Executive Summary

Figure E-1: Regional location of the proposed Yeelirrie Uranium Project

Executive Summary

Cameco Australia Pty Ltd (Cameco), a wholly owned subsidiary of Cameco Corporation, one of the world's largest uranium producers, is proposing to develop the Yeelirrie Uranium Project (the Project) located approximately 660 km north northeast of Perth in the Shire of Wiluna of Western Australia (WA) (Figure E-1).

This Public Environmental Review (PER) has been prepared as part of the process to seek State and Federal approval for the Project under the State *Environmental Protection Act 1986* (EP Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This PER is the key document for joint environmental assessment of the Project by the:

- Western Australian Environmental Protection Authority (EPA) and the Minister for Environment under the EP Act; and
- Commonwealth Department of the Environment (DoE) and the Minister of the Environment under the EPBC Act.

The purpose of the PER is to provide a description and environmental review of the principal elements of the Project, including an environmental impact assessment and description of the proposed environmental management measures for the key environmental factors in accordance with the Environmental Scoping Document (ESD) prepared by the EPA in consultation with the DoE (Appendix A).

The PER is available on Cameco's website (www.cameco.com/australia/yeelirrie/community_information). Hard copies can also be ordered from Cameco's Perth office on +61 (8) 9318 6600.

Project Overview

History

The Yeelirrie deposits were discovered by Western Mining Corporation (WMC) in 1972. Environmental studies were undertaken and a Draft Environmental Impact Statement (EIS) and an Environmental Review and Management Programme (ERMP) were submitted to the WA EPA and Australian Government in 1978. The project was approved by both the Australian and Western Australian governments in 1979.

Between 1980 and 1982 WMC undertook trial mining and operated a pilot processing plant in Kalgoorlie. Following implementation of the Australian Government's 'three mines policy' in 1983, the Yeelirrie project was placed on 'monitored care and maintenance' in 1984.

The Yeelirrie project was purchased by a subsidiary of BHP Billiton Limited (BHP Billiton) in 2005. BHP Billiton referred the proposed Yeelirrie development to the WA EPA under the EP Act in 2009 and the EPA determined the level of assessment as an ERMP with a 10 week public review period. Following the appeals process, the then Minister for Environment determined the public review period be extended to 14 weeks. In 2009 the Federal Environment Minister also determined that the proposed development was a Controlled Action under the EPBC Act. Extensive environmental and mine planning studies were undertaken between 2008 and 2011. This work was finalised and documented in a draft ERMP, however in early 2011, BHP Billiton decided not to proceed with the project and the document was not submitted to Government agencies for review.

In December 2012, Cameco purchased the Project, including the Yeelirrie pastoral lease from BHP Billiton. In November 2014, Cameco terminated the 2009 State referral and submitted a new referral due to changes to the Project. In December 2014, the EPA determined the Project would be assessed as a PER with a 12 week public review period. Cameco also advised the Federal DoE of the change of proponent and proposed variation to the Project. In December 2014, the DoE accepted the proposed variation to the proposal under section 156B of the EPBC Act.

Project Summary

Cameco is proposing to develop the Project, which comprises a uranium mine and associated treatment facilities (Figure E-2). Ore would be mined from shallow pits using open cut techniques. The ore would be processed using alkaline leaching, including the following steps; comminution via SAG milling, atmospheric alkaline leaching, counter current decantation (CCD), followed by direct precipitation of uranium oxide concentrate (UOC), product drying and packaging.

The current reported resource estimate (JORC Code and NI 43-101 compliant estimate) is 127.3 million pounds (Mlbs) (57,742 tonnes) (measured and indicated) with an average grade of U_3O_8 of 0.16% or 1,600 ppm. Over the anticipated 19 year life of the Project, it will produce an estimated 106 Mlbs (48,081 tonnes) of U_3O_8-based UOC for export.

The UOC would be transported by road from the mine site to the Port of Adelaide, South Australia, via the Goldfields Highway, and the Eyre Highway. This environmental assessment covers all transport within Western Australia. Transport within South Australia will be the subject of a separate assessment and approvals processes.

The Proponent

The proponent for the Project is Cameco Australia Pty Ltd, a wholly owned subsidiary of Canadian based uranium miner, Cameco Corporation. Cameco Corporation is one of the world's largest uranium producers with uranium assets on three continents, including Australia. Cameco Corporation's corporate head office is located in Saskatoon, Saskatchewan, Canada.

Cameco Corporation employs more than 3,300 people worldwide, engaged in uranium mining, refining and conversion. Cameco Corporation's vision is to be a dominant nuclear energy company producing uranium fuel. Its goal is to be the supplier, partner, investment and employer of choice in the nuclear industry.

Cameco Corporation measures its safety, environmental, social and financial performance using key performance indicators based around the following four measures of success:

- a safe, healthy and rewarding workplace;
- a clean environment;
- supportive communities; and
- outstanding financial performance.

The overall governance of safety, health, environment and quality at Cameco begins with the Safety Health Environment and Quality (SHEQ) policy, which states the commitment of the senior management of Cameco Corporation to the following principles:

- keeping risks at levels as low as reasonably achievable;
- prevention of pollution;
- complying with, and moving beyond legal and other requirements;
- ensuring quality of processes, products and services; and
- continually improving our overall performance.

Cameco Corporation's results in achieving its key performance indicators are available in the Companies 2014 Sustainable Development Report at www.cameco.com/sustainable_development/2014/.

