Chapter 10 Closure Implementation

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Appendices

Appendix 10.1 Schedule of Activities (Q4 2017 – 2020)
Appendix 10.2 Revegetation Strategy
10 CLOSURE IMPLEMENTATION

This chapter presents the following information:

- A summary of closure implementation strategies and key activities for the Ranger mine.
- A description of the closure work programs for each key closure activity.

The objective is to close and rehabilitate the entire RPA, to form one final landform across the site which will blend with the surrounding landscape. The total area of disturbance in the RPA to be rehabilitated is approximately 950 hectares. As described in Chapter 1, this plan addresses ‘closure activities’ rather than using a formal ‘domain’ model (where closure domains are spatially defined). The closure activities are as follows:

- Pit 1 tailings impoundment and backfill.
- Water treatment.
- Pit 3 tailings and brine impoundment and backfill.
- Tailings dam deconstruction.
- Contaminated sites remediation.
- Processing plant and other infrastructure deconstruction.
- Final landform contouring and revegetation.

The following sections provide an outline of how the preferred closure strategy will be implemented including the current stages of closure across the RPA and staged closure timing. The proposed strategy will be subject to continual revision and updates as works are completed or revised. Changes to the closure strategy will be based on the outcomes of closure studies as they come to hand, and continual assessment of implementation activities to ensure feasibility and a best practice approach to all closure activities.

The closure strategy for each area has been developed through a review of all options with the preferred option selected through a BPT assessment; refer Chapter 8 and Appendix 8.1.

A current schedule of all closure tasks has been developed and is presented in Table 10-1 and is supported by schematics (Figures 10-1 to 10-15). The schedule is indicative, and subject to ongoing revision to reflect the status of closure activities. A schedule for activities that will be occurring in the next 2 years is provided in Appendix 10.1.
Table 10-1: Current schedule of closure tasks

<table>
<thead>
<tr>
<th>Aspect/activity</th>
<th>Task</th>
<th>Stage</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit 1</td>
<td>Installation of prefabricated vertical drains (wicks) within previously transferred tailings.</td>
<td>Complete</td>
<td>2012-2015</td>
</tr>
<tr>
<td></td>
<td>Installation of geotextile and preload activities commence. Finished January 2016.</td>
<td>Complete</td>
<td>2016-2018</td>
</tr>
<tr>
<td></td>
<td>Commencement of Pit 1 bulk backfill, completion due by Jan 2020.</td>
<td>Ongoing</td>
<td>2019-2020</td>
</tr>
<tr>
<td></td>
<td>Revegetation activity commences on the perimeter of the Pit 1 landform.</td>
<td>Scheduled</td>
<td>2021-2024</td>
</tr>
<tr>
<td></td>
<td>Final landform shaping and revegetation.</td>
<td>Scheduled</td>
<td>2025-2026</td>
</tr>
<tr>
<td></td>
<td>Initial backfill of Pit 3 with waste rock completed to form underfill.</td>
<td>Complete</td>
<td>2016-2018</td>
</tr>
<tr>
<td></td>
<td>Underfill drainage layer and extraction pumping system installed.</td>
<td>Complete</td>
<td>2019-2020</td>
</tr>
<tr>
<td></td>
<td>Brine injection bores installed into Pit 3 underfill.</td>
<td>Complete</td>
<td>2021-2024</td>
</tr>
<tr>
<td></td>
<td>Brine injection system - piping and infrastructure installed and commissioned.</td>
<td>Complete</td>
<td>2025-2026</td>
</tr>
<tr>
<td>Aspect/activity</td>
<td>Task</td>
<td>Stage</td>
<td>Timeline</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Brines from the brine concentrator are injected into Pit 3 underfill (ongoing until 2025).</td>
<td>Ongoing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Processing plant to Pit 3 tailings delivery piping and infrastructure installed.</td>
<td>Complete</td>
<td>2023</td>
</tr>
<tr>
<td></td>
<td>Commencement of processing plant tailings and dredged tailings from tailings dam delivered to Pit 3. Completion expected 2020.</td>
<td>Ongoing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Installation of prefabricated vertical drains (wicks) within pit.</td>
<td>Scheduled</td>
<td>2024</td>
</tr>
<tr>
<td></td>
<td>Installation geofabric and initial preload over pit.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commencement of bulk backfilling of Pit 3 and placement of waste material including deconstructed mill and other site infrastructure.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Backfilling of Pit 3 completed, surface contoured to final landform shape, and revegetation commences.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Additional brine injection wells installed into Pit 3 underfill if required.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brine injection infrastructure is decommissioned.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td>Aspect/activity</td>
<td>Task</td>
<td>Stage</td>
<td>Timeline</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Commission the tailings dam dredge and tailings transfer infrastructure.</td>
<td>Complete</td>
<td></td>
</tr>
<tr>
<td>Aspect/activity</td>
<td>Task</td>
<td>Stage</td>
<td>Timeline</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>sites (including LAAs and processing plant area).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commencement of staged removal of infrastructure in LAAs (ongoing to 2025) and remediation and/or infill revegetation of LAA areas as required (ongoing to 2025).</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ongoing processing plant operations until end 2020.</td>
<td>Ongoing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commence decommissioning of the processing plant infrastructure and stockpile for later disposal in Pit 3.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP6 decommissioned.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decommissioning of RP2/RP3, contouring and revegetation.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decommission and demolition of brine concentrator, water treatment plants and other water treatment infrastructure.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contour to final landform and commence revegetation.</td>
<td>Scheduled</td>
<td></td>
</tr>
<tr>
<td>Water treatment and storage</td>
<td>RP6 constructed and commissioned.</td>
<td>Complete</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brine concentrator constructed and commissioned in September 2013.</td>
<td>Complete</td>
<td></td>
</tr>
<tr>
<td>Aspect/activity</td>
<td>Task</td>
<td>Stage</td>
<td>Timeline</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>Brine injection commences; (recommencing 2nd half 2018).</td>
<td>Complete</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Process and pond water treatment. Clean water discharged to, e.g. wetland filter/RP1 (ongoing until 2025).</td>
<td>Ongoing</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td>Brine concentrator capacity increased. Additional process water treatment capacity installed (e.g. this could be an add-on to the brine concentrator).</td>
<td>Scheduled</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td>RP6 converted to process water storage if required.</td>
<td>Scheduled</td>
<td>2012</td>
</tr>
</tbody>
</table>

Ongoing/scheduled
Complete
Figure 10-1: 2012 closure summary
Figure 10-2: 2013 closure summary
Figure 10-3: 2014 closure summary
Figure 10-4: 2015 closure summary
Figure 10-5: 2016 closure summary
Figure 10-7: 2018 closure summary
Figure 10-9: 2020 closure summary
Figure 10-10: 2021 closure summary
Figure 10-11: 2022 closure summary
Figure 10-12: 2023 closure summary
Figure 10-13: 2024 closure summary
Figure 10-14: 2025 closure summary
Figure 10-15: 2026 closure summary
10.1 Pit 1 Closure

ERA commenced deposition of tailings within the mined-out Pit 1 in August 1996. This followed an initial Application to the Minesite Technical Committee (MTC) to deposit neutralised tailings in Pit 1, which was approved by the NT Minister in September 1995 (ERA 1995). In May 2005, ERA sought regulatory approval to increase the tailings deposition level in the pit to an interim 12 metres RL, which was received in August 2005 (ERA 2005). Between 1996 and December 2008, ERA deposited approximately 18.9 million cubic metres (25.6 million tonnes) of tailings into the pit (ATC 2012, CSIRO, 2014). Concurrent with tailings deposition, Pit 1 was also used to store process water.

In 2012 ERA commence the installation of pre-fabricated vertical drains (or wicks) to promote tailings consolidation and dewater the tailings, refer Figure 10-16. The pit was then dewatered to promote consolidation in preparation for construction of a pre-load layer across the entire pit (ERA 2013). Activities associated with the preload commenced in 2012 and continued until January 2016.

Bulk backfill (Table 10-2) of Pit 1 commenced in May 2017, following regulatory approval of the final average tailings level in in pit (Pugh et al., 2016). Bulk backfill involves the movement of 13 million tonnes of rock into Pit 1 and is estimated to be completed by January 2020. Placement of the bulk backfill into the pit will promote further tailings consolidation and expression of process water for treatment, remove Pit 1 from the process water catchment area, as well as facilitate the development of the final landform over the pit enabling revegetation.

Table 10-2: Progress toward Pit 1 closure milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
<th>Milestone 4</th>
<th>Milestone 5</th>
<th>Milestone 6</th>
</tr>
</thead>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced

The backfill and remediation activities that have taken place in Pit 1 from 1995 to present include the following.

- 1995 – 2008:
  - Preparation of the pit to receive tailings.
  - Tailings deposition commences in 1996.
  - Installation of a seepage limiting barrier in the south-eastern part of the pit.
  - Grouting and ongoing monitoring of the seepage limiting barrier.
• Tailings deposition in Pit 1 ceases in 2008.

• 2012:
  • Installation of 7,554 prefabricated vertical wick drains to assist with dewatering the pit, ahead of capping and rehabilitation.

• 2013 – 2016:
  • Installation of a geotextile layer across the exposed tailings surface area and subsequent rock pre-load across the pit, to activate the vertical wick drains and pore water expression.
  • Installation of two decant towers to extract process water expressed during tailings consolidation.
  • A cover of laterite was placed over the northern half the pit, to form the pond water interception layer.

• 2017:
  •Commenced backfill of approximately 13 million tonnes of rock into Pit 1, estimated to be completed by January 2020.
  • Installation of a third decant well.

Figure 10-16: Pit 1 in 2012, showing the installation of approximately 7,700 vertical wick drains

10.1.1 Pit 1 Closure Objectives and Risks
The objectives and/or outcomes relevant to Pit 1 closure include (refer Chapter 6):

• L2 – By the end of operations all tailings must be placed in mined out pits.
• L3 – The tailings are physically isolated form the environment for at least 10,000 years.
• R1 and R2 – Radiation doses to members of the public are below limits and ALARA.
• W1 – Mine derived analytes will not cause dietary (food and water) resources to exceed limits for human consumption in Magela Creek outside the RPA.

• W2 – Mine derived hazards will not cause designated recreational water resources to become unsafe for their designated recreational use in Magela Creek outside the RPA and Gulungul Creek secondary contact sites.

• W3 – Mine derived analytes from surface or ground waters discharged to surface waters outside the RPA do not cause detrimental impact to the ecosystem health of the Alligators River Region, and; there will be no detrimental environmental impact outside the RPA from tailings contaminants for 10,000 years.

• W4 – Mine sourced solutes do not cause increased uranium in sediments off the RPA to levels detrimental to ecosystem health of the region.

• W5 – Surface water quality on the RPA meets the highest ecosystem protection level that is demonstrated to be as low as reasonably achievable.

• C5 – Traditional owners are satisfied that there are no additional water bodies present.

• C7 – Traditional owners satisfied with the water quality and that no silting or sedimentation is occurring.

Environmental risks are described in Chapter 9 and Appendix 9.1. Existing and proposed controls are provided for all risks in Appendix 9.1 with more details of Class III (High) risks, which require active management, provided in Chapter 9. Risks associated with the closure of Pit 1 are summarised below.

**TA1-01:** Water quality in billabongs and creeks on the RPA is not ALARA. (Class II, Moderate), **TA2-01:** Poor quality water from Pit 1 enters offsite water bodies (Class II, Moderate), **TC2-01:** Elevated levels of contaminants (metals) in bush tucker and **TC2-02:** Levels of contamination in offsite drinking water exceed health guidelines.

Placement of the tailings in the pit and the final level of these tailings have been subject to approvals from the regulatory authority, as detailed earlier in this section. These approvals were required to demonstrate that all objectives could be achieved; in particular the outcome that there will be no detrimental environmental impact outside the RPA from tailings contaminants for 10,000 years (Pugh et al., 2016).

The water quality down stream of Pit 1 from backfilled tailings and waste rock has been estimated through groundwater solute transport models, details of which have been provided in Chapter 7, Section 7.7.2.

The identified sources of solutes are from groundwater flow through the tailings mass, groundwater flow through the backfilled waste rock and the flow of pit tailings flux during tailings consolidation. The solute transport model has estimated the solute loads to Magela Creek from each of these sources from the current closure design. These are provided in Chapter 9, Section 9.4.2 and Figure 9.7 and show the loads from Pit 1 to be very low compared to current and background.
Preliminary surface water modelling completed for ground and surface water sources from the final landform and both Pits showed that the concentrations of constituents of potential concern downstream of the Gulungul confluence were predicted to be below the current or proposed guideline values for all scenarios and does not pose a risk to the downstream environment, refer Chapter 7, Section 7.8.

Post closure solute transport will be minimised through both the construction of decant structures, installed to collect contaminated water expressed during consolidation and a plan for placement of different grades of waste rock, refer Section 10.1.2.

**TB1-02:** Erosion and gully formation across landform surface exposes contained tailings in Pit 1 (Class III, High)

All tailings have been placed into the mined out pit as required by L2. Chapter 9, Section 9.4.4 outlines how the final capping of tailings has been designed to mitigate this risk.

**TB1-04:** Consolidation settlement is significantly greater than predicted in Pit 1 (Class III, High)

Section 10.1.2 below outlines the bulk backfill strategy currently being implemented in Pit 1. This has been designed specifically to allow for the consolidation settlement in Pit 1 and outlines the monitoring program in place for consolidation. Chapter 9, Section 9.5.4 provides more details of existing and proposed controls.

**TC1-01:** Radiation doses from the final landform are not ALARA. (Class III, High) and **TC1-02:** Radiation levels from final landform exceed annual dose limits. (Class II, Moderate)

Chapter 9, Section 9.5.7 provides detail of the radiation risks from tailings and waste rock and how they are mitigated.

### 10.1.2 Pit 1 Backfill and Closure Design

The closure strategy for Pit 1, outlined further in this section, has been designed to meet the objectives and mitigate the identified environmental risks outlined in Section 10.1.1.

Mitigations to manage the estimated environmental impacts are subject to continual refinement for the final design and include all engineered controls. Key elements of the design are:

- The removal of pit tailings flux during tailings consolidation; early designs did not include the removal of this flux and showed elevated solutes moving into the environment in the short term. ERA have included decant structures into the Pit 1 (and Pit 3) designs to remove this water and mitigate this risk.

- The placement of mineralised material, in this case low 2s below the water table. ERA data show that the 2s contain more sulfur and more uranium than 1s waste rock. It was conservatively assumed that the sulfur content in the waste rock represents the pyrite content. Placing the 2s so that they remain below the water table will prevent or minimize pyrite oxidation and the associated increased rate of magnesium leaching from the waste rock. A detailed description of the leaching process driven by pyrite oxidation within waste rock located in the vadose zone is provided in INTERA (2016; refer Section 5.2.2).
The bulk backfill of Pit 1 is being completed in accordance with design provided by consulting geotechnical engineers and provides the controls/mitigations to address risk TB1-04 discussed previously.

The pre-load, or initial capping of Pit 1, was carried out in three campaigns from 2013 to 2016. Pre-loading included the placement of geotextile, careful placement of waste rock and later, a thin layer of laterite. During placement of the pre-load 28 settlement standpipes were placed at the locations shown in Figure 10-17. Vertical settlement at each location is monitoring regularly and used to validate the tailings consolidation model. The settlement at each location as of September 2017 is shown in Figure 10-17 to Figure 10-20 with the calculated average tailings level shown in Figure 10-21.

Three decant wells have been installed at the interface of the tailings and waste rock surface. The purpose of the wells is to allow for removal of process water derived from the following sources:

- Water expressed during consolidation.
- Rainfall infiltration through waste rock.
- Groundwater ingress from the surrounding formation while the pit remains as a hydrologic sink.

Permanent decant wells has been constructed at the site of the former settlement plate V location and adjacent to the settlement plate AA. A temporary decant well (or sump) was constructed in the south east corner of the pit. The location of the temporary sump is shown in Figure 10-23.

Tailings consolidation will steadily drive contained process water towards the vertical drains installed in the tailings and up into the waste rock, this will flow to the decant towers where it will be extracted and treated. The volume pit tailings flux that is expressed can be predicted through the settlement monitoring, the volume as of August 2017 is shown in Figure 10-22.

