), aiming to return the operations areas as close as possible to the original landform, with a consequent perceived reduction in closure risk associated with long-term Acid and Metalliferous Drainage (AMD). The Complete Backfill scenario, developed in consideration of the site specific characteristics at MRM, is summarised below.

- After open cut mining is completed in 2037, the entire NOEF would be removed and placed into the final open cut void, along with the South Overburden Emplacement Facility (SOEF) and East Overburden Emplacement Facility (EOEF) (PAF(HW).
- The open cut void would be backfilled with some internal zonation:
  - PAF waste types would be stored below the permanent groundwater level so they remain saturated, with less reactive MS-NAF material filling the rest of the open cut void.
  - A geosynthetic liner (GSL) barrier would be installed from approximately 130 metres below the pit crest, up the sides of the void, with the aim of limiting exchange of groundwater in the more permeable vadose zone and the top 100 m of the open cut rock walls, where permeable faults may be present.
- A low overburden emplacement facility (OEF) (termed the 'Pit OEF') would be formed over the top of the former final void within the mine levee wall (MLW), ranging from approximately 10 m to 25 m in height. This would also have a GSL based cover system applied, encapsulating all non-benign material in the zones at higher risk of water and oxygen exchange. The final landform would be contoured and revegetated.
- The West Overburden Emplacement Facility (WOEF) would remain in its current location and would join onto the new Pit OEF landform. The WOEF would require an enhanced cover system, incorporating a GSL in the cover system as the barrier layer.
- The Tailings Storage Facility (TSF) would remain on land with a low permeability cover system.

<u>Partial Backfill options</u>

The objective of the partial backfill options would be to remove the higher risk overburden material from the NOEF to reduce potential contamination along pathways from the NOEF to surface and groundwater systems, and hence reduce the potential long-term AMD risk associated with the NOEF. Several partial backfill scenarios have been considered:

1. Rehandle the highest risk PAF material plus tailings, with a deep mine pit lake
   - The EOEF (with the higher acid generation risk PAF(HW) material) and the SOEF would be rehandled into lower benches of the final void.
   - The entire mass of tailings (of approximately 100 Mt) will be relocated from its current location in the TSF adjacent to Surprise Creek, and deposited into the open cut void.
   - The remaining open cut void up to the about 15 m below the pit crest would then be rapid filled via harvesting water from the McArthur River during flood conditions to form a mine pit lake approximately 160 m deep, therefore limiting the generation of oxidation products and associated potential risk to the surrounding environment.
2. Backfill to the water table height (large partial backfill), with a shallow mine pit lake
   - The EOEF (with the higher acid generation risk PAF(HW) material) and the SOEF would be rehandled into lower benches of the final void.
   - The rehandle of the NOEF would prioritise PAF(RE) overburden and the existing NOEF PAF cell being placed into the lower parts of the final void where the country rock is less permeable. PAF(HC) and some MS-NAF would be placed above this mass to just below the vadose zone. The non-benign backfill mass would then be capped with a benign cover system. External floodwater would be harvested to create a shallow pit lake, approximately 14 m deep.

- A smaller remnant NOEF, approximately 300 ha in footprint and 80 m in height, would remain in the long-term to the north of the current NOEF. This smaller NOEF would contain mostly MS-NAF overburden in the core (although some mixed-in PAF(HC) would likely also remain), MS-NAF material in the base and halo, and benign materials in the cover.
- The TSF would remain on land, also with a GSL based cover system.

3. Rehandle all Reactive PAF materials plus tailings, with a medium depth mine pit lake
   - The EOEF (with the higher acid generation risk PAF(HW) material) and the SOEF would be rehandled into lower benches of the final void.
   - The tailings, PAF(RE) and PAF(HC) material would also be rehandled into the lower permeability bottom section of the final open cut void.
   - The non-benign backfill mass would then be capped with a benign cover system. The volume above this level would then be rapid filled via harvesting water from the McArthur River during flood conditions to form a mine pit lake approximately 100 m deep.
   - As only a portion of the material has been rehandled into the open cut void, a remnant NOEF of approximately 450 ha in footprint and 80 m in height would remain in the long-term. Similar to the Draft EIS, this smaller NOEF would still contain PAF(HC) overburden and MS-NAF overburden in the core, MS-NAF material in the base and halo, and benign materials in the cover.

<u>Summary and Conclusions</u>

MRM recognise that backfilling of the final void does have some positive environmental aspects and it has been seriously considered as an option at various stages of MRM closure planning, however the positives need to outweigh the negatives for it ultimately to provide a superior solution. As a result of the planning and assessment completed during the preparation of the Draft EIS, McArthur River Mining selected Partial Backfill Option 1 above - the 'partial backfill with the highest risk PAF material plus tailings, with a deep mine pit lake' as the option which provides the optimum environmental solution. This option would see approximately 120 Mt of tailings and non-benign mine waste deposited in the bottom of the open cut final void for permanent subaqueous storage. Both the complete backfill and large partial backfill options were evaluated, and while both have some positive environmental aspects, neither result in a lower residual risk profile and both would lead to early Project cessation. The key reasons McArthur River Mining has not selected them for incorporation into the OMP include:

- For both the Complete and Large Partial Backfill Cases:
  - The McArthur River diversion channel would have to be managed in the long-term. Given the proximity to the surface of large quantities of non-benign waste rock for both the complete and large partial backfill scenarios, any future avulsion (natural realignment) of the McArthur River back into its former course could have significant consequences for downstream environments. By comparison, modelling has shown that if the upstream and downstream levees were to fail in the Draft EIS closure scenario, waste materials in the open cut void would not be remobilised in the water column and transported down the McArthur River.

  - The NOEF core would have been sealed up with advection barriers and possibly the cover system (depending on the timing of rehandling), protecting the overburden from ongoing oxidation. However, were the waste to be rehandled, the core would be opened up once again to oxygen and water, increasing the risk of spontaneous combustion and the overall quantity of oxidation products, including sulphur dioxide. Once these materials are placed in the open cut void, the strategy is to inundate them to prevent further oxidation; but the water used to inundate the rock will have unfettered access to the soluble load of oxidation products. As the water level rises, it will reach levels where it could significantly contaminate the groundwater. The transport and final fate of contamination, while potentially deeper and slower moving, would be very difficult to control. Should it end up expressing in distant surface environments and/or contaminating a large section of regional groundwater, remediation would potentially be impossible.
  - The TSF would remain aboveground and would require management in the long-term. MRM considers that the rehandling of the entire TSF from a location directly adjacent to Surprise Creek would provide a more robust environmental solution than the alternative of leaving two aboveground structures, i.e. the TSF and an OEF (either in its current NOEF location or above a backfilled final void). The complete removal of the TSF results in the complete elimination of a key aboveground structure removing the requirement for rehabilitation and long-term management.
- In addition, for the Complete Backfill Case:
  - The entire volume of overburden mined from the open cut would not fit back in the void below the groundwater table. If all overburden was to be relocated from the NOEF to the open cut, an aboveground Pit OEF would be required above the open cut void, filling through the vadose zone and above the water table. Due to the geochemical properties of the overburden at MRM, many of the principal technical arguments presented in Mudd 2016 for complete backfill are not realised when the concept is applied to the site-specific characteristics at MRM. These include:
    - The aboveground Pit OEF would still present an AMD risk. This is because the Pit OEF would be comprised of Metalliferous/saline NAF, which is not environmentally benign. While the risk of acidic seepage would be reduced, the risk of neutral metalliferous drainage (NMD) and saline drainage (SD) would remain and would still require long-term management into closure.
    - The Pit OEF would be located close to the primary sensitive receptor (McArthur River diversion channel), increasing the risk of potential impacts to the river and downstream environments. The location of the OEF would leave very little room for mitigation of any negative environmental impact from potential seepage. This is a key flaw, as the potential risks associated with the long-term storage of non-benign materials in a structure aboveground are not eliminated by the proposal; they are however transferred to a more sensitive location.

- The risk of AMD transferring from the waste rock material deposited in the vadose zone, into the surrounding groundwater system and environment (via the shallow groundwater) could theoretically be reduced by mitigation strategies, such as completely encapsulating the zone in a GSL. However, there is approximately 6 kilometres (km) of below ground perimeter that would be required to be isolated from fluctuating waters. This would be extremely difficult to implement and maintain into the long-term. If the mitigation did fail, it would be almost impossible to rectify as the possible exchange areas are buried. By comparison, the land-based NOEF provides easy access for repair and maintenance to the cover system barrier layer if required.

The costs associated with both the complete backfill options, and the larger partial backfill options, would render the Project uneconomic and would prohibit the further development of the operation. In this case, the Project would cease, with a consequent loss of employment and associated community investment projects, services, taxes and royalties. The residual environmental risks associated with MRM closing now are not materially different to that of it continuing to operate as proposed in the Draft EIS.

1 Introduction

A number of responses were received through the Draft EIS public and stakeholder consultation process regarding the option of backfilling the final void with overburden from the NOEF upon completion of mining operations. Some of the key specific responses include:

- *"The EIS Response Document must include a realistic scenario which ensures all PAF material is sequenced as deep as possible in the former pit."*
- *"ECNT are interested in further exploration of those options (7 and 8) that would backfill overburden to the pit. While it is apparent that handling of the overburden material would present environmental management challenges during decommissioning works, these options appear to offer a number of long-term environmental benefits that have not been thoroughly considered in this EIS."*
- *"In reviewing the option of complete backfill provided in this EIS, Gavin Mudd highlights the inadequacies of figure 5.10 and the lack of consideration given to the safe emplacement of tailings and PAF wastes into lower section of the mine pit. Critical information regarding historical waste placement, characteristics and volumes is missing from this EIS to enable possible engineering approaches to mitigate leaching risks from wastes in the upper zones. This alternative has not been adequately considered including providing detailed hydrological assessments, acknowledgment that risks can be mitigated and fails to make a strong case that this option should be rejected."*

During the preparation of the Draft EIS, the mine closure option proposed by the Minerals Policy Institute of backfilling the open cut void post-mining with mine waste material as described in "The McArthur River Project: The Environmental Case for Complete Pit Backfill", (Mudd 2016) was investigated and considered along with various other closure scenarios. It should be noted that this report was written prior to the submission of the Draft EIS and therefore did not draw on any of the significant information provided in the Draft or Supplementary EIS reports.

This report addresses stakeholder comments by presenting MRM's assessment of several possible open cut void backfilling scenarios including complete backfilling and partial backfilling options. The scenario proposed by the Minerals Policy Institute is also specifically evaluated and discussed.

A summary of this complete backfill, and various other partial backfill options is provided below. The reasons they were not ultimately selected as the preferred option for the Project are also provided.

