ERA Energy Resources of Australia Ltd

Chapter 11 Closure Monitoring and Maintenance

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11 CLOSURE MONITORING AND MAINTENANCE

This section provides the monitoring program for the Ranger mine across the six closure themes described in Chapter 6: landform; radiation; water and sediment; flora and fauna; cultural; and soil.

Within each theme, is a description of the proposed closure monitoring that covers the stabilisation and monitoring phase (see below). The proposed monitoring programs build on the existing, extensive monitoring regimes currently established for the mining operations at Ranger. The stabilisation phase monitoring regime will be required to assess rehabilitation success with respect to protection of potentially impacted ecosystems and environmental values.

Both the monitoring program and closure criteria may undergo further revision as the outcomes of studies and/or new information become available. Amendments will be incorporated into future iterations of the MCP. Therefore, this chapter is a preliminary indication of the breadth of the monitoring program that will be implemented on the Ranger Project Area (RPA) during the stabilisation and monitoring phase, post January 2026.

11.1 Stabilisation and Monitoring Phase Overview

The stabilisation and monitoring phase is the post-decommissioning timeframe (after January 2026), where the site is progressing towards the development of a long-term stable landform and viable ecosystem, that meets the closure objectives. This phase allows an adaptive management approach to site rehabilitation and closure, whereby the monitoring program will provide ongoing feedback on the performance of the site rehabilitation to identify any issues and inform maintenance activities. However, under the current legislative framework ERA's access to the RPA ceases on 8 January 2026. Discussions are currently underway with key stakeholders to enable ongoing access to the RPA post 2026, in order to undertake minor remedial works and monitoring.

As outlined above, this phase commences in 2026 and will continue until the monitoring program demonstrates that the site has met the required closure objectives and relinquishment of the RPA is achieved. As the length of this time is unknown, ERA have currently assumed 25 years of monitoring.

This phase may require initial materials management as the landform settles over time, subsidence and erosion occur, and the revegetation becomes self-sustaining. During this phase, there may be a requirement to remove passive water management sumps/traps, once they are no longer required. Typical remedial management practices in this phase are described in Table 11-1).

Table 11-1: Examples of remedial work that may be triggered during the stabilisation and monitoring phase

Action	Description
Minor earthworks	• Will be undertaken to repair any erosion or other stability issues, identified by landform monitoring. • May include placement of rock armouring, or stabilising disturbed areas.
Infill planting	• Will be required if more that 65% mortality occurs in the first 6 months; may also be required when an unplanned large-scale event such as a fire or cyclone causes significant additional mortality. • To improve density, and/or species diversity.
Weed control	• Weeds may compete with and smother tubestock, or may increase the risk of fire, and thus increase mortality. • Revegetation monitoring will record if any weed infestations occur on the rehabilitation. • Weed control methods will be species specific, with the most effective controls determined from ERA experience and input from specialists. Weeds are likely to be controlled by a combination of chemical and physical methods (including application of residual and short acting chemicals, seed head cutting and burning).
Fire management	• Fire is a part of the traditional land management of KNP but is a risk to the initial development of rehabilitation; and therefore needs to be controlled. • In an effort to avoid fire in revegetated areas, no understorey will be planted initially; and fire will be excluded for the first 5-7 years until framework species have achieved a minimum diameter of 6 cm. Subsequent to this period, low intensity 'cool burns' will be promoted in the wet and early dry seasons.
Application of fertiliser	• Some of the growth media to be used in rehabilitation may be deficient in nutrients. In order to provide optimum growing conditions, tubestock will be planted with fertiliser pellets and approximately 6-12 months later, a second application of fertiliser will be applied via surface broadcasting. • Monitoring will determine if plants develop signs of nutrient deficiency. • Further fertilisation may be required.
Pest control	• High levels of insect damage can cause plant mortality; young plants may also be impacted by native and feral vertebrate fauna (e.g. wallabies, pigs etc.) • Monitoring of the condition of revegetation will identify significant impacts from pest. • Management of pests may involve spraying with insecticide or other insect treatments and direct management of feral vertebrate fauna (carried-out in accordance with ERA's Fauna Management Plan and in accordance with relevant licences). Fencing may be considered however fencing is costly, requires maintenance, and

Action	Description
	may inhibit the recruitment of native species of benefit to the rehabilitation.
Water management	• Passive water and sediment management ponds will require regular maintenance. • Structures may also need to be decommissioned when no longer required. • Irrigation installed to assist growth of tubestock will require regular maintenance. • Irrigation infrastructure will be decommissioned and removed when ono longer required.

11.2 Landform Monitoring

A number of landform studies have been undertaken to address key closure issues and risks, and inform the design parameters of the final landform. In particular, the construction of the trial landform in 2009 and subsequent studies used to validate design attributes such as landform stability, erosion, topography and visual amenity; and inform the current landform model predictions (refer Chapter 7, Sections 7.3 and 7.5).

The outcomes of these studies have resulted in a final landform topography that incorporates low elevation and slopes to enhance landform stability and visual aesthetics by blending with the surrounding landscape. The focus of the closure monitoring program will be on the surface of the landform and run-off of surface material to onsite sediment basin traps that will direct water to offsite waterways. Monitoring to measure progress towards landform closure criteria will comprise:

- Final landform topography will be documented after completion. It is expected that either airborne and/or terrestrial Lidar (or equivalent) technology will be used to survey and capture the final landform topography. If required, this topography can be used to rerun the 10,000 year landscape evolution model. Specific details on which Lidar techniques will be used have yet to be determined; new information will be incorporated into future iterations of the MCP.
- Post wet season inspections and erosion assessments of the landform to monitor areas of significant erosion to inform maintenance activities.
- Post wet season inspections of designed drainage channels to confirm that they remain in good condition and are preforming as expected.
- Post wet season inspections for bedload in Magela and Gulungul Creeks to ensure that there is no significant bedload coming off the site.
- Continuous turbidity monitoring in Magela and Gulungul Creeks along with regular annual suspended sediment sampling to verify the turbidity/suspended sediment relationship. Turbidity will then be used to determine event based suspended sediment season load. This should trend towards background loads over time.