Stakeholder Consultation

In developing the stakeholder consultation program, Cameco was conscious that significant work had been completed by BHP Billiton. Based on early feedback from consultation, Cameco has undertaken targeted consultation to serve three purposes:

- to provide education and build awareness about uranium mining and related matters (such as radiation, dust, implications for bush tucker and transport);
- to inform stakeholders about the proposed development and to gain feedback; and
- to inform stakeholders about Cameco, including for example, the Companies experience as one of the world's leading uranium miners and one of Canada's leading employers of Aboriginal people.

Regulatory Stakeholders

The concerns of regulatory stakeholders are primarily captured in the Environmental Scoping Document (Appendix A1) and are addressed in the PER.

Local Aboriginal Community

Local Aboriginal community members raised concerns across a range of topics, including,

- radiation and the proliferation of nuclear arms with specific reference to Maralinga, Chernobyl and Fukushima;
- radiation and the impact on bush food and the environment;
- protection of heritage places; and
- employment and community and business development opportunities.

Cameco has attempted to address these issues through presentations and discussions in forums arranged by the Central Desert Native Title Service and in meetings with individual family groups. Discussion on the impacts of radiation and the protection of heritage will continue throughout and beyond the public review period.

The desire to maximise the potential employment and community development opportunities that can come from development is also a very high priority for the local community and this will also be a topic for further discussion.

Local Government Authorities

Local Government authorities have expressed interest in the Project and any implications for local and regional services and service delivery. The transport of radioactive product from the Project (and the industry generally, given there are several other proposed Projects in the region) is a key topic and has been the subject of numerous presentations by Cameco and other companies.

Cameco is committed to continuing engagement with stakeholders throughout each phase of the Project to ensure key issues and relevant impacts and benefits are identified, monitored and appropriately managed.

Project Justification

Approximately 85% of the demand for uranium is supplied from mines, with the remainder supplied from uranium stockpiles or other secondary sources. These stockpiles are being drawn down and are expected to contribute less over time, which means that more primary production will be needed from uranium mines in the future. Cameco estimates about 15% of total supply required over the next decade will need to come from new mines not yet in development.

While WA does not have a commercially productive uranium mine in operation, several projects have either obtained or are seeking environmental approval and are being advanced. The Yeelirrie deposit is the largest known uranium deposit in WA. The proposed Project, which proposes to produce up to 7,500 tpa UOC, is well placed to take advantage of the current and expected growth in demand.

The Project

The Yeelirrie Project would produce up to 7,500 tonnes or 16.5 Mlbs per year of uranium oxide concentrate (UOC) as $UO_4.2H_2O$. Production will peak at this level in the second year of ore processing and steadily decline as the grade of the ore reduces. The average annual production over the 15 year ore processing period will be approximately 3,850 tonnes or 8,500 Mlbs of UOC.

The open pit footprint is approximately 9 km long, up to 1.5 km wide and about 10 m deep. The open pit would be dewatered, mined and backfilled progressively throughout the life of mine (LOM). Prior to commencement of processing, abstracted water from dewatering of active mine areas will be reinjected into areas that will be mined in the future. Once processing commences, dewatering will be used to supplement process water supply instead of being reinjected.

The ore and waste rock would be stockpiled near the open pit before being processed within the metallurgical plant, or backfilled into the pit. The metallurgical plant would use an alkali tank leaching process, followed by direct precipitation, to produce UOC for containerised export from Port Adelaide. All tailings generated during the metallurgical processing of the ore would be deposited to the tailings storage facility (TSF) constructed within the open pit.

The proposed development would necessitate the construction and operation of infrastructure required to support mining and processing, including the supply of water (from pit dewatering and a dedicated borefield) and electricity, workforce accommodation and infrastructure to transport the product.

At the completion of operations, the pit will be backfilled and capped with an engineered cover; development infrastructure would be decommissioned and removed; and the site would be rehabilitated.

The characteristics of the proposed development are summarised in Table E-1 and E-2 are shown on Figure E-2 and E-3.

Table E-1: Proposal summary and key characteristics of the proposed development

Proposal Title:		Yeelirrie Uranium Project
Proponent Name:		Cameco Australia Pty Ltd
Short Description:		The proposal is to mine uranium ore from the Yeelirrie deposit, approximately 70 km south west of Wiluna, and the construction of associated mine infrastructure, including ore processing facilities, water abstraction and reinjection infrastructure, roads, accommodation, offices and workshops, stockpile and laydown areas and evaporation pond. Tailings will be discharged back into the mine open pit.
Physical Elements		
Element	**Location**	**Proposed Extent**
Mine Open Pit	See Figures E-2 and E-3	Clearing of approximately 725.9 ha within a 4,874.6 ha development envelope and no deeper than 15 m below ground level.
Associated Infrastructure	See Figures E-2 and E-3	Clearing of approximately 1,695.9 ha within a 4,874.6 ha development envelope.
Operational Elements		
Element	**Location**	**Proposed Extent**
Mining Rate	Mining with conventional equipment	Up to 14 Mtpa of mineralised ore and non-mineralised material (annual average of approximately 8 Mt).
Ore Processing (waste)	All tailings deposited in open pit	Deposition of up to approximately 3.0 Mtpa.