The key to the backfill design of Pit 1 is to place fill to an elevation such that after the potential settlement due to tailings consolidation, the final design levels are achieved with minimal need for modification of the surface levels.

The aim is to place the low 2s to an initial elevation such that after consolidation the low 2s will be below the water table, the level of which has been determined to be approximately -20 metres RL for Pit 1. The final level of low 2s will be monitored through monthly survey of the backfill surface and the settlement plates.

This backfill philosophy will promote consolidation settlement over the area of the thickest tailings deposit. A decant well is located over this area and the aim is to promote a bowl shape such that process water will drain to the base of the decant well, as soon as possible.

---

1 The laterite layer was placed for operational water management purposes and is not a required part of the pit backfill strategy.
Low 2s will be placed in seven stages using 3 metre paddock dumps. Figure 10-24 presents the final surface at completion of low 2s and shows the concentric design where the low 2s is thickest over the deeper sections of the pit. This is where the consolidation will be greatest. Figure 10-25 shows a cross section through the pit with each stage shown. These figures are based on the assumption that there is no consolidation settlement and are specifically for the purpose of showing the design. In reality the surface level of each stage will change as the tailings consolidate leaving an even surface.

At the completion of low 2s placement, waste rock will be placed in 3 metre lifts to the final landform surface.

Figure 10-17: Pit 1 tailings consolidation monitoring, settlement plates A-I
Figure 10-18: Pit 1 tailings consolidation monitoring, settlement plates J-N

Figure 10-19: Pit 1 tailings consolidation monitoring, settlement plates O-U
Figure 10-20: Pit 1 tailings consolidation monitoring, settlement plates V-BB

Figure 10-21: Pit 1 average tailings level
The design of the revegetation layer is yet to be finalised and is subject to additional approvals. An application was submitted to the MTC in March 2018, which is currently under review and approval. Assuming all approvals have been obtained and no operational delays occur, it is expected that Pit 1 backfill will be completed by January 2020. Revegetation of Pit 1 is expected to commence in 2020, initially on the perimeter of the landform, once backfilling is complete. The revegetation strategy for Pit 1 will be informed by the trial landform studies and other onsite revegetation trials (Chapter 7, Section 7.6) using species composition across the landform that takes into account the topography, water availability, and root depth to minimise the risk of plant roots penetrating the in-pit tailings. It is expected that Pit 1 revegetation and landform construction will be used to inform the final landform revegetation strategy for Ranger.
Figure 10-23: Pit 1 tailings surface as at September 2016 with settlement monitoring locations
Figure 10-24: Pit 1 backfill design showing final stage of low 2s
Figure 10-25: Pit 1 backfill design cross section of low 2s placement

Note:
This figure assumes that there is no tailings consolidation after 23/9/16. The purpose of the plot is to illustrate the development of the depth of low 2s fill. In reality the tailings surface will consolidate as the fill is placed.
10.2 Water Treatment

The main water inventories relevant to closure are those associated with pond water, process water, and brines. Pond water is derived from rainfall that falls on the active mine site catchments and requires active management. Process water is the most impacted water class on site and is derived predominantly from water that has passed through or encountered the uranium extraction circuit, and from rainfall from designated process water catchments. Brine is residue water from the treatment of process water through the brine concentrator or water treatment plant; these brine streams have different chemical and physical properties and are managed separately. For further detail on current water management practices, refer Chapter 3, Section 3.2.9.

To enable the successful closure of Ranger mine, both the pond and process water inventory on site must reduce to a zero balance. Pond water treatment will continue with the existing water treatment plants, with clean water discharged to available wetland filters and LAAs until 2025. Brines from pond water treatment are currently discharged either back to the pond water inventory or sent to the process water inventory, depending upon pond water quality at the time.

ERA are currently in the process of installing a new water treatment plant called a brine squeezer that will further treat the pond water brine to create a release quality water and a more concentrated brine stream. This brine stream will be directed to process water. Operation and eventual discharge of clean water from the brine squeezer will be subject to separate regulatory approval. This application is expected to be submitted to the MTC late 2018.

Process water treatment will continue with the existing brine concentrator, with clean water discharged to available wetland filters. The brine concentrator was constructed in 2012 and commissioned in 2013, brines from the brine concentrator were initially re-circulated back to process water pending construction of the Pit 3 underfill and brine injection bores (refer Section 10.3). Brines were injected into the underfill during 2016; however, operational issues with the Pit 3 underdrain bore have required that brines be diverted back to process water. It is expected that brine injection will resume again in the second half of 2018. Operation of the brine injection system is expected to be operational 80 percent of the time, with the brines diverted back to process water when required.

The diversion of brines to process water causes the process water salt content (measured through total dissolved solids) to increase. The brine concentrator is specifically designed to treat high salt content water; however at total dissolved solids concentration over 120 g/L the efficiency of treatment stats to be effected. ERA regularly monitors for total dissolved solids concentration in process water and also forecasts future concentrations through its operational water balance modelling software OPSIM, refer Chapter 3, Section 3.2.9.6. The most recent forecast has been provided in Figure 10-26, this uses the actual concentration in process water as at November 2017 and assumes brine injection is operational for 80 percent of the time starting October 2018. This shows that the total dissolved solids concentration in process water over time will remain well below 120 grams per litre.
The current OPSIM process water forecast, refer Chapter 3, Section 3.2.9.6, assumes that the current brine concentrator is upgraded to 125 percent of nameplate capacity and that additional process water treatment capacity is installed. This additional treatment will either be in the form of additional brine concentrator trains or through recommissioning and expansion of the high density sludge treatment plant. ERA is currently completing a study to determine the best alternative treatment option and complete required engineering studies. This is expected to be completed during 2018 with an application for the preferred option to be submitted to the MTC during 2019. The milestones for water treatment are summarised in Table 10-3.

### Table 10-3: Progress toward water treatment milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond water treatment MF/RO continues. Clean water discharged to wetland filter/RP1 (ongoing until 2025).</td>
<td>Brine concentrator constructed and commissioned in September 2013. Commencement of clean water discharge from the brine concentrator to wetland filter/RP1. Brines are recirculated to the process water inventory.</td>
<td>Recirculation of brines from brine concentrator to process water inventory ceases; brine injection commences.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Milestone 4</th>
<th>Milestone 5</th>
<th>Milestone 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brine concentrator capacity increased.</td>
<td>Additional process water treatment capacity installed (e.g. this could be an add-on to the brine concentrator).</td>
<td>Decommission and demolition of brine concentrator, water treatment plants and other water treatment infrastructure (offsite disposal).</td>
</tr>
</tbody>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced
As part of the ITWC prefeasibility study, the volume of brine produced by the brine concentrator was been estimated through OPSIM to be 2 gigalitres. The capacity of the Pit 3 underfill has been estimated to be 3 gigalitres, allowing sufficient volume to store all the brines, refer Chapter 7, Section 7.9.

More recently ERA has reviewed these calculations using updated and as built information. The current OPSIM forecast (refer above for assumptions) has indicated that the total brine volume to be disposed will be 1.39 gigalitres for the median (50 percent) rainfall scenario and 1.6 gigalitres for the higher (70 percent) rainfall scenario. This has lower brine disposal volumes because part of the process water is treated via the high density sludge plant. The recalculated volume if all process water was treated using the brine concentrator remains at 2 gigalitres.

The as built details on the waste rock used to construct the underfill and the actual final level of the underdrain (-102 metres RL) were used to re-calculate the actual void volume of 2.48 gigalitres, refer Table 10-4.

<table>
<thead>
<tr>
<th>Type of waste rock</th>
<th>Dry density (t/m³)</th>
<th>Void volume [ML]</th>
<th>Void ratio [-]</th>
<th>Porosity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Actual waste rock mass placed in Pit 3</td>
<td>2.18</td>
<td>2,480</td>
<td>0.22</td>
<td>17.9</td>
</tr>
<tr>
<td>2. Waste stockpile data listed in 2013 laboratory study</td>
<td>2.02</td>
<td>3,308</td>
<td>0.31</td>
<td>23.8</td>
</tr>
<tr>
<td>3a. Laboratory unsaturated compression test result at pit base</td>
<td>-</td>
<td>2,729</td>
<td>0.24</td>
<td>19.6</td>
</tr>
<tr>
<td>3b. Laboratory saturated compression test result at pit base</td>
<td>-</td>
<td>2,187</td>
<td>0.19</td>
<td>15.7</td>
</tr>
<tr>
<td>4a. Laboratory unsaturated compression test (2A sample) result</td>
<td>-</td>
<td>3,453</td>
<td>0.33</td>
<td>24.9</td>
</tr>
<tr>
<td>4b. Laboratory unsaturated compression test (4A sample) result</td>
<td>-</td>
<td>3,684</td>
<td>0.36</td>
<td>26.5</td>
</tr>
<tr>
<td>5a. Laboratory saturated compression test (2B sample) result</td>
<td>-</td>
<td>2,863</td>
<td>0.26</td>
<td>20.6</td>
</tr>
<tr>
<td>5b. Laboratory saturated compression test (4B sample) result</td>
<td>-</td>
<td>3,260</td>
<td>0.31</td>
<td>23.5</td>
</tr>
</tbody>
</table>

As described in Section 10.2.4, the water treatment plants, brine concentrator and all associated infrastructure will be decommissioned and decontaminated in 2025 in preparation for offsite disposal. This date assumes that a zero water balance has been achieved and the process water generated through tailings consolidation has been collected. If this is not the case then water treatment infrastructure will be required to remain, with decommissioning occurring at a later date. Similarly if a zero balance is achieved earlier then decommissioning
can occur earlier and there may be some options for onsite disposal, rather than decontamination and offsite disposal.

In addition to water treatment, process and pond water inventory will be reduced through catchment management, refer Chapter 3 Section 3.2.9. As rehabilitation works progress, catchments will slowly be converted from process to pond and eventually release. The final landform surface will be constructed of the lowest uranium grade material (1s waste rock) and has had erosion and sediment controls engineered, refer Section 10.7, to ensure the lowest possible concentrations of contaminants and sediments in this release water. The quality of this water has been predicted by the surface water model (refer Chapter 7, Section 7.8). An assessment of how such water and sediment quality will affect the environmental values will be conducted using the framework currently being developed by consultants BMT WBM in consultation with stakeholders (Chapter 6, Section 6.4.1.1). This, along with a BPT analysis, will underpin further assessment of what, if any, interventions are needed to achieve ALARA in onsite water bodies.

To meet the wishes of traditional owners and cultural criteria, ERA has committed to not construct or leave additional water bodies on site post closure, where practicable. It is recognised that some form of sumps or water bodies may be retained to capture sediments eroding from the final landform (refer Section 10.7.8). The timing and/or need for their removal are yet to be determined.

10.3 Pit 3 Closure

As identified in Chapter 1, approval of Pit 3 closure will be subject to a standalone assessment via the MTC. A separate application detailing all components of Pit 3 closure is scheduled to be submitted to the MTC by 31 March 2019 (refer Chapter 1, Section 1.4.3 and Appendix 1.2). The information outlined in this section provides an overview of the Pit 3 rehabilitation and closure activities based on closure studies completed to date.

Mining of Pit 3 ceased in November 2012 and works to prepare the pit for closure commenced in December 2012. This involved the placement of 33.7 million tonnes of underfill (waste rock and low grade ore material) within the base of the pit to raise the mined-out pit floor from approximately -265 metres RL to approximately -100 metres RL. The underfill component was completed in August 2014.

The Pit 3 underfill was installed for two purposes, the first to reduce the deposited tailings rate of rise and final thickness of tailings, thus maximising tailings consolidation and minimising the final landform settlement (ERA 2014). The second to provide a final disposal reservoir for brine concentrator brines.

An engineered underdrain was then constructed comprising a nominal 2 metres of waste rock layer to remove both water expressed downwards by the overlying tailings during the consolidation process, and entrained pond water displaced upwards from within the underfill by the brine injection process (ERA 2014). The underdrain was constructed in 2014 and comprises an engineered sump constructed at its low point and a bore installed from behind the rim of the pit to intercept the underdrain sump to allow for collection of the waters for pumped transfer to the tailings dam (ERA 2014).
ERA also completed installation of five brine injection wells drilled directly into the underfill and associated pipework. The injection wells allow brines produced by the brine concentrator to be safely stored within the available void space within the underfill, which is designed to be approximately 3 gigalitres (ATC 2014). Based on operational simulation water balance forecasts, the expected brine production from 2015 to 2026 required to be stored in the underfill is approximately 2 gigalitres. Consequently there is a high degree of confidence that the underfill will contain the life of mine brine production, refer Chapter 7 Section 7.9.

As each injection bore reaches capacity or precipitates foul the surrounding voids within the underfill, the next injection bores will be commissioned. In the event that all bores are exhausted, additional injection bores will be installed on the southern edge of Pit 3 to inject the remaining brine into the Pit 3 underfill.

The brine injection system (concentrator, piping and infrastructure), refer Figure 10-27, was commissioned in 2015 and commenced full scale operation in 2016. The brine injection system ties into the brine concentrator facility concentrated brine tank. A centrifuge pump transfers the hot concentrated brine via a pipeline to a storage (surge) tank. An inline heat exchanger partially reduces the brine temperature to prevent boiling in the pumps and pipelines. The brine is drawn from the surge tank and pumped to designated injection bore via a valved manifold through a brine delivery pipeline.

At the end of 2016 an operational issue was identified with the underdrain bore. Further work on the underdrain bore is currently being undertaken to enable the commencement of brine injection into the Pit 3 underfill in the second half for 2018.

Milestones associated with brine management are presented in Table 10-5.

![Figure 10-27: Flow diagram of brine injection and tailings transfer](image-url)
Tailings transfer to Pit 3 from the processing plant commenced in 2015 and from the tailings dam in 2016 with the commencement of transfer of tailings from the tailings dam to Pit 3. The transfer of tailings from the tailings dam to the deposition points in Pit 3 is described below in Section 10.4. An in-pit extraction pumping system installed in Pit 3 at the end of 2014 enables the return of process water from the tailings slurry mixture to the tailings dam to allow for continued dredging.

Once the tailings deposition into Pit 3 has concluded in 2020, prefabricated vertical drains (wicks) will be installed, similar to those which have been installed in Pit 1. This is estimated to be completed by 2022 and will be followed by the installation of a geotextile layer to provide the required geotechnical strength and allow access for backfill. The geotextile layer will then be covered with a preload layer of waste rock, to activate the wicks. The remainder of Pit 3 will be backfilled with waste rock from the remaining stockpiles, concurrent with the deposition of the deconstructed mill and other site infrastructure into the pit. The surface of the pit will then be contoured to the final landform shape, and revegetation will commence in 2024 (Section 10.7). Pit 3 closure milestones are presented in Table 10-6.

Table 10-6: Progress toward Pit 3 closure milestone

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
<th>Milestone 4</th>
<th>Milestone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open cut mining ceases in November 2012.</td>
<td>Initial backfill with waste rock completed to form underfill.</td>
<td>Underfill drainage layer and extraction pumping system installed.</td>
<td>Processing plant to Pit 3 tailings delivery piping and infrastructure installed.</td>
<td></td>
</tr>
<tr>
<td>Commencement of processing plant tailings delivered to Pit 3.</td>
<td>Commencement of dredged tailings from the tailings dam to Pit 3.</td>
<td>Processing plant and dredged transfer of tailings completed.</td>
<td>Installation of prefabricated vertical drains (wicks).</td>
<td></td>
</tr>
</tbody>
</table>
10.3.1 Pit 3 Closure Objectives and Risks

The objectives and/or outcomes described above for Pit 1 are also relevant to Pit 3 closure (refer Section 10.1.1). Existing and proposed controls are provided for all risks in Appendix 9.1 with more details of Class III (High) risks, which require active management, provided in Chapter 9. Risks associated with the closure of Pit 3 that were not covered in the Pit 1 section are summarised below.

TB1-01: Erosion and gully formation across landform surface exposes contained tailings in Pit 3 (Class I, Low)

All tailings have been placed into the mined out pits as required by objective L2.

