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Ranger Mine: closing a uranium mine surrounded by a World Heritage listed national park

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Abstract

Energy Resources of Australia Ltd (ERA) has owned and operated the Ranger uranium mine since the commencement of operations in 1980. Ranger has been one of Australia's major uranium mines, producing in excess of 132,000 tonnes of uranium oxide over 40 years, one of only three mines globally to do this. Operations at Ranger ceased on 8 January 2021, with the focus of activities now on final rehabilitation and closure.

The mine is surrounded by, but is not part of, the World Heritage listed Kakadu National Park. ERA's rehabilitation strategy has been developed following extensive scientific research, engineering design and stakeholder consultation over the past 30 years. The basis of the strategy is to ensure the surrounding environment will remain protected after closure, as it has been for the entire 40 years of operations, and that rehabilitation of Ranger is to a standard such that it could be incorporated into Kakadu.

This paper discusses the studies and plans associated with tailings management, geomorphic landform design, landscape evolution modelling, cultural reconnection, and revegetation with locally collected native species that underpin this strategy.

Keywords: *uranium mine rehabilitation, landform design, revegetation, in-pit tailings disposal, cultural reconnection*

1 Introduction

Energy Resources of Australia Ltd (ERA) has owned and operated the Ranger since the commencement of operations in 1980. The mine is located within the Ranger Project Area (RPA) adjacent to Jabiru, approximately 260 km east of Darwin in the Alligator Rivers Region of the Northern Territory (Figure 1). The Alligator Rivers Region, an area of about 28,000 km^2, encompasses Kakadu National Park, a World Heritage area listed for its cultural and natural heritage values, and parts of west Arnhem Land, all Aboriginal-owned lands.

Kakadu National Park was listed under the World Heritage Convention for five of a possible 10 criteria, incorporating both cultural and natural attributes (UNESCO 2019) and the entire park is listed as a wetland of international importance under the Ramsar Convention.

The RPA is on the Traditional Estate of the Mirarr and lies within, but does not form part of, Kakadu National Park. It is bounded on the east and north by Magela Creek and its tributaries, and on the west by Gulungul Creek and its tributaries. The disturbed footprint is approximately 30% of the RPA (78.6 km^2). Access to the mine is via the Arnhem Highway.

The area of Kakadu was established as a national park in April 1979, with construction of Ranger commencing in January 1979. Since the original proclamation, the park has been extended to cover an area of almost 20,000 km^2 of the Alligator Rivers Region. Over half of Kakadu is held by Aboriginal Land Trusts on behalf of the Traditional Owners and has been leased to the Director of Parks Australia North.

Kakadu is of great significance for its landforms; its variety of fauna and flora and its rich legacy of Aboriginal art. The park protects an extraordinary number of plant and animal species, including over one third of Australia's bird species, one quarter of Australia's land mammals and an exceptionally high number of reptile,

frog and fish species. Huge concentrations of waterbirds make seasonal use of the park's extensive coastal floodplains.