Operational Elements		
Element	Location	Proposed Extent
Water Abstraction	Dewatering of pits and production from borefield. See Figures E-2 and E-3	Extraction of up to approximately 4.9 GL/a.
Water Reinjection		Reinjection of up to approximately 1.3 GL/a. (1)
GL/a – gigalitres per annum		Ha – hectares
m – metres		Mtpa – million tonnes per annum

Notes:

[1] In the early phase of the project, pit dewatering volumes exceed water demands. The surplus water would be re-injected into the local calcrete aquifer within the confines of the mine footprint.

Table E-2: Other project characteristics

Non-spatial elements	Description
Development operating life	An operational life of 22 years, including 3 years of pre-production dewatering, mining and construction followed by a further 12 years of mining and 15 years of processing. The conclusion of processing would be followed by an estimated 4 years of decommissioning and rehabilitation.
Nature of mineralisation	Shallow-depth alluvial deposit with mineralisation starting from surface to about 10 m below ground level, with a thickness between about 1 to7 m.
Operations summary	Open pit mining and on-site processing of uranium mineralised ore to produce uranium oxide concentrate.
Mining method	Open pit mining using conventional equipment such as excavators, front-end loaders and haul trucks.
Mining rate	Up to 14 Mtpa of mineralised ore and non-mineralised material (annual average of approximately 8 Mt).
Processing method	Alkali leach and direct precipitation.
Production rate	Up to 7,500 tpa of uranium oxide concentrate produced at peak production in the second year of ore processing. The average annual production over the 15 year ore processing period will be approximately 3,850 tonnes or 8,500 Mlbs of UOC as $UO_4.2H_2O$.
Tailings management	In-pit disposal to an engineered tailings storage facility.
Quarry	A quarry supplying approximately 500,000 tonnes of basic raw material would be located about 8 km north of the processing plant.
Waste management facility	A waste management facility would be established on the mining lease, approximately 4 km south east of the metallurgical plant.
Water supply	The development's primary water supply would be sourced from the initial dewatering of the open pit mine and then, as dewatering rates decreased, water would be piped from a network of groundwater wells. Obtaining water from this source would require the construction of pipeline and associated pumping infrastructure. The locations of borefields, access tracks and pipelines have not been finally resolved and are not included in the development drawings.
Annualised (over the 15 year process plant life) average water demand (ML/d)	8.7 ML/d (3.2 GL/a)

Maximum electricity demand (MW)	15
Non-spatial elements	**Description**
Average electricity consumption (MWh/a)	150,000
Maximum diesel demand (KL/a)	80,000 (excluding product transport diesel)
Accommodation village	A village would be constructed about 20 km east of the processing plant, with sufficient accommodation for up to 1,200 people.
Peak construction workforce	1,200
Average construction workforce	500
Peak operational workforce	300
Average operational workforce	225