11.3 Water and Sediment Monitoring

Historical water management data spanning over 30 years underpins the proposed surface water and sediment monitoring program to be established during the stabilisation phase, which is described below.

11.3.1 Surface Water and Sediment

Surface water monitoring is currently undertaken at a number of sites within and outside the RPA (Figure 11-1). Monitoring is undertaken by ERA, SSB and DPIR.

The existing compliance framework involving comparison of water quality between the upstream and mid or downstream gauging sites in Magela and Gulungul creeks will provide the basis to measure the performance of the decommissioned and rehabilitated site. Maintenance of surface water quality past the confluence of the Magela and Gulungul Creeks will ensure protection of the Magela floodplain wetlands. Establishing final surface water and sediment closure criteria is well advanced with water quality parameters and values being established for each of the objectives of this theme (refer Chapter 6, Section 6.4). The existing surface water monitoring program (i.e. weekly grab sampling, continuous monitoring (for data and QA/QC purposes), and event-based sample collection) will initially remain in place for Magela Creek and Gulungul Creek sites with the following changes:

- Monitoring at an additional creek site downstream of the Magela Gulungul confluence.
- Presuming that the monitoring program shows that the surface water quality is conforming/trending to meet closure objectives there will be a progressive transition to:
    - A reduced frequency of grab sampling.
    - Continuous monitoring (of EC and turbidity) only at the upstream sites.
    - A program that can be carried out by a local service provider.

The trigger value system used during the operational phase will be adapted to provide a trigger for investigation and the possible need for maintenance. The current *Action* trigger values for EC and turbidity will be the most likely trigger values to retain for this purpose.

The results from the stabilisation surface water and sediment monitoring program and details of investigations and resulting actions will be reported annually to stakeholders.

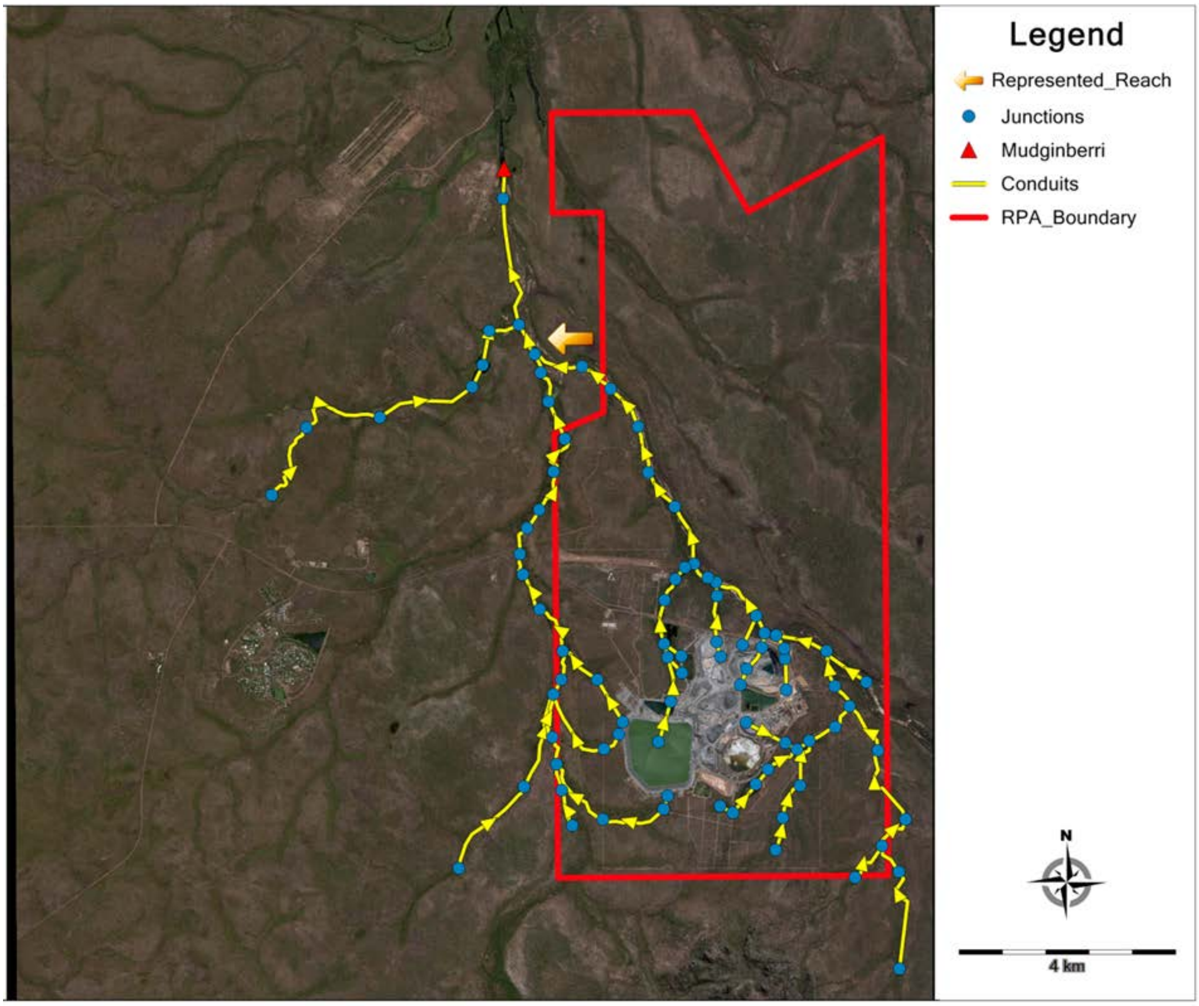

Figure 11-1: Proposed surface water monitoring point (e.g. represented reach) past the Magela Creek and Gulungul Creek confluence