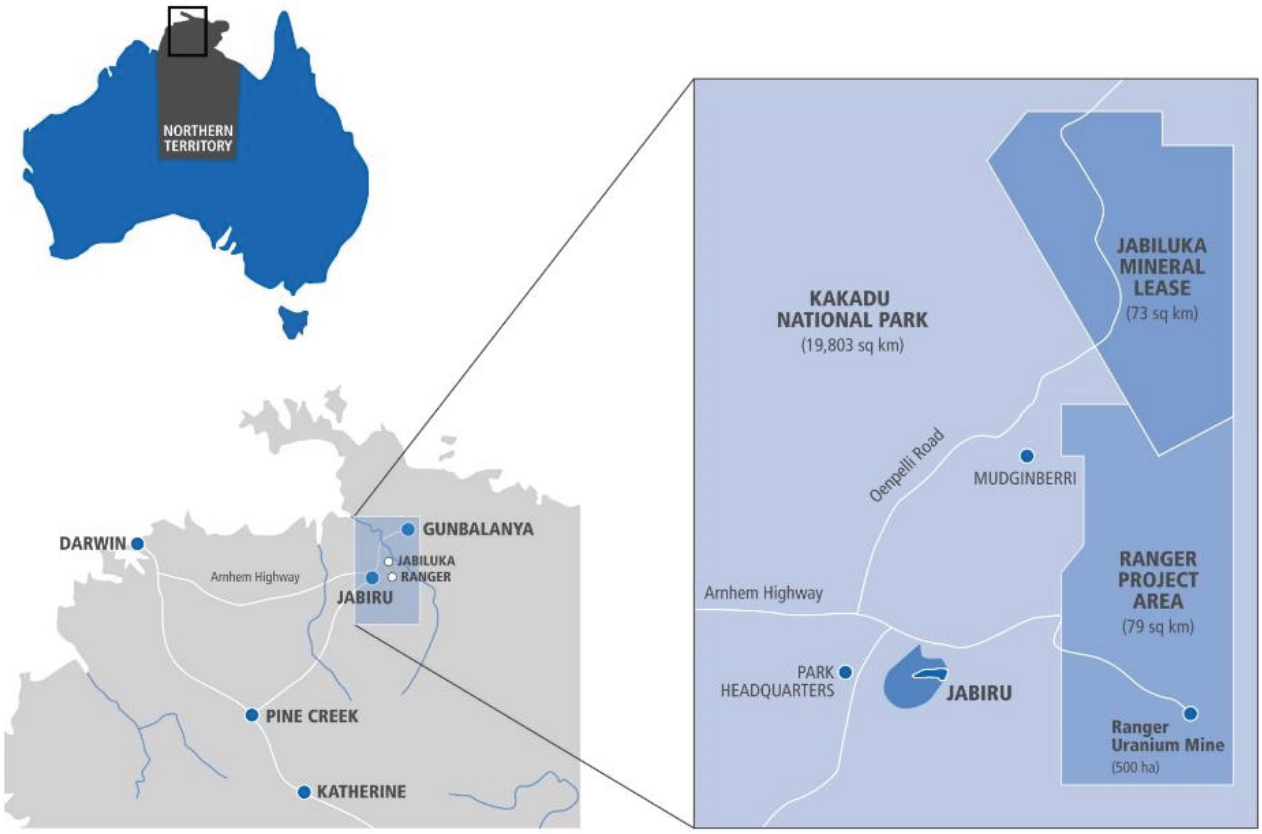

Figure 1 Ranger Mine location

ERA has provided international customers with a reliable supply of uranium oxide for over 40 years. Operations at Ranger are governed by both Australian and Northern Territory legislation and regulations. The key instrument that governs operations at Ranger on a day-to-day basis is the Norther Territory authorisation (the Ranger Authorisation) issued under the Northern Territory's Mining Management Act 2018. The main Commonwealth authority issued under section 41 of the *Atomic Energy Act 1953*(Cth), provides the key tenure and land access approval required for the operations (section 41 of the Authority). The Ranger Environmental Requirements (ERs) are appended to the section 41 Authority and set out environmental objectives which establish the principles by which the Ranger mining operation is to be conducted, closed, and rehabilitated and the standards that are to be achieved. The Ranger Authorisation also incorporates the ERs.

Operations at Ranger ceased on the 8 January 2021, with the focus of activities now on final rehabilitation and closure.

2 Rehabilitation planning and execution

ERA's rehabilitation strategy has been developed following extensive scientific research, engineering design and consultation with Traditional Owners and other stakeholders over the past 30+ years. The basis of the strategy is to ensure the environment surrounded by the mine will remain protected after closure, as it has done for the entire 40 years of operations. Rehabilitation works first commenced at Ranger in 1996 with the preparation of the mined out Pit 1 to receive tailings and remains ongoing today.