Compared to Pit 1, the potential for exposure of tailings in Pit 3 due to erosion processes has been identified as a Class I (low) risk. The lower risk ranking is predominantly attributed to differences in pit geometry. The final depth of consolidated tailings is significantly greater than Pit 1, therefore tailings are less likely to be exposed (Table 10-7). In addition, landform evolution modelling competed by the Supervising Scientist shows tailings in Pit 3 to not be exposed for 10,000 years, refer Chapter 7, Section 7.5.

Placement of tailings in Pit 3 has been subject to approval from the regulatory authority. However, as outlined previously, approval for final Pit 3 closure, including the predicted average final consolidated tailings level in the pit, will be subject to further standalone assessment via the MTC (refer Appendix 1.2).

Table 10-7: Pit 3 versus Pit 1 consolidation

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Pit 1</th>
<th>Pit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tailings depth (maximum)</td>
<td>152 metres</td>
<td>80 metres</td>
</tr>
<tr>
<td>Tailings deposition width: depth ratio(^{(a)})</td>
<td>≥3.5</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Prefabricated vertical drainage wick penetration(^{(b)})</td>
<td>≥12 to 25 percent</td>
<td>up to 48 percent</td>
</tr>
<tr>
<td>Waste rock backfill depth</td>
<td>≥29 metres</td>
<td>≈49 metres</td>
</tr>
</tbody>
</table>

\(^{(a)}\) Ratios determined for minimum pit width at the end of deposition.
Assumed 38 metre wick depth.

TA2-02: Poor quality water from Pit 3 enters offsite water bodies (Class III, High)

As discussed under the water quality risks identified for Pit 1, details of these risks and the controls are outlined in Appendix 9.1 and Chapter 9, Section 9.4.2.

The water quality down stream of Pit 3 from backfilled tailings and waste rock has been estimated through groundwater solute transport models, details of which have been provided in Chapter 7, Section 7.7.3.

The identified sources of constituents of potential concern from Pit 3 to Magela Creek are brine, tailings and shallow waste rock placed above the tailings. The solute transport model has estimated the solute loads from Pit 3 to Magela Creek from each of these sources from the current closure design. These are provided in Chapter 9, Section 9.4.2 and Figure 9.7 and show the loads from Pit 3 to be very low compared to current and background.

As discussed in Chapter 7, Section 7.4.3.3 and Chapter 9, Section 9.4.2, the main source of loading (e.g. magnesium) is from the waste rock cover, contributing over 90 percent to the predicted annual solute loadings. Loads of reactive constituents of potential concern (e.g. uranium, calcium (as magnesium:calcium ratio) manganese, nitrate, total ammonia-N, phosphate, radium-226, polonium-210, copper, lead, cadmium and zinc) have also been estimated with predicted cumulative impacts presenting a low environmental risk post closure.

TB1-03: Consolidation settlement is significantly greater than predicted in Pit 3. (Class III, High)

Chapter 9, Section 9.5.4 list the various controls in place to mitigate this risk. The primary one being the placement of 30Mt of waste rock in the base of Pit 3 as underfill, providing for quicker and more even consolidation.

10.3.2 Pit 3 Backfill and Closure Design

The closure strategy described below for Pit 3 has been designed to meet the objectives and mitigate the identified environmental risks outlined in Section 10.1.1 and 10.3.1 above.

Mitigations to manage the estimated environmental impacts are subject to continual refinement for the final design and include all engineered controls. Key elements of environmental mitigation design described previously for Pit 1 (Section 10.1.1) also apply for Pit 3, in particular the decanting of process water during tailings consolidation and the placement of low 2s below the minimum simulated average water table elevation, which is about 14 metres RL (INTERA, 2015).

The combined tailings from the process plant and tailings dam will fill the Pit 3 void from a starting elevation of approximately -100 metres RL to an estimated -20 metres RL by the end of the deposition phase in 2020 (Figure 10-28) (ERA 2014). This level will then reduce to -30 metres RL at the end of bulk backfill as tailings are consolidated.
Figure 10-28 is representative of the revised Pit 3 backfill strategy that was modelled by (INTERA 2014a) and includes mitigation strategies such as a tailings cap and a waste rock cap. However, further analysis by INTERA demonstrates that there is little benefit to constructing the low-permeability caps in Pit 3 INTERA (2016).

![Figure 10-28: Indicative Pit 3 backfill (INTERA 2014a; Figure 1.2)](image)

Tailings that are being transferred from the tailings dam to Pit 3 was initially planned to be thickened after the first year of operation, once finer material was encountered. A BPT assessment of alternative approaches to tailings treatment was completed in September 2016. The most favourable option to emerge from this assessment was unthickened tailings with prefabricated vertical drains (wicks), based on the experiences of Pit 1 tailings deposition and consolidation (Chapter 8, Section 8.4.3).

Deposition of tailings in Pit 3 is being undertaken using a sub-aerial deposition technique, meaning that the tailings are discharged above the water level from discharge points at the pit crest that enable the formation of a sloping beach across the surface of the pit floor. Decant water is pumped from the lower end of the beach for water management purposes with the water recovery pumps to be located near the former haul road to allow for access and maintenance (ERA 2014). The suitability of this method in the long term for mitigating risk TB1-03 is currently being reviewed by ERA in consultation with stakeholders. It is expected that an application to change deposition method to sub-aqueous will be submitted to the MTC in August 2018. An update on the tailings deposition and associated risk mitigation will be provided in the next review of this closure plan.
10.4 Tailings Dam

As identified in Chapter 1, approval of the tailings dam closure will be subject to a standalone assessment via the MTC. A separate application detailing all components of the tailings dam deconstruction is scheduled to be submitted to the MTC by 1 December 2019 (refer Chapter 1, Appendix 1.2). The information outlined in this section provides an overview of the broader tailings management closure activities based on closure studies completed to date.

The tailings dam was originally constructed in 1979 with first tailings being deposited soon after. As described in Chapter 3, Section 3.2.5, the tailings dam has a dyke (‘turkey nest’) structure, being designed to hold both tailings and process water. Since commissioning it has been subjected to six crest raises with the final being completed in 2012. This involved a 2.3 metre raise to the Ranger tailings dam clay core to a crest level of 60.5 metres RL and was constructed to enable containment of process water and tailings until Pit 3 was prepared to begin receiving tailings in 2015.

Approximately 23 million cubic metres of tailings stored in the tailings dam and must be transferred to Pit 3 to meet the closure objective L2, refer Section 10.4.1. A number of options for transfer of tailings were reviewed by ERA with the use of a dredge selected as best practicable technology as part of the ITWC PFS, refer Chapter 8.

Construction of the tailings dam dredge was completed in 2014 and it was commissioned, along with tailings transfer and water recovery/pumping infrastructure high density polyethylene (HDPE) pipelines in December 2015.

Tailings slurry is reclaimed by the dredge and transferred via the floating HDPE pipeline connected to an overland HDPE pipeline at the edge of the tailings dam for delivery to the deposition points in Pit 3 (Figure 10-29) (ERA 2014). The tailings layer in Pit 3 will consolidate with water being continuously expressed. Expressed water will flow both upwards (decant) to be recovered at the Pit 3 surface and downwards to be recovered at the underdrain layer as shown in Figure 10-30. Decant water from tailings consolidation and rainfall run-off will be pumped via the process water tanks located at the edge of Pit 3 back to the tailings dam (ERA 2014) to allow for the continued floating and operation of the dredging infrastructure.

Figure 10-29: Flow diagram of tailings transfer
From 2015, all production tailings was directed to Pit 3, therefore the process water in the tailings dam will progressively reduce as it is treated by the brine concentrator, and the tailings mass in the tailings dam will be progressively transferred to Pit 3 by dredge operations (ERA 2014). These activities are integral to the successful execution of the closure strategy.

The operation of this infrastructure associated with the tailings dam will allow for the continued reduction and treatment of process water and tailings in the tailings dam, as well as the safe disposal of all future processing waste.

Based on the current dredge performance and with confidence in the implementation of planned improvements, tailings transfer is estimated to be completed by the end 2020. Planned improvements include but are not limited to:

- Upgrade to the winching system.
- Reviewing options to modify or change the cutter head.
- Improvements to dredging method.
- Changes to the cutter mouth.
- Options to pre-treat and/or break up material in advance of the dredge.
- Study into the option for a second dredge.

The dredge removes tailings in 3 - 4 metre cuts across the entire dam; however it currently is restricted from removing the material closest to the wall. The preferred method for removal of this tailings hang up material is being reviewed by ERA, with the preferred option to be notified to stakeholders at the MTC during 2018.
10.4.1 Tailings Closure Objectives and Risks

The closure objectives and/or outcomes relevant to the tailings dam include (refer Chapter 6):

- **L2** – By the end of operations all tailings must be placed in mined out pits.
- **R1** and **R2** – Radiation doses to members of the public are below limits and ALARA.
- **W1** – Mine derived analytes will not cause dietary (food and water) resources to exceed limits for human consumption in Magela Creek outside the RPA.
- **W2** – Mine derived hazards will not cause designated recreational water resources to become unsafe for their designated recreational use in Magela Creek outside the RPA and Gulungul Creek secondary contact sites.
- **W3** – Mine derived analytes from surface or ground waters discharged to surface waters outside the RPA do not cause detrimental impact to the ecosystem health of the Alligators River Region, and; there will be no detrimental environmental impact outside the RPA from tailings contaminants for 10,000 years.
- **W5** – Surface water quality on the RPA meets the highest ecosystem protection level that is demonstrated to be as low as reasonably achievable.
- **C7** – Traditional owners satisfied with the water quality and that no silting or sedimentation is occurring.

Environmental risks are described in Chapter 9 and Appendix 9.1. Existing and proposed controls are provided for all risks in Appendix 9.1 with more details of Class III (high) risks, which require active management, provided in Chapter 9. Risks associated with the closure of the tailings dam are summarised below.

**TA3-01: Uncontrolled release of contaminated material into the onsite environment during tailings transfer to Pit 3 (Class III, high)**

All tailings from the tailings dam are being transferred to Pit 3, as required by L2. The potential for uncontrolled release of tailings during tailings transfer to Pit 3 has been identified as a process safety risk. As such, Ranger’s existing process safety management framework incorporates functional and effective operational controls to mitigate this task.

**TA3-02: Uncontrolled release of process water stored in tailings dam to the environment (Class III, high)**

During decommissioning and rehabilitation, all process water will continue to be managed in accordance with existing operational water management strategy and plan. This has resulted in successful management of process water and tailings for over 35 years.

**TA3-05: Potential migration of contaminants from tailings dam plumes (Class III, high)**

Groundwater around the tailings dam will continue to be an area of concern after site closure; however, the rate of migration will decrease due to the substantial reduction in hydraulic gradient. As discussed in Chapter 9, Section 9.5.3, further groundwater modelling work has commenced to better understand this risk and inform the closure design.
The tailings dam has been an area of concern for surface water during the operational phase and in particular it affected the quality of surface water in the Gulungul Creek tributaries. After site closure, solute loadings from the original tailings dam sources to the Gulungul Creek tributaries are expected to be greatly reduced.

### 10.4.2 Tailings Dam Deconstruction and Closure Design

The deconstruction strategy for the tailings dam has yet to be completed. It will be designed to meet the above objectives and mitigate identified environmental risks, described in the previous section.

At the completion of dredging in late 2020 ERA will be required to remove all residual tailings material to comply with objective L2. In addition any contaminated material at the base of the dam, or on the side walls, may require removal and transfer to Pit 3. The exact amount and proposed method for this is currently being determined by ERA such that all objectives are met and risks outlined in Section 10.4.1 are mitigated and/or managed.

Decommissioning of the dredge and tailings transfer infrastructure will commence once this is completed. The tailings dam may then be used to store process water until 2024 at which time the tailings dam wall will be removed, and then re-contoured and revegetated during 2025. Tailings management milestones are presented in Table 10-8.

A separate application detailing all components of tailings dam deconstruction, including contaminated material management is scheduled to be submitted to the MTC by December 2019 (refer Chapter 1, Section 1.4.3 and Appendix 1.2).

#### Table 10-8: Progress toward tailings management milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredge to deliver tailings from the tailings dam to Pit 3 is under construction. Tailings transfer piping and infrastructure installed.</td>
<td>Commissioning the tailings dam dredge and tailings transfer infrastructure.</td>
<td>Dredging ramped up to full operational capacity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Milestone 4</th>
<th>Milestone 5</th>
<th>Milestone 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging of tailings completed.</td>
<td>Decommissioning of dredge, tailings transfer infrastructure and removal of remanent tailings/contaminated material from tailings floor and walls.</td>
<td>Tailings dam converted to process water storage.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Milestone 7</th>
<th>Milestone 8</th>
<th>Milestone 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process water storage in the tailings dam ends, and decommissioning commences.</td>
<td>Commencement of the removal of tailings dam walls and contouring.</td>
<td>Final landform contouring complete and revegetation commences.</td>
</tr>
</tbody>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced
10.5 Contaminated Sites Management

The decommissioning of contaminated sites other than Pit 1, Pit 3 and the tailings dam will require active management through to 2025, to ensure that the final outcome demonstrates as low as reasonably achievable (ALARA) principles on the RPA (refer Chapter 11). The information outlined in this section provides an overview of additional contaminated site closure activities.

10.5.1 Contaminated Sites Closure Objectives and Risks

The closure objectives and/or outcomes relevant to contaminated sites include (refer Chapter 6):

- R1 and R2 – Radiation doses to members of the public are below limits and ALARA.
- W1 – Mine derived analytes will not cause dietary (food and water) resources to exceed limits for human consumption in Magela Creek outside the RPA.
- W2 – Mine derived hazards will not cause designated recreational water resources to become unsafe for their designated recreational use in Magela Creek outside the RPA and Gulungul Creek secondary contact sites.
- W3 – Mine derived analytes from surface or ground waters discharged to surface waters outside the RPA do not cause detrimental impact to the ecosystem health of the Alligators River Region.
- W4 – Mine sourced solutes do not cause increased uranium in sediments off the RPA to levels detrimental to ecosystem health of the region.
- W5 – Surface water quality on the RPA meets the highest ecosystem protection level that is demonstrated to be as low as reasonably achievable.
- S1 – Impacted soils are remediated to as low as reasonably achievable to protect the environment.
- C7 – Traditional owners satisfied with the water quality and that no silting or sedimentation is occurring.

The closure strategy for addressing contaminated sites has been designed to meet the above objectives and mitigate identified environmental risks, described in Chapter 9 and Appendix 9.1. For example, ineffective decommissioning of contaminated sites has been identified as a cause for three potential risks (e.g. TA2-03, TA3-06, TA3-07), resulting in risk rankings from Class I to Class III. The existing and proposed controls relevant to these risks are addressed contextually, as they apply to each contaminated site discussed below.

Numerous studies have been undertaken to determine contamination levels across the RPA as well as in specific areas of potential concern. The recent site conceptual model for Ranger mine (Chapter 7, Section 7.7), reviewed information from these studies in relation to areas of interest/concern within the RPA to identify the constituent(s) of potential concern recorded and their predicted receptors and transport pathways post-closure.
The key findings relating to contamination in the areas of interest/concern such as the processing plant, LAAs, Ranger 3 Deeps and the final landform are as follows:

- **Processing Plant Area**
  
  Potential migration of groundwater plumes within the processing plant is identified as a Class II (moderate) risk *(TA3-06: Potential migration of contaminants from other legacy plumes (e.g. processing plant)).* Studies between 2006 and 2009 revealed that groundwater beneath the processing plant area had been affected by various constituents of potential concern. However, a lack of impact to the nearby downgradient bores suggests that migration of contaminants from the processing plant area is extremely slow. Operational monitoring data and analysis from groundwater bores in the vicinity of the processing plant area are reported annually to the MTC, in accordance with ERA's statutory reporting obligations under the Ranger Authorisation.

  Contaminated runoff and/or groundwater discharge from the processing plant area is not expected to be an area of concern for surface water either now or after closure, based on the distance from the processing plant area to Corridor Creek and Georgetown Billabong and the low constituents of potential concern concentrations seen in bores adjacent to Corridor Creek and Georgetown Billabong.

  The processing plant area is an area of concern for soil contamination and as such, contaminated material from the processing plant footprint and surrounding areas will be recovered for later placement in Pit 3 (see Section 10.5).