2 Complete Backfill Scenario

2.1 Background

In 2016, the Minerals Policy Institute published a report titled "The McArthur River Project: The Environmental Case for Complete Pit Backfill" (Mudd, 2016), which proposed a mine closure option for MRM based on backfilling the final open cut void with mine waste material.. The report, published prior to the submission of the Draft EIS, was not commissioned by McArthur River Mining and it is believed that limited site specific data was utilised. The author states the principal technical arguments for complete pit backfill, include:

- *"Sulfidic waste is below ground level and erosion of engineered soil covers is avoided;*
- *Sulfidic waste is below the water table, and given the low solubility of oxygen in water and the time it takes for oxygen to diffuse through the thick cover of mine wastes, this almost eliminates the availability of oxygen to drive the biogeochemical process of sulfide oxidation and AMD;*
- *Deep-rooted trees cannot penetrate through and compromise any engineered soil covers, since thick roots provide open pathways for the infiltration of water;*
- *Sulfidic waste is well below the zone where interaction with the above ecosystem would be important, such as tree roots and burrowing animals;"*

The conceptual scenario is schematically presented in **Figure 1**.

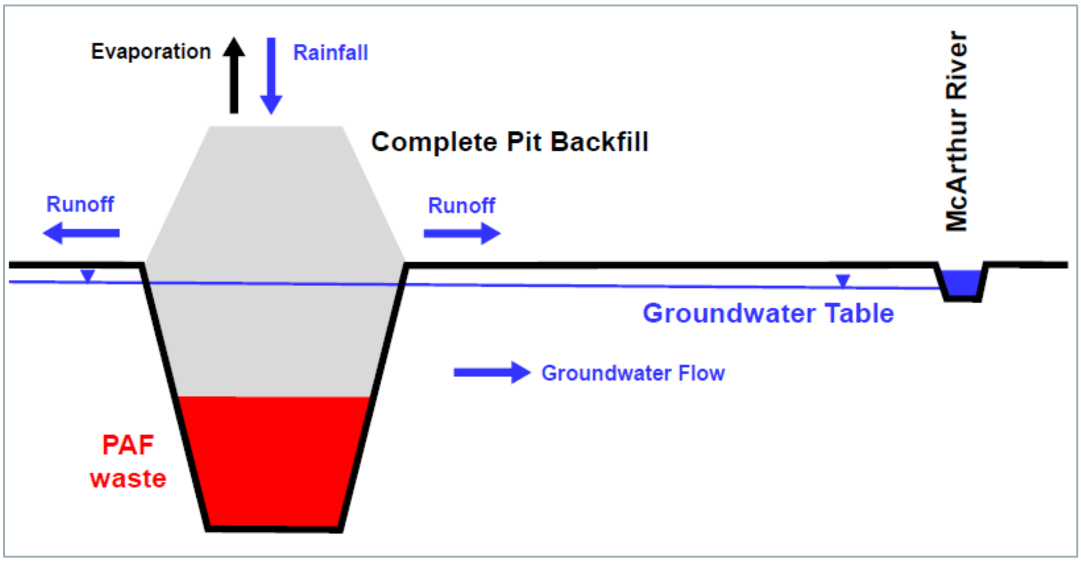

Figure 1 Conceptual representation of the McArthur River site after the end of mining assuming PAF wastes are smaller in volume than NAF wastes and PAF wastes are buried deep in the former open cut (Mudd, 2016)

In this scenario, PAF waste is placed deep below the water table, while the remainder of the void and the aboveground OEF is filled with environmentally benign non-acid forming (NAF) rocks. However with reference to a more likely scenario at MRM, the report acknowledges:

"The more realistic scenario, however, is that the PAF materials will be significantly greater in volume than NAF materials that they reach towards the top of the pit and potentially even remain above the re-established groundwater table after mining, as shown in ***Figure 1.****"*

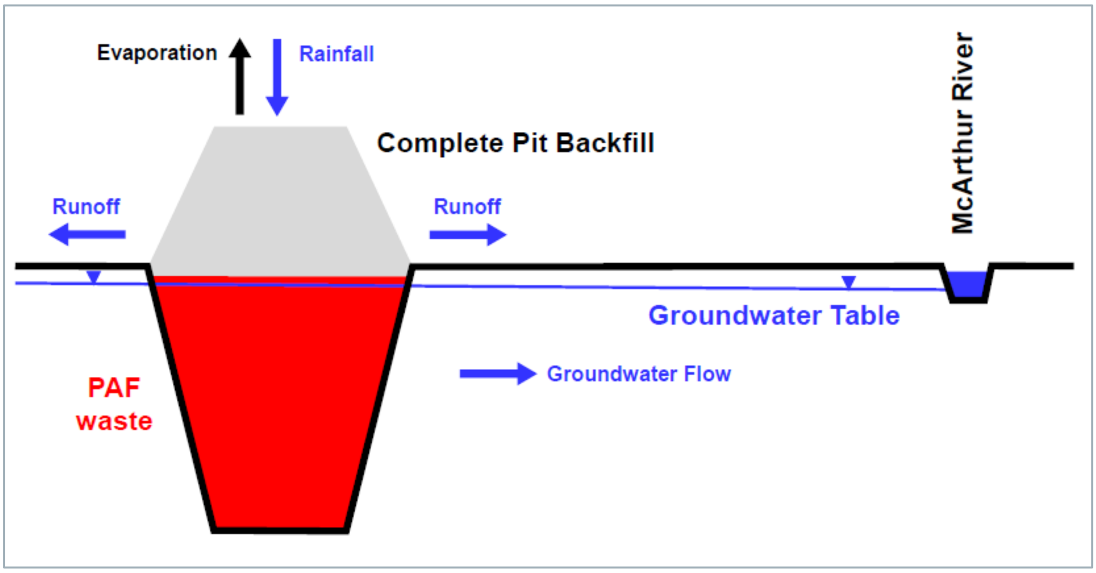

Figure 2 Conceptual representation of the McArthur River site after the end of mining assuming PAF wastes are greater in volume than NAF wastes and PAF wastes are buried deep in the former open cut but still approach ground surface (Mudd, 2016)

With regards to this conceptual scenario, Mudd 2016 notes:

"The vast majority of the PAF wastes would be below the water table and present minimal AMD risk, a small quantity would remain above the water table and exposed to fluctuating infiltration and oxygen ingress given the wet–dry tropical climate of the region— leading to some AMD generation, which would seep into the deeper wastes within the pit and create potential to flow downgradient into the surrounding groundwater system."

While the conceptual model presented in Figure 2 is closer to the MRM situation than the one presented in Figure 1, this conceptual model is only partially correct and does not take into consideration all the geochemical properties of the overburden at MRM.

Estimations of LOM waste rock proportions indicate circa 35% of PAF lithologies (PAF(HC), PAF(RE) and PAF(HW) (refer to the waste classification table in Draft EIS Chapter 6 – Materials Characterisation for more detail on material types). Preferentially placing the PAF at the bottom of the open cut would indeed result in all the PAF being located below the water table and hence in a low-oxygen environment. However, 85% of the remaining NAF material is classed as metalliferous/saline (MS-NAF(HC) and MS-NAF(LC)). These classes are not considered environmentally benign and may generate AMD if exposed to oxygen in the form of both NMD and SD. Only 15% of the NAF material is considered environmentally benign and their use has to be prioritised in the cover systems.

When the actual proportions of non-benign materials in the mine plan are considered, the complete backfill option may be better represented by **Figure 3**.

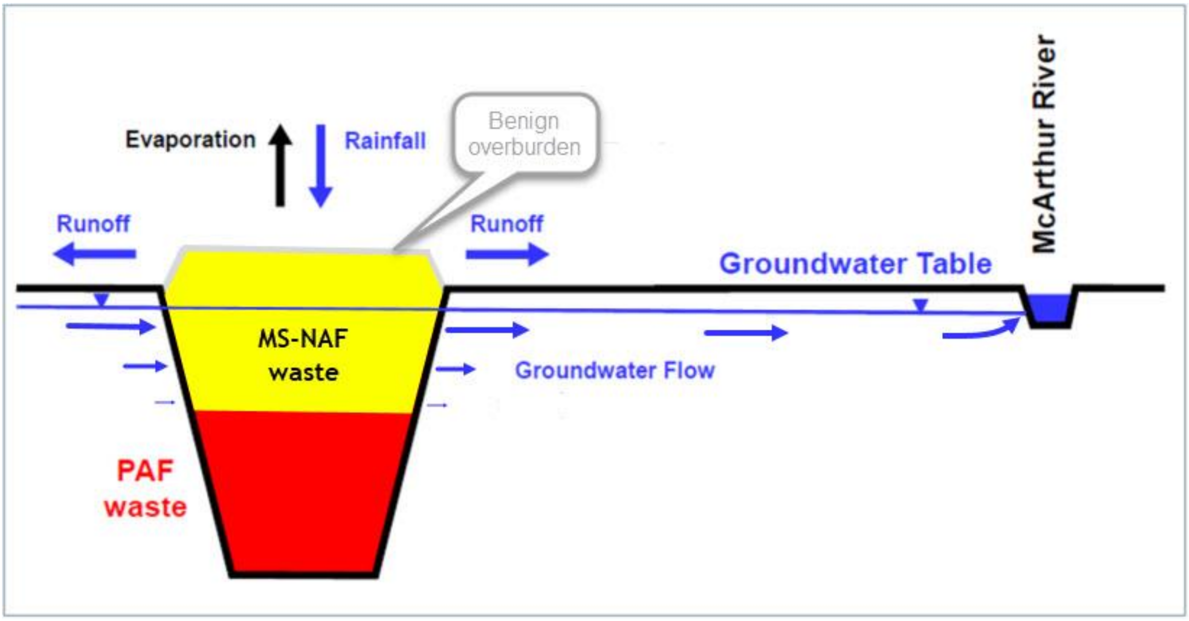

Figure 3 Conceptual representation of actual McArthur River complete backfill scenario (modified from Mudd 2016 schematic)

As identified by both Mudd and MRM, non-benign overburden stored above the fluctuating water table without adequate isolation would lead to AMD generation and migration. Hence, considering the reality of the MRM deposit as depicted by Figure 3, and the necessity to store significant quantities of MS-NAF material through and above the water table and in the aboveground Pit OEF, a number of the principal technical arguments presented for complete pit backfill are significantly less effective or completely eliminated. In particular, this scenario does not eliminate the need to manage AMD; the risk of seepage acidification is very low, however NMD and SD would still need to be managed in the long-term.

Mudd 2016 also acknowledges some of the potential key risks or disadvantages with complete pit backfill:

"Some issues of pit backfill include:

- *potential groundwater quality impacts (especially if AMD is already occurring in mine wastes and there is migration of solutes from the mine wastes into the surrounding groundwater),*
- *major costs involved, and*
- *the expansion of volume in rock when it is blasted and mined—meaning that waste rock may occupy a greater volume than the original pre-mined rock and some sulfidic wastes may still sit above the post-mining groundwater table and be subject to oxidation and AMD risks."*

These three key issues, along with a number of other significant factors, form the basis of MRM's decision not to adopt the complete backfill option in the OMP. These risks and issues are described further below.

