

Climate change and mine closure: initial risk assessment of the Ranger Mine closure plan

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Abstract

Climate change is a growing concern that can potentially affect the performance, implementation and outcomes of mine closure. Energy Resources of Australia (ERA) is closing its Ranger Mine and implementing a Mine Closure Plan. 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. Climate change stressors have been considered in several major aspects during this process and are also considered informally within many project risk assessments and activities. A formal climate change risk assessment of the mine closure was conducted as recommended by the International Council on Mining and Metals (ICMM) good practice (closure) guideline. Two face-to-face and one online stakeholder workshops were held to undertake a first pass assessment of climate change risk to, and from, mine closure. Briefings were provided on climate projections for the target area, based on the best available information. The assessment was informed by expert elicitation from experts within and outside of ERA including government and Traditional Owner representatives. Additional information was drawn from published literature. An overview of the assessment process was presented and included discussion on the likelihood and consequence tables to underpin the risk analysis ensuring participants were comfortable with the approach. A mid-range (RCP4.5) and a business-as-usual (RCP8.5) climate change scenarios were selected to determine when any major risks might occur. In assessing risk, the current Mine Closure Plan and activities were discussed, and their role in addressing relevant climate change risks was assessed to enable any residual risk to be identified. There were 37 potential risks identified in four key areas:

- 1. Onsite activities (management and monitoring).*
- 2. Revegetation.*
- 3. Onsite and receiving water quantity, quality and ecology.*
- 4. Erosion and sediment.*

Recommendations were made including to update the assessment as new climate change data and information becomes available. Significant engagement with Traditional Owners of the area will be critical to ensure that climate change adaptation is integrated into the long-term management of the site.

1 Introduction

Climate change is a growing concern for organisations, governments and individuals globally. It is an issue that can potentially affect the performance, implementation and desired outcomes of important activities such as mine closure. The importance of considering climate change in mine closure is recognised by the International Council of Mining and Minerals (ICMM) who provide a list of concerns to be considered in their *Integrated mine closure: good practice guide* (International Council on Mining and Metals 2019).

Energy Resources of Australia (ERA) is closing its Ranger Mine and implementing a Mine Closure Plan (Energy Resources of Australia Ltd 2020). The mine is located within the Ranger Project Area (RPA), about 260 km east of Darwin in the Northern Territory of Australia. It is situated on Aboriginal land, and is surrounded by, but separate from, Kakadu National Park (KNP) a World Heritage Place and Ramsar wetland site. The mine is

bounded on the east and north by Magela Creek and its tributaries and on the west, by Gulungul Creek and its tributaries. Flows from these creeks enter the extensive Magela floodplains to the north enroute to Van Diemen Gulf (Figure 1).