- **LAAs**
  
  The risk of migrating contaminants from the LAAs are identified as a Class I (low) risk *(TA3-07: Potential migration of contaminants from legacy sites (e.g. land application areas, wetland filters)).*

  Several studies have been undertaken of individual or grouped LAAs between 1993 and 2010 investigating various soil contamination levels, radiological status of soils and other soil properties.

  In one of the studies (Akber et al., 2011), over 200 soil samples collected from across all of the LAAs found that radionuclides applied to the LAAs have been retained in the soil profile between depths of 5 and 10 centimetres. These bound radionuclides have a low leachability and will therefore be unlikely to impact the aquatic environment downstream.

  Akber (2015) also conducted a study of the uranium distribution in the LAAs. The study found that sprinkler irrigation of RP2 water has resulted in an increased concentration of uranium (and other radioisotopes) in the soils of the LAAs. Uranium load varies in the LAAs, depending upon the site use duration, concentration in the applied water and the applied water volume.

  Uranium distribution is non-uniform both in the vertical and horizontal direction. In the vertical direction, the uranium concentration decreases exponentially with depth and little applied uranium is expected to reach below 0.2 metres depth from the surface.
In the horizontal direction, the applied uranium loads seem to exist in strips along the irrigation lines. The leaf litter in the LAAs has elevated uranium concentration which is likely due to both the foliar uptake during the sprinkler irrigation with RP2 water and the root uptake.

Studies undertaken on radiological contamination in the RPA (Akber & Lu, 2012) show that although some concentration of radiological elements does occur, radiation doses to members of the public are very low on all LAAs areas and with the exception of Magela A and B, are below the exemption levels published in the ARPANSA National Directory (ARPANSA, 2014). While these results indicated that no remediation for radiological contamination is required, a soil sampling and testing program is currently being developed to determine if this assumption is still valid. This work will be progressed during 2018 and reported in the next iteration of the MCP.

The LAAs are not considered to be areas of concern for groundwater or surface water post-closure for various reasons including (but not limited to): nearly 20 years of wet season flushing between when the LAAs were decommissioned and when the site will be closed; groundwater chemistry has improved in some LAAs since switching from the application of RP2 water to clean water; and transport of U and/or $^{226}$Ra on sediment in surface water runoff is possible, but will likely result in small quantities entering surface water bodies and will be diluted on entry.

Further information on the outcomes of the radiation studies completed in the LAAs is provided in Chapter 7, Section 7.4.2.

- **Ranger 3 Deeps**
  
  As identified in Chapter 1, approval of closure of the Ranger 3 Deeps exploration decline would be subject to a standalone assessment via the MTC. A separate application detailing all closure activities associated with the closure of the exploration decline is scheduled to be submitted to the MTC by 30 November 2019 (refer Chapter 1, Section 1.4.3 and Appendix 1.2).

  The Ranger 3 Deeps decline and ventilation shaft are not considered a potential area of concern for the post-closure period. Modelling of constituents of potential concern migration from closure of an entire proposed Ranger 3 Deeps mine concluded that impacts to Magela Creek will be negligible (INTERA 2014b).

- **Final Landform Waste Rock**

  Waste rock is identified as one of the primary sources of contaminants post closure that may impact downstream water bodies and is identified as a Class III (high) risk **TA2-03: Poor water quality from cumulative sources (e.g. landform, legacy sites, etc) enters off-site water bodies.** Details of this risk and the controls are discussed in Chapter 9, Section 9.2.4 and Appendix 9.1.

  Waste rock is one of four mine wastes identified by solute transport modelling and conceptual modelling (see Chapter 7, Section 7.7.1.6). Waste rock is a potential constituent of potential concern source for Pit 1, Pit 3, Ranger 3 Deeps, the tailings dam
and the final landform constructed with waste rock. However, landform waste rock will leach constituents of potential concern, with concentrations for runoff much lower than those for groundwater that infiltrates to the water table through the waste rock.

Further information on the leaching properties and predicted sources of constituents of potential concern from waste rock are provided in Chapter 7, Section 7.7.1.6 and associated discussion for each of the smaller-scale conceptual model areas identified above and in Chapter 7, Section 7.7.

Engineering controls to mitigate environmental impacts arising from the waste rock landform have been designed and modelled. The system of controls comprises 4 components designed to minimise erosion and sediment discharge from the final landform, thereby minimising the transportation of waste rock solutes to the offsite environment. Details of the design features of the system are provided in Section 10.7.8.

### 10.5.2 Cumulative Impacts

The risks of cumulative impacts to off-site water bodies from sources other than waste rock are also a consideration for the Class III risk **TA2-03** discussed above.

Additional work is scheduled as part of the feasibility study, which commenced in September 2017, to determine the requirement and approaches for remediation and/or to develop specific revegetation strategies for contaminated sites (Table 10-9). The remediation of contaminated sites will be assessed and managed in accordance with the closure criteria outlined in Chapter 6.

Asbestos types, for example, were identified through an initial audit of Ranger and selected surrounding locations by Environmental Health Services in February 2003, and a subsequent audit by SLR Consulting in 2016. The quantities of asbestos across the site are relatively small and are located in clearly defined areas. Asbestos shall be removed by an appropriately qualified contractor and buried in Pit 3.

The assessment of contaminated sites commenced in 2018 and remediation and/or infill revegetation, where determined to be required, is schedule for 2019 onwards. The staged removal of infrastructure in LAAs is ongoing and will continue, as required, to 2025.

Table 10-9: Progress toward contaminated sites milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
<th>Milestone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of radiation contamination in LAA soils indicates doses are below exemption level.</td>
<td>Determine need for remediation and/or revegetation strategy for contaminated sites (including LAAs and processing plant area).</td>
<td>Commencement of staged removal of infrastructure in LAAs (ongoing to 2025). Remediation and/or infill revegetation of LAA areas as required (ongoing to 2025).</td>
<td>Remediation of temporary landfill site near Pit 3 and any other contaminated soils within the mine footprint, and placement of material into Pit 3.</td>
</tr>
</tbody>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced
10.6 Demolition and Decommissioning

The infrastructure in the RPA has been divided into demolition work packs to determine the estimated tonnage of infrastructure to be removed from each area or building.

Prior to the demolition of some components of the processing plant, ERA will be required to obtain a decommissioning permit from Australian Safeguards and Non-Proliferation Office (ASNO). The request for permit will outline nominal timeframes and estimated start/completion dates for the decommissioning of infrastructure associated with the leaching and solvent extraction circuits, including product packing. This is mainly to support timely inspections and/or verification by ASNO or IAEA agency inspectors during decommissioning. A decommissioning permit for these infrastructure will need to be in place after the cessation of U₃O₈ production and before demolition commences (Botha, 2017 pers. comm., 20 July).

Furthermore, the ITWC BPT identified the need to develop a management plan, “… to ensure that contaminated plant items (e.g. calciner, etc) can be placed in appropriate long-term repositories (e.g. within the tailings layer or in the R3-Deeps decline etc.).” This approach remains relevant to the current demolition and decommissioning strategy and will be developed as a component of future iterations of the MCP.

10.6.1 Demolition Objectives and Risks

The closure objectives and/or outcomes specifically relevant to contaminated sites are provided below (refer Chapter 6):

- **L1** – Remove all plant, equipment, buildings and other structures; some infrastructure may remain on the RPA provided approval of the traditional owners and the Commonwealth minister is given.
- **C5** – Traditional owners are satisfied that there are no additional water bodies present.

No risks were identified that are directly related to demolition activities, or where demolition activities are considered a cause. All demolition activities will be undertaken in accordance with current operational controls. For example, existing water management structures and controls will remain in place until the infrastructure is removed, to minimise potential erosion and/or contaminants entering creeks from surface water run-off.

10.6.2 Demolition methods

The following demolition methods are proposed for Ranger closure:

- All services connecting to a structure such as cables and piping will be disconnected.
- Structures will be demolished using excavators with shear / grapple attachments, with high-reach excavators being used where necessary. Where applicable, large sections such as silos will be disconnected and lowered to the ground with cranes. Explosives

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2 Refer Appendix 8.1, page 47.
may be required where structures cannot practically be dismantled using the above method.

- Sections will be further dismantled at ground level where required and loaded onto trucks for disposal.
- Foundation demolition shall be executed using excavators and rock breakers.
- Pavements (bitumen or concrete) and associated infrastructure such as kerbs, gutters and gully pits will be demolished using excavators and rock breakers.
- Large assemblies containing major voids, such as tanks, vessels and structural pre-assemblies, shall be disassembled and/or crushed to eliminate such voids. For example, large storage tanks will be cut into segments, prior to disposal in Pit 3. Indicatively, assemblies with a minimum cross-sectional diameter of 4 metres shall be disassembled/crushed, however actual requirements will be determined at the time.
- Material will be transported to Pit 3 using ERA mine haul trucks. A ramp will be constructed on the southern face of the pit for loads to be transported to the bottom. In some cases materials may be dumped from the top of the pit wall and allowed to fall to the bottom, however this will be done in a controlled manner and is subject to appropriate risk assessment.
- All excavations will be filled with compacted material and the site trimmed and graded.

The following list summarises the proposed demolition for concrete and buried items:

- All concrete suspended slabs and slabs on ground shall be demolished.
- All minor underground services, such as pipes 100 nominal bore or less and cables that are within 1 metre of the finished surface level shall be demolished.
- All buried items including concrete footings, pipes greater than 100 nominal bore and sumps that are within 3 metres of the finished surface level shall be demolished.
- Underground tanks shall be appropriately remediated or removed.
- Buried items that are deeper than 3 metres below the finished surface level, such as deep foundations, shall be demolished to a depth of 1 metre below the finished surface level, with the remaining voids filled with material from the 1P stockpile.

### 10.6.2.1 Processing Plant Closure

The processing plant will continue operating until 2020. Following the cessation of tailings transfer from the plant to Pit 3, the processing plant infrastructure will be removed in 2021 and stockpiled for later disposal into Pit 3. Contaminated material from the processing plant footprint and surrounding areas will be also be recovered for later placement in Pit 3 (refer Section 10.5.1). In 2024, the final landform will be contoured and revegetation will commence (Table 10-10). To manage potential contamination (e.g. surface water run-off) associated with the deconstructed processing plant during decommissioning and remediation works, the existing water management structures and controls surrounding the processing plant will remain in place until the infrastructure is removed.
Table 10-10: Progress toward processing plant closure milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ongoing processing plant</td>
<td>Commence decommissioning of the processing plant</td>
<td>Contour to final landform and commence revegetation.</td>
</tr>
<tr>
<td>operations until end 2020</td>
<td>infrastructure and stockpile for later disposal in Pit 3.</td>
<td></td>
</tr>
</tbody>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced

10.6.2.2 Water Storage

Retention Pond 6 (RP6) was constructed in 2012 to provide additional water storage and management capacity. RP6 has a capacity of 1 gigalitre, is double-lined with a high density polyethylene liner, and connects to the existing RP2 via a two-way pumping transfer system.

The retention ponds hold surface run-off water that has come into contact with mineralised materials such as low grade ore stockpiles and is managed according to quality. Pond water is treated to high standards by ERA's micro filtration reverse osmosis (MF/RO) treatment system prior to controlled release via constructed wetland filters or irrigation on LAAs. If required, RP6 will be converted to a process water storage area any time from 2018.

RP6 will be decommissioned in 2024 and all components, including the lining, will be placed in RP2. RP2 and RP3 will be decommissioned in 2025, any contamination remediated, and the landforms of RP6, RP2 and RP3 will be contoured and revegetation will commence as summarised in Table 10-11. RP1 will be retained temporarily post-closure to manage water quality runoff from the final landform (Water Solutions, 2017).

Table 10-11: Progress toward water storage milestones

<table>
<thead>
<tr>
<th>Milestone 1</th>
<th>Milestone 2</th>
<th>Milestone 3</th>
<th>Milestone 4</th>
<th>Milestone 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP6 constructed and</td>
<td>RP6 converted to process water storage if required.</td>
<td>RP6 decommissioned.</td>
<td>RP6 contouring and revegetation.</td>
<td>Decommissioning of RP2/RP3, contouring and revegetation.</td>
</tr>
<tr>
<td>commissioned.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Green - milestone reached; Orange - activity underway, Unfilled – activity not commenced

10.7 Final Landform

As identified in Chapter 1, approval of the final landform will be subject to a standalone assessment via the MTC. A separate application detailing all components of the final landform construction is scheduled to be submitted to the MTC by 4 May 2018 (refer Chapter 1, Section 1.4.3 and Appendix 1.2). The information provided in this section provides an overview of the final landform closure activities based on closure studies completed to date.
10.7.1 Landform Closure Objectives and Risks

The closure objectives and/or outcomes relevant to final landform construction include (refer Chapter 6):

- **L5** – Best available modelling demonstrates that erosion rates return to that of comparable natural landscapes.
- **L6 to L9** – Drainage channels are installed and maintained to manage erosion for each catchment and are comparable to landforms in surrounding undisturbed areas.
- **L10** – Sediments from erosion of the landform do not cause sand to infill in Magela and Gulungul creeks and associated billabongs.
- **L11** – Suspended sediment loads in Magela and Gulungul Creeks will be approaching background.
- **W1** – Mine derived analytes will not cause dietary (food and water) resources to exceed limits for human consumption in Magela Creek outside the RPA.
- **W2** – Mine derived hazards will not cause designated recreational water resources to become unsafe for their designated recreational use in Magela Creek outside the RPA and Gulungul Creek secondary contact sites.
- **R1** – Radiation doses to members of the public are ALARA.
- **R2** – Radiation doses to members of the public are below limits.
- **R3 & R4** – Minimise the deleterious radiation effects on terrestrial and aquatic biota to a level where they would have a negligible impact on the maintenance of biological diversity; the conservation of species; or the health and status of natural habitats, communities, and ecosystems.
- **F6 to F11** – Long term, viable ecosystem requiring maintenance similar to adjacent areas of KNP.
- **C2 to C4** – Landform design supports cultural land use: An-berrk, savanna woodland; An-bouk, riparian margins; An-gabo, water courses; An-labbarl, billabongs; traditional owners satisfied with the landform.
- **C6** – Traditional owners satisfied that the riparian zones are in good condition.
- **C7** – Traditional owners satisfied with the water quality and that no silting or sedimentation is occurring.
- **C8 to C11** – Traditional owners are observing improvement in the progression of revegetation on the landform.
- **C12 to C13** – Traditional owners are observing improvement in biodiversity on the landform.

The closure strategy for final landform construction, outlined in this section, has been designed to meet these objectives and mitigate identified environmental risks, described in Chapter 9 and Appendix 9.1.
Landform risks not previously addressed under Pit 1 and Pit 3 closure (Sections 10.1 and 10.3), include:

- Class II (moderate) risk **TB1-05**: Landform does not meet the values (e.g. land uses) that are expected from the stakeholders.
- Class III (high) risk **TB1-06**: Excessive erosion impacts landform stability and revegetation success.
- Class II (moderate) risk **TB1-07**: Legacy erosion areas persist post 2026.

Existing and proposed controls for risk TB1-06 are discussed in Chapter 9, Section 9.4.4. Engineering controls for risk TB1-07, will be addressed by the stabilisation works discussed in Chapter 11, Sections 11.1 and 11.2. ERA anticipates that ongoing stakeholder consultation combined with the extensive level of detail provided in this MCP and separate applications submitted to the MTC will ensure that the final landform meets the expectations of stakeholders (risk TB1-05).

10.7.2 Final Landform Construction

Construction of the final landform will involve significant backfill into pits and the redistribution of appropriate materials to ensure the final landform meets closure requirements. The activities to be undertaken to construct the final landform can be grouped into areas of the RPA based on the timing of their availability to be used for reclamation. The reclamation consists of four main areas; the Pit 1 area, the tailings dam area, the processing plant area and the Pit 3 area (including the stockpile area). Reclamation areas are shown in Figure 10-31 and Table 10-12 provides summary quantitative values for each area.