The overall goal for rehabilitation of Ranger is outlined in the ERs:

> *"The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park"* (Supervising Scientist 2019)

The ERs also set out a number of environmental objectives relevant to rehabilitation and closure that have formed the framework for ERA's closure planning. These objectives relate to the revegetation of disturbed areas, the management of radiation doses to members of the public, the erosion characteristics of the final landform surface, and the final disposal of tailings and water quality. This paper discusses the studies and plans associated with tailings management, the final landform and ecosystem establishment.

2.1 Tailings management

Tailings at Ranger must be stored such that they are physically isolated from the environment for 10,000 years and any contaminants arising do not cause any environmental impact for 10,000 years. To achieve these objectives, in-pit tailings disposal is the only available option.

Tailings management during operations involved the interim disposal into the Ranger Tailings Dam with final disposal planned to occur into both mined out Pits 1 and 3, when available. Pit 1 received tailings from 1996 to 2008 and was then prepared for final capping. This involved an initial period of evaporative drying and the installation of pre-fabricated vertical drains (wicks) to assist in dewatering the tailings and relieving excess pore pressure to allow later stages of backfill to progress. A number of settlement plates were installed across the tailings surface to allow for the tracking of tailings consolidation and validation of the tailings consolidation model. Geofabric was placed over the tailings surface prior to the placement of waste rock in ever increasing thicknesses. Initial material movement was via low ground pressure equipment and long reach excavators, followed by a smaller fleet of articulated trucks and finally the full heavy mine fleet of haul trucks. The capping works were completed in August 2020 and revegetation of the surface completed in January 2022 (Figure 2).

Figure 2 Revegetation progressing on Pit 1

Several learnings from Pit 1 backfill and capping have been taken into the design of the Pit 3 tailings storage facility. An initial underfill was completed that included the transfer of 33 Mt of material into the base of the pit to create a flat surface for tailings deposition. This flat surface minimised the rate of rise of the tailings during deposition and reduced the time required for final consolidation. An underdrain layer was placed on top of the underfill and an underdrain bore installed to allow the extraction of downwards consolidation flow. The Pit 3 conceptual design developed from Pit 1 learnings has been provided in Figure 3.