The location for monitoring for the different objectives and outcomes are:

- Downstream of the confluence between Magela and Gulungul Creek, and GCLB for off-site ecosystem protection.
- The current compliance points MG009 and GCLB, just inside the boundary of the RPA, and Coonjimba and Georgetown billabongs, for protection of ecosystems on the RPA.
- Downstream of the confluence between Magela and Gulungul Creek for recreation and drinking water quality.
- On the RPA water quality in Magela and Gulungul Creek and sedimentation in the billabongs will be ALARA.

Monitoring of water quality at all the sites downstream of the decommissioned mine site will also enable early detection of issues that may potentially affect the Magela floodplain further downstream.

The proposed stabilisation monitoring program details are summarised in Table 11-2.

Table 11-2: Parameters and locations for surface water monitoring to assess compliance with closure criteria for each outcome focus

Location	Parameter (grouped by outcome with most restrictive criteria)	Outcome/ environmental value	Frequency
Magela Creek downstream of the Gulungul confluence and GCLB	Turbidity, Mg, U, Mn, NH_3-N, NO_2, NO_3, Total-P, Total-N	Ecosystem protection outside the RPA	Continuous monitoring for EC (Mg) and turbidity. Event based grab sampling. Scheduled grab sampling for other parameters. Initially monthly during the wet season with frequency reduced over time based on performance.
	Mn, SO_4^{2-} Visual clarity and surface films	Diet and recreation*	Scheduled grab sampling, initially monthly during the wet season with frequency reduced over time based on performance.
Gulungul Billabong	U in sediment	Ecosystem protection outside the RPA	Accumulation in sediments limited by U in water criteria. Sample at end of decommissioning to demonstrate achievement.
MG009, GCLB, MCUS, GCC	Turbidity Mg, U, Mn, NH_3-N, NO_2, NO_3,	Ecosystem protection within the RPA	Continuous monitoring for EC (Mg) and turbidity. Event based grab sampling. Scheduled grab sampling for other parameters. Initially weekly with frequency reduced over time based on performance.
Upstream sites	Continuous EC and turbidity will be measured at the upstream creek sites. Data for other parameters from upstream are not relevant to assessing if criteria are met. EC and turbidity data will provide information on natural seasonal fluctuations.		

* NB: All drinking water and recreation parameters have less restrictive criteria than for ecosystem protection.

11.3.2 Groundwater Considerations

Environmental Requirement 2.3 *"… provides for minimum restrictions on the use of the area."* However it was agreed during the Closure Criteria Working Group meeting of 19 August 2008 that groundwater extraction for purposes other than monitoring would not be allowed on the RPA, post closure. The minutes of the meeting state: *"… that a constraint on groundwater abstraction from Ranger operational area and some surrounds will be needed to prevent bores being sunk in areas where water may be unsuitable for use."*

In this context, the primary objective of the closure groundwater monitoring program will be to confirm that measured time series changes to water quality are consistent with the hydrogeological model predictions and that the regional groundwater environment remains protected. The results of solute transport modelling (INTERA 2014a, 2014b) indicate that solutes at depth in the backfilled pits will enter low-permeability hydrogeological units (non-aquifers) and migrate away from solute sources at very low rates. The modelled flux rates from these units to shallow and deep aquifers and surface water bodies are very low. It is thus not appropriate to set concentration-based groundwater closure criteria for these units. Ongoing monitoring of groundwater will provide data to validate these solute transport model predictions and assumptions.

Monitoring 'envelopes' in the four sub-catchments; Gulungul, Coonjimba, Djalkmarra and Corridor Creek, will be progressively refined during decommissioning. The 'envelopes' will comprise new and/or existing monitoring bores.

The overall objective of the groundwater monitoring program is to monitor changes in groundwater head and solute concentrations for comparison against expected changes in the groundwater system (i.e. changes in groundwater heads and flow direction and changes in concentrations of selected solutes). This monitoring regime is intended to demonstrate that solute transport velocities and concentrations are consistent with modelling predictions and that the receiving environment remains protected.

Groundwater monitoring programs have been proposed for both Pit 3 (Djalkmarra catchment) (Simpson *et al.*, 2013) and Pit 1 (Corridor Creek), as a component of the Pit 1 notification (Lu *et al.*, 2009), which received NT and Commonwealth regulatory approval in April and May 2017, respectively. Both programs have been designed to target pathways for transport of solutes into the environment and the various hydrolytic units defined in the groundwater conceptual model. An extra new bore has been proposed for Pit 3 to be installed after completion of backfilling of the waste rock to monitor head and solute concentration changes in the Pit 3 shallow waste rock backfill, which is expected to be a source for solutes of potential concern. This source area monitoring bore is called New Bore 3. The final program will be expanded with continued stakeholder engagement and advice from INTERA.