2.2 Scenario Features/Assumptions

The following is a summary of the complete backfill scenario developed and assessed during the Draft EIS. This represents the further development of the basic final void backfill concept proposed in Mudd 2016 utilising site specific data and information from MRM.

The option involves rehandling the entire completed NOEF into the final open cut void once mining is complete in 2037. The rationale is to fully remove overburden material from the NOEF to reduce potential contaminant pathways from the NOEF to surface and groundwater systems, and place the overburden inside the MLW where the perception is it would have a lower risk of impact on the external environment.

The key points regarding the scenario are:

- Not all NOEF material can be accommodated below the natural surface level in the final void. Due to the waste rock swell factor in the order of 25-35% (as a result of fragmentation and swelling through the blasting process), excess NOEF overburden would need to be placed in a specially constructed 'Pit OEF'. This would be up to 25 m in height and would need to be constructed over the backfilled final void, extending from the West Overburden Emplacement Facility (WOEF) to the MLW (**Figure 4**).
- Rehandled material would contain stored oxidation products resulting from oxidation during the mining and dumping process, prior to construction of the NOEF cover system. These secondary minerals would be soluble and immediately transportable to the environment.
- Floodwater would be harvested during construction to rapidly saturate the backfilled rock in the pit void to restrict oxidation. This would see the water table recover to levels similar to the pre-mine levels much quicker than through groundwater and rain inflows alone.
- There would be virtually no ongoing oxidation occurring in rock stored below the permanent groundwater table due to subaqueous storage following saturation and groundwater table recovery. Some connectivity would remain between the backfilled final void and the McArthur River via palaeochannels and shallow groundwater systems. At MRM, the permeability of the host rock reduces with depth; below a certain depth, the load transfer would be slow and the likelihood of contaminants migrating away laterally would be very low. The upper zone of the backfilled final void (with moderate permeability but below the permanent water table) would have some risk of connection with the regional groundwater and surface water systems. However, the shallow vadose zone (in the region of fluctuating water table and variable permeability) is very likely to contain pathways for the exchange of waters.
- Due to the large volume of non-benign waste, non-benign material would have to be stored in the more permeable upper zone and vadose zone where oxidation and migration of oxidation products is more likely.
- Priority would be placed on returning all the waste rock to the final void; therefore the tailings would remain in a surface TSF so as not to consume final void capacity for the replaced overburden. Justification for this assumption is provided below:
    - The tailings material is PAF(HC), but due to the lack of available capacity within the final void after the higher priority PAF material has been placed into it, the tailings material cannot be stored below the expected interactive groundwater zone. However, the tailings are extremely fine-grained and naturally maintain high saturation when covered due to their material properties. So if the tailings cannot be stored subaqueously as per the Draft EIS, the risk of ongoing oxidation and AMD generation in the open cut location versus the current TSF location with a suitable cover system, is not considered to be materially different.

- If the tailings were placed in the pit with all of the NOEF material, the Pit OEF would be another 45 m higher, taking the total peak Pit OEF height to approximately 70 m, which is comparable to the current NOEF. MRM considers that the site wide residual risk of tailings and waste rock storage in the final void (with a much higher Pit OEF) is not materially different and so would leave the tailings in the aboveground low height TSF with a suitable low permeability cover system. Therefore, the TSF would require long-term landform and seepage management systems and processes, as with the Pit OEF.

2.3 Scenario Description

To comprehend the risks associated with backfill and pit lake options, the geology and hydrogeology of the final pit void needs to be understood. At MRM, the highly permeable palaeochannels and associated transported sediments adjacent to the open cut currently transmit approximately 8 megalitres per day (ML/day) of shallow groundwater into the mining operations. These alluvial sediments reside in the top of the vadose zone. The vadose zone (approximately 10,032RL down to 10,000RL) comprises the zone in soil or rock where groundwater and atmosphere are in contact. This zone generates both anoxic and oxic conditions depending on the depth to the water table and to a lesser extent the medium. This vadose zone presents a high risk of transmission of contaminants from these elevations to the receiving environment. Based on site drilling investigations and pit wall mapping, the upper wall rocks down to 9,900RL (approximately 130 m below ground level) have a high likelihood of localised permeable fault and fracture zones, which are also potential pathways from the pit void to the receiving environment. These key zones must be considered in assessing the risk of the various final void backfill options.

At the completion of open cut mining, and incorporating the in-pit dumping in the latter years, the final void would have a capacity of approximately 129 million cubic metres (MCM) up to 9,900RL, (see **Figure 4** below). A further 115 MCM of capacity exists up to the 10,000RL, which is the base of the vadose zone. By comparison to the total NOEF overburden material fill volume of approximately 385 MCM, this total of 244 MCM is insufficient to store the overburden below the permanent groundwater level. Therefore, it is necessary to place waste above the permanent groundwater level. This would result in the development of a Pit OEF, through the vadose zone and up to 25 m in height above the backfilled open cut void, as indicated in **Figure 5**.

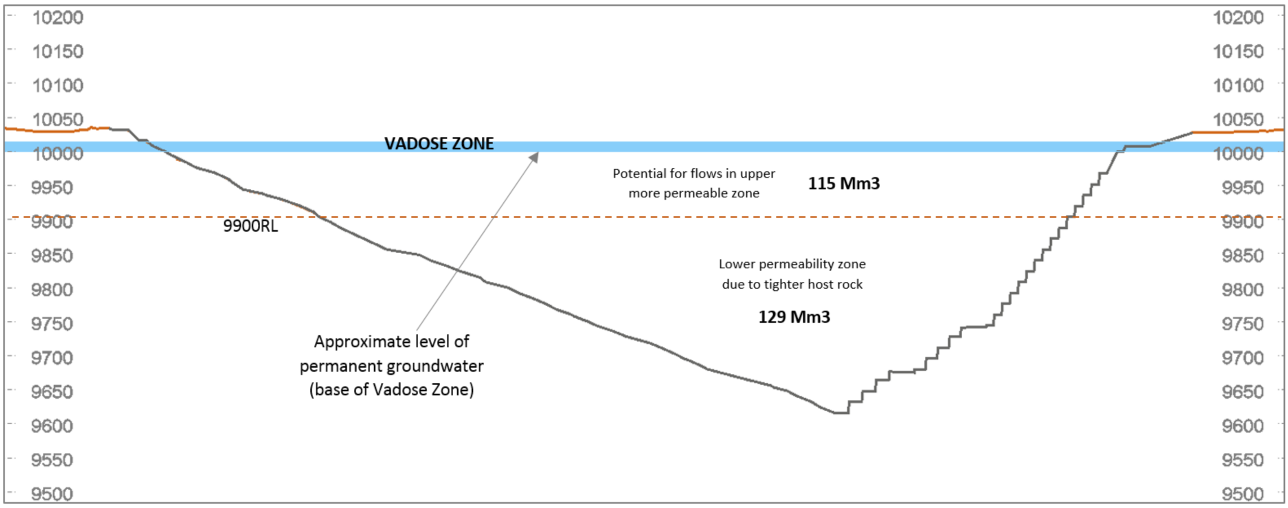

Figure 4 Final Void Cross-Section

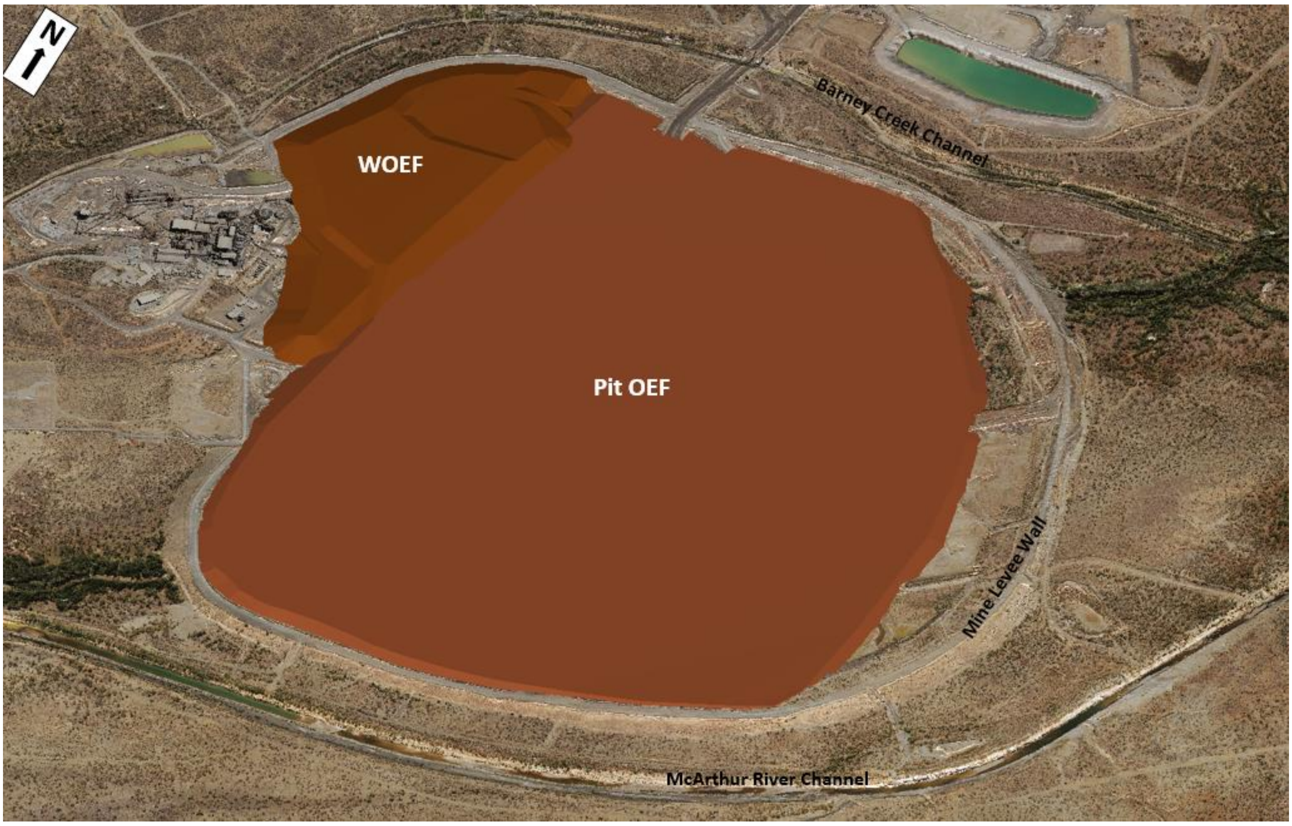

Figure 5 Complete Pit Backfill Dump Final Surface

Placement of only benign material in the vadose zone would be ideal, however this would require 74 MCM of benign waste, which is not available from either the NOEF or the Woyzbun Quarry, and so an extra external quarry would be required (see **Section 3.3.1** for further information on this option). An alternative to benign fill is to isolate the waste fill in this zone using barrier layers to restrict water transmission between the surrounding geology and the backfilled waste. The concept is shown in Figure 7 below. At 9,900RL, a 0.5 m thick Compacted Clay Liner (CCL) would be constructed across the full footprint of the backfill, to form a barrier to vertical water movement. It was assumed that the Emu Plains Borrow Pit to the northeast of the NOEF would be used to supply the 580,000 cubic metres (m^3) of clay required.