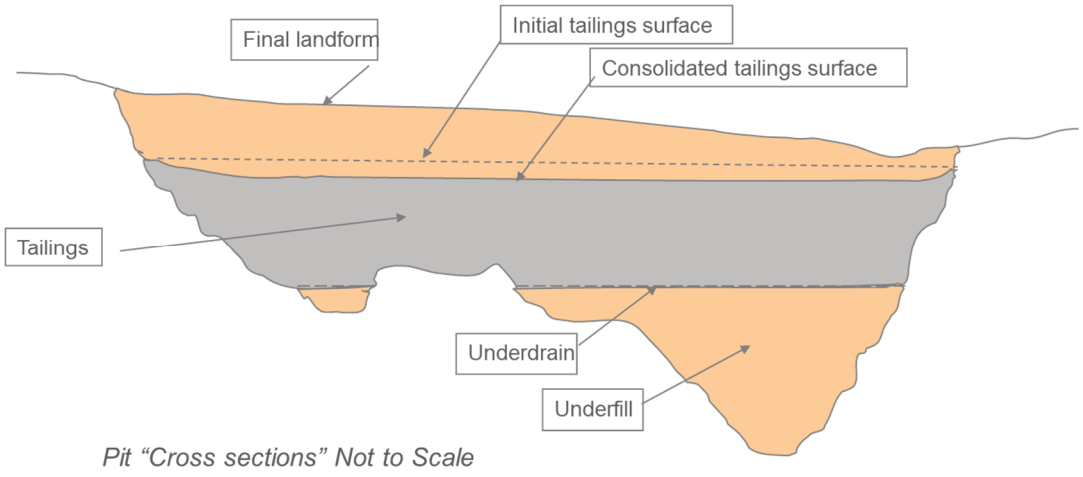

Figure 3 Conceptual design of Pit 3 tailings storage and capping

Following completion of the underfill in 2015, Pit 3 became available for tailings storage. Tailings from the Ranger processing plant were directed to the pit and material historically stored in the tailings dam commenced transfer to the pit for final disposal. The bulk of transfer was undertaken using cutter suction dredges with the final remnants being transferred using load and haul. All tailings were confirmed as removed from the Tailings Dam to the mined out Pit 3 in December 2021 (Figure 4). Pit 3 is currently being prepared for final capping work.

(a) (b)

Figure 4 Ranger tailings dam at the commencement of dredging (a) and following all tailings removal (b)

ERA has undertaken extensive post-closure solute transport modelling of both groundwater and surface water and the interaction between them to inform and assess the in-pit tailings disposal plan described above. Groundwater modelling specialists INTERA were engaged in 2010 to commence the development of a groundwater model that would adequately assess the risks to the environment over 10,000 years. This work was completed in 2021 with the finalisation of the site wide, calibration-constrained, predictive groundwater model with uncertainty analysis. This model provides probabilistic simulations of solute loads to the creeks for 20 contaminants of potential concern that form the input into the Ranger surface water model to predict

post-closure water quality. Subsequent risk assessments described by separate papers in these proceedings (Iles & Rissik 2022; Iles 2022) determined if the predicted water quality would be acceptable or if changes to the management of specific contaminant sources was required. This approach was used to refine ERA's in-pit tailings disposal design for Pit 3 to ensure, and demonstrate that, ERA can meet the overall objective of not causing detrimental environmental impact for 10,000 years.

The Ranger tailings dam has now been successfully converted to the Ranger water dam and will be used to store the water remaining at the completion of uranium processing until it has all been treated to a standard that can be released to the environment. Following the treatment of this water inventory the dam will be deconstructed in such a manner that any remnant contaminants of concern will not impact the environment. ERA has engaged INTERA to assist with the solute transport modelling of decommissioning options that will inform the subsequent risk and vulnerability assessments; undertaken following the processes described by separate papers in these proceedings (Iles & Rissik 2022; Iles 2022; Richardson et al. 2022).

2.2 Landform and ecosystem establishment

The final surfaces of both pits and the dam will be blended with the remaining waste rock stockpiles to form the final landform waste rock surface. The design of the final landform has been determined using a digital terrain model of natural analogue areas with the aim of producing a landform that is both similar to the original pre-mining surface and will blend into the natural surrounding landscape. ERA is currently in the process of designing the final version of the landform. Each version of the landform has been subjected to landform evolution modelling to assess the geomorphic stability over timeframes ranging from decades to millennia and confirm that the tailings will remain isolated for at least 10,000 years. The landform evolution modelling historically has been undertaken by the Supervising Scientist (Lowry et al. 2013), with ERA recently developing this capability in-house. The outcomes of the modelling (Figure 5) have been used to iteratively update the final landform design over the years, with each version getting closer to meeting the closure criteria and the latest version now focusing on minor changes only; including the concavity of slopes and detailed drainage networks.

