9.12 Rehabilitation and Decommissioning

A conceptual Mine Closure Plan (MCP) has been developed for the Project and is presented in Appendix O1. It covers closure-related aspects associated with the mining of the uranium oxide resource and the operation of the mine site, including mine pits and tailings storage facilities, and deals with the way in which the major elements of the operation will be rehabilitated and closed in accordance with the DMP / EPA Guidelines for Preparing Mine Closure Plans (DMP/EPA, 2015).

The purpose of the MCP is to provide a strategic planning and implementation framework for the closure of the Project by:

- identifying those aspects relating to decommissioning and closure which may impact on the environment, health and safety, and may be of concern to regulatory agencies;
- providing a basis for consultation with regulators and identified stakeholders regarding the post-mining land uses of the project area and agreed completion criteria;
- developing management strategies to be implemented as part of the project's design, construction and operation to minimise impacts and site closure requirements; and
- identifying closure costs to establish adequate financial provisions.

The major closure domains which have been identified for the Project comprise of:

- Open Pit (to be backfilled).
- In-Pit Tailings Storage Facility (TSF).
- Uranium processing facility.
- Accommodation Camp.
- Quarry.
- Other support infrastructure.

Given the early stage of this development, and the long expected life of mine (i.e. 22 years), the current MCP covers only the Backfilled Mine Pit and In-Pit TSF closure domains in detail. Closure of the remaining processing and supporting infrastructure domains is discussed, however more detail will be included in subsequent versions of the MCP. As required by the Guidelines for Preparing Mine Closure Plans (DMP/EPA, 2015), once the Project has commenced the MCP will be submitted for review and approval by the EPA every three (3) years as part of the continual mine closure planning process.

The total open pit mining area is approximately 9 km long, with a variable width up to approximately 1.5 km wide, and about 10 m deep. The pit will be progressively dewatered and excavated in blocks, as outlined in Section 6. The open pit will be progressively backfilled with process tailings, and the land surface rehabilitated. Tailings deposition will occur in stages, into ten tailings cells, with the remaining portions of the pit being backfilled with waste material ("Backfilled Mine Pit" areas). As such, the mine pit will be completely backfilled at closure, and no open void will remain. Tailings and waste volumes are detailed in Section 6.

Progressive rehabilitation is favoured by Cameco, and wherever practicable, timely rehabilitation of post-mine landforms will occur following the cessation of mining activity in the area. The proposed mining schedule, presented in Section 6, includes cover placement, backfilling and commencement of revegetation starting after completion of the first TSF cell, in Year 11 of the Project. All remaining open pit areas that are not converted to TSF cells will be backfilled with mine waste in Years 19 to 22 of the operation.

9.12.1 EPA Objective

The primary EPA objective relative to site closure is to ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner. Relevant closure aspects include:

- clearing of vegetation and site works;
- water abstraction and reinjection;
- pits;
- tailings storage facility;
- alterations/ diversion to surface water flows;
- waste dumps; and
- quarry.

As discussed previously, the current conceptual MCP covers only the Backfilled Mine Pit and In-Pit TSF closure domains. Closure of the remaining processing and supporting infrastructure domains will be included in subsequent revisions of the Plan.

9.12.2 Relevant Legislation and Policy

- EPA/DMP (2015) Guidelines for Preparing Mine Closure Plans, Perth, Western Australia.
- EPA 2006. Guidance for the Assessment of Environmental Factors. Rehabilitation of Terrestrial Ecosystems. No. 6. June 2006. EPA, Perth, Western Australia.
- Department of Minerals and Energy (1999) Guidelines for the Safe Design and Operating Standards for Tailings Storage, Perth, Western Australia.
- Department of Mines and Petroleum (2013). Tailings Storage Facilities in Western Australia – Code of Practice
- Government of Western Australia (2003) Western Australian State Sustainability Strategy, Perth, Western Australia.
- Department of Industry, C'th (2006) Leading Practice Sustainable Development Programme for the Mining Industry.

9.12.3 Studies and Investigations

A series of baseline environmental studies has been undertaken to describe the existing environment. These are discussed in Sections 9.1 to 9.11, and have also been considered throughout the development of the MCP. A number of additional closure-specific studies have been undertaken in order to extend the knowledge gained from the baseline studies, and to further support sustainable rehabilitation and closure of the Project. Closure-specific studies included:

- Long term (10,000 years) landform evolution modelling, presented in Section 9.10.
- TSF cover system, addressed in Section 6, and seepage modelling, discussed in Section 9.5.
- Post-closure groundwater model, including contaminant transport discussed in Section 9.5.
- Post-closure surface water assessment, discussed in Section 9.4.
- ERICA assessment of potential post-closure radiation impacts on non-human biota presented in Sections 9.1 and 9.3.

9.12.3.1 Landform evolution modelling

Two of the major soil types considered suitable for mine closure covers, the Surficial Loam and Surficial Clay, (discussed in Section 9.10) were tested for their erosive potential under laboratory conditions. A laboratory-scale rainfall simulator was used to measure the interrill (raindrop impact) erodibility whilst the rill erodibility and critical shear stress of the materials under overland flow conditions was tested using a 1.8 metre-long erosion flume. The details of the laboratory testing are provided within the study report (SWC, 2015) (Appendix O2).

The results of the laboratory testing were used to conduct landform evolution modelling using the SIBERIA model over a 10,000 year climate scenario. The following two model scenarios were developed for each of the two soil materials:

1. Base case model: Soil erodibility values were kept constant throughout the entire 10,000 year modelling period. This is considered a “worst case” model scenario, as it assumed that no surface-stabilising vegetation or soil cover (e.g. cryptogam or plant material) will develop, and the soil will remain in a similar condition as it was in shortly after completion of the backfilling process.
2. Time-varying erodibility model: Soil erodibility values are constant for the first 100 years of the simulation, and decrease to 1/10th of the original values thereafter. This scenario estimated the effects of vegetation and surface cover development over time, and allowed for 100 years’ worth of erosion before significant vegetation re-establishment occurred.