A zone termed "Halo-Sides" was conceptualised above this CCL, where further barrier layers would be formed. Due to the roughness of the void walls, it is considered impossible to successfully install a very low permeability barrier down the walls without incurring damage. An alternative construction method was therefore devised. MS-NAF would be tipped on the inner part of the "Halo-Sides" zone at a 1V:2.5H slope, stopping before the toe reached the pit wall. An under-liner of fine-grained alluvial material would be applied to form a relatively smooth foundation. A GSL barrier would be installed down this face, and joined to the barrier at the bottom, forming a continuous barrier around the entire final void perimeter. Non-benign fill would then be placed between the GSL and the final void wall. This would be repeated for each lift, all the way to the surface (as indicated in **Figure 6**). Thus, groundwater migrating toward the final void would be repelled by the GSL barrier, and would have to move around the backfilled final void, only contacting benign materials. However, with a perimeter of approximately 6 km and an area of 2,100,000 m^2, this is an extremely large area to install a liner on, at difficult angles, with no defects. Unlike the NOEF barrier layer, punctures and tears caused by rocks and differential settlement could not be repaired as the barrier would be completely buried.

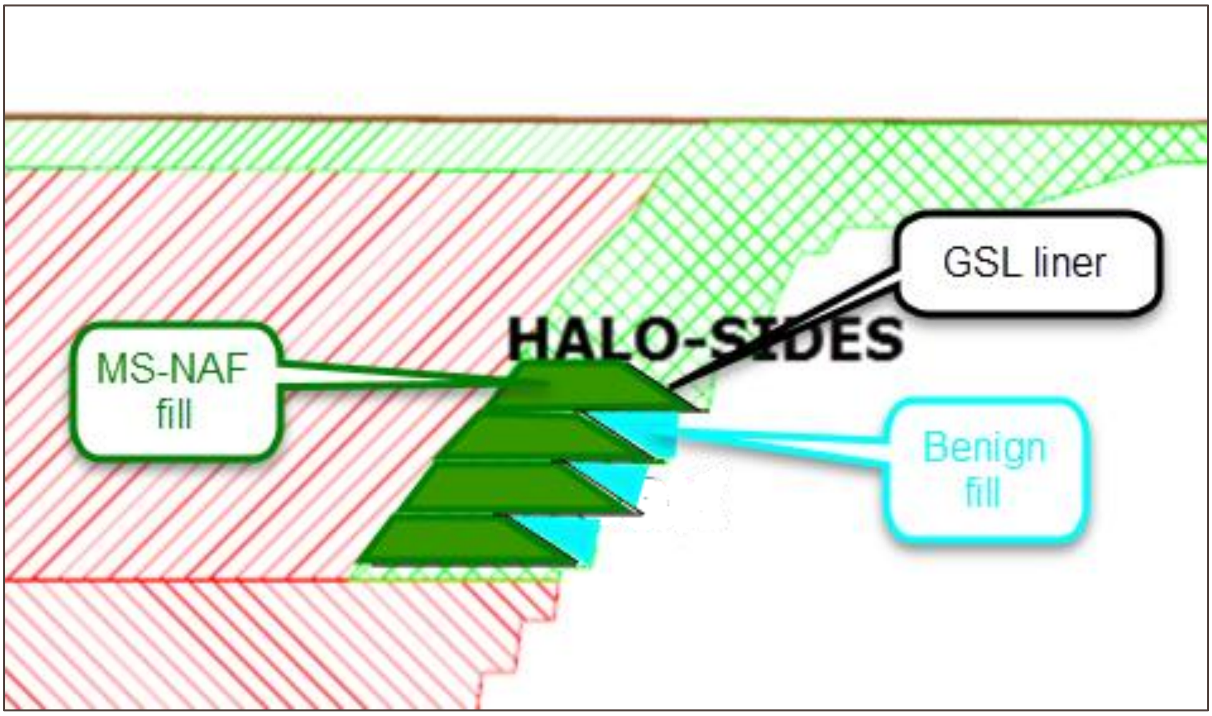

Figure 6 GSL Liner Configuration

This option of using a GSL as a barrier layer was selected as the most appropriate assumption for incorporation in the assessment of the complete backfill scenario.

Figure 7 and **Figure 8** below provide indicative schematics of this backfill scenario.

The OEF fill materials would be hauled down the remnant haul ramps to the active 8 m tiphead. Ancillary machines would push the fill out and maintain levels and road surfaces. All placement of waste would progress from the bottom of the final void up, in 8 m benches. The most reactive materials – the PAF(RE) and PAF(HW) – would be placed in the "Core-Lower" zone, well below both the permanent groundwater level and the "Core-Upper" zone, which has potential for more permeable wall rocks. Activities would see these materials stored subaqueously as soon as possible to limit oxidation – however, groundwater inflows and rain would be insufficient to achieve this. Therefore, each wet season, 2 GL to 8 GL of floodwater would be harvested from the NOEF Perimeter Runoff Dams (PRODS) or the McArthur River to inundate that years placed waste. Backfilling would continue up to the finished height of the Pit OEF, which would be from 8 m to 25 m above the original ground level (with a slope to achieve surface drainage). The "Halo-Top" and "Halo-Sides" zones would use MS-NAF materials, as per the NOEF internal architecture.

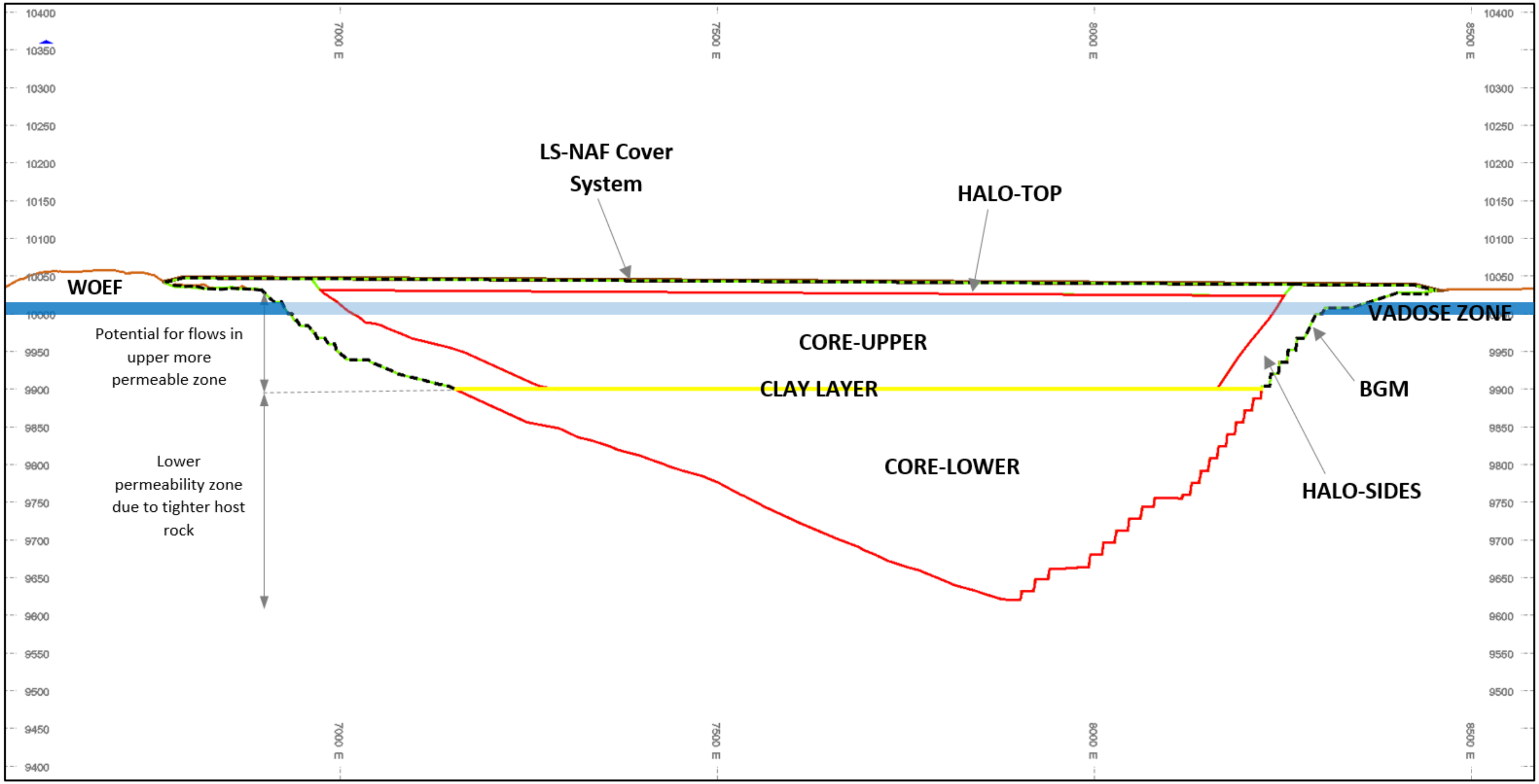

Figure 7 Complete Backfill OEF Cross Section (2D)