Table 10-12: Summary values for reclamation areas

<table>
<thead>
<tr>
<th>Reclamation area</th>
<th>Cut m³</th>
<th>Fill m³</th>
<th>Net m³</th>
<th>Net (cut/fill)</th>
<th>Area (ha)</th>
<th>Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit 3 void</td>
<td>8,000</td>
<td>30,432,000</td>
<td>-30,424,000</td>
<td>Fill</td>
<td>75</td>
<td>-60,848,000</td>
</tr>
<tr>
<td>Processing plant</td>
<td>1,701,000</td>
<td>3,838,000</td>
<td>-2,137,000</td>
<td>Fill</td>
<td>116</td>
<td>-4,274,000</td>
</tr>
<tr>
<td>Pit 1 area</td>
<td>1,831,900</td>
<td>6,510,000</td>
<td>-4,678,100</td>
<td>Fill</td>
<td>84</td>
<td>-9,356,200</td>
</tr>
<tr>
<td>Tailings dam area</td>
<td>8,517,000</td>
<td>6,258,000</td>
<td>2,259,000</td>
<td>Cut</td>
<td>286</td>
<td>4,922,000</td>
</tr>
<tr>
<td>Under stockpiles</td>
<td>36,257,000</td>
<td>955,000</td>
<td>35,302,000</td>
<td>Cut</td>
<td>237</td>
<td>70,604,000</td>
</tr>
<tr>
<td>Total</td>
<td>48,314,900</td>
<td>47,993,000</td>
<td>321,900</td>
<td>Cut</td>
<td>798</td>
<td>1,047,800</td>
</tr>
</tbody>
</table>

Table 10-12 illustrates that the final landform is designed to a near perfect material balance. However, these volumes do not illustrate the total movements. This is due to the need for a cut of mineralised material to be made underneath the stockpiles, and the remaining voids will subsequently be refilled with non-mineralised material.
The following sections summarise the steps required to backfill and construct the final landform across each area, based on the most recent mine plan.

Waste rock that will be placed as part of the final landform construction, including pit backfill, will be made up of grade 2 and grade 1 waste rock. Details of the uranium and sulfur content of this material have been provided in Chapter 3, Section 3.2.8.

The surface layer (or landform cover) will be made up of entirely grade 1 material. The thickness of this material above any grade 2 material will need to be at least 2 metres\(^3\), to ensure any gamma radiation is sufficiently attenuated (refer Chapter 7, Section 7.4.1.1). The maximum uranium content of grade 1 material currently planned to form this surface layer is 200 parts per million U\(_2\)O\(_6\) (170 parts per million uranium or 2 Becquerels per gram) with an average of 80 parts per million U\(_2\)O\(_6\) (68 parts per million uranium or 0.8 Becquerels per gram). This is below that currently considered to be radioactive according to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA 2014).

\(^3\) The exact thickness of this final layer will depend upon the height of the selected final paddock dump, more details on this have been provided in Section 10.4.5.
The use of grade 1 material (<0.02 percent U₃O₈) for this final layer will be confirmed using both the stockpile grade block model and truck load gamma analysis via a discriminator.

10.7.3 Pit 1 Area

Pit 1 bulk backfill commenced in May 2017. The Pit 1 area will be backfilled using both grade 1 and low grade 2 waste rock materials from stockpiles. The backfilling will occur in three stages:

- 2.0 million cubic metres of low grade 2 material will be placed into Pit 1 in concentric rings to accelerate consolidation.
- An additional 1.1 million cubic metres of the same material will be placed into Pit 1 and the consolidation process will be monitored.
- 3.2 million cubic metres of grade 1 material will be placed over the previous layers of grade 2 material to cover the entire pit surface.

The backfill plan proposes to place the low grade 2 material below the water table (generally 20 metres RL), and the non-mineralised grade 1 material above the water table up to the final landform level. Based on tailings consolidation studies to date, there is expected to be 1.4 million cubic metres of tailings consolidation in Pit 1 and this volume will supplement the low grade 2 material in anticipation of the low grade 2 material subsiding to the 20 metres RL. This will occur over the relatively long time frame to late-2019. During this time, subsidence will be monitored and the backfill program adjusted to achieve the desired result (refer Section 10.1).

The low grade 2 and some grade 1 material will be sourced from stockpiles that are currently being mined for processing. The bulk of the grade 1 material to be used in backfilling Pit 1 will be sourced from the stockpile area adjacent to Pit 1 (Figure 10-32), with any additional grade 1 material required to complete the final landform surface sourced from other stockpiles to the north of Pit 1.
10.7.4 Tailings Dam Area

ERA are currently undertaking an assessment to determine the best method for remediation of the tailings dam contaminated material; in-situ or removal and burial. If remediation works are required these will be completed prior to the commencement of material movement in 2024 (refer Section 10.4.2).

Approximately 1.8 million cubic metres (3.6 million tonnes) of material within 150 metres of the tailings dam crest will then be dozed toward the final landform surface, followed by the movement of 5.4 million cubic metres (10.8 million tonnes) of wall material to the final landform in the tailings dam area via truck and shovel method.

A total of 2.3 million cubic metres (4.6 million tonnes) of material on the north wall of the tailings dam will be left to be moved by 2025. Mineralised material excavated from this location will be placed in Pit 3, with the balance of the excavated material to be placed into the final landform in the stockpile area.
The other components of the tailings dam area; the clay borrow pit at the proposed location for Retention Pond 5 (RP5) and, if required, the Corridor Creek wetland filter to the south-east, will be reclaimed during 2025 (Figure 10-33).

Figure 10-33: Tailings dam area

**10.7.5 Processing Area**

Once decommissioning of the plant and all demolition and disposal of the processing plant infrastructure into Pit 3 has concluded in approximately 2024, backfilling of the plant area will commence (Figure 10-34).

The total rock fill required for the plant area is significant (2.1 million cubic metres or 4.1 million tonnes), mostly due the height of the final landform over RP2 (approximately 23 to 28 metres). The backfill material for the processing plant area will be sourced from the last stages of stockpile in the stockpile area, which will all be grade 1 material. The run-of-mine (ROM) pad will be reclaimed and made contiguous with the Pit 1 area in 2021.
10.7.6 Pit 3 Area

Bulk backfill of Pit 3 will involve the largest material movement in the construction of the final landform – a total of approximately 30 million cubic metres (60 million tonnes).

Once the tailings transfer to Pit 3, natural consolidation, wick placement and preloading is complete (see Section 10.3.2) the bulk backfill of Pit 3 will commence. It is expected that it will take approximately 22 months to complete this activity.

The source of material for the early stages of backfill will be low grade 2 material from the southern areas of the stockpiles. During the Pit 3 backfill, the bulk material will be discriminated to ensure that low grade 2 material is kept below the low grade 2 rock cap, to mitigate the transport of solutes from the waste rock material to the downstream environment.

Grade 1 material sourced from the lowest benches of the central stockpiles (augmented by some material sourced from the north wall of the tailings dam) will be used to bring the Pit 3 area up to the final landform elevation (approximately 15 to 26 metres). The final stage of the Pit 3 backfill and contouring is scheduled to be completed by 2025 (Figure 10-35).
10.7.7 Landform Design and Bulk Backfill Techniques

The final landform will be constructed and contoured to meet the closure criteria for the landform theme as described in Chapter 6, Section 6.2.

As outlined previously in Chapter 7, (e.g. Sections 7.3 - 7.6), the design of the final landform has been subjected to a large number of studies and assessment to establish the current version 5. This version incorporates design for both erosion control and ecosystem establishment, such that both have the maximum potential for success, (refer Chapter 7, Section 7.5).

Backfill techniques have been designed to maximise the plant available water potential stored in the final landform waste rock (F11), minimise the potential for erosion and sediment runoff (L5; L6 to L9; L10; L11; W1; W2; R1 to R4; C2 to C4; C6 and C7) and maximise ecosystem development (F6 to F11; C8 to C13). An analysis of the thicknesses and locations of backfill across the final landform was conducted, resulting in three main categories or areas of backfill technique (Figure 10-36).
Figure 10-36: Categories of backfill techniques

Category A represents the areas of the final landform that will be underlain by original ground. This is an important aspect of the backfill because it guarantees a compacted layer at a predetermined horizon. Category A represents approximately 70 percent (532 hectares) of surface area of the final landform within the aqua line (Figure 10-36) but excluding the pits and grade 1 stockpiles.

A great deal of this area requires less than 1 to 3 metres of fill. In the central area the backfill required ranges to up to 13 metres, but generally is around 8 to 10 metres. This suggests the following backfill approach:

- Tightly spaced paddock dumping should provide an approximate 4 metre lift. By spacing out the paddock dumped loads and dozer work, the thin sections of fill can be placed efficiently. This means the depth to the natural ground surface will often be less than 4 metres below the surface.

- A second lift can create the final landform in the thicker fill areas. This means compacted layers occur at 4 metres intervals, and with less than 4 metres at the thin sections. Under this approach, it should be unnecessary to complete a third lift.

Category B represents the areas underlain by existing stockpiled grade 1 material and tailings dam walls that will not require further infilling but will be reduced (cut) and left as final landform surfaces. These areas lie within the yellow boundaries (Figure 10-36) and represent approximately 15 percent (113 hectares) of the entire rehabilitated footprint.
These areas will be more compacted compared to other areas which will undergo backfilling, because the grade 1 material has been buried and undisturbed for a long time at the base of the stockpiles. Therefore these areas will need to be ripped in order to support successful revegetation. The depth of the natural ground surface in these areas varies from 1 to 12 metres. After bulk backfill it will be generally around 6 to 10 metres above natural ground surface.

Category C represents the areas that lie within Pit 1 (40 hectares) and Pit 3 (75 hectares). These areas lie within the red boundaries and represent approximately 15 percent of the entire rehabilitated footprint. The approach in these areas is to initially use the grade 2 material from the upper portions of the stockpiles for placement below the groundwater table in each pit.

For Pit 1, the grade 2 material will be distributed in a specific pattern ranging in thickness from 1 to 7 metres. The backfill will be undertaken using haul trucks and dozers. The grade 1 material to be placed on top of Pit 1 is generally a thicker fill layer of up to 10 metres. This material could be placed across the pit in one 10 metres tip head, alternatively it can be layered in two lifts of paddock dumping, which would allow for compaction between layers.

For Pit 3 the bulk backfill approach for the placement of the grade 2 material will differ from that used in Pit 1 because the initial layer is generally much thicker; between 35 and 40 metres thick. Following the placement of an initial thin layer, subsequent layers will be placed in 10 metre lifts. Decommissioned plant material will be also be deposited into the pit during these lifts. The final layer of grade 2 material will be placed at a surface elevation that grades from 6 mRL to 14 mRL. This surface is 8 metres below the final land surface.

The bulk backfill to the final landform elevations across Pit 3 will be placed in a single 8 metre tip head or 2 x 4 metre paddock dump lifts. The latter approach is preferred to provide for the opportunity of additional compaction between layers to improve water holding capacity in the final landform soils.

10.7.7.1 Bulk Backfill Method

This section broadly describes the overall bulk backfill approach to be applied across the final landform. It is divided into five plan view sections (south to north), in order to explain the different methods of bulk backfilling that will be applied across the variable final landform elevations (e.g. cut and/or fill). The overall approach to bulk backfilling across areas of high variability in elevation will require active management to avoid unnecessary rework of the final landform across these sectors. Again methods employed, for example paddock dumping and layering will maximise the plant available water potential stored in the final landform waste rock, minimise the potential for erosion and sediment runoff and maximise ecosystem development.
A backfill contour map is provided as Figure 10-37. It shows the contour depths of the final rehabilitated footprint, that correspond to the plan view backfill sections 1 to 5. Proposed landform cuts are shown in tan regardless of the length or depth of cut that is required.

Figure 10-37: Backfill contour map

Figure 10-38 shows the plan view (west to east) for bulk backfill purposes. For areas where the backfill will be more than 5 metres (Section 1), tight paddock dumping would be the applied technique followed by smoothing of the surface by dozers prior to the placement of additional layers. In this sector, paddock dumps will be wider where the backfill is thin and tighter where they are thicker. An example of the thickest fills over the tailings dam is the central area of Section 1. The bulk backfilling in this vicinity will be 1 to 2 layers of paddock dumping followed by dozer spreading between layers. In the eastern areas of Section 1, 1.5 metre cuts will occur.
For Section 2 (Figure 10-39), the same bulk backfill approach will be applied across the western portion of this sector (i.e. across the tailings dam). In the central area, the bulk backfill required is between 5 and 10 metres; therefore the 2-layer paddock dumping method described for Section 1 will be applied.

In the east of Section 1, across Pit 1, the bulk backfills are very specific. The initial bulk backfill layers will be grade 2 material and range between 6 to 7 metres. Placement of this material will be undertaken based on special instructions from tailings experts (e.g. Fitton, 2015). The fill depth of the grade 1 material above grade 2 rock is likely to facilitate a 10 metre tip head to progress in a specific plan view progression.
Over the entire area of Section 3 (Figure 10-40), the bulk backfill strategy will consist of very minor cuts and fills towards the extremities and relatively large cut and fill processes towards the middle. At the extremities, spaced paddock dumping will occur, as the original ground level in these areas ranges from 2 to 3 metres below the final landform. In the central region of Section 3, the likely approach will be 2 to 3 paddock dumps each at a spacing to create a compacted layer about 4 metres below the surface.

![Figure 10-40: Bulk backfill plan view, Section 3](image)

Over Section 4 (Figure 10-41), there will be minor fills towards the west, graduating to 5 m fills towards the centre and larger fills across Pit 3. Pit 3 bulk backfill will also include grade 2 material at 6 metres RL to 14 metres RL, which as in the case of Pit 1, is below the water table. Like Pit 1, Pit 3 will also be "capped" with grade 1 material.

![Figure 10-41: Bulk backfill plan view, Section 4](image)
In Section 5, the bulk backfilling will be focussed on Pit 3 (Figure 10-42). It is important to note that the final landform is generally 8 metres above the grade 2 material layer. After the placement of the grade 2 material over Pit 3, a single 8 metre tip head can be progressed over the top of this layer.

![Figure 10-42: Bulk backfill plan view, Section 5](image)

### 10.7.8 Erosion and Sediment Control

Water Solutions were engaged to develop a concept design for controlling erosion and sediment discharge from the Ranger mine final landform (Hart, 1982). The designs were based on:

- The design flow rates determined in the landform flood study, refer Chapter 7, Section 7.5.2.
- Advice in a range of relevant guidelines.
- The professional experience of the consultant Water Solutions.

A system with four key components was developed, as follows:

- **Component 1 – Surface Treatment:** Measures on the hillslopes to reduce erosion and sediment discharge.
- **Component 2 – Drainage Channel Treatment:** Measures along the more defined drainage lines to reduce erosion and sediment discharge.
- **Component 3 – Edge Sediment Basins:** The design of sediment basins around the edge of the final landform to capture sediment discharging from the landform.
- **Component 4 – Second Layer Sediment Basins:** Where the terrain permits, a second sediment basin has been positioned further downstream from the final landform, providing a second layer of protection to limit sediment discharge from the site.

Key concepts and design features for each component have been summarised in the following sections.
Component 1 – Surface Treatment

Measures to limit erosion and sediment discharge on the general surface of the landform are arguably the most critical – if erosion can be limited in these locations, the amount of sediment that must be dealt with downstream can be significantly reduced.

ERA has developed a revegetation strategy for the site, described in Section 10.8.3. Revegetation is a critical action in reducing erosion from the site – the roots act to bind the soil together, the canopy helps intercept direct rainfall on the soil surface, and the leaf matter and woody debris falling from this vegetation will, in the longer term, help to protect the surface.

Measures that will be employed on the hillslopes to reduce erosion and sediment discharge. Include:

- Ripping 0.5 metres deep along the contour at 4 metre intervals, creating rough contour banks which will slow runoff and encourage infiltration.
- Use of a "Rotree" cultivator (or similar) to cultivate holes for the tubestock. The circular depressions created by the cultivator will again slow runoff and encourage infiltration.
- Use the limited available woody/vegetative debris/rocks to create selected small areas of habitat, and also slow runoff and encourage infiltration.
- Apply a concave slope approach to the final landform terrain, where the slope gradually reduces as the catchment area uphill/upstream increases.
- Gently shape the terrain to direct flow towards the minor drainage lines protected by the recessed rock checks in Component 2 below.
- Vegetate the slope, including ground cover, as soon as reasonably possible, to help bind the soil and reduce erosion. If removal of ground cover (weeds) is required to allow the tubestock to grow, poison in place/remove selectively, in order to retain the benefit the weeds apply in resisting erosion.