Both programs include the installation of new bore but have utilised existing bores where possible. The location and screening parameters of the proposed Pit 1 and Pit 3 monitoring bores are provided in Table 11-3, Figure 11-2 and Figure 11-3.

Table 11-3: Parameters for proposed and existing monitoring bores for Pit 1 and Pit 3 closure

Bore ID	Easting (MGA94)	Northing (MGA94)	Depth (m)	Screen from (m)	Screen to (m)
Proposed Bore 1 (Pit 1)	273962.9	8596487.9	35*	2	35
Proposed Bore 2 (Pit 1)	273965	8595950	8*	2	8
Proposed Bore 3 (Pit 1)	274174	8596230	35*	2	35
MB-L	273933.071	8595934.988	50	14	16
R1C3-1	273977	8595978	22.25	16.25	22.25
MS4	274311.45	8598254.52	9.25	6	9.25
MS4-A	274311.45	8598254.52	5.25	1.45	5.25
P3-4B	237824.7	8598301.1	100	60	99.5
New bore 1 (Pit 3)	274301.2	8598257.4	28	18	28
New bore 2 (Pit 3)	274298.1	8598258.4	61	41	61
New bore 3 (Pit 3)	274246.1	8598125.6	14	8	14
New bore 4 (Pit 3)	273730	8598392.7	8	2	8

* Final depths are likely to change depending on the depth of weathering.

Figure 11-2: Proposed location of Pit 1 monitoring bores

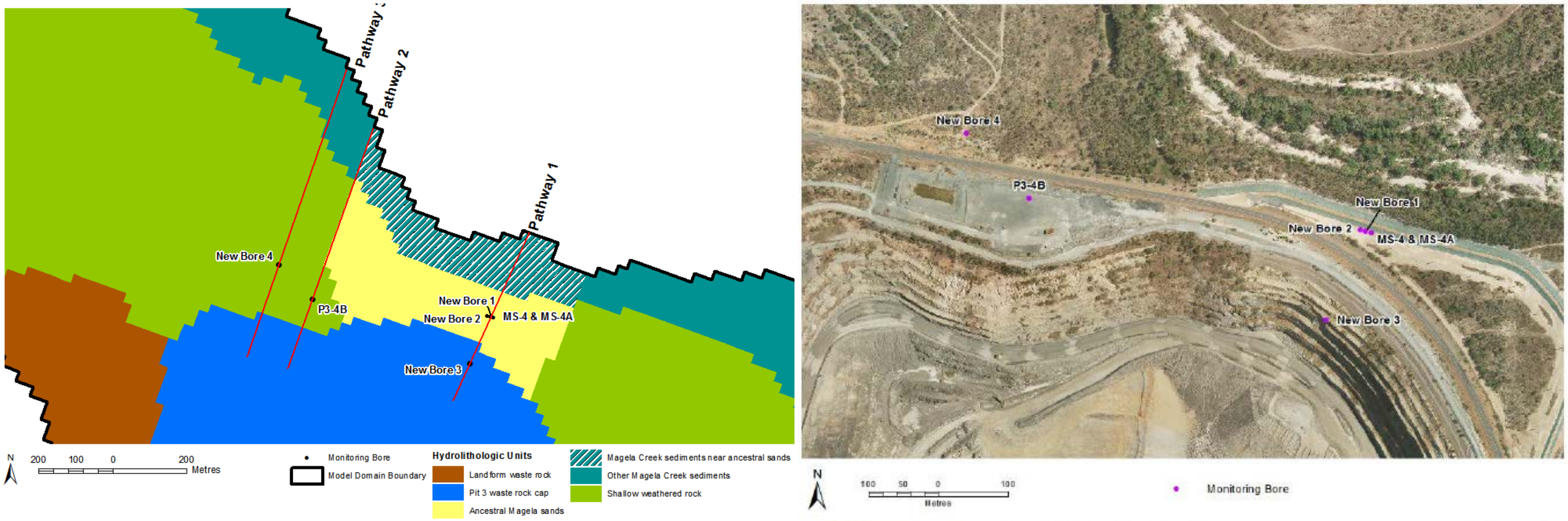

Figure 11-3: Location of Pit 3 monitoring bores

A similar monitoring regime will be implemented across the other sub-catchments. This may be in the form of monitoring bores within hydrolithic units; or in the form of primary, secondary and tertiary bores staged at various distances down-gradient of each potential contaminant source to provide background water quality data, expeditious verification of model predictions or to detect longer range effects of solute migration.

The proposed monitoring will comprise monthly measurements of standing water level and quarterly sampling and chemical analysis of, for example, pH, EC, Ca, Cl, HCO_3^-, K, Mg, Mn, Na, SO_4^{2-}, and U.

11.4 Radiation Monitoring

The proposed final landform monitoring for radiological performance has been structured around the exposure pathways for radiation due to the potential access to and final land use of the area. These pathways are inhalation of Long Lived Alpha Activity (LLAA e.g. radioactive dust), inhalation of radon progeny (Potential Alpha Energy Concentration; PAEC), ingestion of radioactive material in (or with) food or water, and external irradiation from gamma rays (and beta particles). Given the possible post-closure use of the landform, the critical group will be Aboriginal people using the site for traditional activities including transient camping and the gathering of traditional bush foods for consumption.