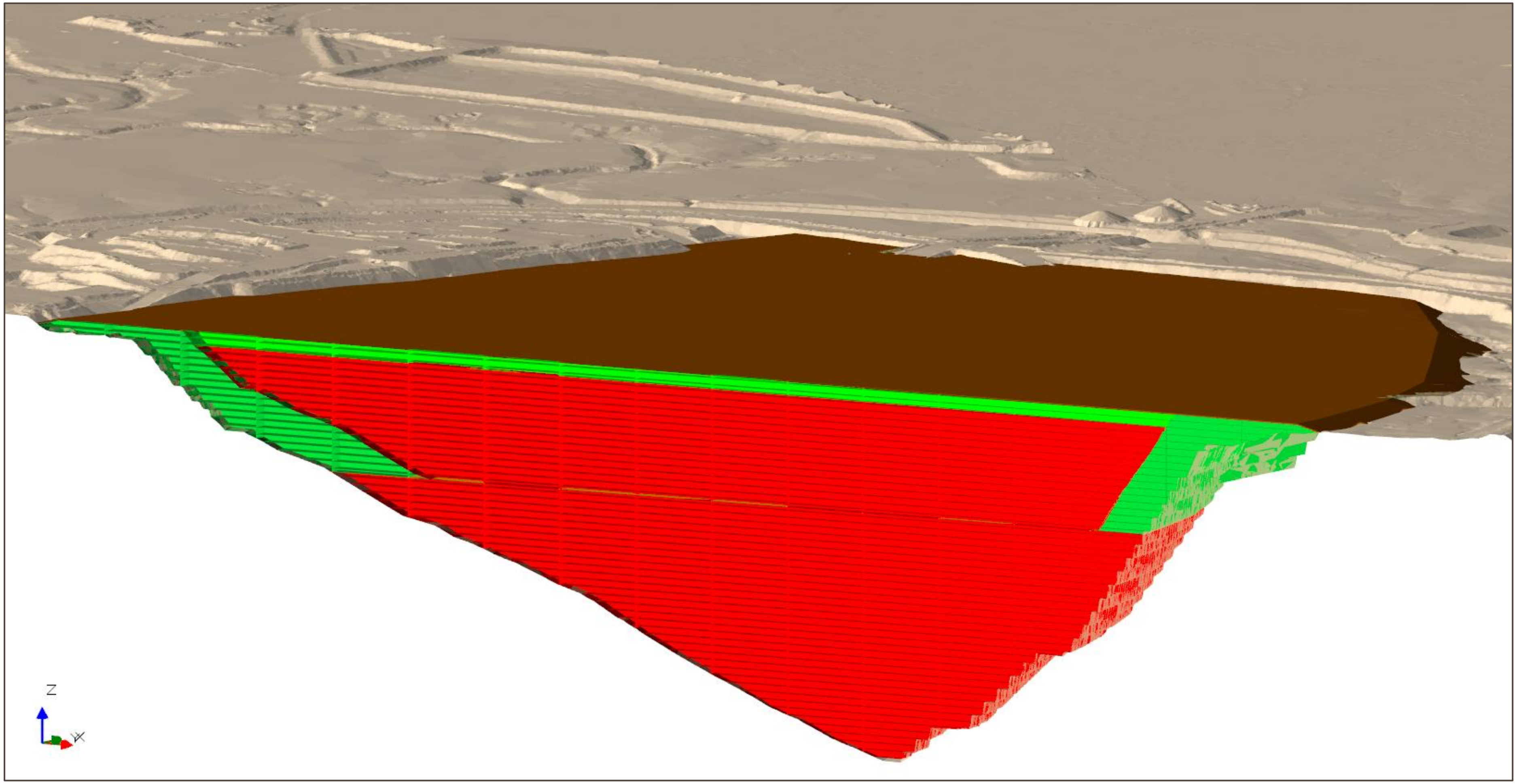

Figure 8 Complete Backfill OEF Cross Section (3D)

The non-benign Halo zones would need to be completely isolated from the external environment to limit oxidation and transport of oxidation products. To achieve this, the barrier layer that was used on the upper final void walls (Halo-Sides) would be continued to completely encapsulate the Halo-Top zone. The final landform of the Pit OEF would be designed to utilise the thick compacted clay core of part of the MLW to form part of the barrier to the receiving environment. Thus, the GSL up the sides of the "Halo-Sides" zone would be run across the prepared ground to tie into the core of the MLW, then from the top of the MLW over the Halo-Top. The aboveground fill (including the relevant sections of the MLW) would then receive the rest of a cover system, similar to that of the NOEF: a drainage layer, growth media layer, topsoil and vegetation. The cover system would incorporate surface drainage to enable water to be directed to water management structures inside the MLW for the required construction period, and then directed to drain through openings in the levee wall via sediment traps once runoff water quality would meet the external discharge quality requirements (**Figure 9**).

All of this encapsulation would require in the order of 8,200,000 square metres (m^2) of GSL.

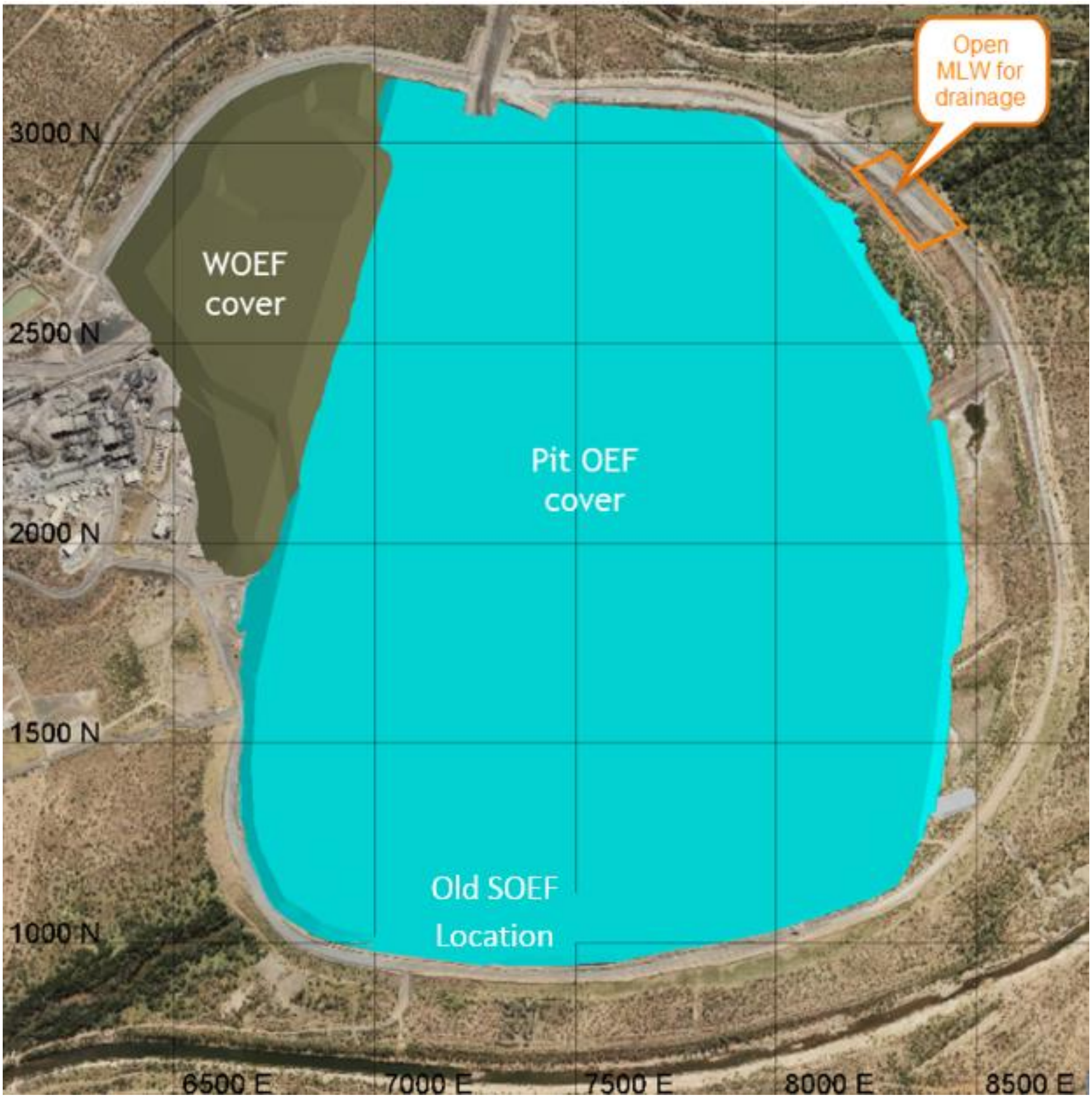

Figure 9 Plan View of Final Cover

2.3.1 Alternate Vadose Zone Option

As indicated previously, placement of only benign material in the vadose zone would be ideal as this would require 74 MCM of benign waste – which is not available from either the NOEF or the Woyzbun Quarry. A possible target for this material is located to the north of the NOEF, in a dolomite rock unit. **Figure 10** below shows this possible benign quarry, located outside of main drainage lines. A quarry with a 130 ha footprint (1500 m x 950 m) down to 76 m deep could be mined. This quarry would remain as a void, and would fill to an undetermined level with groundwater and surface water. This additional material would also make the Pit OEF approximately 40 m higher than the scenario proposed in **Figure 5** and **Figure 9**, resulting in a 65 m high OEF, which is similar in height to the current NOEF (70 m high).

This option was ultimately not selected as the option of using a GSL as a barrier layer was found to be more cost effective, and has the added benefit of avoiding the external quarry (and associated quarry lake in closure) which would be required for the provision of the required benign material.

Figure 10 Possible Benign Quarry for Vadose Zone

2.4 Key Risks of Complete Backfill

The key risks of the complete backfill option are outlined below.

2.4.1 Environmental risks

The aboveground Pit OEF would still present an AMD risk. This is because the Pit OEF would be comprised of Metalliferous/saline NAF which is not considered environmentally benign. While the risk of acidic seepage would be reduced, the risk of NMD and SD would remain and would still require long-term management.

The Pit OEF would be located extremely close to the primary sensitive receptor (McArthur River diversion channel), increasing the risk of potential impacts to the river and downstream environments. The location of the OEF would leave very little room for mitigation of any negative environmental impact from potential seepage. This is a key flaw, as the potential risks associated with the long-term storage of non-benign materials in a structure aboveground are not eliminated by the proposal; they are however transferred to a more sensitive location.

It should be noted the EOEF proposed in the Phase 3 Development Project, which at that stage was situated outside of the existing flood protection bund between the MLW and the McArthur River Diversion Channel and would have been made of non-benign NAF material, was not progressed once MRM understood its geochemistry more accurately and the risk associated with storage of non-benign material in such close proximity to the primary sensitive receptor.

The proposed Complete Backfill case has sought to mitigate the risk of AMD transferring from the backfilled vadose zone into the surrounding environment (via the shallow groundwater) by completely encapsulating the non-benign waste in this zone within a GSL barrier layer. However, there is approximately 6 km of belowground final void perimeter to isolate from fluctuating waters. This would be difficult to construct without defects, and would be extremely difficult if not impossible to identify where defects have occurred and then to repair them. By comparison, the land based NOEF provides easy access for repair and maintenance to the cover system barrier layer if required.

The NOEF core would have been sealed up with advection barriers and possibly the cover system (depending on the timing of rehandling), protecting the overburden from ongoing oxidation. However, the core would be opened up during the rehandling process, giving large quantities of rock new access to oxygen and water, increasing the risk of spontaneous combustion and the overall quantity of oxidation products, including sulphur dioxide. Once these materials are placed in the open cut void, the strategy is to inundate them to prevent further oxidation; but the water used to inundate the rock will have unfettered access to the soluble load of oxidation products. As the water level rises, it will reach levels where it could significantly contaminate the groundwater. The transport and final fate of contamination, while potentially deeper and slower moving, would be very difficult to control. Should it end up expressing in distant surface environments and/or contaminating a large section of regional groundwater, remediation would potentially be impossible.