Component 2 – Drainage Channel Treatment

Design criteria for the Ranger final landform drainage channels were developed using the outputs from the landform flood study (Chapter 7, Section 7.5.2). Both long and short term scenarios were developed. For long term conditions, where erosion protection is principally provided by the vegetation in and around the channel, design was based on an Annual Exceedance Probability (AEP) 1 in 2 event peak velocity under 1.5 metres per second, and a AEP 1 in 50 event peak velocity under 2.5 metres per second. For short term conditions, where erosion protection is principally provided by the rock protection measures, design was based on events up to the AEP 1 in 10 event.

The AEP 1 in 10 event was chosen for the short term case based on a number of factors, including:

- To match the structural stability event (and design capture efficiency) used in the sediment basin design.
- To provide a reasonable balance between construction and maintenance costs.
• The conveyance area between the high banks on a creek typically contains events up to around the AEP 1 in 10 event, so reinforcing this area should assist in the long term stability of the drainage channels.

As discussed in Chapter 7, Section 7.5.2, the short term case is expected to cover conditions in the first decade or two after construction of the final landform. Consideration was given to setting design criteria in the very short term case, i.e. to cover conditions immediately after construction, when no vegetation is present and when the landform material has undertaken little consolidation. Designing the drainage channels to be fully stable for large events when no vegetation is present would likely require full lining, which is not preferable from an environmental perspective. Thus the design criteria have been set as above. If a large event occurs immediately after construction, some erosion would be expected, and this will be addressed through the site monitoring and maintenance program.

An analysis of the slopes on the drainage paths on the final landform was conducted, with slopes for the lower sections of the identified sub-catchments extracted from the final landform terrain and shown in Table 10-13. It can be seen that slopes vary from about 1 in 30 (3 percent) to 1 in 200 (0.5 percent), with the larger catchments tending to have lower slopes, although this is not always the case.

For this preliminary drainage channel assessment, the cross-section was assumed to be a standard 5 metre wide channel with 1:10 side slopes. A Manning’s n of 0.05 was assumed, representing the presence of some vegetation in the channel. A minimum side protection height of 0.5m was adopted, while for larger flow depths a freeboard of 0.3 metres was applied. The results are shown in Table 10-11, demonstrating that the peak velocities for AEP 1 in 2 and AEP 1 in 50 long term (LT) events are comfortably under the target velocities in the nominated design criteria (1.0 – 1.5 metres per second and 2.0 – 2.5 metres per second respectively).

These initial calculations indicated that velocities are modest as long as wide drainage paths are maintained. However the landform evolution modelling undertaken by the Supervising Scientist (Chapter 7, Section 7.5.1) indicates that there is tendency for deep gullies to form, particularly in the upper catchment areas. The mechanism here is likely to be that, once erosion commences in a particular area, it will tend to concentrate the flow and erosion will then continue to deepen the gully in that location.

Hence there is a need for some erosion protection measures to help maintain a wide drainage path and limit the likelihood of deep gullies forming on the landscape, particularly while the vegetation is getting established. A series of recessed rock checks are have been designed to serve this purpose. These features are buried below the surface of the gully at regular intervals, and are designed to provide a level of insurance against possible future gully erosion. Key design features of these rock checks:

• Are 1 metre wide by 1 metre deep, buried into the profile of the minor drainage channels.

• Follow the shape of the drainage channel, i.e. lower in the middle, with the flow width gradually increasing as the flow depth increases.
• Have sufficient side height to limit the likelihood of being bypassed. (Preliminary side protection heights are provided in Table 10-13.)
• Spaced out along the drainage line at intervals to provide a 0.5 metres level drop between checks. That is, are 15 metres apart on a slope of 1 in 30, 25 metres apart on a slope of 1 in 50, etc.
• Commence when the upstream catchment area reporting to that drainage line exceeds about 7.5 hectares. (Estimated from the approximate upstream area reporting on the gullies from the Supervising Scientist landform evolution modelling results, (refer Chapter 7, Section 7.5).)
• A minimum rock size d50 of ~200 millimetres.
• Once constructed the recessed rock check will be filled with soil – vegetation will not be restricted from growing over the recessed rock check.

An indicative sketch of the key elements of the recessed rock check design is provided in Figure 10-43.

Table 10-13: Drainage channel assessment for each sub-catchment

<table>
<thead>
<tr>
<th>Upstream subareas</th>
<th>Catchment area (ha)</th>
<th>Bed slope (1 in X)</th>
<th>ST AEP 1 in 10 flow (m³/s)</th>
<th>Side protection height (m)</th>
<th>LT AEP 1 in 2 flow (m³/s)</th>
<th>LT AEP 1 in 2 velocity (m/s)</th>
<th>LT AEP 1 in 50 flow (m³/s)</th>
<th>LT AEP 1 in 50 velocity (m/s)</th>
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<td>7.3</td>
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<td>CR09</td>
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<td>CR09,CR10</td>
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<td>1.2</td>
<td>1.0</td>
<td>2.4</td>
<td>1.2</td>
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</tbody>
</table>
Figure 10-43: Key elements of the concept recessed rock check hydraulic design
Once the vegetation gets well established, both in the drainage channel and on the edges of the drainage channel, the vegetation should largely take over in providing appropriate erosion resistance for the drainage channels.

To increase the timing at which this occurs any fast growing ground cover will allowed to grow in these drainage channels to provide erosion resistance in the short term. If this groundcover is a weed then this will be done in sections down the channel, rather than simultaneous clearing of the whole channel length. Poisoning of weeds in place will allow the weed vegetation/roots to provide some stability as a new ground cover gets established. Where possible, natural ecological succession processes will be allowed to gradually replace the initial fast growing (weed) species with the desired longer term species.

The tubestock planted on the final landform hillslopes will be continued up to and into the defined drainage channel, i.e. tubestock will be planted along the edge and within the designed drainage gullies. The trees and vegetation planted beside and within the drainage channels will play a key role in its long term stability. However it is expected that there will be limited high mortality within the drainage channels

Where possible, preference will be given to placing material with a higher proportion of gravel and rocks along the drainage lines between the rock check structures, to encourage these sections to armour up quickly with some flow. It is noted that the waste rock material does contain a significant fraction of larger material, and the recessed rock checks are providing insurance against severe erosion, and it is thus not considered necessary to fully armour the drainage channels at the time of initial construction.

One of the surface treatment options detailed in Component 1 above, was the concave slope approach. The preliminary drainage channel assessment provided in Table 10-14 was based on the standard slopes of the Ranger final landform. A preliminary drainage channel design has been prepared assuming a concave slope approach has been applied; where the drainage channel slope consistently decreases as the upstream catchment increased.

The catchment areas in Table 10-13 vary from 8 to 175 hectares, and the slopes from about 1 in 30 to 1 in 200. Based on this, preliminary drainage channel sizing for concave slopes has been completed for a small, medium and large catchment area, refer Table 10-14.

<table>
<thead>
<tr>
<th>Catchment size</th>
<th>Catchment area (ha)</th>
<th>Bed width (m)</th>
<th>Bed slope (1 in X)</th>
<th>ST AEP 1 in 10 flow (m³/s)</th>
<th>ST AEP 1 in 10 velocity (m/s)</th>
<th>Side protection height (m)</th>
<th>LT AEP 1 in 2 velocity (m/s)</th>
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<td>30</td>
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<td>1.2</td>
<td>1.6</td>
<td>0.9</td>
<td>1.2</td>
</tr>
</tbody>
</table>
In the final landform design the actual slope and catchment area will be used in the calculation of the required channel dimensions.

**Component 3 – Edge Sediment Basins**

The following design criteria were developed for the Ranger final landform sediment basins:

- **Design Operation Flow** – The 1EY⁴ event, e.g. the event likely to be exceeded once a year on average during the establishment phase of the site. This event is used for the sizing of the settling pond area in the sediment basin.

- **Design Capture Efficiency** – 90 percent capture efficiency for particles 0.125 millimetres (very fine sand) and above. The design capture efficiency is also used for the sizing of the settling pond area in the sediment basin.

- **Design Overtopping Flow** – The AEP 1 in 10 event, i.e. the event which has a 10 percent chance of being exceeded in any one year during the establishment phase of the site. Used for the structural design of the rock weir wall for the sediment basin.

The design overtopping flow was set at the AEP 1 in 10 event principally to achieve the design capture efficiency. With the rock weir wall designed to remain largely stable in events up to the AEP 1 in 10 event this will assist in achieving the 90 percent capture efficiency objective.

It is noted that the sediment basins are temporary in nature. At this stage it is unknown how long the stabilisation and monitoring phase will take, but based on the trial landform vegetation plots it appears it will be at least 10 years for the vegetation to become fully mature. Regular monitoring and maintenance will be required throughout this phase. Accumulated sediment will need to be removed, and any identified damage should be repaired promptly.

Consideration was given to setting the design overtopping event to an AEP rarer than the AEP 1 in 10 event. However there are a number of reasons why this is not considered desirable. Firstly maintenance may include an annual disassembly/reassembly of the rock weir, in order to clear sediment blocking flow through the structure. A rock size able to be handled on a regular basis is thus desirable. Secondly, an excessively large rock size may also reduce the amount of check the rock weir provides to lower, more regular flows, which may reduce sediment capture rates.

The key details of the sediment basin design, from downstream to upstream, are as follows:

- A rock apron will be included downstream of the rock weir wall, providing some protection against erosion of the toe of the rock weir, and providing some transition to the natural channel downstream.

- A leaky rock weir wall providing a check on flows, slowing the water down to allow larger particles to settle out in the settling pond upstream.

---

⁴ EY = exceedances per year.
• The rock weir wall will have a 1 in 2 upstream slope, a 1 in 4 (minimum) downstream slope, a crest length (in the direction of flow) of about 3 metres, and a height of about 1.2 metres.

• Rock protection will be included on the sides of the rock weir overflow, limiting the likelihood for flow to erode around the side of the structure.

• A settling pond upstream of the rock weir wall, with the area of this pond sized to achieve the design capture efficiency.

• The settling pond will have an aspect ratio of at least 3 Length to 1 Width and a hydraulic efficiency of at least 0.5 (Healthy Waterways, 2006).

• Depth of the settling pond will be at least 0.6 metres, with approximately another 0.6 metres below that for sediment storage purposes. (This is the reason for the 1.2 metre rock weir height.)

• The bed of the settling pond will be set so that it drains through the rock weir, i.e. no creation of a permanent pond upstream of the rock weir. A nominal slope will be included on the settling pond bed to encourage drainage in a downstream direction. The upstream end of the settling pond will not be more than 0.6 metre above the base of the rock weir wall. (Ideally the settling pond should not be deeply dug into the terrain, so that when the weir is removed a reasonably consistent grade remains on the drainage channel.)

• Rock will be placed on the bed of the settling pond, mainly to act as a marker to tell the maintenance team when to stop removing accumulated sediment. General waste rock may be appropriate for this purpose, as velocities within the settling pond are not expected to be high.

• At the upstream end of the settling pond a transition section may be required in order to match up with the drainage channel topography upstream. Flow velocity through the transition will be checked in detailed design - some rock may be required depending on the slope of the transition section.

• A geotextile will likely be required under the placed rock to reduce the risk of fines being mobilised from the foundation of the leaky rock weir and downstream apron.

An indicative sketch of the key elements of the leaky rock weir sediment basin design is provided in Figure 10-44. Table 10-15 provides a summary of the preliminary settling pond dimensions for each sediment basin and Table 10-16 the preliminary rock sizing, side protection heights and downstream slopes.

The edge sediment basins will be located on local drainage lines at the edge of the final landform terrain, refer Figure 10-45.

The rock weir sediment basins will be decommissioned after the site is considered to be stable.
Figure 10-44: Key elements of the concept sediment basin hydraulic design

Table 10-15: Sediment basin - settling pond sizing

<table>
<thead>
<tr>
<th>Upstream subareas</th>
<th>Catchment area (ha)</th>
<th>ST 1EY flow (m³/s)</th>
<th>Basin area (m²)</th>
<th>Basin width (m)</th>
<th>Basin length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge basins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CJ01,CJ02,CJ03</td>
<td>175</td>
<td>13.7</td>
<td>4097</td>
<td>37</td>
<td>111</td>
</tr>
<tr>
<td>CJ04</td>
<td>44</td>
<td>4.2</td>
<td>1257</td>
<td>20</td>
<td>61</td>
</tr>
<tr>
<td>CJ06</td>
<td>14</td>
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<td>516</td>
<td>13</td>
<td>39</td>
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<tr>
<td>CR06,CR07</td>
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<td>1156</td>
<td>20</td>
<td>59</td>
</tr>
<tr>
<td>CR09,CR10</td>
<td>49</td>
<td>4.5</td>
<td>1359</td>
<td>21</td>
<td>64</td>
</tr>
<tr>
<td>CR11</td>
<td>37</td>
<td>3.7</td>
<td>1098</td>
<td>19</td>
<td>57</td>
</tr>
<tr>
<td>CR13,CR14,CR15</td>
<td>119</td>
<td>9.4</td>
<td>2807</td>
<td>31</td>
<td>92</td>
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<tr>
<td>DJ01,DJ02</td>
<td>81</td>
<td>6.7</td>
<td>2010</td>
<td>26</td>
<td>78</td>
</tr>
<tr>
<td>DJ04,DJ05</td>
<td>60</td>
<td>5.3</td>
<td>1602</td>
<td>23</td>
<td>69</td>
</tr>
<tr>
<td>Upstream subareas</td>
<td>Catchment area (ha)</td>
<td>ST 1EY flow (m³/s)</td>
<td>Basin area (m²)</td>
<td>Basin width (m)</td>
<td>Basin length (m)</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>DJ06</td>
<td>8</td>
<td>1.0</td>
<td>308</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>DJ08</td>
<td>33</td>
<td>3.4</td>
<td>1025</td>
<td>18</td>
<td>55</td>
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<tr>
<td>GU01</td>
<td>29</td>
<td>3.1</td>
<td>930</td>
<td>18</td>
<td>53</td>
</tr>
<tr>
<td>GU03</td>
<td>21</td>
<td>2.4</td>
<td>721</td>
<td>16</td>
<td>47</td>
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<tr>
<td>GU05</td>
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<td>1.5</td>
<td>438</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td>GU06</td>
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<td>1.8</td>
<td>548</td>
<td>14</td>
<td>41</td>
</tr>
<tr>
<td>GU09</td>
<td>10</td>
<td>1.3</td>
<td>395</td>
<td>11</td>
<td>34</td>
</tr>
</tbody>
</table>

**Second layer basins**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CJ01-CJ07</td>
<td>375</td>
<td>19.4</td>
<td>5810</td>
<td>44</td>
<td>132</td>
</tr>
<tr>
<td>CR05-CR16</td>
<td>439</td>
<td>25.1</td>
<td>7542</td>
<td>50</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 10-16: Sediment basin - rock sizing