The detailed landform evolution modelling results are presented in Appendix O1, which includes figures showing the output digital elevation models (DEM). In general, both of the tested cover materials resulted in similar soil movement over the model period. In all cases, the majority of sediment loss was predicted to occur on the valley slopes, with a net deposition occurring in many areas of the valley floor near the rehabilitated landform. Some gullying of the backfilled profile is evident, but due to the very gentle land slopes (i.e. typically ≤0.25°, or 4 m elevation change per km), this is isolated. Diffusive sediment transport (i.e. raindrop impact erosion) appears to be the dominant erosion mechanism, which in most areas does not result in sediment loss from the cover system, but short scale, localised sediment transport within the cover system. The “time-varying erodibility” model scenarios showed similar patterns of soil movement to the “base case” scenarios, although the overall volume of soil eroded was smaller for the “time-varying erodibility” scenarios due to the inclusion of a modelled erosion reduction after an initial 100 year period simluating the development of vegetation cover and other soil stabilising agents (e.g. cryptogam, leaf litter etc.).

For the “base case” model, soil losses of ≥0.5 m occurred over approximately 80% and 50% of the former TSF area for the surficial clay and surficial loam, respectively. Soil losses of ≥1.0 m occurred over approximately 40% and 20% of the former TSF area for the surficial clay and surficial loam, respectively. Some deep gullies were predicted at depths of up to 2 m at some isolated locations.

While the degree of sediment loss from the backfilled profile predicted by the “time-varying erodibility” model was reduced from the “base case” model after the first 100 years, gully features were still evident on the final landform after the 10,000 year model period. Gully depth within the TSF area was up to approximately 1.5 m deep in both of the modelled materials, although the extent of gullying was greater in the clay. Despite this, the majority of the soil over the rehabilitated TSF cells was predicted to remain intact, with gullying only occurring in some isolated areas. Soil losses of <0.5 m were predicted over approximately 75-80% and 80-85% of the former TSF area for the surficial clay and surficial loam, respectively.

Whilst the “time-varying erodibility” model scenarios were considered to be the more realistic of the two models, as they include a degree of soil stabilisation, resulting from factors such as plant or cryptogam growth or litter cover that is expected to increase with time after rehabilitation. The erosion potential used is still highly conservative due to the following assumptions:

- zero initial surface cover (e.g no woody debris or plant litter, no contour ripping etc.); and
- no vegetation for the first 100 yrs of modelling.

Results from the model senarios show that whilst the majority of the TSF cover system is expected to remain intact (i.e. <0.5 m of erosion over 10,000 years), some gully formation was predicted in isolated locations. This will not result in exposure of tailings materials, but has the potential to reduce the effectiveness of the cover system to limit filtration of rainwater into the TSF cells, and thus may result in increased leaching of minerals from the tailings.

Prior to commencement of rehabilitation activities Cameco will seek to refine the predicted erosion

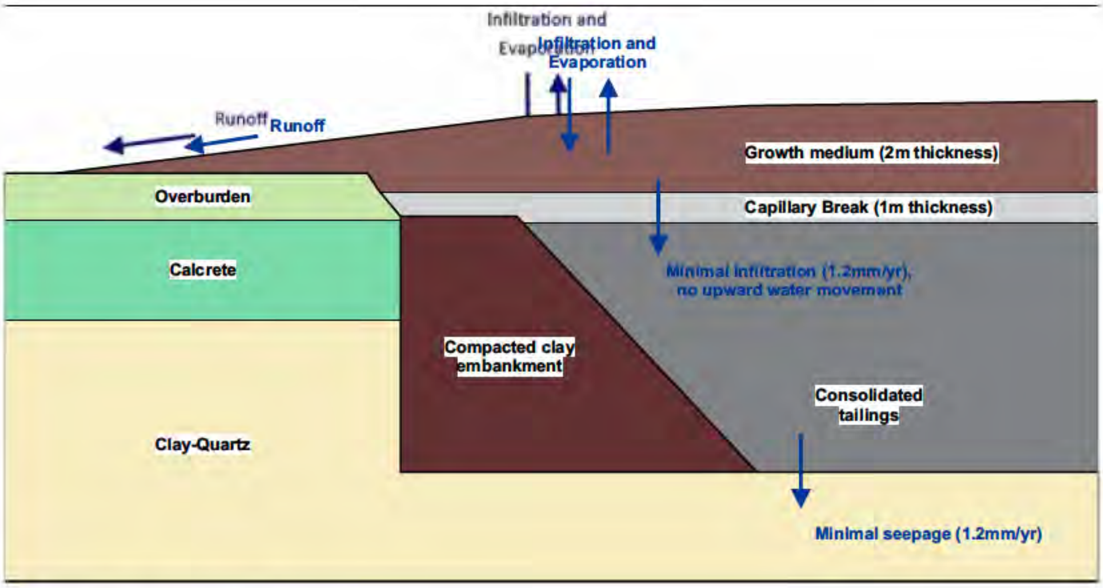

Figure 9-67: Proposed TSF cover design.

potential during the early stages of rehabilitation (i.e. first 100 years post closure) in order to establish more realistic erosion potentials during this period and undertake an investigation into the feasibility of alternative cover materials or rock armouring materials in order to determine if a higher level of sability is achievable.

9.12.3.2 TSF cover system modelling

The proposed TSF cover system design is shown in Figure 9-67. It consists of a 1 metre-thick layer of waste calcrete (clean and partially mineralised), placed directly above the consolidated tailings material to act as a capillary break. This limits the upward movement of water and solutes from the tailings into the growth medium. The capillary break will in turn be overlain by at least 2 m of the stockpiled surficial loam soil. This native soil will act as a growth medium for rehabilitation species and, due to its relatively large water holding capacity, will limit infiltration through the profile by absorbing the majority of rainwater.

Unsaturated zone modelling was conducted using HYDRUS to investigate the effectiveness of the TSF cover design at limiting infiltration into the TSF cells. The known properties of the cover system soils (see Section 9.10) were included in the model, along with daily climate obtained from Wiluna, which was calibrated using the Yeelirrie data. A continuous record of daily rainfall and evaporation data was available for a 14 year period between April 1972 and May 1985 (inclusive). Average annual rainfall depth during this period was 237 mm/yr, which is essentially equal to the long term average of 238 mm/yr. Average annual evaporation during the modelled period was 2,121 mm/yr, which is less than the long term average of 2,412 mm/yr, making infiltration of water into the profile above average during this period. Six large storm events were included in the record for this period, four events approximating a 1:10-yr ARI storm event (85 mm rainfall in 24 hrs), and two events approximating a 1:5-yr ARI storm event (70 mm in 24 hrs). In addition a 1:100 yr ARI storm event (equating to 158 mm in 24 hrs) was inserted into the climate record to simulate high rainfall and ensure the model included the expected range of rainfall ARIs.