The TSF, which is located directly adjacent to Surprise Creek, would remain aboveground in this scenario, resulting in two aboveground structures, i.e. the TSF and the Pit OEF, requiring long-term management, rather than the single NOEF proposed in the Draft EIS.

The McArthur River diversion channel would have to be managed into the long-term. Given the proximity to the surface of large quantities of non-benign waste rock for both the complete and large partial backfill scenarios, any future avulsion (natural realignment) of the McArthur River back into its former course could have significant consequences for downstream environments. By comparison, modelling has shown that if the upstream and downstream levees were to fail in the Draft EIS closure scenario, waste materials in the open cut void would not be remobilised in the water column and transported down the McArthur River.

2.4.2 Health and Safety risks

Re-exposure of overburden material during re-mining from the NOEF would increase the risk of (and subsequent exposure of people to) sulphur dioxide generation and spontaneous combustion, posing a health and safety risk to sensitive receptors (refer to Draft EIS Chapter 13 – Air Quality).

The risks associated with undertaking another mining activity (NOEF back into open cut) with associated impacts of logistics, surface water management, rehabilitation delays, long-term TSF management, dust generation and fuel consumption (and greenhouse gas emission (GHG)) also bear consideration.

2.4.3 Financial risks

- Maintenance of the McArthur River diversion channel and the MLW would be required into the long-term.
- A network of monitoring bores around the MLW would have to be installed and maintained to identify AMD seepage originating from the backfilled void. Mitigation strategies such as cut-off trenches, permeable reactive barriers, recovery bores and recovery trenches may be required to meet the environmental objectives of the system. As the oxidation products are stored from aboveground all the way through the full final void depth, there is a higher likelihood that recovery would need to service greater depths than NOEF-related seepage, adding to technical complexity and cost.
- The TSF would be required to be encapsulated and maintained into the long-term. Preventing the retreatment of the TSF reduces the mine life by approximately 10 years, and the subsequent economic and social benefits that result from extending the operational period.
- The extreme cost of rehandling the NOEF and backfilling the final void would mean that the Project would no longer be economically viable.

2.5 Key Advantages of Complete Backfill

The key advantages of the complete backfill option include:

- Complete removal of the NOEF, with simpler long-term maintenance for the NOEF domain;
- A reduction in long-term AMD generation risk by for the most reactive materials by storage in a subaqueous setting with a low risk of further oxidation and slower contaminant transport once deposited and inundated;
- A lower final OEF landform with consequent reduction in erosion risk and visual impact; and
- Additional employment for the 12 year period of backfill operations.

2.6 Assessment

The various alternatives considered in the Draft EIS were evaluated using a multi-criteria analysis (MCA) (see Draft EIS Chapter 5 – Project Alternatives). The analysis considered both short- and long-term effects as well as local and regional effects (as required by the EIS Terms of Reference). Four categories were used in the assessment:

- **Environmental performance**: ranks the overall expected environmental performance of the option being assessed independently of any costs or technical difficulty in execution.
- **Constructability**: ranks the technical difficulty of achieving a satisfactory outcome for the option being assessed. The constructability criteria involve both a scientific and engineering component as well as a cost component.
- **Financial costs**: the expected overall cost to the project of implementing the option.
- **Social and stakeholder benefits**: includes benefits in terms of employment creation and planned community investment projects, services, taxes and royalties.

While complete backfilling of the open cut with mine waste (Alternative 7) scored relatively highly in the Environmental Performance category, it scored poorly in the constructability, financial cost and societal/stakeholder benefits categories, resulting in it being ranked eighth out of the eight alternatives considered. Some reasoning behind the scoring is included below:

- **Environmental performance –** Environmental performance is expected to be reasonably high however, from both a local and regional effects perspective, poor quality groundwater from the stored load in the backfilled overburden has the potential to migrate into the external groundwater environment. This groundwater would then likely express into surface water features. Also, due to the above surface portion of the overburden in this scenario, it is still left with similar long-term seepage management requirements as the existing NOEF. This scenario does not remove the TSF, with the associated need to manage potential AMD from two aboveground facilities.
- **Constructability –** Constructability was scored low, due to the works required and complexities around safely deconstructing the existing NOEF, sealing up the more permeable upper zone in the final void, construction of the barrier layers to protect the vadose zone from flushing out oxidation products during the wet/dry season cycling, and the complexities associated with identification and subsequent remediation of deeper contaminated groundwater.
- **Financial cost –** The very high costs associated with this alternative would render the Project uneconomic, resulting in the cessation of mining and the consequent loss of employment, community benefits, services, taxes and royalties.
- **Societal and stakeholder benefits –** Societal and stakeholder benefits was scored based on the assumption that (due to the prohibitive financial cost) the Project would cease, potentially with a prolonged period of care and maintenance resulting. As there would be no mine production (ore), it is assumed that all the benefits that flow from continuing operations would cease, including employment, contributions to the Community Benefits Trust (CBT), contributions to Northern Territory (NT) based businesses, services to Borroloola, royalties and taxes.

3 Partial Backfill Scenarios

In acknowledging that complete pit backfill may not provide the optimum solution, Mudd 2016 notes, *"Overall, it is important to consider all impacts and risks and contrast aboveground rehabilitation of mine wastes with the costs and benefits of pit backfill, even if only partial."*

As part of the Draft EIS, MRM investigated three different partial backfill options, each of which is described further below.

3.1 Option 1 – Rehandle PAF(HW) with highest risk of acid generation plus tailings

3.1.1 Scenario Description

While neither scenarios for the complete backfill nor the large partial backfill were identified as providing the best overall option, MRM does agree that final void backfill can play a part in reducing the environmental closure risk, and as such, concepts in line with the principles presented in Mudd 2016 have been proposed for the closure of MRM and therefore included in the Project Description of the **Draft EIS**. These include:

- Approximately 16 Mt of mine waste will be placed into an In-Pit-Dump (IPD) during the final 6 years of mine operations. This will be stored in the lower permeability zone towards the bottom of the final void. Investigations will also continue into potential options to increase the amount of in-pit dumping achievable during the mine operations period.
- The entire mass of tailings (approximately 100 Mt) will be relocated from its current location in the TSF adjacent to Surprise Creek, into the open cut void after the cessation of mining.
- Mt of the high pyrite PAF(HW) material with the highest risk of acid generation stored in a temporary stockpile inside the MLW (in the revised EOEF), will be rehandled into the open cut void once mining is complete.

These materials will be stored below the water table in a subaqueous environment, therefore limiting the generation of oxidation products and associated potential risk to the surrounding environment.

3.1.2 Advantages

The key advantages of this scenario include:

- Complete rehandling of the tailings into the open cut void Lower Zone, well below the expected interactive groundwater zone and well below any turbulent lake currents that may remobilise tailings. MRM considers the rehandling of the tailings from the TSF directly adjacent to Surprise Creek, and therefore the complete elimination of a key aboveground rehabilitation structure, to provide a more robust environmental solution than the alternative of managing two aboveground structures, i.e. the TSF and the NOEF. The additional 10 years of mine life associated with the TSF operations period also offers the economic and social benefits associated with continuing operations (i.e. employment, services, community investment, taxes, royalties etc.).
- Subaqueous disposal of the highest risk PAF material.

  - Potentially environmentally deleterious materials, including the tailings, in-pit dumped overburden and the rehandled 5 Mt of the most pyritic material, will be disposed deep below the water table thereby significantly inhibiting any further oxidation. While the tailings and the rehandled PAF will be associated with a pre-existing load of soluble oxidation products, the reduced quantities and the final depth of the material means that risks to the regional groundwater are limited compared to either the complete backfill or large partial backfill.
- When the additional 10 years of tailings reprocessing is considered, the NOEF will have been closed and fully rehabilitated for 16 years (with some sections up to 27 years) while an operational presence is maintained at MRM. This represents a significant reduction in risks associated with the NOEF closure as there will be a relatively long presence on site prior to mine closure to monitor and conduct minor remediation as required in the early years when most adjustments to the landform are likely to be required.
- Safest final depth of tailings and rehandled waste into the mine pit lake of all the backfill options.
  - Hydrodynamic and geochemical modelling of the Mine Pit Lake indicates that under this scenario (with waste located 160 m below the surface), an environmentally acceptable water quality will be maintained for both the backflow scenario and the secondary flow-through scenario.
- Provides a mine pit lake with the greatest volume of water relative to potential contaminants, and due to its large mass, will be less sensitive to variations in factors which potentially impact water limnology and quality, and therefore has the highest likelihood of meeting the water quality objectives.
- No rehandling of the NOEF waste after 30 years, re-opening the NOEF and re-exposure to oxygen and water.
- The location of the NOEF further away from the primary sensitive receptor (McArthur River diversion channel) is considered safer than the location of the Pit OEF, as required for a complete backfill case.
- The aboveground construction of the NOEF means that critical components such as barrier layers are easily accessible for maintenance and repairs, should they be required.
- Potential seepage pathways at the NOEF will be confined to surface drainage and shallow groundwater where mitigation and remediation will be simpler and likely to be more successful. Potential contamination of deeper groundwater associated with the complete backfill case, which could be impossible to remediate, is avoided.

3.1.3 Key Risks

The key risk of this solution compared to the full backfill scenarios is the storage of PAF material aboveground in the NOEF. While the highest risk material will be disposed of subaqueously in the pit void, PAF(RE) and most PAF(HC) will be encapsulated within the NOEF, where the potential for seepage of poor quality water remains. Note however that the Draft and Supplementary EIS demonstrates that with the proposed mitigation measures in place, the potential impact of the proposed mining operations on surface flows and water quality in the receiving waters downstream of MRM will be insignificant, and the site closure objectives can be achieved.

3.1.4 Assessment

This option was ranked as the overall optimum solution and is presented as the preferred solution in the Draft EIS. The key criteria considered in the selection included environmental performance and financial cost:

- **Environmental Performance –** this option was selected as having the highest environmental performance due to several key factors:
    - Land-based TSF and the associated risk of potential AMD associated with maintaining the facility aboveground is eliminated
    - Subaqueous disposal of the highest risk PAF material.
    - No rehandling of the waste after 30 years, re-opening the OEF and re-exposure to oxygen and water.
    - The location of the NOEF further away from the primary sensitive receptor (McArthur River) is considered safer than the location of the Pit OEF, as required for the complete backfill case.
    - The aboveground construction means that critical components such as barrier layers are easily accessible for maintenance and repairs, should they be required.
    - The presence of PAF in the NOEF is not a material risk due to the architecture, construction methods, progressive rehabilitation, and water management as proposed in the Supplementary EIS.
    - Unsaturated and geochemical modelling of the NOEF conducted as part of the Draft EIS shows that the risk of seepage acidification is low, even under hypothetical modelled conditions of acidification of PAF(RE) cells and with double the amount of expected PAF.
- **Constructability** – Retaining all overburden in place would lead to a straight forward rehabilitation process. The NOEF would be constructed to a high level of performance initially, avoiding the need for rehandling and its associated complexities (managing gas and water and associated extra oxidation products, plus dust hazards). Maintenance is expected to be straightforward, with only a low level of complexity and intervention anticipated to meet the performance criteria.
- **Financial costs** – Whilst the costs to the Project under this scenario, with its enhanced environmental controls, would be higher than the Phase 3 Development Project, the Project will remain viable whilst limiting the potential impacts and costs associated with residual risks. The full life-cycle costs of the site have been considered, with some higher up-front costs being committed to so that a reduction in risk and ongoing costs may be realised.
- **Societal and stakeholder benefits** – Societal and stakeholder benefits was scored based on the assumption that as this scenario is economically viable, the Project continues its mine and TSF operations until 2047 as defined in the Project description, and all the benefits of the ongoing operation, including employment, CBT contributions, investment in the community etc. continue to be realised.