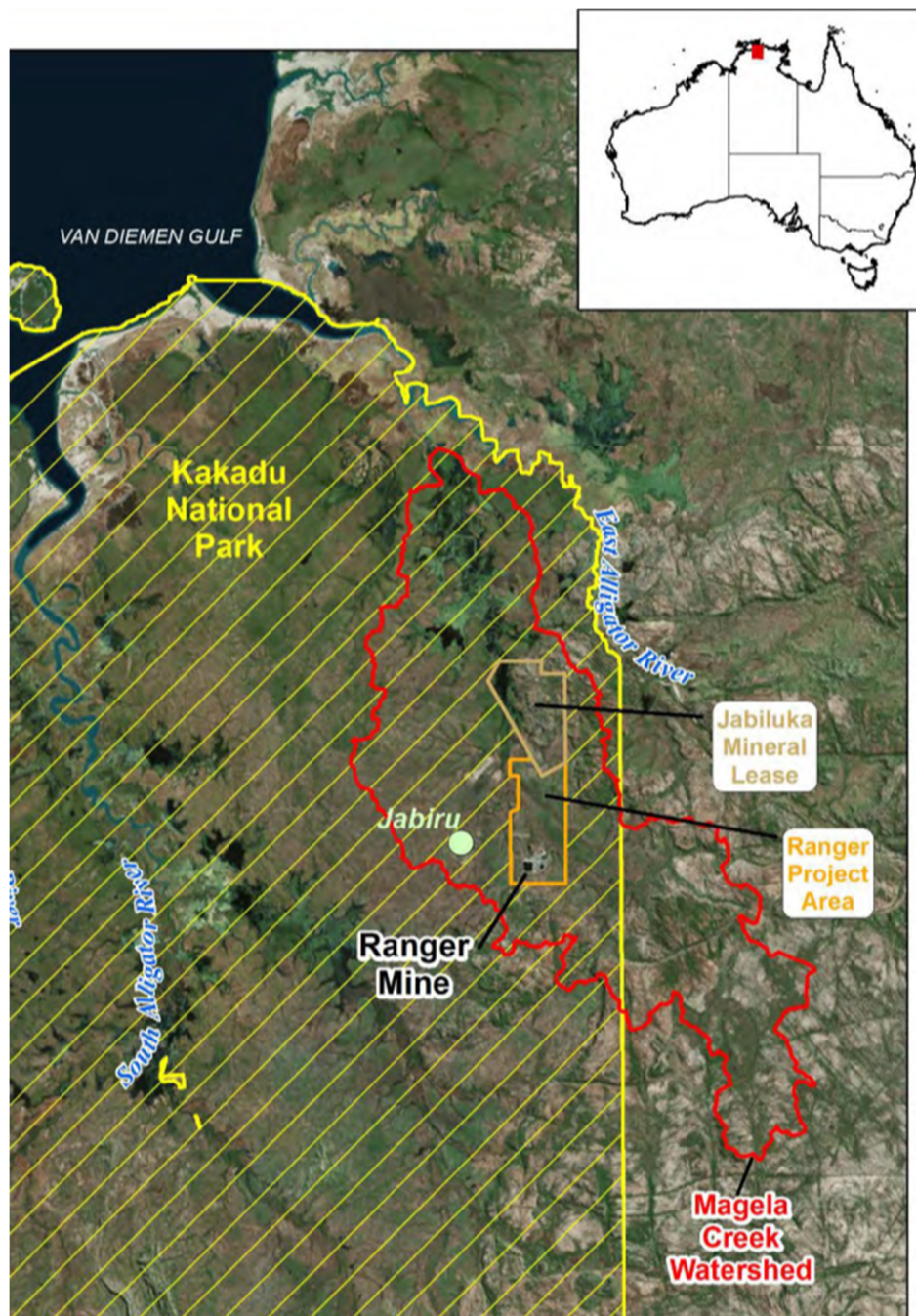


Figure 1 RPA and mine site location (Iles & Rissik 2021)

ERA's rehabilitation strategy has been developed following extensive scientific research, engineering design and consultation with the Mirrar Traditional Owners and other stakeholders over the past 30+ years.

The environmental requirements for mine closure include:

- Protecting the health of people and ecosystems in the area (particularly from the effects of contaminated waters).
- Minimising erosion.

- Establishing vegetation similar to surrounds to form an ecosystem the long-term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park.
- Ensuring tailings remain buried and do not cause a detrimental impact for 10,000 years.

Once closure criteria are met, or on a trajectory to being met, the site will be relinquished to the Traditional Owners. Given the long-term nature of the environmental requirements, the high ecological and cultural values of the surrounding area, climate change implications are an important consideration.

Climate change stressors have been considered in several major aspects during the closure planning process and are considered informally within many project risk assessments and activities. This project was initiated to conduct a formal climate change assessment to identify potential climate change risks to, or from, Ranger Mine closure and to:

- Determine if additional investigations or actions are required to adapt the Mine Closure Plan to ensure closure success.
- Identify broader potential climate change impacts that might occur in the area, irrespective of mine closure, to identify a need to prepare for these challenges and to consider if mine closure can present an opportunity to adapt to them.

2 Methodology

The risk assessment followed a process consistent with the International Risk Management framework ISO31000. Specifically, the first two steps in the C-CADS framework (and guidelines) were followed (Figure 2). The later steps in the framework will be implemented by ERA within their own risk management framework which follows a similar approach.