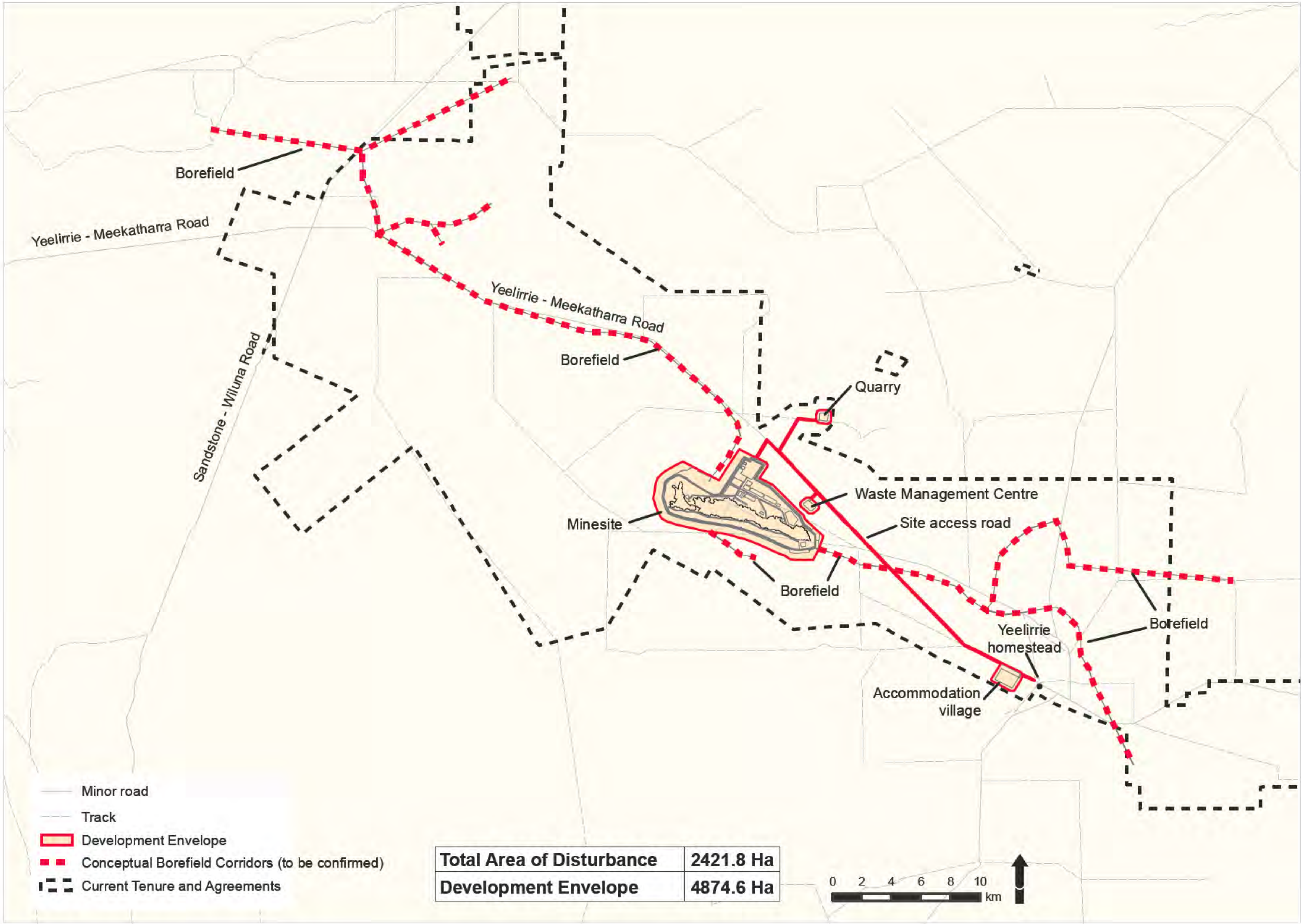
Regional Setting

The Yeelirrie Uranium Project is located in the Shire of Wiluna approximately 660 km north east of Perth and 420 km (or 500 km by road) north of Kalgoorlie-Boulder. The Project area is located in the Murchison bioregion, and in the Eastern Murchison (MUR1) subregion.

The Murchison bioregion is characterised by low hills and mesas separated by flat colluvium and alluvial plains. Vegetation is predominantly low mulga woodlands. The bioregion is one of the main pastoral areas in Western Australia, although mining (gold, iron ore and nickel) is the greatest income generator in the region. The Project is located on Yeelirrie Pastoral Station (owned by Cameco) which is currently destocked. Major population centres are Cue, Laverton, Leinster, Leonora, Meekatharra, Mount Magnet and Wiluna.

The Eastern Murchison subregion is characterised by "its internal drainage, and extensive areas of elevated red desert sandplains with minimal dune development". It contains salt lake systems associated with the occluded Palaeodrainage system, red sandplains and broad plains of red-brown soils and breakaway complexes. The Project occurs in the Yeelirrie catchment which drains to the southeast into Lake Miranda. The Project is located in the valley floor of the Yeelirrie Playa catchment drainage line on the confluence of two main drainage lines, although there are no permanent surface water drainage features.

Vegetation contains Mulga Woodlands which are often rich in ephemeral species, saltbush shrublands, Halosarcia shrublands and hummock grasslands.