LLAA and PAEC will be measured towards the end of the dry season for the initial five-year period following construction of the final landform. At this time of year, lower soil moisture results in increased Rn exhalation rates and higher dust concentrations in air. Monitoring will be undertaken over at least a one week period each dry season using ether:

- High volume samplers (LLAA) or Alpha Prisms (PAEC) targeting areas with increased activity present in the sediments; or
- More passive techniques that integrate over a longer time period such as track etch detectors (PAEC) or passive dust samplers (LLAA) over a three to six month period.

Potentially contaminated waters will be monitored in conjunction with the water and sediment monitoring program with grab samples taken in Magela Creek both downstream and upstream of the confluence of Magela and Gulungul creeks. Samples will initially be taken monthly during creek flow, with this reducing over time to annually once low levels have been confirmed. Results of this monitoring program will be used to determine ingestion dose from drinking water and eating bush foods, refer Chapter 7 details for methods.

At the completion of decommissioning activities, an airborne radiometric survey with targeted ground surveys for external gamma dose rate and ^{226}Ra in soils will be undertaken to determine the gamma dose from the final landform.

11.5 Flora and Fauna Monitoring

A flora and fauna monitoring program will be developed for rehabilitation and closure, taking into consideration the information provided by the monitoring of established reference sites referred to in Chapter 7, Section 7.6.3.1. The monitoring program will comprise of vegetation plots and fauna trapping transects to address terrestrial flora and fauna.

The monitoring program to be implemented would be developed to capture relevant information as the revegetation progresses. For example, the early fauna monitoring (e.g. years 1 through 3), is likely to focus on incidental observations of vertebrates and invertebrates. As the vegetation establishes, there will be an increase in monitoring to include trapping and systematic observation-based surveys to determine the presence of major functional groups. In the initial stages of revegetation (e.g. years 1 through 5), the flora monitoring will focus on species survival rates, which will inform remediation works.[1] As saplings develop, a more comprehensive suite of parameters addressing ecosystem development and closure criteria will be introduced (refer Chapter 6, Table 6-7).

The proposed survey frequency of flora and fauna across the final landform is: three, six and 12 months (year 1); annually (years 2 through 5, inclusive); one-off surveys every five years (e.g. at years 10, 15, etc).

11.5.1 Feral Animal Monitoring

ERA currently undertakes feral animal monitoring and culling to manage densities of particular species on the RPA, such as pigs. This practice will be continued during the initial maintenance period after commencement of post-closure monitoring (e.g. years 1 to 5). Feral animals will be culled if densities become too high and other remedial actions will be taken if feral animals are adversely affecting physical works (e.g. damaging wetlands or revegetation on the final landform) or significantly compromising recolonisation by native fauna. As the landform develops, feral animal monitoring and management will revert to that which is followed within Kakadu National Park.

11.5.2 Weed Monitoring

ERA has undertaken annual weed surveys and mapping across the RPA since 2003 (refer Chapter 2, Section 2.4.4.2). This body of work will inform the ongoing weed monitoring and subsequent corrective actions required to meet closure criteria, particularly within the first 1 to 5 years, whilst the revegetation is establishing.

11.6 Cultural Monitoring

Garde (2015) describes a process by which to monitor the success of rehabilitation using a set of cultural health indices. Garde (2015) states that there are very few established models or methodologies to inform such a program. One notable example comes from New Zealand: *Cultural Health Index for Streams and Waterways: Indicators for Recognising and Expressing Maori Values* (Tipa & Teirney, 2003, 2006). The index attempts to apply indicators that Maori land owners use to assess the health of waterways.

The proposed indicators that could be used to reflect traditional owners' attitudes towards the progress of rehabilitation are largely based on visual and aesthetic factors proposed in Garde (2015), provided in Table 11-4.

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[1] Infill planting requirements will be informed by frequent site inspections over the course of the first 1 – 2 years until vegetation establishment.

Table 11-4: Suggested indicators of cultural health of rehabilitated site (Garde, 2015)

Landscape surface	Vegetation	Riparian zone	Biodiversity
Size of rocks	growth rate	presence or absence of artificial water bodies	natural species numbers and diversity
Presence/absence of erosion	botanical diversity	visual impressions of water quality, sedimentation, silting of rehabilitated water courses	impressions of hunting potential
Accessibility	correct species for ecological zone	condition of water course margins, creek banks	impressions of vegetable food availability
General aesthetic (does it look 'natural')	presence/absence of weeds		

The design of the program will involve long-term periodic assessment of attitudes and opinions of traditional owners and their kin in relation to the dynamics of rehabilitation over time. These assessments will be undertaken annually and will determine whether or not the traditional owners feel that rehabilitation in the RPA is progressing towards a desirable trajectory.

Measurements of impressionistic responses are scalar and individual indices are averaged out to provide a score. Scalar numeric assessment will also be accompanied by discursive data that provides a rationale for the score given. There is provision to provide other comments; these are hoped to provide an indication of areas that require management. Scores are to be calculated annually and then compared to determine whether or not perceptions of rehabilitation are moving in a trajectory that demonstrates achievement of cultural objectives as determined by traditional owners and their relevant kin.

There are a number of options for determining final scores. The first option is for sites to be individually assessed by a number of Indigenous stakeholders (barriredweleng 'traditional owners' and djunggai 'mother's country managers') and their scores collated and averaged. The second option is for the assessment to be done as a group activity where consensus on a score is established by the group at each site during visitation. This will be determined closer to the completion of decommissioning in consultation with GAC.