<table>
<thead>
<tr>
<th>Upstream subareas</th>
<th>ST 1 in 10 AEP flow (m³/s)</th>
<th>Weir width (m)</th>
<th>Downstream weir slope (V:H)</th>
<th>Weir rock d50 (mm)</th>
<th>Side protection height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Edge basins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CJ01,CJ02,CJ03</td>
<td>25.7</td>
<td>37</td>
<td>1:8</td>
<td>350</td>
<td>0.9</td>
</tr>
<tr>
<td>CJ04</td>
<td>7.4</td>
<td>20</td>
<td>1:4</td>
<td>300</td>
<td>0.7</td>
</tr>
<tr>
<td>CJ06</td>
<td>2.9</td>
<td>13</td>
<td>1:4</td>
<td>250</td>
<td>0.6</td>
</tr>
<tr>
<td>CR06,CR07</td>
<td>6.9</td>
<td>20</td>
<td>1:4</td>
<td>300</td>
<td>0.6</td>
</tr>
<tr>
<td>CR09,CR10</td>
<td>8.2</td>
<td>21</td>
<td>1:4</td>
<td>350</td>
<td>0.7</td>
</tr>
<tr>
<td>CR11</td>
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<td>19</td>
<td>1:4</td>
<td>300</td>
<td>0.6</td>
</tr>
<tr>
<td>CR13,CR14,CR15</td>
<td>17.7</td>
<td>31</td>
<td>1:6</td>
<td>350</td>
<td>0.8</td>
</tr>
<tr>
<td>DJ01,DJ02</td>
<td>12.5</td>
<td>26</td>
<td>1:4</td>
<td>350</td>
<td>0.7</td>
</tr>
<tr>
<td>DJ04,DJ05</td>
<td>9.7</td>
<td>23</td>
<td>1:4</td>
<td>300</td>
<td>0.7</td>
</tr>
<tr>
<td>DJ06</td>
<td>1.7</td>
<td>10</td>
<td>1:4</td>
<td>250</td>
<td>0.5</td>
</tr>
<tr>
<td>DJ08</td>
<td>5.9</td>
<td>18</td>
<td>1:4</td>
<td>300</td>
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</tr>
<tr>
<td>GU01</td>
<td>5.4</td>
<td>18</td>
<td>1:4</td>
<td>250</td>
<td>0.6</td>
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<tr>
<td>GU03</td>
<td>4.1</td>
<td>16</td>
<td>1:4</td>
<td>250</td>
<td>0.6</td>
</tr>
<tr>
<td>GU05</td>
<td>2.4</td>
<td>12</td>
<td>1:4</td>
<td>250</td>
<td>0.5</td>
</tr>
<tr>
<td>GU06</td>
<td>3.1</td>
<td>14</td>
<td>1:4</td>
<td>250</td>
<td>0.6</td>
</tr>
<tr>
<td>GU09</td>
<td>2.2</td>
<td>11</td>
<td>1:4</td>
<td>250</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Second layer basins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CJ01-CJ07</td>
<td>36.1</td>
<td>44</td>
<td>1:10</td>
<td>350</td>
<td>0.9</td>
</tr>
<tr>
<td>CR05-CR16</td>
<td>47.0</td>
<td>50</td>
<td>1:10</td>
<td>350</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Component 4 – Second Layer Sediment Basins

Where the terrain permits, a second sediment basin has been positioned further downstream from the final landform, providing a second layer of protection to limit sediment discharge from the site. Includes:

- Two second layer sediment basins on the Coonjimba and Corridor Creek sub-catchments, sited on the location of former constructed waterbodies, refer Table 10-15, Table 10-16 and Figure 10-45.

These basins are designed using a similar approach as the edge sediment basins.
10.8 Revegetation

As identified in Chapter 1, approval of the final landform will be subject to a standalone assessment via the MTC. A separate application detailing all components of the revegetation plan is scheduled to be submitted to the MTC in 2018 (refer Chapter 1, Section 1.4.3 and Appendix 1.2). The information provided in this section provides an overview of current revegetation plan based studies completed to date.

There is approximately 950 hectares of land to rehabilitate and revegetate for the successful closure of Ranger mine, including 759 hectares of waste rock covered area. As discussed previously, assessments of radiation risk and chemical contamination risk will determine whether the LAAs (approximately 200 hectares) will need remediation before revegetation.

The revegetation works include three broad components:

- **Site preparation** – includes preparation of the ground surface (surface ripping and cultivation):

  To achieve a successful and sustainable revegetation on waste rock growth medium (substrate) it was proposed that a layer 4 to 7 metre thick waste rock is required to establish adequate plant available water (refer Chapter 7, Section 7.3.5).

  Reconstruction of the plant growth medium zone was discussed previously in Section 10.7.7. Basically, a layer of growth medium made up of either: a) entirely waste rock; b) waste rock over natural ground (ripped if compacted); or c) entirely natural soil, will be required to achieve successful revegetation. The latter two options where natural soils occur as part of the media are assumed to have sufficient plant available water to support sustainable revegetation.

  The requirement of the 4 to 7 metre thick waste rock material to ensure adequate water holding capacity in the substrate, only applies to the waste rock only scenario (a). This growth medium (i.e. the uppermost layer of the reconstructed landform) will be predominantly constructed by paddock dumping 1 to 2 layers of waste rock. Layer(s) of partial compaction resulting from the movement of the heavy vehicles will further improve the water holding capacity of the required plant growth medium zone.

  As outlined above, underlying compacted natural ground within the required growth medium zone will be deep ripped as detailed in Section 10.7.7.

  As outlined in Section 10.7.4, ERA are currently undertaking an assessment to determine the best method for remediation of the tailings dam contaminated material, prior to revegetation of the reshaped area.

- **Revegetation** – the establishment (planting seedlings supplemented by direct seeding) and management of plants on disturbed sites where the natural recruitment of vegetation is unlikely to satisfy closure criteria.

- **Maintenance and monitoring of the revegetation** (discussed in Chapter 11, Section 11.5).
10.8.1 Revegetation Closure Objectives and Risks

The closure objectives and/or outcomes relevant to revegetation of the final landform include (refer Chapter 6):

- F1 – Revegetate the disturbed sites of the RPA using local native plant species.
- F2 to F5 – Species composition and community structure is similar to adjacent areas of KNP.
- F6 to F13 – Long term, viable ecosystem requiring maintenance similar to adjacent areas of KNP.
- C8 to C11 – Traditional owners are observing improvement in the progression of revegetation on the landform.
- C12 to C13 – Traditional owners are observing improvement in biodiversity on the landform.

The closure strategy for revegetation outlined further in this section, has been designed to meet these objectives and mitigate identified environmental risks, described in Chapter 9 and Appendix 9.1.

**TB2-01: Consolidated tailings level impacts revegetation success in Pit 3 (Class I, low) and TB2-02: Consolidated tailings level impacts revegetation success in Pit 1(Class I, low)**

As outlined previously, all tailings have been placed into the mined out pit as required by L2. The potential for consolidated tailings in the pits to affect the revegetation has been identified as a Class I (low) risk for both pits.

On the final landform, the thickness of the waste rock cover over Pit 1 and Pit 3 is greater than the typical root zone/depths and is of sufficient thickness to support adequate plant available water (refer Chapter 7, Sections 7.3.5). For example, the average thickness of the final waste rock cap over Pit 1 is greater than 10 metres compared to Pit 3, which is between 35 and 40 metres. In addition, plant species selection and distribution for the pit areas, and for the remainder of the final landform will be informed by the results of the trial landform; plants being chosen based on topographic and predicted edaphic conditions (refer Section 10.8.3.1 and Chapter 7, Section 7.5.1).

**TB2-03: Insufficient volume or quality of viable seed stock available for whole of site revegetation (Class II, moderate)**

The importance of the seed collection program cannot be understated. Kakadu Native Plants Pty Ltd has submitted a permit and an environmental impact assessment to collect seed from within Kakadu National Park, which has recently undergone public review and comment. Seeds are harvested primarily by hand by a small, local indigenous workforce across a seed collection zone of approximately 6,600 square kilometres. The large size of the collection zone enables collection of a wide range of genetically diverse, locally sourced plants for use in large-scale revegetation activities. Seed collection practices are such that plants are protected from consecutive years’ harvesting through the use of GIS and Bininj regional knowledge, thereby protecting and maintaining the genetic diversity of the native flora and fauna of the park.
TB2-04: Low plant propagation success in the nursery (Class III, high) and TB2-05: Low plant survival rates in the field during establishment and vegetation decline at mature stage (Class III, high) and TB2-06: Inability to plant-out landform within timeframe (Class III, high).

Chapter 9, Section 9.4.5 outlines how the proposed revegetation strategy and controls have been developed to mitigate these risks. TB2-04 is also a potential cause for risk TB2-06; the controls associated with this risk are also discussed in Chapter 9, Section 9.4.5.

Mitigations to manage the estimated environmental impacts are subject to continual refinement and include all engineered controls. Key elements of the design are:

- A revegetation strategy informed by the trial landform studies and other onsite revegetation trials (Chapter 7, Section 7.6), supplemented by expert seed collection and propagation knowledge and implementation provided by long term contractors Kakadu Native Plants Pty Ltd.

- Implementation of a multifaceted approach to the backfill and landform construction/contouring that includes subsurface compaction layers to enhance water availability, partial/selective contour ripping to promote surface roughness, infiltration and local accumulation of the litters and fines.

10.8.2 Site Preparation

To capture resources (e.g. water, fine sediments, seeds, litters/organic matters, nutrients, etc) close to plants; to create micro habitats for seed germination and ground dwelling fauna; and to reduce erosion and facilitate water infiltration to deeper rooting zone, the finished waste rock final landform surface will be ripped along the contour.

10.8.2.1 Surface Ripping and Cultivation

Rip lines will be installed approximately 4 metres apart and to an approximate depth of 0.5 metres using a dozer with a single tine. This spacing is consistent with the recommendations of the flood study (refer to 10.7.8) and is important for the safe operation of the excavator and all-terrain vehicles used to facilitate planting. The proposed rip line spacing also helps to meet the cultural criterion (C3) of constructing a traversable final landform (refer Section 10.7.7).

Tubestock will be planted between the rip lines, at sites pre-cultivated by a "Rotree" cultivator (or similar) attached to an excavator (Figure 10-46). Cultivated holes for planting seedlings will be distributed such that the resulting vegetation will look 'natural' (e.g. Figure 10-47). Site cultivating down to about 1 metre will inevitably bring some rocks to the surface, but they will be close to the tree stems and should therefore not interfere with people traversing the landform.

For a comparison, the area on the current trial landform constructed using only waste rock was ripped 2 metres apart to a depth of approximately 0.5 metres (Figure 10-47). It is expected that on the final landform the 'flat' surface area between rip lines will be about double that on the trial landform. Although some trees will be planted within this space, there will still be plenty of flat, traversable areas. Figure 10-47b (Saynor et al., 2012) shows the importance of rip lines...
at increasing the water resident time on the landform surface, thus increasing the amount of water to infiltrate to below surface and deeper into the rooting zone.

Service tracks approximately 200 metres apart will be established on the final landform to facilitate activities, such as planting, irrigation, fire and weed management, and post planting monitoring. The tracks will also provide pathways for easy traversing.

Figure 10-46: "Rotree" cultivator attached to a 20 tonne environment excavator (at Jabiluka)
Figure 10-47: View of the tree distribution and also the flat ground space among trees at Jabiluka revegetation site, Feb 2016. (Note that the surface at Ranger will be rougher due to waste rock substrate.)

Figure 10-48: Photos (a, b) of the erosion plot 1 (dry) and plot 2 (wet) on the trial landform. With larger spacing between rip lines, there will be more flat area for traversing than shown above.

10.8.3 Revegetation Strategy and Implementation

Revegetation will be guided by ERA's revegetation strategy (Appendix 10.2) that is developed based on the learnings from over 30 years of revegetation, understanding of the analogue vegetation and especially the findings from the revegetation on the trial landform since 2009 (refer Chapter 7, Sections 7.3 and 7.6). Ongoing monitoring of the trial landform revegetation will continue to inform the final approach to revegetation of the RPA.
Site revegetation plans will be prepared for each area to be revegetated. These plans will detail all revegetation activities, how these activities will be implemented and the schedule of implementation over a five year period. Included will also be maps, field layout plans, monitoring and reporting requirements for each area. The plans will also include any on-ground activities required with respect to the identification of planting boundaries, planting configuration and location of species, monitoring plots and service tracks. This approach will ensure that lessons learnt from previous revegetation trials are incorporated in the future revegetation activities.

The overarching approach to revegetation is outlined below.

### 10.8.3.1 Species Selection and Plant Distribution

A generic revegetation species list, including density of species in the natural analogue areas was presented in Table 7-27, in Chapter 7, Section 7.6.3. For revegetation of the final landform, the initial planting density will be about 1,000 plants (trees and shrubs) per hectare, with provision for a further 200 plants per hectare, for infill planting depending on the survival results 6-12 months after initial planting. The aim is to achieve a long term density and composition that is similar to the woodland of the surrounding area, and to establish a functional and sustainable vegetated landform.

Furthermore, based on the learnings from analogue vegetation studies and the trial landform (Chapter 7, Sections 7.3 and 7.6), the selection and distribution of vegetation (e.g. species, composition and density) across the final landform will be established according to micro-ecology of the site – i.e. the topography (crest, mid slope, low slope and toe of the landform, drainage channel, and riparian zone) and properties of the underlying substrate. A general design is presented in Table 10-17. Further to this cultural aspects will be taken into account for the distribution and location of species across the landform.

Table 10-17: General design – species selection and plant distribution

<table>
<thead>
<tr>
<th>Topography/underlying substrate</th>
<th>Broad vegetation community</th>
<th>Dominant and/or distinguishing tree or shrub species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest</td>
<td>Mixed eucalypt woodland or Dry mixed eucalypt woodland</td>
<td><em>Eucalyptus tetrodonta, E. phoenicea, E. tintinnans, Corymbia dijuncta, C. porrecta, Corymbia bleeseri, Acacia mimula, E. miniata (less), Terminalia ferdinandiana, Xanthostemon paradoxxus, Cochlospermum fraseri, Livistona humilis, C. foelscheana, E. tectifica, Terminalia pterocarya, Corymbia dunnlopana (formerly C. setosa), Erythrophleum chlorostachys; Grevillea decurrens, Grevillea pteridifolia</em></td>
</tr>
<tr>
<td>Convex slope</td>
<td>Dry mixed eucalypt woodland</td>
<td><em>E. tectifica, C. foelscheana, E. tetrodonta, E. tintinnans, E. phoenicea, Terminalia pterocarya, Acacia mimula, X. paradoxxus</em></td>
</tr>
<tr>
<td>Concave slope</td>
<td>Mixed eucalypt woodland</td>
<td><em>Acacia mimula, E. tetrodonta, C. porrecta, E. miniata, Xanthostemon paradoxxus, Terminalia ferdinandiana, C. foelscheana, C.</em></td>
</tr>
<tr>
<td>Topography/underlying substrate</td>
<td>Broad vegetation community</td>
<td>Dominant and/or distinguishing tree or shrub species</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Toes of the landform</td>
<td>Low land woodland species</td>
<td>Eucalyptus latifolia, Pandanus spiralis, Erythrophleum chlorostachys, Livistona inermis, Syzygium eucalyptoides subsp. bleeseri, Planchonia careya</td>
</tr>
<tr>
<td>Drainage channel</td>
<td>Resilient to erosive environment</td>
<td>Mainly deciduous species and resilient to erosional slope; need more investigation and trials. Could try Cochlospermum fraseri, Calytrix extipulata, Calytrix achaeta</td>
</tr>
<tr>
<td>Riparian zones which are potentially high in solute concentration</td>
<td>Melaleuca woodland</td>
<td>Species similar to those around RP1, including Melaleuca viridiflora, Pandanus spiralis, Planchonia careya</td>
</tr>
</tbody>
</table>

A list of understorey species has been established based on previous local trials and seed biology studies (Bellairs & McDowell, 2012) for an ongoing study (Lu, 2017). This list is provided in Table 10-18 and will be refined based on the outcomes of the study.

Table 10-18: Potential understorey grass and legume species (Lu, 2017)

<table>
<thead>
<tr>
<th>Genus and species</th>
<th>Lifeform</th>
<th>Size (metres)</th>
<th>Notes</th>
<th>Substrate</th>
</tr>
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<td>Genus and species</td>
<td>Lifeform</td>
<td>Size (metres)</td>
<td>Notes</td>
<td>Substrate</td>
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**LEGUMES – Herbs (8)**

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<td>Galactia tenuiflora</td>
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<td>Tephrosia nematophylla</td>
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<td>Uraria lagopodioides</td>
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<td>prostrate</td>
<td>Uraria</td>
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<tr>
<td>Vigna lanceolata</td>
<td>Perennial herb</td>
<td>vine</td>
<td>Vigna</td>
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<td>Vigna vexillata</td>
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**LEGUMES – shrubs (6)**

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<td>Galactia megalophylla</td>
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<td>Indigofera</td>
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<td>Senna leptocladia</td>
<td>Shrub</td>
<td>2.0</td>
<td>Senna, Cassia</td>
<td>Sandstone hills</td>
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<td>Tephrosia polzyga</td>
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<td>Tephrosia reticulata</td>
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<td>&gt;0.4</td>
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### 10.8.3.2 Provision of Seeds and Seedlings

ERA has been working extensively with Kakadu Native Plants Pty Ltd, a locally owned and run indigenous supplier, to provide seedlings for much of the revegetation projects that have occurred both at Ranger and Jabiluka over the past 15 years. This supplier has extensive expertise in local plants including seed biology, propagation, revegetation and weed and fire management.