Total Area of Disturbance	2421.8 Ha
Development Envelope	4874.6 Ha

Figure E-2: Project overview

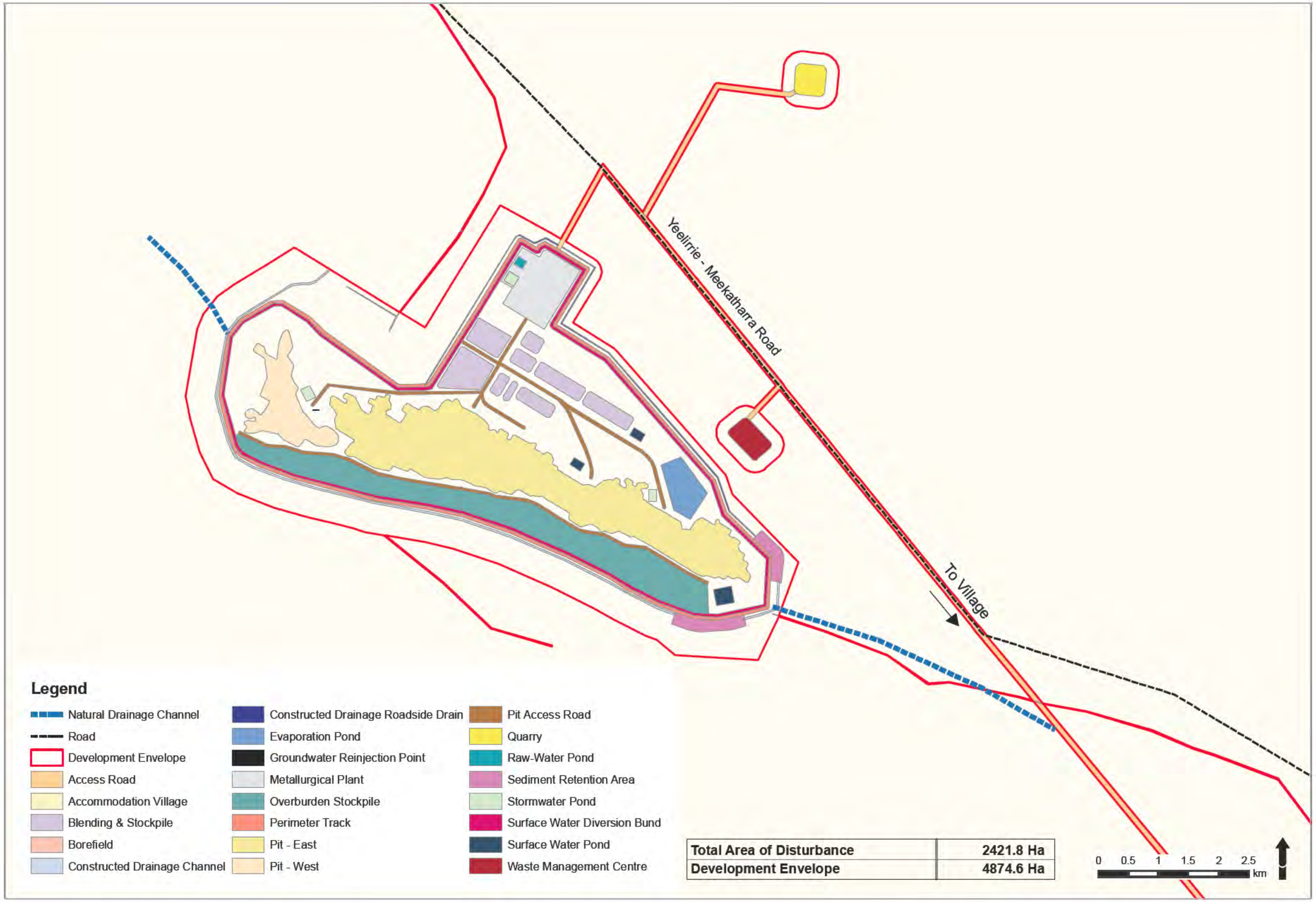


Figure E-3: Conceptual Project layout

There are four heritage sites registered with the WA Department of Aboriginal Affairs (DAA) that are within the Yeelirrie Project area, but not within the areas proposed to be disturbed by the Project.

Key Environmental Factors, Potential Impacts and Management

The following tables (Table E-3 and Table E-4) summarise the key environmental factors relevant to the Project, their potential impacts, proposed management measures and predicted outcomes.

Table E-3: Summary of potential impacts, proposed mitigation and management measures and commitments.

Key Environmental Factors	
Environmental Factor: 1	Flora and Vegetation
EPA Objective:	To maintain the representation, diversity, viability and ecological function at the species, population and community level.
Potential Impacts:	General • Clearing of up to 2,421.8 ha of native vegetation. • Clearing of more than 70% of Mulga *Acacia ayersiana*, *Grevillea berryana* Shrubland (CMGbS) on Calcrete from within the Study Area. 99% of this community is also within the predicted 1 m drawdown contour. The component species are widespread and abundant where they occur, however the regional representation of the community is not known (most likely due to low intensity mapping outside local Study Area). • Indirect impacts on groundwater dependent vegetation due to groundwater abstraction and reinjection. • Indirect impacts to vegetation dependent of surface water due to alterations and disruptions to surface water flows. • Introduction and spread of weeds or plants from outside the local area, into mining areas and adjacent native vegetation through movement of vehicles and materials. • Altered fire patterns. • Indirect impacts on flora and vegetation from dust. • Uptake of radionuclides. ERICA modelling indicated the expected dose rate for all plant groups expected to be less than the screening level of 10 µGy/h, with the exception of lichen and bryophytes. These organisms derive most of their nutrients from dust falling on them. However, lichen and bryophytes are known to be particularly radio-resistant and a threshold no-effect dose rate has been estimated to be 125,000 µGy/h, with some diversity reduction observed at 1.1 Gy/h (UNSCEAR 1996). Consequently no effect on lichens and bryophytes is expected from dust emissions from the Project. Conservation Significant Species • This will include clearing of the Western population of the Threatened species *Atriplex* sp. Yeelirrie Station, which is present on the orebody. • A small proportion of Priority 3 species *Bossiaea eremaea* (4.29% of population in Study Area), *Eremophila arachnoides* subsp. *arachnoides* (11.84%) and *Euryomyrtus inflata* (0.3%) will also be affected. There will be no direct impacts on Priority 1 species *Rhagodia* sp. Yeelirrie Station, but indirect impacts may result from changes to surface water drainage patterns and affect a small proportion of the population within the Study Area (4.8%).

Key Environmental Factors	
Management Measures:	General - Avoid and Minimise • Clearing will be kept to the minimum area required for safe and efficient operation in accordance with the Flora and Vegetation Management Plan to be developed for the project. • Cameo will conduct Level 2 surveys of borefields and corridors and any other areas not covered by the existing Level 2 flora survey and provide a report of the survey as part of an application for a Clearing Permit prior to the commencement of ground disturbing activity. • Cameco will implement ground disturbance procedures that will apply to all clearing activities. Clearing will not be conducted during or immediately after rain to reduce the risk of erosion and damage to soil structure. • All earth moving equipment and other vehicles or machinery will be cleaned of all soil and seeds before mobilisation into new clearing areas. Weed control will be undertaken for infestations with the potential to spread. • A vegetation condition monitoring program will be implemented to monitor potentially groundwater dependent vegetation communities within the drawdown zone and compare with control sites. Contingency measures will be developed, should there be a risk of impacts on groundwater dependent communities. • As part of monitoring of the integrity of surface water diversion and management structures, Cameco will also monitor nearby vegetation health. • Dust management and suppression measures will be undertaken (refer to Environmental Factor 8). • Hot work permits will be required for any work that may generate an ignition source. Fire extinguishers will be available in all work areas and personnel will be trained in their use. General – Rehabilitate • Vegetation removed during clearing activities will be temporarily stockpiled to be used as mulch and a seed source in revegetation. Overburden material that is suitable for rehabilitation will be stripped and stored in low stockpiles to retain seed viability and be protected from erosion and accidental disturbance. • Disturbed areas that are no longer required will be progressively rehabilitated over the life of the mine. The pit will be progressively backfilled and rehabilitated from year 11. Conservation Significant Species - Avoid and Minimise • Cameco will continue to implement the Conservation Species Management Plan. Measures will include protection of the Eastern Population of *Atriplex* sp. Yeelirrie Station and implementation of a research plan and a translocation program for the reestablishment of the Western Population of the species. Work undertaken to date provides reasonable evidence to indicate that this could be achieved. • Cameco will avoid direct disturbance of *Rhagodia* sp. Yeelirrie Station where practicable. Cameco is proposing to establish a protected area for the known population present inside the Development Envelope.
Commitments:	• Develop and implement a Flora and Vegetation Management Plan. • Develop and implement a Conservation Species Management Plan.
Outcomes:	Residual impacts on significant flora are predicted to occur as a result of implementation of the Project and therefore offsets are proposed (Section 12.4) Taking into account the Project design, the proposed management measures, and the proposed implementation of a revegetation and offset strategy to replace the Western population genotype of *Atriplex* sp. Yeelirrie Station, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and community level.