The HYDRUS model predicted approximately 17 mm of infiltration over the 14-year model period. This equates to an average of approximately 1.2 mm/yr seepage through the TSF cells. This rate of infiltration is within the range of infiltration scenarios used to conduct the contaminant transport modelling (discussed in more detail under "Post-closure groundwater environment", below), and the cover system is therefore expected to effectively limit infiltration of water into the TSF cells to a relatively small quantity for which the potential impacts are understood.

9.12.3.3 Post-closure groundwater modelling – groundwater levels

As described in Section 9.5, dewatering blocks and associated trenches will be used to lower groundwater levels within the proposed mine pit to at least 1 m below the pit floor during mining operations. A total volume of 18.6 GL (Mm^3) is expected to be extracted from the surficial aquifer for dewatering purposes, with a further 46 GL (Mm^3) being extracted from neighbouring bore fields as process water supply. The maximum extent of the combined drawdown of the four well fields and the dewatering activity is expected to occur at the end of the milling operation (i.e. end of year 18). The predicted maximum extent drawdown contours were therefore used as the starting point for post-closure groundwater model scenarios, as outlined in the groundwater study report (Cameco, 2015d) (Appendix I1).

At closure, the mined-out pit will be filled with tailings and overburden and covered with an engineered cover system. Due to the change to the *in situ* geologic medium (i.e. calcrete was mined out and replaced with tailings cells), changes to the local groundwater flow field and recharge and discharge rates are expected. A post-closure groundwater model was therefore developed, incorporating the expected changes in hydraulic parameters within the mining area, as summarised in Table 9-80. As a comparison, the hydraulic conductivity values used for the *in situ* calcrete ranged from 1-700 m/day.

Table 9-80: Hydraulic parameters of tailings and TSF embankments (Cameco, 2015(a))

Material	Hydraulic Conductivity (m/day)		Storage (Dimensionless)	
	Lateral	Vertical	Specific Yield	Porosity
Tailings	3.46×10^{-3}	3.46×10^{-3}	0.10	0.50
TSF Embankments	1.42×10^{-4}	1.42×10^{-4}	0.05	0.45
Non-TSF cell backfill	4.0×10^{-2}	4.0×10^{-2}	0.05	0.40

Modelling of the closure period was completed to simulate the groundwater level recovery process around the mine pit and well fields, to estimate the time required for the groundwater systems to reach a new steady state condition, and to identify any residual changes to the groundwater table configuration. The results of this modelling are discussed in detail in the modelling report (Cameco, 2015(a)) and presented in Section 9.5 , however the general findings can be summarised as follows:

- Groundwater table recovery is evident in the short-term after cessation of abstraction, with the major part of the recovery to baseline levels occurring over a 50-year period.
- Water table recovery is predicted to occur more quickly beneath the valley floor compared to areas higher upslope. For example, the water table at the pit location is predicted to recover to baseline levels within 100 years, but small residual drawdowns would persist in the area of the nearby Northern Well Field for more than 200 years.
- Within the TSF area, the water table recovers to levels about 0.5 m below the baseline elevations. This suggests a new steady state due to the local geologic medium property changes.

While some minor changes in the down-valley groundwater flow path are expected at the local scale in the vicinity of the pit, no permanent changes were predicted. This is somewhat counterintuitive, as a large volume of calcrete material (which is highly porous and conductive, $K \approx 500$ m/d) will be removed from the mining zone, and replaced with tailings cells (which have a very low conductivity, $K = 10^{-4}$ m/d). It might be expected that down-gradient groundwater flows would "back up" upstream of the TSF cells. However, the geologic cross-sections indicate that reasonably contiguous "high" transmissivity sands exist directly to the south of the pit area; at their narrowest, they are approximately 2 km wide, and extend approximately 20 m below the water table. This sandy alluvium therefore represent 8-10 times the cross-sectional area of the calcrete aquifer that is to be removed from the mining area, and it is therefore expected that this strata has sufficient capacity to avoid any "backing up" of water upstream of the TSF cells. This is supported by the hydrological model results.

9.12.3.4 Post-closure groundwater modelling – groundwater quality

The post-closure groundwater model was further used to conduct predictive long term contaminant transport modelling, with the objective of assessing the movement of selected constituents of concern (COCs) in tailings pore water and their potential impact in a post closure environment (Cameco, 2015(d)) (Appendix I1). A range of scenarios was tested by varying input values for key model parameters, including the distribution coefficient (K_d), COC source term concentrations, recharge rate through the tailings cover, and evapotranspiration extinction depth. A total of 100 different scenarios were tested.

Five COCs (chloride, uranium, vanadium, arsenic, and molybdenum) were selected for inclusion in the model, and their likely source term concentrations and K_d values were determined based on the expected properties of the process tailings material. These are summarised in Table 9-81. The COCs were chosen for inclusion in the contaminant transport model because:

- Arsenic and molybdenum are expected to be the least retarded in the Yeelirrie hydrogeological environment because they exist as negatively charged species.
- Uranium and vanadium are of particular concern because of the geochemistry of the carnotite deposit.
- Chloride is included because it is a non-retarding conservative tracer.

Table 9-81: "Base-case" contaminant transport model input parameters

Constituent	Source Term (mg/L)	Distribution Coefficient, Kd (cm^3 g^{-1})		Recharge rate through tailings (mm/yr)	ET extinction depth (m)
		Loams	Clay-quartz		
Cl	26,000	0	0	0.24	5
U	180	420	1.1	0.24	5
V	79	480	2.7	0.24	5
As	4.6	350	1.3	0.24	5
Mo	2.1	47	0.67	0.24	5

Details of the model results are provided in Section 7.5-7.6 of the study report (Cameco, 2015(b), and maps of the predicted contaminant plumes for each of the 100 scenarios are provided as figures attached to the study report. It should be noted that all predicted values represent concentrations above (in addition to) baseline concentrations. Considering that concentrations for COCs vary over several orders of magnitude, concentrations for all COC plumes are presented in the figures with a log scale (for example -1 means 10^{-1} = 0.1 mg/L, 2 means 10^{2} = 100 mg/L).

Major findings of the "base case" predictive long term (15,000-year) solute transport models include:

- A conservative non-sorbing tracer (chloride) was predicted to travel as far as 50 km to the east of the Project Area, mainly along the valley, with elevated concentration (>10 mg/L) in very limited local areas, and low concentration (< 10 mg/L) in most areas. Beyond a distance of 1 km west of the deposit. The increase is considered negligible when compared to the baseline concentrations.
- Other simulated COCs (including uranium, vanadium, arsenic and molybdenum) are limited to a distance on the order of several hundred meters longitudinally along the valley. This limited transport is due to sorption of COCs to solid geologic medium.