The C-CADS framework was developed to provide a nationally consistent decision support framework to support coastal managers seeking to understand present-day and future climate change, its impacts and possible response options (Palutikof et al. 2019). It is a suitable framework for coastal and non-coastal locations and is used nationally and internationally (Palutikof et al. 2019).

C-CADS identifies three levels of assessment.

1. A first pass assessment is a quick and straightforward way to get an overview of exposure to climate change risk.
2. A second pass assessment takes a standard risk assessment approach based on readily available information and expert knowledge.
3. A detailed (third pass) assessment is useful where the first and second pass assessments identify a potentially high risk. It involves the evaluation of fine-scale and targeted information and data. This step involves data gathering, which may be costly, and typically involves contracting a specialist consultant(s).

ERA has conducted many risk assessments while developing the closure strategy and has examined some aspects at a detailed (third pass) level to assess impacts or sensitivity of modelling to a changing climate (e.g. landform erosion and groundwater solute transport modelling). First and second pass assessments of the overall closure strategy were conducted in this assessment.

Information on applying the C-CADS framework is available at CoastAdapt (2017). Application of the first two steps of the framework is discussed below.



Figure 2 C-CADS adaptation risk management framework, consistent with ISO31000 (based on Palutikof et al. 2019)

2.1 Identify challenges

Identifying the challenges was a critical step in the risk assessment process and enabled the appropriate framing of the project. This initial step focused on developing a clear understanding of desired outcomes, defining the periods, area and scale to focus on in the assessment.

A project Inception Workshop was held with a number of stakeholders, which included a first pass (high level) risk screening. Participants discussed and agreed on the climate change scenarios that would be used for the assessment, the spatial extent and time frames of the assessment (considering the timing of closure activities, the expected evolution of the closed mine site and regulatory requirements) and identified key stakeholders to be involved in the assessment workshops.

Expert opinion, simple maps, figures and climate change projections were used to determine the scale of the climate challenge and develop a list of potential risks relevant to mine closure. Through understanding where risks may be present and what may be affected, the team fine-tuned and prioritised the approach for the next steps in the risk assessment. This included understanding what detailed information was required.

2.2 Assess risks and vulnerabilities

The second stage of the process was to determine the vulnerability and risk to the mine closure from the effects of climate change.

A stakeholder workshop was held in Darwin to undertake the second pass assessment of climate change risk to, or from, the closure of the mine. The second pass risk assessment was based on existing information, maps and a process of expert elicitation which included experts from within and outside of ERA. An additional online workshop was conducted with bushfire experts (not available for the second workshop) to gather additional expert input into this important aspect.

The workshops commenced with a briefing on global and downscaled climate projections for the target area, based on available information obtained from reliable resources including the Commonwealth Scientific and Industrial Research Organisation (CSIRO 2014), along with the Bureau of Meteorology (BoM) (CSIRO and BoM 2015) and the National Climate Change Adaptation Research Facility (NCCARF). Additional information was drawn from published peer reviewed literature.

An overview of the risk assessment process was then presented and included discussion on the likelihood and consequence tables to underpin the risk analysis and to ensure that all participants were comfortable with the approach. Stakeholders reaffirmed the outcomes from the Inception Workshop for the project including what areas should be covered by the assessment and the projected time frames that should be covered in the assessment. It was agreed that Jabiru and the airport were not to be included in the assessment and that the main time frames to be considered were 2030 (initial post-closure ecosystem establishment phase), 2050, and 2100 (best available long-term projections). A mid-range climate change scenario of RCP4.5 was selected and a business-as-usual climate change scenario of RCP8.5. These are based on scenarios used in Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change 2013) reports. Using these two possible futures would help to determine when any major risks were likely to occur. There is little difference between the climate change projections of the two scenarios until after 2050.