Key Environmental Factors

<table>
<tr><th>Environmental Factor: 2</th><th>Subterranean Fauna</th></tr>
<tr><td>EPA Objective:</td><td>To maintain the representation, diversity, viability and ecological function at the species, population and assemblage level.</td></tr>
<tr><td>Potential Impacts:</td><td>General
Removal of subterranean fauna habitat through the excavation of the pit.
Habitat loss / alteration of areas within groundwater drawdown contours and reinjection areas.
Impacts to habitat from ground disturbance, stockpiling and surface contamination and backfilling with tailings.
Priority Ecological Community (PEC)
Approximately 37% of the inferred calcrete habitat within the Yeelirrie Priority 1 PEC will experience groundwater drawdown of >0.5 m. Approximately 60% of the adjacent inferred playa area will also experience groundwater drawdown of >0.5 m.</td></tr>
<tr><td>Management Measures:</td><td>General - Avoid and Minimise
Groundwater abstraction rates will be managed to minimise potential environmental impacts and the required Project water supply volume will be reduced as far as practicable throughout the life of the Project.
Groundwater abstraction rates and groundwater levels will be monitored to confirm predicted drawdown levels.
Preferentially locating well fields in the alluvium/weathered bedrock aquifers in the areas north of the valley floor and north of the proposed pit to limit impact to the palaeochannel.
Not locating any abstraction wells within the palaeochannel to the northwest of the pit.
Investigating opportunities to improve the groundwater abstraction scheme and reduce the impact to stygofauna during a Definitive Feasibility Study phase of the Project prior to the commencement of dewatering.
Management of the PEC and Restricted Species - Avoid and Minimise
Cameco will work with DPaW to define the Yeelirrie PEC, determine the impact on the PEC and to develop additional management options.
Cameco is proposing to locate wellfields in the alluvium/weathered bedrock aquifers in the areas north of the valley floor and north of the proposed pit.
Cameco will limit groundwater drawdown in the palaeochannel to the northwest of the pit where there are a number of species that have only been sampled in this area.
Rehabilitate
As per Environmental Factor 12 (Rehabilitation and Decommissioning)</td></tr>
<tr><td>Commitments:</td><td>Develop and implement a Groundwater Operating Strategy including a Groundwater Management Plan.
Develop and implement a Subterranean Fauna Management Plan.</td></tr>
<tr><td>Outcomes:</td><td>Residual impacts on subterranean fauna are predicted to occur as a result of implementation of the Project and therefore offsets are proposed (Section 12.4).

Taking into account the Project design, the proposed management measures, and the proposed offset strategy of ongoing investigations to better understand species habitat and expand the range of species potentially impacted, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.</td></tr>
</table>

Key Environmental Factors	
Environmental Factor: 3	Terrestrial Fauna
EPA Objective:	• To maintain the representation, diversity, viability and ecological function at the species, population and assemblage level.

Potential Impacts:	General
	• Loss and/or fragmentation of habitat from vegetation clearing, changes to surface water patterns, abstraction and reinjection of water.
	• Increased risk of collisions with vehicles.
	• Exposure of birds to process water ponds in evaporation pond. The uranium concentration in the evaporation pond is expected to be below 60 mg/L. The Uranium No Observable Impact Level (NOAEL) benchmark for ingested water is 68.8 mg/L for birds or 6.995 mg/L for mammals (Sample *et al.* 1996). Therefore for birds, uranium concentrations are expected to be below NOAEL benchmark. The risk to most mammals is expected to be low as the pond will be fenced to exclude macrofauna.
	• Radiation doses to fauna. ERICA modelling indicated the expected dose rate for all groups of fauna as a result of the Project was below the screening level of 10 µGy/h. Therefore no significant radiation impacts on terrestrial fauna are expected to occur as a result of the Project.
	• Attraction of feral and predatory fauna to areas used for water storage or food wastes, increasing pressure on native fauna.
	• Entrapment of fauna in open excavations.
	• Dust, noise and vibration impacts.
	• Light impacts on nocturnal species.
	• Loss of habitat through changes to the fire regime.
	
	Conservation Significant Species
	• Potential impacts including loss of habitat, changes to hydro-ecology and dust generation on conservation significant vertebrate fauna as a result of the Project are expected to be negligible or minor.
	• Potential impacts including loss of habitat, changes to hydro-ecology and dust generation on conservation significant invertebrate (short-range endemic) fauna as a result of the Project are expected to be negligible or minor with the exception of moderate impacts on the following species:
	  • Isopods Platyarthridae/Bathytropidae and Pseudolaureola sp.
	  • Mygalomorphs *Aname* ‘MYG212’ and Barychelidae; and
	  • Pseudoscorpion Cheridiidae.