3.2 Option 2 – Backfill below Vadose Zone with Shallow Mine Pit Lake

This option was presented as alternative number 8 in the Draft EIS. It involves rehandling a portion of the NOEF overburden material back into the final void, so that it fills the final void to below the vadose zone (i.e. to below both the water table and the unconsolidated alluvial material), but retains an approximately 30 m deep final void that can be filled with approximately 10-15 m of water to form a shallow mine pit lake (**Figure 11**).

The rationale is to remove the highest risk overburden material from the NOEF to reduce potential contaminant pathways from the NOEF to surface and groundwater systems, but (unlike the complete backfill option) avoids placing contaminated materials in the highest risk zone of the final void.

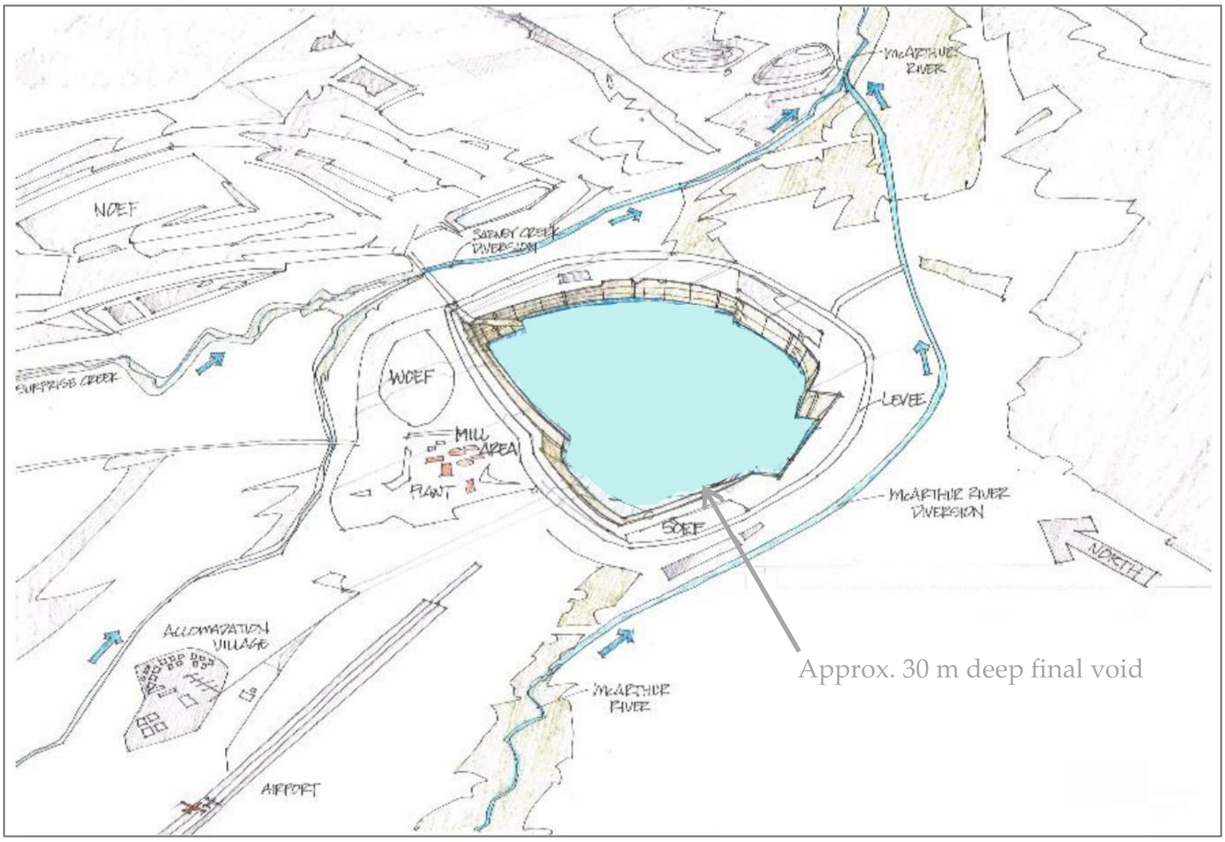

Figure 11 Partial Backfill of Final Void Schematic

3.2.1 Scenario Description

Key assumptions for this partial backfill option include:

- As per the complete backfill scenario, the rehandled NOEF material would contain stored oxidation products resulting from oxidation during the mining and dumping process, prior to construction of the NOEF cover system, that are soluble and immediately available to the environment, hence requiring mitigation during relocation or placement. Limited ongoing oxidation would occur in overburden stored below the permanent groundwater table due to subaqueous storage following groundwater table recovery, but a significant contaminant load would initially be placed in the final void.
- The EOEF and part of the SOEF would still be rehandled back into the open cut void.
- Some connectivity would remain between the open cut final void and McArthur River via palaeochannels and shallow groundwater systems. The permeability of the host rock and orebody reduces with depth; so below a certain depth, the load transfer would be slow and the likelihood of water migrating away laterally would be very low.
- Priority would be placed on returning non-benign overburden to the final void, therefore the tailings would remain in a surface storage facility, so as not to consume final void capacity for the overburden.

This alternative would require the backfill of the final void to below the vadose zone then capping with a cover system (CCL or GSL, alluvial material and benign rock (LS-NAF(HC)) material). Backfilling of PAF(RE) overburden, PAF(HW) overburden and the existing NOEF PAF cell would be prioritised and placed into the lower parts of the final void where the country rock is less permeable. This scenario would include:

- PAF(HC) material and MS-NAF material would be placed in the upper zone. An option could be to co-dispose this overburden with selected rehandled tailings to create a lower permeability mass with a lower risk of contaminant migration and oxidation. In the upper benches with identified zones of moderate (or higher) permeability, a low permeability barrier (e.g. tailings, CCL or a GSL) would be placed around the perimeter to limit groundwater flow through the potentially contaminated material.
- A 1 m thick CCL (or thinner GSL) would be placed over the waste or tailings/waste mixture, just below the level of the natural interface of rock and alluvium, followed by a nominal 4 m of alluvial material and LS-NAF(HC) rock. The volume above this level could seasonally fill with water from rainfall and shallow groundwater inflows, particularly via the palaeochannels.
- Not all NOEF material can be accommodated in the final void due to material swell factor, in the order of 25-35%. Therefore, a smaller remnant NOEF would remain in the long-term. This smaller final NOEF would have an area of approximately 300 ha (similar to the existing footprint) to a height of 80 m (the current height limit), located to the north of the current NOEF, further away from sensitive receptors (McArthur River). The architecture of this facility would be as per the full-size NOEF and would contain largely MS-NAF overburden in the core (although some PAF(HC) would still remain), MS-NAF material in the base and halo, and a GSL and benign materials (LS-NAF(HC) and alluvial material) in the cover.
- Ongoing maintenance of the McArthur River diversion channel and the bulk of the MLW would be required. A network of monitoring bores around the MLW would be installed to detect contaminated seepage originating from the facility. Mitigation strategies such as cut-off trenches, permeable reactive barriers, recovery bores and recovery trenches may be required to meet the environment objectives of the system.

3.2.2 Advantages

The key advantages of this alternative include:

- Removing a large portion of PAF material from the NOEF;
- Storage of the PAF(RE) materials in a subaqueous setting with a low risk of further oxidation and contaminant transport once deposited and inundated, and the initial contact water was treated;
- Reduced risk of NOEF erosion due to the lower height compared to a 140 m high NOEF;
- Reduced NOEF visual impact, as a result of reduced height; and
- Reduced NOEF water management requirements due to a smaller footprint and being further away from the surrounding creeks.

3.2.3 Key Risks

The key potential risks identified for this partial backfill alternative include environmental, health and safety and cost risks, as discussed below.

- The NOEF core, after being successfully encapsulated for up to 30 years, would be re-exposed to oxygen and water, thereby increasing the oxidation rates (i.e. contaminant loads) in the overburden that must be managed. The original contaminant load, plus the increased load, would then be placed into the final void; and would require ongoing management. With the re-exposure of overburden this increases the risk of generation of (and subsequent exposure of people to) dust, sulphur dioxide and spontaneous combustion.

- The oxidation products would include soluble contaminants with a high potential for effects on the environment. Despite mitigation options such as water treatment and barrier layers, there would still be oxidation products stored in zones with potential connections to the external receiving environment to be managed.
- The NOEF would need to be constructed almost as two separate facilities comprising a temporary section around the existing NOEF designed to be rehandled, with no subsequent permanent cover system; and a permanent section designed to remain on Emu Plains with an appropriately designed full cover system. The additional risks associated with this include:
    - To enable rehandling of overburden while maintaining a stable landform, the NOEF would need to be constructed to a lower height; hence the disturbance footprint would be greater than if the NOEF was constructed as a permanent facility to the preferred 140 m height. A larger footprint would create more ground disturbance. The remaining NOEF would also have a large footprint with the potential for net percolation (NP) and subsequent seepage.
    - The remaining NOEF would contain largely non-benign materials and would still require management of similar risks to that of the proposed NOEF, such as AMD, erosion, surface water management, and groundwater management.
    - The capability for progressive rehabilitation would be reduced as there would be a need to keep both the permanent and temporary sections of the NOEF along with connecting roads open at all times.
- The distance between the top of the non-benign waste stored in the void and the post-mining recovered water table level would be reduced, increasing the risk of mixing and contaminant transport out of the mine pit lake during flood events.
- Very high costs would be associated with the creation of a large footprint, low height OEF during operations, followed by the rehandling of a large portion of this overburden material (and combined with the rehandling of tailings material for any co-disposal in the Upper Zone). This would render the Project uneconomic. The Project would cease, with a consequent loss in employment and other benefits associated with ongoing operations, including contributions to the CBT, contributions to NT based businesses, services to Borroloola, royalties and taxes.
- The TSF, which is located directly adjacent to Surprise Creek, would remain aboveground in this scenario, resulting in two aboveground structures, i.e. the TSF and the Pit OEF, requiring long-term management, rather than the single NOEF. The benefits of processing the tailings over a period of ten years would not be realised.