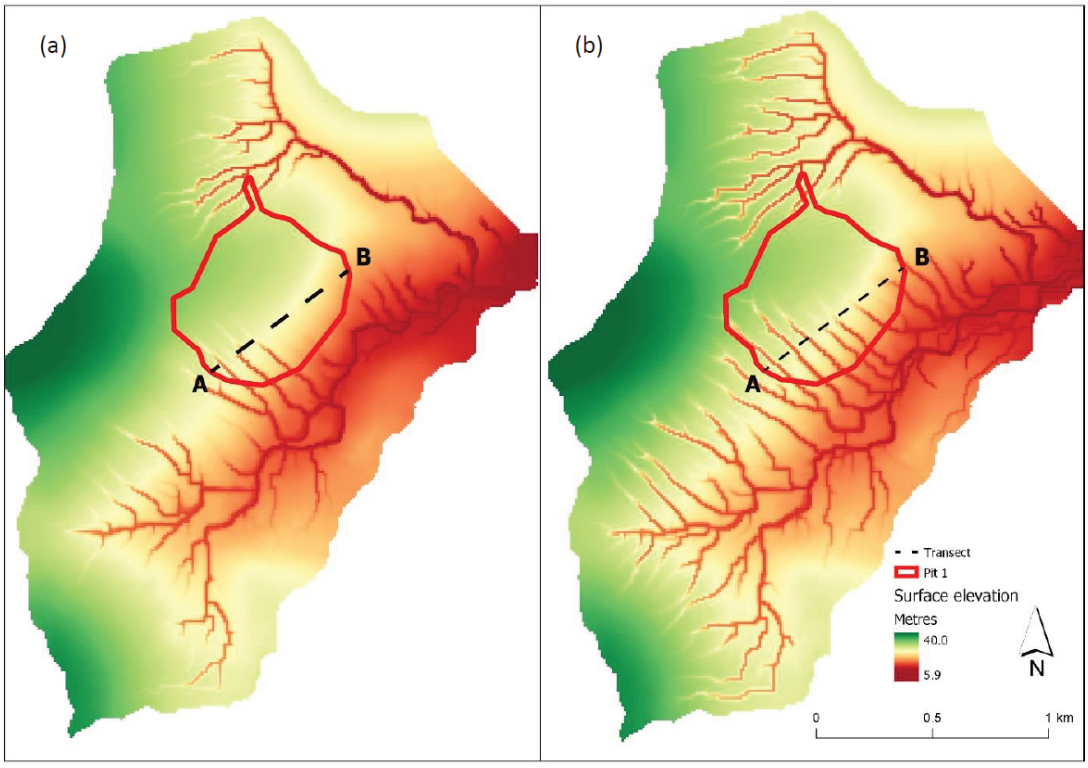

Figure 5 Surface of Corridor Creek catchment after a simulated period of 10,000 years under (a) dry and (b) wet rainfall scenarios

Revegetation at Ranger will occur with local native plant species directly on to the waste rock landform, as no topsoil is available. ERA commenced studies into revegetation of a waste rock surface soon after commencement of operations and in 2008 made the decision to create a trial landform to enable the long-term tracking of revegetation trajectories (Figure 6). The trial landform, along with other studies has enabled ERA to determine the best methods for establishing a long-term sustainable ecosystem on waste rock material and given ERA the ability to demonstrate rehabilitation capability to stakeholders. The trial landform has provided ERA with valuable information that has informed closure planning; this has included:

- Trialling various revegetation species establishment methods for both overstory and understory.
- Assessment of erosion rates, radiation doses, run-off water quality.
- Test the vegetation's resilience to bush fire and develop effective methods for managing revegetation deviated states.
- Assess the effect of burning on erosion.
- Establish expected trajectories for closure.

Figure 6 Ranger mine trial landform

The final waste rock surface covers 795 hectares and will be hand planted with over 1,000,000 small seedlings that are grown on site from seed collected locally within Kakadu National Park. The target ecosystem is a *Eucalyptus tetrodonta/miniata* savanna woodland. To achieve this ERA has developed a Species Establishment Research Plan (SERP) database of 165 flora species, including 21 overstorey tree species, 74 midstorey tree and shrub species, and 70 understorey species (or genus). The selection of these species and their placement across the landform is based on previous stakeholder consultation, historic and recent reference site surveys, hydroecology studies, and consultation with Charles Darwin University researchers, local indigenous ecology experts, and Traditional Owners. The species included in the database will continue to be refined as outcomes from the trial landform studies and monitoring, ongoing revegetation trials, risk assessments and further stakeholder consultations are completed.