Several different recharge rates were modelled to cover the range of anticipated cover system scenarios (recharge rates of 0.24 mm/yr up to 6 mm/yr). When the recharge rate to the groundwater through tailings and backfill cover was increased from 0.1% of average annual rainfall (base case) to 2.5% (0.24 to 6.0 mm/yr, respectively), the following results were obtained:

- The tracer (chloride) plume was shown to have a significant increase in concentration above the base scenario at the pit. However the maximum eastward extent of the plume front (0.01 mg/L contour) did not change significantly, suggesting that non-sorbing COC transport is not significantly affected.
- The maximum extent of the predicted uranium, vanadium, arsenic, and molybdenum plumes increased significantly. The uranium plume was predicted to extend approximately 6 km to the east (0.2 mg/L contour); compared to the several hundred metres predicted by the base case model.
- Downward transport of contaminants to the deeper model layers (e.g. Layer 8: weathered granite) also increased.

As discussed under "TSF cover system modelling", above, a HYDRUS model of the engineered cover system predicted 1.2 mm/yr seepage through the TSF cells. This rate of infiltration is well within the range of infiltration scenarios used to conduct the contaminant transport modelling, with the upper bound infiltration scenario modelled using an infiltration rate five times higher than that predicted from the HYDRUS model at 6 mm/yr.

Variations in input values for K_d and ET extinction depth were also modelled to determine the sensitivity to these factors.

- Travel distances for uranium were modelled for an increase in K_d of 0.1 x base case resulted in an increase from several hundred metres to 1,100 m downgradient.
- A change in Extinction Depth from 5 m to 3.5 m also resulted in an increase from several hundred metres to 1,200 m downgradient.
- A 20% increase in source concentrations resulted in only minor changes to the predicted COC plumes.

9.12.3.5 Post-closure surface water modelling

Post-closure scenarios were conducted using the surface water model described previously in Section 9.4. A digital elevation model of the proposed post-mine land surface was used as the key input to the model, with all other hydrological and meteorological properties remaining the same as the pre-development and operational scenarios. The post-mine landform has been designed with a slight rise in the centre (1 to 2 m above the surrounding land surface), and shaped specifically to mimic the hydrologic regime of the pre-mining profile of the pre-mining calcrete ridge.

Figure 9-68 shows a conceptual image of the project area post mine closure with the drainage lines reinstated to flow around the closed pit similar to pre-mining conditions. Continuity of flow has been maintained in both of the parallel flow channels running on either side of the deposit. A comparison of elevation cross-sections, comparing the pre-mine and proposed post-mine landforms are presented in Figures 9-69 and 9-70.

Peak flow and flood modelling were conducted within the proposed development area for various size storm events, ranging from the 1:1-yr ARI event up to the PMP event. A summary of key results of the post-closure model is presented in Table 9-82 and Table 9-83, compared to the results of the baseline hydrological assessment to indicate the expected change in flood level and flood-flow velocity induced by the post-mine landform.

In general, the post-closure model predicted flood depths that were slightly greater directly upslope of the deposit (see "upstream reaches"), with downslope flood depths generally unaffected (see "downstream reaches"). The upslope affect was greatest in the northern flow channel, owing to

Figure 9-68: Conceptual mine closure landform

the slightly restricted shape of this channel as compared to the pre-mine landform. The greatest increases in predicted flood depth occurred at the location of the restriction of flow, on the north-eastern corner of the deposit (see "Yeelirrie Playa"). The sourthern flow channel was less affected, with flood depth changes within ±0.25 m of baseline.

Similarly, peak flood flow velocities were not predicted to vary significantly from the baseline, at locations upstream and downstream of the deposit. Predicted changes in velocity were < 0.2 m/s in these areas. However, increased flow velocity is expected at the location of the restriction in the northern "Yeelirrie Playa" flow channel. Velocity was predicted to increase on the order of 0.2 – 0.4 m/s for storm events up to the 1:1,000-yr ARI event, as compared to baseline. This is considered to be a relatively modest increase and, given the relatively low overall flow velocities (generally less than 0.8 m/s at all locations), is not expected to result in significant changes to sediment erosion or deposition rates in this area.

Flood waters are not expected to overtop the backfilled TSF area for storm events of less than the 1:100-yr ARI event. All storms larger than this will likely overtop the TSF area, although this has not been specifically modelled.

Table 9-82: Comparison of modelled baseline and post closure flood depths

Event ARI	Baseline maximum flood depth (m)			Post-closure maximum flood depth (m)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
1:20-yr	≤ 0.5	≤ 0.5	0.5 – 1.0	0.10 – 0.25	-0.1 – 0.10	0.10 – 0.25
1:100-yr	1.5 – 2.0	0.5 – 1.0	1.5 – 2.0	0.10 – 0.25	-0.1 – 0.10	> 2.0
1:1,000-yr	2.0 – 2.5	1.5 – 2.0	2.0 – 2.5	0.25 – 0.50	-0.1 – 0.10	1.0 – 2.0
PMP	> 5.0	> 5.0	> 5.0	0.25 – 0.50	-0.1 – 0.10	> 2.0

Table 9-83: Comparison of modelled baseline and post-closure peak flood flow velocity