The assessment scale will be in a bilingual format that includes information in both Gundjeihmi and English. Each site will not necessarily be assessed for all indicators as some may not be relevant. For example, an indicator such as size of rocks will only be relevant at those sites where high levels of disturbance has required reconstruction of the landform with waste rock. Riparian sites will be assessed for relevant indicators which will not apply to other areas e.g. condition of water course margins will obviously not apply to assessment of areas away from water courses. An example of what the scalar measurement tool has been provided in Table 11-5.

Table 11-5: Example of scalar measurement tool for cultural criteria monitoring

ga-djalbolkwarre yerre	**ga-bolkwarre yiga ga-bolkmakmen gun-yahwurd**	**kareh ga-bolkmakmen gare lark**	**ga-bolkmakmen wurd**	**bon, ba-bolkmakminj wanjh**
no improvement yet noticed	some minor improvements	some areas improved, some areas not	noticeable return to healthy state in most areas	satisfactory return to natural state
1 | 2	3 | 4	5 | 6	7 | 8	9 | 10

Cultural monitoring will need to be conducted at a number of sites that collectively provide a cross section of the range of site types where rehabilitation has been carried out. An assessment of cultural criteria will need to be conducted at each of the chosen sites on an annual basis. Examples of proposed sites are as follows:

- Retention Pond 1 (RP1).
- Gundjinba Billabong (Coonjimba Billabong).
- Tailings dam (TSF) rehabilitated landform (the tailings dam).
- Garnbouh Djang (Tree Snake Dreaming).
- Pit 3 rehabilitated landform.
- Retention Pond 2 (RP2) rehabilitated landform.
- R34 archaeological site (quartz reef with grinding cupules).
- Georgetown Billabong (Madjawulu).
- Pit 1 rehabilitated landform.
- Brockman irrigation area (i.e. Corridor Creek LAA).

Figure 11-4 provides two alternatives for suggested cultural assessment sites and proposed access roads.

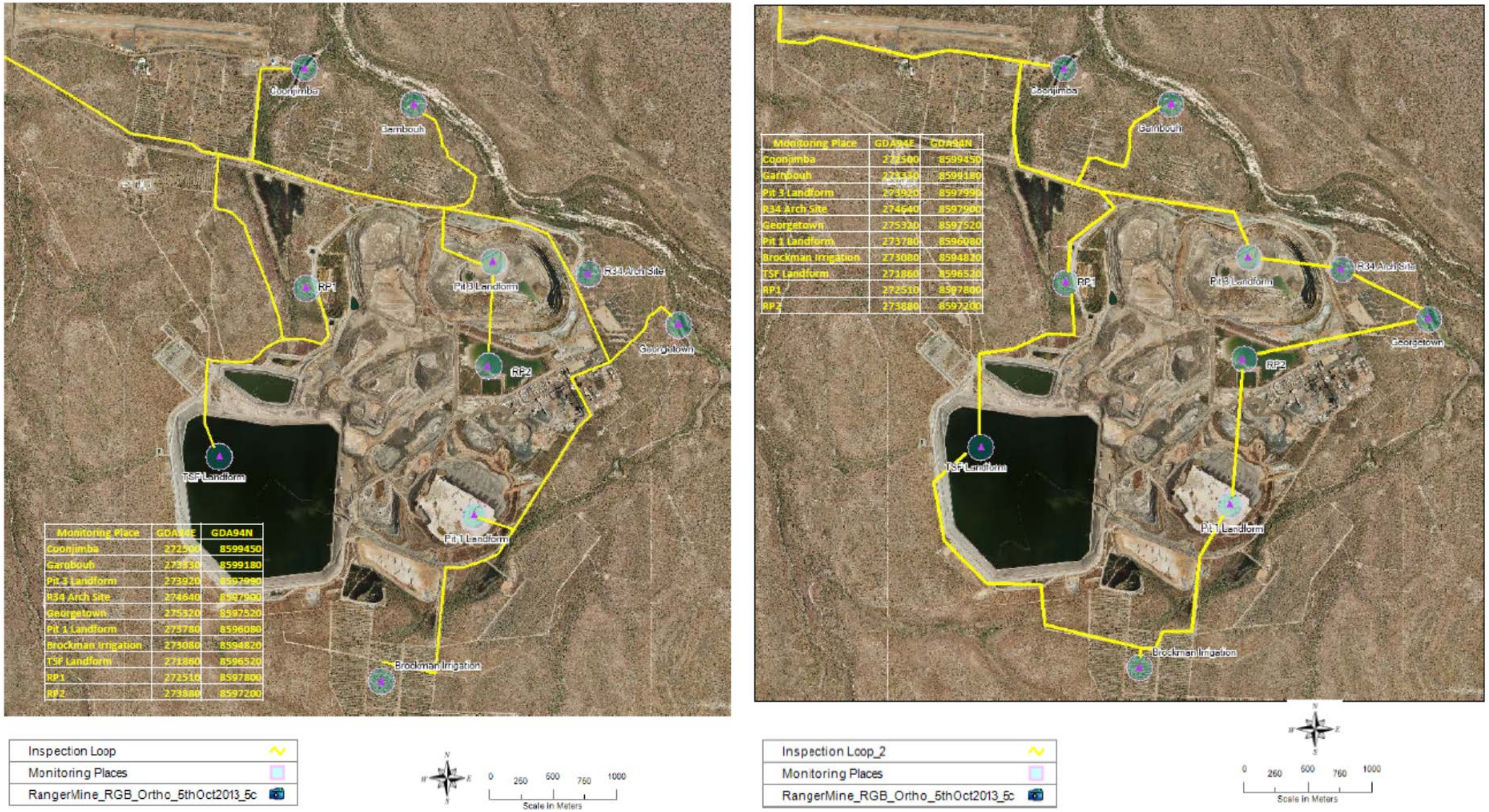

Figure 11-4: Two alternatives for proposed cultural criteria monitoring sites and access roads

11.7 Soils Monitoring

Soil remediation across the RPA will occur prior to decommissioning, and will be based on the Ranger contaminated site register and identified sites where contamination could occur as a result of the storage of inorganic and organic chemicals, and solute migration from mine-related activities. This register has been developed in conjunction with a number of targeted assessments undertaken at known contaminated sites on the RPA (refer Chapter 7, Sections 7.4.2 and 7.7.1 for conceptual modelling).