Management Measures:	General - Avoid and Minimise • Cameco will minimise habitat loss from ground disturbance and clearing activities in accordance with a Flora and Vegetation Management Plan to be developed for the Project. • There will be no unauthorised driving off tracks, night driving will be limited, and vehicle speeds will be restricted around the Project Area and sensitive habitats. • The evaporation pond will be inspected daily for fauna and bird access. Should fauna visitations to the facilities be considered significant, measures will be taken to deter fauna. • Dust suppression along access roads will be managed in accordance with the Dust Management Plan to be prepared for the Project. • Waste disposal areas around the site will be maintained with inert and putrescible waste disposed of to a fenced landfill. • The presence of introduced fauna species and pests will be monitored and appropriate control measures implemented if necessary.

Key Environmental Factors	
	• Changes to surface water flow regimes will be managed in accordance with a Surface Water Management Plan to be developed for the Project. • Removal of stock and decommissioning of existing stock watering points (in consultation with stakeholders) across Yeelirrie Station. • Hot work permits will be required prior to commencing any activity that may create an ignition source. Cameco will prepare and implement a Fire Prevention and Management Plan. **General – Rehabilitate** • Disturbed areas that are no longer required will be progressively rehabilitated over the life of the mine. • The pit will be progressively backfilled and rehabilitated from year 11. **Conservation Significant Species – Avoid and Minimise** • Training on the identification and reporting of conservation-significant fauna species will be included in the Cameco site induction. • The ground disturbance guideline will ensure that areas to be cleared are first inspected by qualified environmental personnel to determine if there are any significant habitats or signs of significant fauna activity. Training on vegetation clearing procedures will be included in an environmental induction. • Work with DPaW and local indigenous groups to assist in the implementation of a landscape scale fire management program to manage habitat for conservation significant species.
Commitments:	• Develop and implement a Fauna Management Plan.
Outcomes:	Taking into account the project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.

Environmental Factor: 4	Hydrological Processes and Inland Water Quality (Surface Water)
EPA Objective:	To maintain the hydrological regimes of surface water so that existing and potential uses, including ecosystem maintenance, are protected. To maintain the quality of surface water, sediment and biota so that the environmental values, both ecological and social, are protected.
Potential Impacts:	• Alteration of the natural water surface water drainage patterns and water balance due to diversion of surface water flows around, and collection of surface water within the Development Envelope. • Alteration of surface water flows which may result in changes to natural erosion and deposition patterns and increase turbidity of surface water. • Alteration of hydrology of creeks from groundwater abstraction and reinjection if there is a connection with the groundwater. • Risk of overtopping TSF or evaporation pond following extreme rainfall events. • Contamination of surface water as a result of loss of containment of ore or pregnant liquor solution. • On closure the backfilled pit is not expected to be inundated except under a 1:1,000 year ARI or Probable Maximum Precipitation (PMP) events, at which time surface water could infiltrate the closed landform.

Key Environmental Factors	
Management Measures:	**Avoid and Minimise** • Cameco will develop a Surface Water Management Plan to minimise the impacts on surface water and ensure no release of contaminants to the environment. • Construction of a surface water diversion bund that has been designed to divert water around the mine site. • The surface water diversion bund will be developed in two stages to minimise the amount of runoff and rainfall that would collect within the mine and require management. • Construction of a flood retention bund to retain potentially contaminated floodwater within the bund, from a 1-in-1,000 year ARI flood event. • Manage the diversion and retention bunding to operate the Site as a 'no release' site. • Stormwater runoff will be captured in a series of stormwater ponds located within the mine site designed to capture a 1-in-20 year ARI event. If however, rainfall exceeds design capacity, the stormwater would be directed to inactive pits. • Sedimentation basins will be constructed at the downstream (eastern) ends of the diversion channel. • The ROM pad and other stockpile areas would be compacted to control seepage and would be graded so that runoff and seepage would be directed to a storm water runoff pond. Water captured in the ponds would be used to supplement the water supply for the processing plant. • Storage areas for process chemicals and liquors will be sealed and bunded to ensure that and process spills can be contained and easily cleaned up. **Rehabilitate** • On closure, all mineralised material will be processed or placed back into the open pit which will be backfilled and an engineered cover constructed over the in-pit TSF. • Surface water drainage patterns will be reinstated around the final landform. • Other aspects as per Environmental Factor 12 (Rehabilitation and Decommissioning)
Commitments:	• Develop and implement a Surface Water Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objectives with regards to Hydrological Processes and Inland Water Quality (Surface Water).

Environmental Factor: 5	Hydrological Processes and Inland Water Quality (Groundwater)
EPA Objective:	To maintain the hydrological regimes of groundwater so that existing and potential uses, including ecosystem maintenance, are protected. To maintain the quality of groundwater so that the environmental values, both ecological and social, are protected.