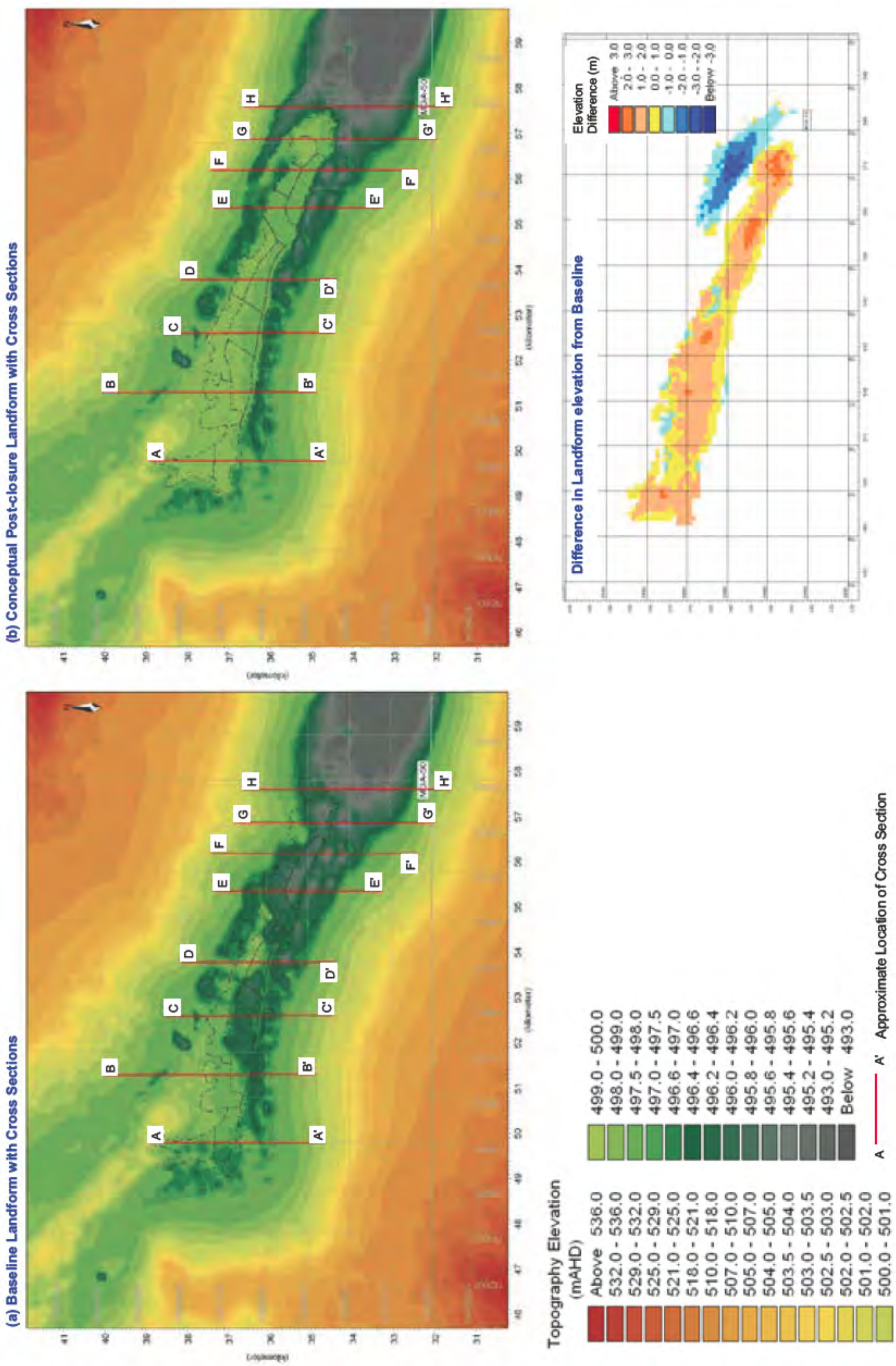

Figure 9-69: Cross section locations – baseline landforms and conceptual post closure landforms.

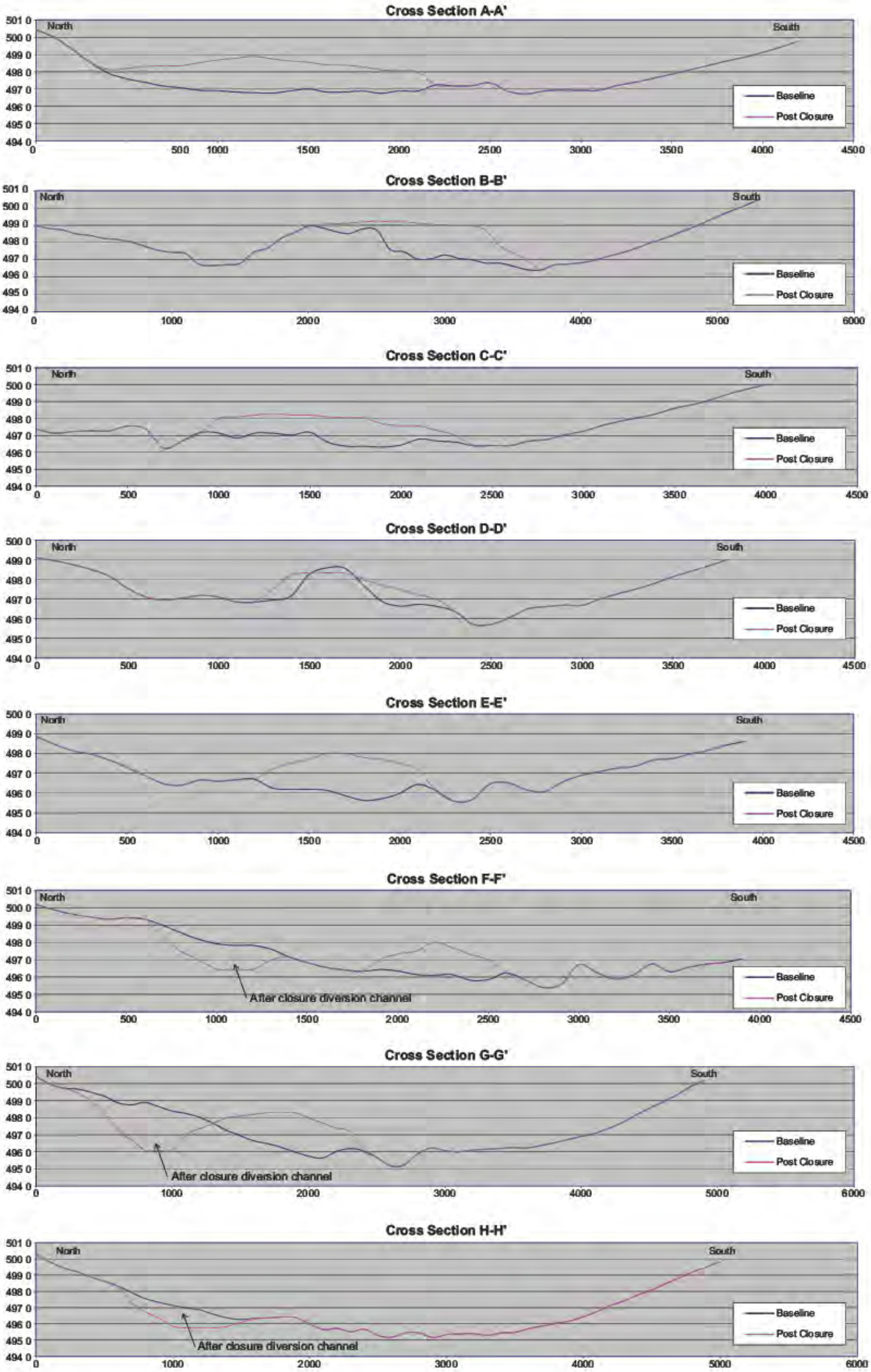

Figure 9-70: Comparison of basecase and conceptual landforms. Cross sections A, B, C, D, E, F, G and H.