Discussion took place about assessing climate related risks for longer time periods associated with the mine closure including when preliminary modelling indicated peak contaminant loads would likely be discharged through the groundwater (~270 years; this has since changed) and in 10,000 years to be consistent with regulatory conditions. There are few climate change data available for those periods and the uncertainties associated with them is extreme. Accordingly, it was agreed that there was little merit in including these risks in the risk assessment activity.

For each time frame and climate change scenario the group then worked through the planned closure activities to identify the risks associated with the relevant climate stressors identified in the first pass risk screening. There were 37 potential risks discussed and assessed. The risks for each climate stressor and area of impact are shown in Table 1.

Table 1 A summary of the potential risks for relevant climate stressors. Note this is a summary and categories had more than one risk associated with them

Climate stressor	Revegetation and terrestrial ecology (and onsite activities)	Onsite and receiving water quantity, quality and aquatic ecology	Erosion and sediment
Increased heat	Workforce heat exposure. Species tolerance, survival and growth rates. Weeds and pest. Soil biota and nutrient cycling.	Increased contaminant mobility and toxicity (toxicity-based guideline values set for 30°C). Increased evaporation (see lower water levels below). Decreased dissolved oxygen, increased algal blooms. Shift to heat tolerant species. Change to reptile sex ratio.	Loss of protective vegetation cover.
Sea level rise and salinity	N/A	Loss of downstream freshwater refugia. Shift to saline tolerant species. Change to ionic strength (toxicity guideline values set for low ionic conditions). Reduced gradient alters hydraulic head (implications for solute transport modelling).	Wave action causing erosion (if reaching mine site).
Rainfall and drought	Suitable planting conditions (schedule and worker health and safety). Plant survival. Irrigation requirements.	Lower water levels – loss of dilution, connectivity and dry season refugia sites, exposure of acid sulphate soils.	Erosion during extreme rainfall (landform design tested by modelling).
Cyclone and storms	Vegetation damage. Increase leaf litter (fire load).	Riparian damage.	Road damage. Loss of protective vegetation cover.
Bushfire	Changing fuel loads and vegetation community. Flora mortality (and implications for fauna). Susceptibility of revegetation community versus analogue community. Reduced length of season suitable for planned burns.	Riparian damage.	Loss of protective vegetation cover.

The risks were then analysed using the Rio Tinto standard matrices for likelihood, consequence and risk scoring used by ERA. This ensured consistency between the analyses process and risk scores for the climate change assessment with other risk assessments undertaken by ERA.

The consequence types considered were onsite environment, offsite environment, compliance and health and safety for the period when staff will remain onsite.

3 Results

Risks were classified into four key areas:

1. Onsite activities (management and monitoring).
2. Revegetation and bushfire.
3. Onsite and receiving water quantity, quality and ecology.
4. Erosion and sediment.

The summary statistics from the risk assessment clearly show the trajectory of risks over time as climate change hazards increase in magnitude and likelihood (Figure 3).

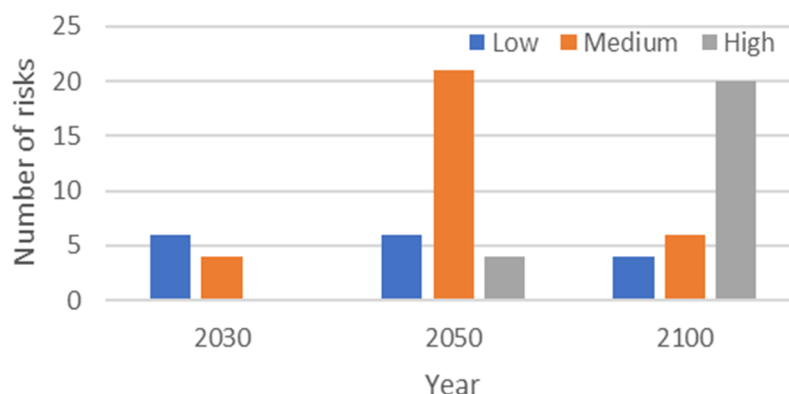


Figure 3 Number of low medium and high risks identified over three indicative time frames. Note in 2100 the workforce conducting closure work was no longer at risk as that would not be ongoing at that stage

In general, most risks were considered low (unlikely, low consequence) for the projected climate for 2030. It is noted that this is the climate regime that is expected during the decommissioning and early post-closure period.