3 Cultural reconnection

There is recent evidence of Aboriginal occupancy of the Kakadu region dating back more than 65,000 years. Central to closure planning at Ranger are the Mirarr people, who are the Traditional Owners of the land

encompassing the Ranger and Jabiluka mineral leases. In addition to the mineral leases, Mirarr country extends to the town of Jabiru and parts of Kakadu National Park.

ERA commenced working with the Northern Land Council and the Gundjeihmi Aboriginal Corporation in 2013 to develop cultural closure criteria. Anthropologist and linguist Murray Garde was engaged to conduct consultations with the Mirarr on the re-creation of a cultural landscape in which Traditional Owners could resume traditional practices. The specified requirements are that:

- Landform can be accessed, and is readily traversable, by people.
- Culturally important flora and fauna are present.
- The number of major water bodies (billabongs and major drainage lines) present on the RPA does not exceed the number before mining commenced.
- Traditional practices have resumed (e.g. burning, harvesting).
- Visual connection with key cultural sites is re-established.

The consultations also supported the development of a post-closure land use statement that reflects the relationship between the Mirarr and the land (as per the World Heritage values) and covers both the social and cultural use that 'existed before the mine was built', as opposed to the culture that 'currently exists'; having been modified by over 40 years of mining. The overall aim being to return the country so it can again be used as it once was. These cultural closure criteria and the land use are documented in the Ranger Mine Closure Plan that is updated annually and available on the ERA website (ERA 2020).

More recently ERA has been working with the Northern Land Council and the Gundjeihmi Aboriginal Corporation to support a Mirarr Traditional Owner cultural reconnection steering committee (Brady et al. 2021). This work commenced with a site visit by the Mirarr to the freshly constructed Pit 1 final landform surface to obtain feedback on the shape and texture of the surface and the various methods for ripping and/or scarification that could be used. Based on feedback received more features were placed onto the surface in the form of rock piles for fauna habitat. These structures were designed based on visits with the Mirarr to local rocky outcrops. Several habitat areas were placed onto the Pit 1 surface in lines that will eventually link areas of cultural significance to create walking habitat trials.

The design and placement of the habitat areas was completed by Peter Christophersen a local indigenous man who owns and operates the local indigenous business Kakadu Native Plant supplies. ERA has a long-term partnership with Kakadu Native Plant supplies for the supply of seeds, the propagation of seedlings, revegetation of the final surface, and land management. Mr Christophersen's local knowledge of plants and land management has been integral to the design of the revegetation strategy at Ranger.

In March 2021 the Mirarr joined ERA to complete the planting of the first trees on the Pit 1 surface. This was a significant event for both ERA and the Mirarr and is an important first step in the process of healing country. Since this initial planting regular visits of the cultural reconnection steering committee have occurred. Each visit has provided ERA with valuable information about the wishes of the Traditional Owners and has allowed for the adaption of the closure plan in order to deliver a final rehabilitated site that will not only meet the environmental requirements for protection of Kakadu National Park in the long-term but meet the requirements of the traditional land custodians.

4 Conclusion

ERA is set to deliver best in class rehabilitation at its Ranger mine. Closing a uranium mine surrounded by a World Heritage listed national park is not without its challenges; however, this will be achieved through the delivery of a rehabilitation plan that is based on over 30 years of scientific research and ongoing consultation with Traditional Owners and other stakeholders.

The rehabilitation of Ranger presents a unique opportunity for ERA and the wider mining community to demonstrate sustainable mining is possible in sensitive environments, delivering economic and other benefits to society without leaving adverse legacies for future generations.

The successful completion of closure at Ranger forms part of ERA's renewed purpose to 'Create a positive legacy and achieve world class, sustainable regeneration of former mine assets'.

Acknowledgement

The author acknowledges the Mirarr people, the Traditional Owners of the land on which the Ranger mine is situated, and whose quality of reconnection to land and water relies on the successful rehabilitation of the mine site and protection of the surrounding environment.

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