Event ARI	Basecase maximum flow velocity (m/s)			Post-closure maximum flow velocity (m/s)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
1:20-yr	0.0 – 0.2	0.0 – 0.2	0.0 – 0.2	< 0.2	< 0.2	< 0.2
1:100-yr	0.2 – 0.4	0.2 – 0.4	0.4 – 0.6	< 0.2	< 0.2	0.2 – 0.4
1:1,000-yr	0.6 – 0.8	0.6 – 0.8	0.6 – 0.8	< 0.2	< 0.2	0.2 – 0.4
PMP	0.8 – 1.0	1.0 – 1.5	1.0 – 1.5	0.2 – 0.4	< 0.2	0.6 – 0.8

9.12.3.6 Post-closure radiation assessment

Impact on non-human biota

The most significant dispersion pathway for radionuclides resulting from the Project is expected to be via Project-generated dust, and this has potential implications for flora and fauna in the vicinity of the project. A Tier 2 ERICA assessment was therefore undertaken to determine potential dose rates to the surrounding environment. An atmospheric dispersion model was used to map the predicted dust plume, which is expected to extend approximately 5 km from the operational site areas (0.1 g/m^2/month contour). A highly conservative maximum radiation deposition rate of 5 g/m^2/month was used in the model, resulting in a corresponding increase in soil radionuclide concentration of 50 Bq/kg.

The ERICA study concluded that only one of the 14 organism families assessed (lichens and bryophytes) was likely to exceed the screening dose rate of 10 uGy/h based on these conservative assumptions. Lichens in particular do not have a well-developed root system, and derive most of their nutrients from dust falling on them. Consequently, they might be expected to receive a higher dose from the fallout of mine and processing dust, than is the case for other organisms. However, the assessment concluded that lichens are extremely radioresistant, with a threshold no-effect dose rate over 10,000 times the default screening rate. Lichen and bryophytes are therefore not considered to be at significant risk of impact.

In summary, The non-human biota assessment (outlined in Section 9.3.5 of the fauna chapter and Section 9.1.5 of the flora chapter) was conservatively conducted at the Project boundary and determined that the operating Project will not have an impact on non-human biota.

Once the mine closes, emissions into the environment will significantly reduce therefore media concentrations will reduce over time as operationally deposited radionuclides mix further in surface soils. An additional ERICA assessment for post closure was therefore not conducted because the impacts would be less than the operationally determined impacts, giving negligible impacts.

Radon exhalation from the closed TSF

Cameco proposes to cover the completed tailings cells with at least 1 m of capillary break material and at least 2 m of growth medium. The capillary break will be constructed from compacted coarse material, likely to be calcrete while the growth medium will be local soils and previously stockpiled mine overburden.

The completed cover will provide an effective barrier to radon by increasing the diffusion time of radon through the cover material to the surface and then into the atmosphere. A longer diffusion time increases the chance that the radon decays within the cover material and is not released to the atmosphere.

A conservative radon emission rate of 50 Bq/m^2/s per % uranium for tailings has been used to estimate the radon emission. For an average ore grade of 1,600ppm uranium, the radon emission rate from tailings is therefore calculated to be 8 Bq/m^2/s. Applying the reduction factor gives a covered tailings radon emission rate of 0.08 Bq/m^2/s.

During earlier site assessment work by the AAEC (AAEC 1978), naturally occurring radon emission rates were measured to be 3.7 Bq/m^2/s (atop the orebody) and 0.37 Bq/m^2/s (away from orebody).

9.12.3.7 Waste Management

Planning for the management of waste and demolition material at closure is an important aspect for any project, but even more so for a uranium project where items including mobile and stationary plant and equipment may be contaminated with a build up of radioactive material.

Precautionary procedures need to be put in place to ensure that any item leaving site for reuse or recycling is monitored and meets radiation levels for materials going off site. The issue of radiation contamination often means that a greater volume of material is required to be buried on site upon completion of mining to avoid contamination off site.

At the end of mining, all equipment will be tested for contamination. Where recycling is practicable, items will be decontaminated to approved radiation levels before leaving site. Items that cannot be properly decontaminated, or where recycling is impracticable, will be buried in the open pit in an approved manner. In all cases records of the disposal, including type of material, quantities and locations will be kept.

At this stage of the planning it is not possible to estimate to any reasonable level of accuracy the volumes of materials that might be salvaged off site or need to be buried on site. An estimate may be possible at definitive feasibility stage and information generated then would be incorporated into updates to the MCP.

9.12.4 Management

In Section 8 of the MCP, identified closure issues were grouped into the two closure domains (Backfilled Mine Pit and In-Pit TSF) with three overarching closure principles. The process and methodology used to identify principal closure issues follows the Leading Practice Sustainable Development in Mining handbooks published by the Department of Industry, Tourism and Resources as related to mine closure (DITR, 2006a) and mine rehabilitation (DITR, 2006b). Each closure domain was analysed in respect to the closure data as outlined in Section 7 of the MCP, with the management strategies for each issue being a direct outcome of the domain specific constraints (data-based) and leading practice in the industry (concept-based).

A summary of the identified potential post-closure impacts and associated management strategies is presented in Table 9-84 and Table 9-85 (and in more detail in Section 8 of the MCP). Section 9 of the MCP describes how the management measures are planned to be implemented, throughout LOM and post-closure, while Section 10 of the MCP provides a description of the ongoing closure monitoring and reporting program.

Completion Criteria

The primary commitments relevant to site closure are related to meeting the site-specific Completion Criteria, detailed in Section 6 of the MCP, and outlined below in Table 9-85.

The overall rehabilitation objectives for any given mine feature (e.g. backfilled mine pit, TSF) are primarily based on the closure objectives and agreed post mine land use discussed in Section 5 of the MCP. Cameco's rehabilitation objectives for the landforms which will be present at closure (i.e. backfilled mine pit and tailings storage facilities within the mine pit) is to ensure that they are safe, stable and non-polluting whilst being capable of sustaining the agreed post operational land use.