Risks were greater for the climate projected for 2050 with a number of medium and high risks identified. Many of these risks are landscape risks that will be manifest across the broader landscape of Kakadu but will be actively managed on the mine site as part of the management and monitoring period.

In the longer term, between 2050 and the climate projected for 2100, when the effects of climate change are likely to become more extreme, a number of high risks were identified. These are also risks that will affect the landscape not just the rehabilitated mine site. It was agreed that successful implementation of the Ranger Revegetation Plan will result in an ecosystem on the mine site similar to that in the surrounding landscape and which is no more vulnerable to these risks than the natural landscape.

Most of the potential risks associated with climate change are risks that have already been identified and captured in ERA's risk register for management. High level details of the findings are provided below with some high level options for addressing or further understanding the risks for ERA to consider in steps 3 and 4 in the C-CADS framework.

3.1 Onsite activities

Most onsite activities will be complete in the coming years before large changes to the climate occur. Health and safety plans and assessments are conducted routinely and consider the hazards posed by climatic conditions.

Heat is a major hazard the workforce is exposed to during revegetation activities. This risk is reduced through adaptations in the health and safety plan which is regularly reviewed as part of the continuous improvement

process. The approaches to reduce heat impact on workers at that time should consider any new climate information or technology that is available.

3.2 Revegetation and bushfire

Climate stressors such as heat, drought and bushfire have been considered in the development of a revegetation plan for the site. This includes important aspects such the selection of vegetation and their distribution across the landscape to match water needs and availability, planting schedules and methods that consider heat and water needs, and the longer term management, maintenance and monitoring.

Short-term risks to revegetation will be actively managed. Vegetation lost or damaged from climate related (and other) pressures will be replaced, or management procedures will be adjusted, until the site meets the close out conditions (aka closure criteria) with the ecosystem on a trajectory to being self-sustainable, resilient and similar to the surrounding systems. Following this, climate related risks are considered to be landscape issues which will affect the whole park and are not related to mine closure activities.

The revegetation plan is well thought out. Being an issue that is vulnerable to climate change, it is important that the changing climate continues to be considered as the plan undergoes review, both planned and in response to monitoring results.

Risks of bushfire were discussed, and initial discussion indicated that onsite risks will be managed as part of mine closure activities, including replacement of lost or damaged vegetation and use of traditional burning methods to promote a fire resilient vegetation community and manage fuel loads. Planting fire resistant species from drier areas south of the mine was considered but not favoured. In the longer term, the rehabilitation goal is that mature revegetation is similar to surrounds and so should be as resilient to natural disturbance regimes, particularly fire. At that stage bushfire risk at the site will be managed as part of the larger landscape through local land management processes. It is important that this is undertaken in partnership with Traditional Owners and based on Traditional Knowledge.

3.3 Onsite and receiving water quantity, quality and ecology

Water quantity and water quality (surface and groundwater) may be affected by a changing climate. Transport modelling of contaminants in ground and surface water has been undertaken using current climatic conditions. The sensitivity of groundwater modelling to climate change was considered to be low by the experts in attendance. This conclusion is supported by qualitative analysis since completed. For surface water transport modelling it was recommended that future modelling consider a changing climate. This could entail using different model scenarios to events which have occurred in the past or assessing the sensitivity of the model outputs to changed climate conditions. It was considered important that the models account for, or are sensitive to, non-stationarity in conditions and data which are used to calibrate existing models. It is also important that scenarios such as prolonged drought periods are accounted for, including being followed by drier and hotter (more evaporative) wet seasons. Models are being reviewed for their sensitivity to climate change and relevant scenarios to model are being agreed through stakeholder and peer review processes.