3.2.4 Assessment

While this alternative did score higher than the complete backfill option in the Draft EIS Multi-criteria Analysis (**Table 5-9, Chapter 5 – Project Alternatives, Draft EIS**), it too scored poorly in the Constructability, Financial Cost and Stakeholder/Societal Benefits categories, and was ranked 7 out of the 8 closure alternatives assessed. Some reasons for the allocated scoring include:

- **Environmental performance** - Environmental performance is expected to be reasonably high due to the avoidance of placing contaminated fill in the vadose zones, and attempting to seal off the fill beneath with a cover system and a shallow water body. However, this option does not eliminate the TSF and the associated risk of potential AMD associated with maintaining the facility aboveground.

- **Constructability** - Constructability was scored low, due to the works required and complexities around safely deconstructing the existing NOEF, sealing up the more permeable upper zone in the final void, construction of the barrier layers to protect the vadose zone from flushing out oxidation products during the wet/dry season cycling, and the complexities associated with identification and subsequent remediation of deeper contaminated groundwater.
- **Financial cost** - The very high costs associated with this alternative would inhibit Project feasibility.
- **Societal and stakeholder benefits** - Societal and stakeholder benefits was scored based on the assumption that (due to the significant financial cost) the Project would cease, with a prolonged period of care and maintenance resulting. As there would be no mine production (ore), it is assumed that contributions to the CBT would cease in the short-term, thus investments in the community would not be realised.

3.3 Option 3 – Rehandle all PAF(RE) plus tailings

3.3.1 Scenario Description

Due to the reduced capacity available in the final void once the tailings has been relocated, consideration was given to relocation of only the highest risk waste type stored in the NOEF and EOEF - i.e. PAF(RE) and PAF(HW) - back into the open cut either on top of or co-disposed with the relocated tailings. This scenario would include:

- The tailings, PAF(HW) and PAF(RE) material would be rehandled into the lower permeability bottom section of the final open cut void. It is likely that the tailings and waste materials would have to be co-disposed, as tipping the rock waste onto unconsolidated tailings is likely to pose geotechnical and health and safety issues.
- Note that it is assumed that the existing NOEF PAF cell and Central West PAF cell would also be removed in their entirety, due to having small amounts of mixed PAF(RE) in there that could not be reasonably separated out during rehandling. Therefore, the total volume to be rehandled would be approximately 68 MCM.
- A nominal 5 m thick layer of LS-NAF(HC) rock would be placed over the tailings/waste mixture. The volume above this level would then be rapid filled via harvesting water from the McArthur River during flood conditions to form a mine pit lake approximately 100 m deep.
- As only a portion of the material has been rehandled into the open cut void, a smaller remnant NOEF would remain in the long-term. This smaller final NOEF would have an area of approximately 450 ha to a height of 80 m (the current height limit), located to the north of the current NOEF, further away from sensitive receptors (McArthur River). The architecture of this facility would be as per the full size NOEF and would contain PAF(HC) overburden and MS-NAF overburden in the core, MS-NAF material in the base and halo, and benign materials (LS-NAF(HC) and alluvial material) and a GSL in the cover.

3.3.2 Advantages

The key advantages of this alternative include:

- Removing the most potentially reactive overburden from the NOEF;
- Storage of the most reactive materials in a subaqueous setting with a low risk of further oxidation and contaminant transport once deposited and inundated; and

- Lower risk of contaminant transport from the final void compared to the complete backfill scenario due to no non-benign materials being placed in the upper vadose zone and a reasonably deep lake;

3.3.3 Key Risks

The key negative aspects associated with this option include:

- Similar to the complete backfill option, the PAF(RE) cells, after being encapsulated for up to 30 years, would be re-exposed to advection and diffusion, substantially increasing the oxidation rates and therefore the release of additional contaminants including sulphur dioxide and also the risk of spontaneous combustion. The oxidation products would include soluble contaminants with a high potential for effects on the environment. Significant dust would also be generated when rehandling through historic areas of spontaneous combustion.
- The OEF would need to be constructed in a manner which would make the PAF(RE) cell easily recoverable with minimal disturbance to the remainder of the waste material NOEF. The likely result of this would be the construction of a new separate and temporary PAF(RE) OEF, or an expansion of the proposed NOEF disturbance footprint, and the increased potential environmental impacts associated with the additional disturbance area.
- The remaining NOEF would contain largely non-benign materials and would still require management of similar risks to that of the proposed NOEF, such as AMD, erosion, surface water management, and groundwater management.
- The distance between the top of the non-benign waste stored in the void and the post-mining recovered water table level would be reduced, increasing the risk of mixing and contaminant transport out of the mine pit lake during flood events.
- The cost associated with relocating even this portion of the NOEF would be significant, and similar to the complete and large partial backfill alternatives, would result in the premature closure of the operation.

3.3.4 Assessment

- **Environmental performance –** Environmental performance is expected to be reasonably high due to the avoidance of placing contaminated fill in the vadose zones, and sealing off the potentially reactive material beneath a cover system and water body.
- **Constructability –** Constructability was assessed to be moderate, due to the works required and complexities around safely deconstructing the existing NOEF.
- **Financial cost –** The costs associated with this alternative would cause the premature closure of the operation.
- **Societal and stakeholder benefits –** Societal and stakeholder benefits were considered poor, based on the assumption that (due to the financial cost) the Project would cease, with the loss of all the benefits (e.g. taxes, services, employment, community investment projects), associated with continuing operations.

4 Summary and Conclusions

Although often prescriptively proposed as "best practice" by a number regulatory bodies and sustainability organisations, fully or partially backfilled pits may sometimes lead to poorer regional closure outcomes than retaining a pit lake of some form (McCullough, 2013). As a result, mine closure planning requires a case-by-case strategy considering all site-specific risks, known information and scientific data.

MRM recognise that backfilling of the final void does have some positive environmental aspects and it has been seriously considered as an option at various stages of MRM closure planning, however the positives need to outweigh the negatives for it ultimately to provide superior solution. As a result of the planning and assessment completed during the preparation of the Draft EIS, McArthur River Mining selected the 'partial backfill with the highest risk PAF material plus tailings, with a deep mine pit lake' as the option which provides the optimum environmental solution. This option would see approximately 120 Mt of tailings and non-benign mine waste deposited in the bottom of the open cut final void for permanent subaqueous storage. Both the complete backfill and large partial backfill options were evaluated, and while both have some positive environmental aspects, neither result in a lower residual risk profile and both would lead to early Project cessation. The key reasons McArthur River Mining has not selected them for incorporation into the OMP include:

- For both the Complete and Large Partial Backfill Cases:
    - The rehandled NOEF waste rock would contain significant quantities of soluble secondary oxidation products resulting from oxidation during the mining and dumping process, prior to construction of the NOEF cover system. Re-excavation during removal would reintroduce the waste rock to oxygen and water, increasing the risk of spontaneous combustion and the overall quantity of oxidation products, including sulphur dioxide. While placement of the waste rock within the open cut void below the water table would significantly reduce any future oxidation, filling the entire void would place a large pre-existing soluble load above and within the water table which could potentially significantly contaminate the groundwater. The transport and final fate of contamination, while deeper and slower moving, would be very difficult to control. Should it end up expressing in distal surface environments and/or contaminating a large section of regional groundwater, remediation would potentially be impossible.
    - The McArthur River diversion channel would have to be managed into the long-term. Given the proximity to the surface of large quantities of non-benign waste rock for both the complete and large partial backfill scenarios, any future avulsion (natural realignment) of the McArthur River back into its former course could have significant consequences for downstream environments. By comparison, modelling has shown that if the upstream and downstream levees were to fail in the Draft EIS closure scenario, waste materials in the open cut void would not be remobilised in the water column and transported down the McArthur River.
    - The TSF would remain aboveground and would require management in the long-term. MRM considers that the rehandling of the entire TSF from a location directly adjacent to Surprise Creek would provide a more robust environmental solution than the alternative of leaving two aboveground structures, i.e. the TSF and an OEF (either in its current NOEF location or above a backfilled final void). The complete removal of the TSF results in the complete elimination of a key aboveground structure requiring rehabilitation and management.
- In addition, for the Complete Backfill Case:

- The entire volume of overburden mined from the open cut would not fit back in the void below the groundwater table. If all overburden was to be relocated from the NOEF to the open cut, an aboveground Pit OEF would still be required above the open cut void and above the water table. Due to the geochemical properties of the overburden at MRM, many of the principal technical arguments presented by Mudd 2016 for complete backfill are not realised when the concept is applied to the site-specific characteristics at MRM. These include:
  - The aboveground Pit OEF would still present an AMD risk. This is because the Pit OEF would be comprised of Metalliferous/saline NAF which is not environmentally benign. While the risk of acidic seepage would be reduced, the risk of NMD and SD would remain and would still require long-term management into closure.
  - The Pit OEF would be located close to the primary sensitive receptor (McArthur River diversion channel), increasing the risk of potential impacts to the river and downstream environments. The location of the OEF would leave very little room for mitigation of any negative environmental impact from potential seepage. This is a key flaw, as the potential risks associated the long-term storage of non-benign materials in a structure aboveground are not eliminated by the proposal, they are however transferred to a more sensitive location.
  - The risk of AMD transferring from the waste rock material deposited adjacent to the vadose zone, into the surrounding groundwater system and environment (via the shallow groundwater) could theoretically be reduced by mitigation strategies, such as completely encapsulating the zone in a GSL. However:
    - There is approximately 6 km of perimeter to try to isolate from fluctuating groundwaters. This would be extremely difficult, if not impossible, to isolate over that length into perpetuity. If something goes wrong and it leaks, it would be almost impossible to identify where the issue lay, and then get back and carry out the required repairs.
    - By comparison, the NOEF has about 8.9 km of perimeter exposed to occasional flood waters – stored above the groundwater table, with a basal CCL and GSL cover system over the top. As it is aboveground, any defects in the cover system are much more easily detectable, accessible and can be repaired.
    - The MRM closure plan for the pit would not have broken waste material stored in the vadose zone, so after an initial period of wall rock oxidation, there is no long-term exchange of groundwater through contaminated materials.

The costs associated with both the complete backfill options, and the larger partial backfill options, would render the Project uneconomic and would prohibit the further development of the operation. In this case, the Project would cease, with a consequent loss of employment and associated community investment projects, services, taxes and royalties. The residual environmental risks associated with MRM closing now are not materially different to that of it continuing to operate as proposed in the Draft EIS.

5 References

Mudd, 2016, The McArthur River Project: The Environmental Case for Complete Pit Backfill.

McCullough, 2013, Mine Closure of Pit Lakes as Terminal Sinks: Best Available Practice when Options are Limited.