The purpose of completion criteria is both to provide a set of goals for rehabilitation efforts to work towards and provide a demonstration that a given domain or landform has achieved the rehabilitation objectives. This in turn delivers confidence to both regulators and post operational land users that these domains or landforms are capable of sustaining over the long term the agreed post mine land use, utilising normal management practices.

The development of completion criteria is most effective where it is undertaken as an iterative management approach. As such, the development of completion criteria will continue throughout the remaining planning stages of the Project and through the operational period of the mine to allow integration of data from ongoing rehabilitation trials, research and monitoring.

The goals of this iterative development approach are to progressively refine baseline data accuracy, the effectiveness of monitoring activities and rehabilitation trial procedures to develop measurable metrics based on site specific data, providing confidence that completion criteria can fulfil the intended role within the mine closure planning framework. As such the completion criteria presented at this stage are preliminary in scope, and are represent the first stages of the iterative management approach discussed in the MCP.

In addition to this and as previously discussed, prior to commencement of rehabilitation activities Cameco will seek to refine the predicted erosion potential during the early stages of rehabilitation (i.e. first 100 years post closure) in order to establish more realistic erosion potentials during this period and undertake an investigation into the feasibility of alternative cover materials or rock armouring materials in order to determine if a higher level of sability is achievable.

Summary of Management Measures

- Establish rehabilitation objectives and completion criteria in consultation with key stakeholders, based on the findings of monitoring and research that are appropriate to the agreed post-mine land use.
- All plant and associated infrastructure will be demolished and removed at the conclusion of operations, subject to negotiations with key stakeholders.
- Conduct progressive rehabilitation (where practicable) in accordance with the MCP. Commencement of rehabilitation during operations will enable rehabilitation methods to be refined throughout the LOM.
- The backfilled pit will be constructed with an engineered cover as determined by geotechnical modelling.
- The surface of the backfilled pit will be raised above the surrounding topography similar to the pre-mining topography and surface water flows will be reinstated around the final landform.
- Ongoing weed management throughout operations and weed monitoring and control post-closure until completion criteria are achieved.
- Implementation of the monitoring programs outlined in the MCP, until agreed completion criteria are achieved.

9.12.5 Commitments

Cameco commits to;

- Reviewing and implementating the Mine Closure Plan.

9.12.6 Outcomes

Closure and rehabilitation of the Project in accordance with the Mine Closure Plan will ensure construction of a safe, stable, non-polluting post-mine landform that is capable of sustaining agreed post-operational land use, and does not impact on surrounding environmental values or uses.

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Rehabilitation and Decommissioning.

Table 9-84: Identification of potential closure issues

	Overarching Closure Principle	Safety	Stability		Non-Polluting		Sustainability	
	Closure Issue		Geotechnical Stability	Erosion	Geochemistry	Hydrology	Hydrogeology	Rehabilitation
Domains	Backfilled Mine Pit	Gamma radiation from backfilled material exceeds background levels. Radon exhalation from backfilled material exceeds background levels / human health criteria.	Unconsolidated backfill material slumps resulting in unstable and undulating land surface.	Backfilled soil profile results in restricted surface water channel, and causes increased fluvial erosion of the valley floor and sediment transport. Rainfall-induced erosion of the backfilled soil profile results in an unstable surface and poor rehabilitation performance. Flood flows over the backfilled soil profile cause excessive soil loss and poor rehabilitation performance.	Possible development of neutral metaliferous drainage / excessive solute transport from backfilled material into regional aquifer.	Backfilled pit voids may affect water quality through erosion of backfill material and sedimentation of surrounding environment.	Residual groundwater table drawdown persists at closure, thus impacting on subterranean fauna or GDE ecosystem functioning.	Re-establishment of vegetation and ecosystem function not meeting closure goals. Surface cover not constructed to design. Spread of weed species inhibiting local species re-establishment.
	In-Pit Tailings Storage Facility (TSF)	Gamma radiation levels on surface from process tailings likely exceeds background levels. Radon exhalation from process tailings exceeds normal background levels / human health criteria.	Unconsolidated tailings material slumps resulting in unstable and undulating land surface.	Backfilled soil profile results in restricted surface water channel, and causes increased fluvial erosion of the valley floor and sediment transport. Rainfall-induced erosion of the backfilled soil profile results in an unstable surface and poor rehabilitation performance. Flood flows over the backfilled soil profile cause excessive soil loss and poor rehabilitation performance. Erosion of the backfilled soil profiles result in exposure of the tailings material.	Leaching of contaminants of concern (COC) from the TSF cells into the groundwater system, thus impacting on downstream subterranean or GDE ecosystem functioning. Leaching of COCs into the groundwater system, thus impacting on downstream water users. Leaching of COCs into the groundwater system, resulting in potential loss of value for future beneficial uses.	Erosion of the backfilled soil profile and sedimentation of the surrounding environment. Exposure of tailings material through excessive erosion of the backfilled soil profile leads to contamination of the surrounding environment.	Residual groundwater table drawdown persists at closure, thus impacting on subterranean fauna or GDE ecosystem functioning. Low-permeability tailings cells cause "blockage" of down-gradient groundwater flow, resulting in permanent changes to local groundwater levels.	Re-establishment of vegetation and ecosystem function not meeting closure goals. Tailings cover not constructed to design. Spread of weed species inhibiting local species re-establishment.