Long dry and highly evaporative periods may dry out billabongs and expose previously unexposed potential acid sulphate soils (PASS) and result in the forming of acid sulphate soils (ASS). This could have impacts on fauna and flora in the area. This has been identified as a risk previously and is being considered in the mine closure strategy. ERA is conducting/planning work to increase the knowledge of ASS extent and behaviour.

There are risks associated with impacts of higher temperatures of water bodies which can impact fauna and flora directly but can also affect tolerance of species to contaminants. The Supervising Scientist Branch is reviewing this issue. Reduced water inflow at times and greater rates of evaporation can result in lower flushing rates and loss of connectivity in waterways. This could reduce the ability of certain taxa to move away from areas with poor quality water and/or to recolonise areas when water conditions are favourable. These risks were considered more likely in RCP8.5 scenarios beyond 2050. These risks should be

re-considered once revised surface and groundwater modelling has been completed and climate change scenarios are updated by the IPCC.

Sea level rise beyond 2050 is likely to impact low lying areas of the park (at a distance from the RPA) (BMT WBM 2010; Bayliss et al. 2018), reducing the extent of freshwater billabongs and waterways and the associated floral and faunal communities. Upstream sites will become important refugia including freshwater bodies on and adjacent to the mine site. This cannot be influenced by the mine closure, although there is potential to consider the opportunity for creating additional freshwater bodies on the mine site to provide refugia. It is recommended that the influence of sea level rise in comparison to the mine's location be reviewed when sea level rise in the park is reassessed using updated information from the IPCC sixth assessment report.

3.4 Erosion and sediment

Risks of erosion and runoff of sediment which may occur during cyclones and large storms were identified. Any impacts which occur during the post-closure maintenance and management period will be addressed. The risk of gullyng is considered to be low as there are no steep slopes on the site. The inherent risk had already been reduced as the final landform shape and water flows are designed to avoid erosion in at risk areas identified through landform evolution modelling that considered future rainfall conditions (e.g. Lowry et al. 2016). Any impacts of erosion on waterbodies and access roads will be addressed during the management period. The closure objectives are for a landform with erosion characteristics similar to surrounds and management of the site will remain a company responsibility until monitoring and modelling show this is or will be achieved. Longer term risks following handover will be landscape in nature and will be managed by the appropriate agents through local land management practices.

4 Summary and recommendations

This climate change risk assessment for closure of Ranger Mine went beyond and was more detailed than a 'first pass' assessment and involved a large body of site-specific studies and expert elicitation.

Climate change is likely to have a significant affect across the Kakadu region. Most impacts are likely to occur beyond 2050. Climate change has implications for the mine closure. Long-term impacts specific to the mine have been considered in the landscape design, revegetation plans and solute transport modelling to inform contamination management. Short-term impacts will be actively managed. These are predominantly related to the revegetation and erosion management on the site. In the longer term, most climate change risks are landscape in nature and will affect the entire park.

A list of recommendations was provided in the project report (Rissik & Iles 2020) and has been incorporated into ERA's risk register and Mine Closure Plan. Many of the risks were already registered and are being actioned. ERA has commenced action on the others or is reviewing them in discussion with stakeholders and scientific peers. Recommendations from the risk assessment fall in the following areas:

- Water flow and water quality modelling calibration and potential future conditions. Aspects to consider include non-stationarity and patterns of wet and dry expected in future.
- Changes to hydrology and temperature and implications for contaminant discharge and receptor susceptibility.
- Review of climate change risks (including to workers) following model updates when new information becomes available (e.g. following release of IPCC Assessment Report 6 in 2022).
- Obtaining data to support updated sea level rise modelling for the area when new IPCC data are available. Determining the level of sea level rise required for saltwater intrusion to reach the mine and the extent of freshwater habitat loss. (This is not a mine closure impact but will inform discussions on the potential role of mine water bodies as refugia.)

- Reviewing contaminant exposure and receptor sensitivity due to increased heat and prolonged drying of waterbodies.
- Continued adoption of traditional burning practices.
- Tracking climate change monitoring conducted by CSIRO and BoM to identify any rapid on-set of climate change which may increase the risks or require additional/earlier adaptation action.

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