Seed collection of agreed local native species provided in the species list in Table 7.27, in Chapter 7, Section 7.6.3 will be acquired from Kakadu Native Plants Pty Ltd. Kakadu Native Plants Pty Ltd will raise the tubestock using biodegradable pots. In later years when demand intensifies, it may be necessary to use additional, approved nurseries to raise tubestock to supplement the tubestock production; Greening Australia has been engaged in discussions regarding native plant supplies.
10.8.3.3 Tree and Shrub Planting, and Establishment of Understorey

To ensure planting sites are prepared to a condition which will achieve high plant survival rates and rapid early growth, the following will be undertaken:

- Planting holes will be cultivated mechanically (Section 10.8.2).
- All sites will be free of weeds at the time of planting (the dimensions to be specified in each site revegetation plan); pre-planting residual herbicide may be used, and a weed-control buffer zone (approximately 200 metres) around the revegetation site will be maintained.
- Handling and planting of seedlings and the application of fertiliser will follow the standard operating procedure.
- Weed control will be undertaken by the application of knockdown, selective and residual herbicides in accordance with the standard operating procedure.
- Tubestock planted on waste rock will be watered by irrigation (e.g. stadium impact sprinklers); tubestock planted in LAAs will be watered using watering cart.
- Watering of tubestock will be undertaken at a frequency and for a duration that minimises soil moisture deficit for newly planted seedlings. In order to encourage the plants to develop deep root systems for drought resilience and anchorage against strong wind, the revegetation will not be continually irrigated for an extended period of time.

Once the overstorey and mid-storey are fully established, seed will be directly sown onto the final landform to facilitate the development of the understorey. There is opportunity for introducing low fuel, low vigour native ground cover species, especially legumes, as soon as possible.

10.9 Contingencies

The Ranger closure project has a number of contingency options that are available should the preferred option either cannot be implemented or is found to not achieve the desired outcome. The majority of these options have been discussed in Chapter 8 as part of the best practical technology assessment with some specifics are outlined further in this section.

In addition to these contingency options, ERA is committed to completing rehabilitation and the achievement of the environmental requirements. Current the closure schedule indicates that this can be completed by the closure date of January 2026. (If for some reason this changes then the contingency will be to apply to allow rehabilitation activities to continue past this date.)

10.9.1 Water Treatment

The final volume of process water that will require treatment prior to the end of closure is directly dependent upon rainfall. Should a number of higher than predicted wet seasons occur, in particular late in the closure project, then additional water treatment capacity may be required in order to meet the final closure date in January 2026.
In the case of a very large late wet season, ERA may not be able to treat all the process water prior to the final closure date. In this case an application would be submitted to the MTC requesting that water treatment infrastructure, including any ponds, be allowed to remain on site for a period to allow for completion of this treatment. This would be requested under the current Clause 2.3 of the ERs.

Where all the major stakeholders agree, a facility connected with Ranger may remain in the Ranger Project Area following the termination of the Authority, provided that adequate provision is made for eventual rehabilitation of the affected area consistent with principles for rehabilitation set out in subclauses 2.1, 2.2 and 3.1.

Current contingencies for additional process water treatment include expansions to the current brine concentrator and recommissioning and expanding the current high density sludge plant.

10.9.2 Tailings Transfer

As discussed in Section 10.4 the current dredge is not performing as expected and a dredging improvement plan has been activated. This includes the assessment of an option for a second dredge. ERA has recently implemented a study into this that will be completed during 2018. The outcomes of this study will be included in the next update of the MCP.

10.9.3 Brine Injection

The brine concentrator produces a concentrated brine stream that is currently injected into the Pit 3 underfill voids. This brine injection occurs into a 5 injections wells installed directly into the underfill (refer Section 10.2). In the case that all the injection wells scale up or fail then ERA's primary contingency is the installation of directionally drilled wells from the edge of Pit 3 into the underfill. To provide confidence in this option ERA completed a pilot directionally drill hole during the ITWC prefeasibility study.

Should injecting brine into the Pit 3 underfill cease to be a viable option then there are no other similar injection options due to the following:

- Pit 1 lacks an underfill layer.
- No deep isolated porous formations have been identified at the Ranger site.
- The existing Ranger 3 Deeps decline volume of 117,605 cubic metres precludes it from being an acceptable storage.

As part of the best practical technology assessment, a number of alternative brine disposal options were reviewed and assessed. If a full failure of the brine injection system occurs, or the underfill void is filled then one of the following options, from the assessment, will be progressed.
Brine pH, composition and salt concentration prevents it being discharged into a local water way, transported to an off-site repository or sold to another organisation. Therefore, the only potential alternative disposal option remaining is to convert the brine solution into a solid by crystallisation, calcination, precipitation or cementation and then co-disposing with the Pit 3 tailings or backfill. Should one of these alternatives be required further assessment would be required followed by application for approval from the MTC.

10.9.4 Tubestock Production

ERA has two contingency options to mitigate potential issues associated with tubestock production:

- Option 1 is to reinstate the Ranger nursery, situated on the site of the current exploration yard, north of Jabiru East LAA. This will ensure tubestock production capacity of between 500,000 and 700,000 stems per annum.

- Option 2: Discussions have been held between ERA and Greening Australia to engage their services to grow tubestock from seeds provided by ERA, should the need arise. Under this option, Greening Australia would be required to supply tubestock in accordance with the intended production procedures (e.g. soilless substrate, mycorrhiza inoculation, fertilising, etc).
10.10 References


Bellairs, S & McDowell, M. 2012. *Seed biology research to optimise germination of local native species to support the rehabilitation of the Ranger mine site (Final Report 2006-2011)* School of Environmental and Life Sciences, Charles Darwin University, Darwin. February 2012, p 287.


Fitton Tailings Consultants Pty Ltd. 2015. *Pit 1, Final Pre-load Works, Design Report Ref 1504.02R01 Rev 0*. Victoria. 7 September 2015, p 36.


Lu, P. 2017. *Understorey establishment on waste rock at the Ranger mine site*. In collaboration with Sean Bellairs (Charles Darwin University) and Peter Christophersen (Kakadu Native Plants Pty Ltd), Darwin. 16 May 2017, ARRTC presentation, p 9.


APPENDIX 10.1 SCHEDULE OF ACTIVITIES (Q4 2017 – 2020)
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<td>Dredge northern ramp</td>
<td>8-Dec-17</td>
<td>22-Aug-18</td>
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<td>Wall clean-up and removal of foreign objects</td>
<td>20-Feb-18</td>
<td>18-Jan-19</td>
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APPENDIX 10.2 REVEGETATION STRATEGY
Revegetation Needs

There are approximately 950 hectares of surface area to be rehabilitated and revegetated for the successful closure of Ranger mine. This includes 759 hectares of waste rock covered area with the remaining 191 hectares being disturbed natural savanna areas with "natural soil".

Revegetation Strategy

1. Develop different revegetation strategies for different land surface: waste rock covered landform vs disturbed natural land with a 'soil' layer (e.g. land application areas).

Re-established vegetation on the disturbed natural land (e.g. LAAs) will be similar to vegetation in close proximity of the area; while re-established vegetation on the waste rock covered landform will be similar to the vegetation of the "broad surrounding areas". Despite the "novel" ground conditions (e.g. a waste rock substrate), which are not present in the natural environment, re-established vegetation will still be broadly similar to the adjacent Kakadu National Park.

Although the disturbed natural land with soil (e.g. the LAAs) might seem to have all the physical and chemical characteristics of the natural soil for plant growth, revegetation in those areas presents its own challenges, particularly the threats of "weeds" (including local native aggressive acacias and spear grasses), fire, herbivores and competition for resources from surrounding vegetation. The strategy below mostly applies to the waste rock covered final landform and disturbed natural ground (e.g. LAAs).

2. Identify the likely physical and chemical constraints of the final landform that will influence both the initial establishment and the long-term growth, development and functioning of revegetated plant communities.

This concentrates on characterising geomorphic and hydrological features, in different facets of the landform, that will determine (a) seasonal water availability for vegetation (e.g. infiltration, run-off and internal drainage characteristics; profile moisture storage capacity), and (b) chemical fertility and any potential phytotoxicity in the waste rock substrate, and/or materials below (e.g., floor of the former tailings dam).

ERA's water balance study of the waste-rock-only cover (Ranger trial landform) indicates that the water holding capacity of the waste rock substrate is lower than natural soil at analogue sites. A waste rock cover layer of 4 – 7 metre thick would provide sufficient plant available water to a revegetation (Chapter 7, Section 7.3.5).

Although roots will potentially be capable of exploring deeper rock substrates (e.g. >4 metres), low water holding capacity near surface (1 – 2 metres) could affect the initial establishment of the vegetation. Evidence from the trial landform indicates that subsurface and surface preparation methods such as partial compaction of subsurface layers as a result of paddock dumping and heavy machine movement and rip lines will improve the water holding capacity of the waste rock substrate. However the competing needs for revegetation, solute generation and cultural criteria shall be carefully considered and optimised.
3. **Maximise surface roughness and "patchiness" during site preparation.**

The aim is to create a heterogeneous land surface that has (a) localised run-on/ runoff zones for control and capture of sediment, water and nutrients, and (b) microhabitats for seedling establishment and litter accumulation/decomposition, to encourage natural flora recruitment and ground dwelling fauna.

Traditional owners have concerns about rough surfaces left after landform formation for traversing country. However, large size rocks brought to the surface during ripping (creating useful habitat structure) is purported to be less a problem than rip lines themselves.

Further negotiation is required; for example, land owners may be satisfied with the knowledge that by the time vegetation is established (10 – 20 years), weathering of rocks and smoothing out of the rip lines will have occurred. Also, a recent flood study completed for ERA indicates the preferred spacing between rips lines is 2 – 4 metres compared to the 2 metre intervals adopted on the trial landform (Water Solutions, 2017). The proposed 4 m spacing would provide greater ease of traversing. Pitting of the surface during planting cultivation could partially reduce surface runoff.

4. **Identify and describe vegetation types that are ecologically and technically realistic target endpoints (or ‘habitats’), for different facets of the final landform, based on the likely physical and chemical environments that will be created.**

The identification of vegetation types has so far mainly be based on surveys in the surrounding natural landscape that are potential geomorphic analogues of those created on the final landform (based on the reasonable assumption that many of the environmental determinants of vegetation distribution will be similar in these settings). Such work has been completed by joint ERA/ERISS studies and is described in Chapter 7, Section 7.6.

Although the majority of the landform will be revegetated to open Eucalyptus woodland vegetation type, it still requires refinement of some of the target vegetation species once the design features of the final landform are finalised (e.g. for drainage lines, or for potentially thinly covered and/or waterlogged areas such as the former tailings dam floor). Design of the vegetation community structure (species and density) shall also take account of the geochemical property of the substrate (Brennan, 2005).

5. **Use seed collected within Kakadu National Park for all species.**

The use of seed collected from Kakadu National Park ensures that the genetic make-up of the revegetation is consistent with local populations or "provenances" of each individual species and meanwhile provides buffer for adapting to future global change (see Chapter 7, Section 7.6.2).

The focus is on initially establishing a floristic composition that is dominated by a diverse range of the long-lived ‘framework’ species. It is essential that framework species dominate the initial floristic composition of the revegetation to promote maximum opportunity to establish, compete effectively, and capture much of the site nutrient and plant-available water resources. These species give the revegetation its longer term stability, predictability and fire resistance. It is desirable to establish a diverse range of these taxa and to include representatives in these taxa that are characteristic of different strata (canopy, mid and ground layers). If these species
do not dominate the floristic composition at the end of the first dry season, active management will be required to deflect the vegetation back towards a developmental trajectory that has a predictable long-term result.

6. **Introduce a range of mycorrhizal fungi from local environments to aid in the establishment of the framework species.**

This is especially important where vegetation is being established directly into waste rock. An effective method has been to incorporate mycorrhizal fungi in the potting mix for the tube stock propagated in the nursery.

7. **Include non-aggressive local native acacias but avoid the use of high densities of aggressive Acacia species.**

The planting or sowing of larger stature Acacia species (e.g. *A. latecence*) will be limited due to their suppressive effects on the slower-growing framework species, which are much less competitive until they have established underground regenerative structures. However, low densities of small-stature Acacias (e.g. *A. mimula* and *A. gonocarpa*) from the ground stratum of natural woodlands, will be included because of their contribution to the site’s long-term nitrogen economy.

*A. holosericea* although a desirable species culturally (Garde, 2015), will not be planted due to its aggressiveness. Due to its natural presence in the surround area, natural recruitment could occur in the revegetated area. If natural recruitment occurs in large numbers, culling might be needed to control the competition. Native legume plants will be trialled by direct seeding to improve nitrogen level in the nitrogen-poor substrate.

8. **Avoid actively re-introducing grasses and vigorous herbaceous species in the first 5 years.**

Highly vigorous native grasses and herbs will not be introduced on the final landform as they have the potential to outcompete with the slower to establish framework species. Only low vigour native grasses in initially low densities will be introduced by direct seeding. A range of species typical of the analogue habitats will be used. ERA will consider introducing as many legume species as possible during the early establishment of the understorey species on the final landform.

9. **Use nursery-grown planting stock to establish the framework species.**

Based on current technology this will (a) significantly reduce the risk of planting failure associated with erratic rainfall and extreme temperatures, (b) accelerate the speed of vegetation development and (c) overcome the high unpredictability of establishing a final revegetated landform from current direct seeding techniques. However, if reliable and predictable direct seeding methods can be achieved for some species, these techniques will be used in combination with planting of nursery tubestock.
10. Apply fertilisers in a strategic manner using formulations and delivery methods that maximise their effectiveness.

Slow release fertiliser will be incorporated into the potting media for all planting stock, at rates that provide a significant ‘residual’ effect on growth after planting out. Some fertiliser will also be applied during the first wet season to facilitate more rapid seedling growth, especially if direct seeding is used; however this fertiliser will not be of a highly soluble formulation. Additional fertiliser will be applied in the subsequent 2 to 4 years to ensure vegetation structural development is not inhibited and that sufficient site nutrient recapitalisation occurs.

11. Provide irrigation to new planted/sown plants.

Irrigation of new planted tubestock/direct seeded plants ensures good plant survival rates across all species during dry season and even during erratic wet season conditions. However, irrigation will only be applied for 6 months or so, to avoid dependence of trees on a consistent watering regime. Limited watering also allows trees to develop deep root systems to withstand strong prevailing winds known to occur in the region.

12. Rigorously control potentially threatening weed species, both on and in proximity to the final landform.

Weed is the most critical driver causing failure of the reconstruction of the ecosystem. A buffer zone around the final landform will be established also the current ERA weed management practices will continue on the final landform during the post decommissioning and stabilisation phase.

13. Exclude fire from the revegetation areas during the first 5 – 8 years after establishment.

Dependent on the stage of development in the revegetation (e.g. framework species achieving a minimum girth size of 6 centimetres), low intensity fire could be introduced in years 5 – 8 both to reduce fuel loads and to "adapt" the framework species to future fire regimes.

Due to the low quantity of fines and organic maters at surface of the waste rock substrate, it is unlikely a substantial amount of understorey would be established based on the observation on the trial landform.

14. Design and implement a rigorous and scientifically-based strategy for ongoing evaluation of the performance of the revegetation.

Such a monitoring strategy will provide measurable criteria and associated auditable standards that can be used progressively during the revegetation process to (a) assess progress towards the desired outcomes, (b) to identify problems and, if necessary, initiate appropriate management interventions and (c) demonstrate compliance, or otherwise, against relevant closure and lease relinquishment criteria. The preliminary monitoring strategy is described in Chapter 11, Section 11.5, which continue to be updated in future iterations of the Ranger Mine Closure Plan.
REFERENCES