Table 9-85: Management of potential closure issues

Overarching Closure Principle		Safety	Stability		Non-Polluting		Sustainability	
Closure Issue			Geotechnical Stability	Erosion	Geochemistry	Hydrology	Hydrogeology	Rehabilitation
Domains	Backfilled Mine Pit	Post mine radiation assessment has shown that ambient radiation doses to human receptors will be similar to the pre-mine environment. Ongoing monitoring of radiation throughout LOM and closure activities.	Backfilled pit is constructed to stable design as determined by geotechnical modelling.	Backfill mimics the shape of the pre-mine calcrete ridge, allowing surface flows to pass relatively unimpeded. Backfill is raised above surrounding topography to limit interaction with down-valley surface water flows. Landform slope angles of <0.5° Erosion-resistant soils for rehabilitation capping.	Bottle leach testing confirms potential for leachate run-off from stockpiled waste materials is low. Sampling of waste rock material and monitoring of surface and groundwater.	Backfill mimics the shape of the pre-mine calcrete ridge, allowing surface flows to pass relatively unimpeded. Backfill is raised above surrounding topography to limit interaction with down-valley surface water flows. Landform slope angles of <0.5°. Use erosion-resistant soils for rehabilitation capping.	Modelling of post-mine environment showed recovery within 0.5 m of groundwater levels in the post-closure environment – No additional management proposed.	Progressive rehabilitation program designed to detect problems with approach prior to mine closure. Development and implementation of construction management system to ensure correct design followed. Development and implementation of weed management program.
	In-Pit Tailings Storage Facility (TSF)	Post mine radiation assessment has shown that ambient radiation doses to human receptors will be less than the pre-mine environment. Ongoing monitoring of radiation throughout LOM and closure activities.	In-pit TSF pit cells are constructed to stable design as determined by geotechnical modelling. Management of tailings deposition determined by geotechnical testing and trials. TSF cover system is constructed to stable design as determined by geotechnical modelling.	Backfill mimics the shape of the pre-mine calcrete ridge, allowing surface flows to pass relatively unimpeded. Backfill is raised above surrounding topography to limit interaction with down-valley surface water flows. Landform slope angles of <0.5°. Use erosion-resistant soils for rehabilitation capping.	Construction of cover system specifically designed to minimise infiltration and leaching. Sampling of tailings material and monitoring of surface and groundwater. Ongoing groundwater monitoring is designed to detect potential groundwater quality issues throughout LOM.	Backfill mimics the shape of the pre-mine calcrete ridge, allowing surface flows to pass relatively unimpeded. Backfill is raised above surrounding topography to limit interaction with down-valley surface water flows. Landform slope angles of <0.5°. Use erosion-resistant soils for rehabilitation capping.	Modelling of post-mine environment showed full recovery of groundwater levels in the post-closure environment – No additional management proposed.	Progressive rehabilitation program designed to detect problems with approach prior to mine closure. Development and implementation of construction management system to ensure correct design followed. Development and implementation of weed management program.

Table 9-86: Yeelirrie domains (backfilled mine void and in-pit tailings storage facilities) completion criteria.

Subject	Objective	Criteria	Verification Tools	MCP Section
1.1 Safety	Site is safe for use under the agreed post mine land use(s)	Hazards which may endanger safety of humans or animals are identified and eliminated where possible. Residual safety hazards have been identified and appropriate management controls developed and implemented.	Relevant regulator guidelines have been met. Mine safety inspection audit.	Sections 8 and 10
1.2 Landform safety	Final landforms are safe	Landforms have been constructed as per management and operation guidelines for each domain	Rehabilitation audit monitoring confirms landforms constructed to design guidelines. Monitoring results display landform safety in relation to design criteria and relevant guidelines.	Sections 9 and 10
2.1 Landform Stability	Final landforms are stable	Landforms have been constructed as per management and operation guidelines for each domain	Rehabilitation monitoring confirms landforms constructed to design guidelines. Environmental reports available for review	Sections 9 and 10
2.2 Surface Stability	Constructed surface of landforms are stable and do not display significant erosion beyond that modelled	Surface of landforms have been constructed in accordance with guideline specifications for each domain	Rehabilitation monitoring confirms landform surfaces constructed to design guidelines. Rehabilitation monitoring results indicate surface is stable and within modelled limits	Sections 9 and 10
3.1 Sedimentation	Landform surfaces not prone to sediment transport beyond natural geomorphic processes	Surface of landforms have been constructed in accordance with guideline specifications for each domain	Rehabilitation monitoring confirms landform surfaces constructed to design guidelines. Rehabilitation monitoring results indicate surface is stable and within modelled limits	Sections 9 and 10
4.1 Sustainability	Rehabilitation is sustainable and suitable for the agreed post mine land use	Ecosystem function as defined by monitoring methods shows increasing trend and are comparable to baseline data	Rehabilitation monitoring shows ecosystem resilience and functioning are progressing along agreed trajectories towards sustainable post mine land use	Sections 8 and 10

Subject	Objective	Criteria	Verification Tools	MCP Section
4.2 Growth medium	Suitable growth medium is in place to facilitate rehabilitation and agreed post mine land use	Surface of landforms have been constructed using material identified as suitable for use in accordance with specific requirements for each domain	Rehabilitation monitoring confirms landform surfaces constructed to design guidelines Material movement scheduling records confirm landform surface have been constructed with suitable materials	Sections 9 and 10
4.3 Vegetation development	Vegetation is suited to the agreed post mine land use	Vegetation communities are suited to the agreed post mine land use and display resilience in ecosystem function	Rehabilitation monitoring shows ecosystem resilience and functioning are progressing along agreed trajectories towards sustainable post mine land use	Sections 8 and 10
4.4 Provenance	Vegetation is of local provenance	Vegetation communities are composed of local provenance species	Rehabilitation monitoring confirms local provenance species are forming vegetation communities	Sections 8 and 10
4.5 Weeds	Presence of weeds does not limit the sustainability of rehabilitation or its potential to sustain agreed post mine land use	Vegetation communities display resilience in ecosystem function	Rehabilitation monitoring shows ecosystem resilience and functioning are progressing along agreed trajectories towards sustainable post mine land use	Sections 8 and 10
5.1 Surface Hydrology	Mining related impacts on natural surface water flows is minimised	Landforms have been constructed as per management and operation guidelines for each domain	Rehabilitation monitoring confirms landforms constructed to design guidelines. Surface hydrology investigation/monitoring confirms surface drainage has returned to near natural flow and velocity	Sections 9 and 10
5.2 Groundwater Hydrology	Mining related impacts on groundwater quality and environmental receptors have been minimised	Monitoring results show groundwater quality within modelled constraints down gradient of mine closure domains	Groundwater monitoring of down gradient bores for contaminants of concern	Sections 8 and 10
6.1 Visual Amenity	Visual amenity of constructed landforms is comparable to original profiles	No new above ground landscape features with each domains land-surface backfilled to close to original profiles	Rehabilitation monitoring confirms landforms constructed to management guidelines. Environmental reports available for review	Sections 9 and 10
6.2 Heritage	No unauthorised disturbance of heritage sites during rehabilitation and access to sites of significance preserved	Landforms have been constructed as per management and operation guidelines for each domain	Rehabilitation monitoring confirms landforms constructed to management guidelines. Stakeholder register has been completed Site heritage register has been maintained.	Sections 9 and 10