Ranger's key environmental receptors are the surface water bodies adjacent to the mine site. These receptors are far away from contaminated sites. Groundwater velocities in the underlying formations are low, and the weathered rock underlying the site tends to retard most contaminants. Nevertheless, further characterisation of contaminants at some contaminated sites on the RPA may be required to determine vertical extent, lateral extent and/or mass of contamination.

It is intended that the degree of remediation required for each contaminated site will be based on soil concentrations at these locations compared to local background concentrations or the published investigation levels (i.e. Health Investigation Level (HIL) and/or Environment Investigation Levels (EIL)). If soil concentrations in each site are shown to be below the screening levels then no further remediation or assessment will be required.

However, if concentrations of contaminants are above screening levels then a detailed site investigation and/or remediation plan will be developed. Under this scenario, monitoring and reporting may be required to demonstrate that the risk is ALARA.

Further work on the proposed framework to develop of soil contamination management options across the RPA will be undertaken during the feasibility study in 2017-18.

11.8 Trigger, Action Response Plan (TARP)

The monitoring program described in Sections 11.2 to 11.7 have been summarised into a preliminary TARP, which will also be updated in future iterations of the MCP based on agreement of closure criteria and the outcomes of ongoing studies. The TARP is presented in Table 11-6.

Table 11-6: Trigger, Action, Response Plan

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Landform					
Topographic shape	Sites: Entire landform Parameters: Topography Analysis: Visualisation and comparison to planned landform. If needed provided for Landscape Evolution Modelling (LEM) Frequency: When practical upon completion of final landform	Describe final landform against planned landform. Confirm LEM predictions for tailings encapsulation Potentially provide updated information for LEM.	Final landform varies significantly from planned landform and subsequent LEM results show critical erosion over tailings areas	Reshape landform or armour potential erosion areas until LEM shows.	Site Environmental Officer (or delegate)
Erosion (local scale)	Sites: Sensitive receptor areas and drainage channels Parameters: Field inspection, notes and photographs Analysis: Identify erosion problem areas Frequency: Annually after the wet season	Identify erosion problem areas and any maintenance required to drainage channels	Significant erosion – rill erosion > 40 cm depth, sheet erosion or hostile soil environment prevents revegetation (>0.1 ha) Erosion around drainage channels	Site-based plan and action as required. Repairs to area identified	Site Environmental Officer (or delegate)
Bedload	Sites: Water courses that direct water off site and associated sediment basins Parameters: Field inspection, notes and photographs Analysis: Identify bedload moving off site Frequency: Bi-annually before and after the wet season	Identify bedload being transferred off site	Bedload identified moving offsite	Site-based plan and action as required. May require additional works including modifying the sediment control basis	Site Environmental Officer (or delegate)
Turbidity	Sites: Monitoring points upstream and downstream of site Parameters: Turbidity (fine suspended sediment (FSS)) Analysis: BACIP analysis (Moliere & Evans, 2010) Frequency: Ongoing monitoring, analysis after wet season	Assess site denudation rates	Turbidity trajectory not transitioning to control environment levels after 5 years	Site-based plan and action as required. May require additional surface stabilisation and/or revegetation or works including modifying the sediment control basin.	Site Environmental Officer (or delegate)
Water and sediment					
Surface water and sediment – turbidity and aesthetic	Sites: Magela Creek downstream of the Gulungul confluence, also upstream sites (turbidity and other parameters) Parameters: Turbidity at both sites and other aesthetic parameters (e.g. clarity, colour, surface films) at downstream site only Analysis: Physical and observational analysis of samples Frequency: Continuous monitoring for turbidity, event and scheduled grab sampling (decreasing gradually from weekly to wet season only over time)	Identify EC, turbidity or aesthetic surface water and sediment quality issues	Samples exceed specific screening criteria defined in closure criteria	Monitor trends and develop site specific action plan as required.	Site Environmental Officer (or delegate)
Surface water and sediment – other parameters	Sites: Magela Creek downstream of the Gulungul confluence, MG009, GCLB Parameters: Various parameters (e.g. EC, Mg, U, Mn, NH_3-N, NOx, Total-P, Total-N) Analysis: Chemical analysis of samples and continuous EC Frequency: Ongoing monitoring for EC (Mg), scheduled grab sampling (decreasing gradually from weekly to wet season only)	Identify surface water and sediment quality issues	Samples exceed specific screening criteria defined in closure criteria	Monitor trends and develop site specific action plan as required.	Site Environmental Officer (or delegate)

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Surface water and sediment – U in sediment	Sites: Gulungul Billabong : U in sediment Analysis: Chemical analysis of samples Frequency: Sample at end of decommissioning	Identify increased uranium in sediments off the RPA	Samples exceed specific screening criteria defined in closure criteria	Monitor trends and develop site specific action plan as required.	Site Environmental Officer (or delegate)
Groundwater	Sites: Monitoring 'envelopes' in the four sub-catchments; Gulungul, Coonjimba, Djalkmarra and Corridor Creek Parameters: Standing water level and Mg Analysis: Physical and chemical analysis of samples Frequency: Standing water level monthly, chemical analysis quarterly	To confirm groundwater level and chemistry is behaving according to modelled predictions, within the documented uncertainties.	Analysis indicates that groundwater is not tracking according to model predictions	Site-based plan and action as required.	Site Environmental Officer (or delegate)
Radiation					
LLAA and PAEC inhalation	Sites: Entire site Parameters: LLAA and PAEC (mSv per year) Analysis: High volume samplers and continuous radon decay product monitors or more passive techniques such as radon track etch detectors and passive dust samplers Frequency: High volume samplers and continuous radon decay product monitors over a one week period each dry season, passive techniques over a three to six month period. Monitoring for the initial five-year period following construction of the final landform.	To confirm radiation doses to members of the public are below limits	Exceedance of the baseline radiation dose as defined in the closure criteria	Action plan to mitigate identified pathway to ALARA. Apply additional restrictions on the use of the land in consultation with traditional owners.	Site Environmental Officer (or delegate)
Food and water contamination	Sites: Magela Creek downstream of the Gulungul confluence, also upstream sites Parameters: Ra-226, U-238 (other isotopes if risk identified) Analysis: Gamma spec analysis Frequency: initially monthly during the wet season, decreasing to annually over time	As above	As above	As above	Site Environmental Officer (or delegate)
External gamma radiation	Sites: Entire site Parameters: Radiation dose rate (µGy/h) Analysis: Airborne radiometric survey with ground gamma survey and soil sampling for Ra-226 for ground truthing, Frequency: At the completion of rehabilitation activities	As above	As above	As above	Site Environmental Officer (or delegate)
Flora and fauna					
Flora species composition	Sites: Vegetation plots and fauna trapping transects across entire site Parameters: Provenance, species composition (tree and shrubs) and species relative abundance, canopy architecture, canopy cover index, ground cover index and tree distribution Analysis: vegetation and fauna survey analysis Frequency: three, six and 12 months (year 1); annually (years 2 – 5, inclusive); one-off surveys every five years (e.g. at years 10, 15, etc)	To determine whether species composition and community structure is similar to adjacent areas of KNP	Exceedance of final criteria defined in closure criteria	Site-based plan and action as required	Site Environmental Officer (or delegate)

Aspect	Monitoring		Response		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
Ecosystem maintenance	Sites: vegetation plots and fauna trapping transects across entire site Parameters: Reproduction (flowering and seeding), recruitment / regeneration, nutrient cycling, fire resilience, resilient to wind and drought, plant available water, weed composition and abundance and presence of native fauna. Analysis: vegetation and fauna survey analysis. Frequency: three, six and 12 months (year 1); annually (years 2 – 5, inclusive); one-off surveys every five years (e.g. at years 10, 15, etc).	To determine whether the long term, viable ecosystem requiring maintenance is similar to adjacent areas of KNP	As above	As above	Site Environmental Officer (or delegate)
Cultural					
Landform (and infrastructure)	Sites: Retention Pond 1 (RP1), Gundjinba Billabong (Coonjimba Billabong), Tailings Storage Facility (TSF) rehabilitated landform (the tailings dam), Garnbouh Djang (Tree Snake Dreaming), Pit 3 rehabilitated landform, Retention Pond 2 (RP2) rehabilitated landform, R34 archaeological site (quartz reef with grinding cupules), Georgetown Billabong (Madjawulu), Pit 1 rehabilitated landform, Brockman irrigation area (i.e. Corridor Creek LAA) Parameters: size of rocks, presence / absence of erosion, accessibility, traversable, general aesthetics (does it look 'natural'), presence or absence of artificial water bodies, condition of water course margins, creek banks Analysis: Cultural Health Index - Field observations Frequency: Annually	To determine whether traditional owners are satisfied that the landform design supports cultural land uses, there are no additional water bodies present and the riparian zones are in good condition.	Conditions identified in closure criteria not met.	Site-based plan and action as required.	Site Environmental Officer (or delegate)
Water and sediment	Sites: as above Parameters: Visual impressions of water quality (colour, flow, expected clarity, visible contaminants), silting, sedimentation. Analysis: Cultural Health Index - Field observations Frequency: Annually	To determine whether traditional owners are satisfied with the water quality and that no silting or sedimentation is occurring	Conditions identified in closure criteria not met	Site-based plan and action as required	Site Environmental Officer (or delegate)
Flora and fauna	Sites: as above Parameters: Vegetation growth rate, vegetation diversity, correct species for ecological zone, presence of weeds, natural species numbers and diversity appropriate for stage of rehabilitation, traditional practices of burning and harvesting have resumed Analysis: Cultural Health Index - Field observations Frequency: Annually	To determine whether traditional owners are observing improvement in the progression of revegetation and biodiversity on the landform	Conditions identified in closure criteria not met	Site-based plan and action as required	Site Environmental Officer (or delegate)
Soils					
Contamination	Sites: Sites in the Ranger contaminated site register Parameters: Various contaminants Analysis: Contaminated soil assessment based on local background concentrations or published investigation levels Frequency: Prior to decommissioning and as identified by assessment.	To ensure impacted soils are remediated to as low as reasonably achievable to protect the environment	Screening levels for intended land use are exceeded.	If concentrations of contaminants are above screening levels then a detailed site investigation and/or remediation plan will be developed, requiring further monitoring.	Site Environmental Officer (or delegate)

11.9 References

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