Key Environmental Factors	
Potential Impacts:	• The estimated total volume of water from wellfield sources needed to meet the water demand is approximately 46 GL over the life of the Project. • Groundwater abstraction, mine pit dewatering and aquifer recharge, could potentially impact groundwater availability to groundwater dependent ecosystems and other groundwater users. • Maximum groundwater drawdowns in the Western, Northern and Eastern brackish well fields are expected to be approximately 2, 5 and 3 m, respectively. Around the mine pit the drawdown will typically exceed 7 m. • The predicted water level drawdown in the palaeochannel shows that there is no notable interference between the proposed abstraction at Yeelirrie and the Albion Downs palaeochannel wellfield. • Prior to the commencement of processing, water from mine dewatering will be re-injected into the underlying aquifers. Groundwater mounding around the injection wells is predicted to increase groundwater levels to a maximum of 1 m. The reinjection well will be located within the open pit. • Precipitation of solids could occur due to mixing of groundwater chemistry during the reinjection process. • Storage of ore and mine waste in stockpiles, and tailings in the TSF, could result in contamination of the groundwater. • Seepage from the in-pit TSF carrying uranium, vanadium, arsenic and molybdenum may travel several hundred metres longitudinally along the valley, but is not expected to reach beyond the eastern boundary of the pit. Seepage may extend up to 600 m north and 200 m south of the in-pit TSF. • Groundwater levels are expected to recover significantly within 50 years following cessation of dewatering and to baseline levels within 100 years. No discernible change in groundwater flow is expected at the catchment scale.
Management Measures:	Design - Avoid • Cameco has decided on a Project implementation strategy to allow for storage of tailings in the open pit thereby avoiding additional groundwater impacts from an above-ground facility. The in-pit TSF will have under drainage to capture any leachate for use in the metallurgical plant. General – Avoid and Minimise • Cameco will prepare and submit a detailed Groundwater Operating Strategy including a Groundwater Management Plan as part of the application of a 5C groundwater license. • Groundwater abstraction rates will be managed to minimise potential environmental impacts and the required Project water supply volume will be reduced as far as possible throughout the life of the Project. • Groundwater abstraction rates and groundwater levels will be monitored to confirm predicted drawdown levels. • Cameco will continue baseline monitoring of groundwater wells to increase levels of confidence around the response of groundwater to rainfall events. Rehabilitate • As per Environmental Factor 12 (Rehabilitation and Decommissioning).
Commitments:	• Develop and implemment a Groundwater Operating Strategy including a Groundwater Management Plan..
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objectives with regards to Hydrological Processes and Inland Water Quality (Groundwater).

Key Environmental Factors

Environmental Factor: 6	Human Health (Radiation)
EPA Objective:	To ensure that human health is not adversely affected.
Potential Impacts:	• Dust emissions from areas where mineralisation is near the surface, or ore and mineralised waste stockpiles are present. • Radon gas emanation from disturbed areas where mineralisation is near the surface. • Contamination of air, soils, sediments, surface or groundwater by radionuclides through dust emissions, surface water runoff or seepage. • Gamma radiation exposure from potential build-up of radionuclides. • Estimated radiation doses to Cameco's Yeelirrie workforce shows that these are predicted to be less that the guideline dose limits. • The potential radiation exposure pathways for members of the public within the Development Envelope and along the transport routes are: inhalation of radioactive dusts, gamma exposure, inhalation of radon decay products and ingestion of water, animals or plants that come in contact with emissions. The estimated radiation exposure of the general public is predicted to be less than the guideline dose limit of 1 mSv/y (+ background).
Management Measures:	Design - Avoid The Project has been designed to ensure that human and ecological radiation exposures are as low as reasonably achievable (ALARA) and comply with Australian Standards, codes of practice and guidelines. General • Cameco will develop a Radiation Management Plan and obtain approval to implement the Plan prior to commencement of the Project. Incident response planning will be included as part of the overall site Emergency Response Plan. • Qualified radiation protection personnel would be employed to implement the management plan. • All personnel will be appropriately trained. • A data management system will be used to store and manage all information relating to radiation management and monitoring. General - Avoid and Minimise • Operations will be divided into 'clean' and 'potentially contaminated' areas. Access to controlled areas will ensure that only those who have been properly trained in radiological protection measures are admitted. • Movement of vehicles from the potentially contaminated areas will be via a washdown bay to remove all mineralised material. Generally vehicles that are likely to be regularly in contact with higher grade uranium mineralisation will be kept within the contaminated area. • A specific radiation safety work permit system will be implemented. • The time spent in high dose areas by individual workers will be limited, through careful rostering and scheduling of those workers operating ore recovery equipment, backed up by detailed monitoring. • Radiation monitoring results will be reviewed on an ongoing basis to determine the adequacy and effectiveness of engineering and management controls and reduce radiation exposures of people and the environment. • As part of the operational ALARA program, a series of action levels would be established to ensure that radiation exposures remain controlled.

Key Environmental Factors	
	Mining - Avoid and Minimise • All heavy equipment operating in the pit will have air-conditioned cabs with effective air filtration systems. • Dust management measures will be implemented in accordance with the Dust Management Plan. **Process Plant - Avoid and Minimise** • Crushers and conveyor transfer systems will be fitted with appropriate dust control measures, including the use of water sprays and/or dust extraction at dust generating sources. • The process plant uses wet processing which minimises dust generation. • All operational areas in the plant will be bunded. Spillage will be collected and returned to the processing vessels or to the tailings storage facility. **Mineralised Waste Management - Avoid and Minimise** • Stockpile areas will be compacted to minimise infiltration and bunded to capture potentially contaminated surface water, which will be transferred to the process plant. • Dust management measures will be implemented in accordance with the Dust Management Plan. **Tailings Management - Avoid and Minimise** • Tailings will be pumped from the processing plant to the TSF in a slurry form. Tailings will be kept moist during operations to prevent dust lift off. **Waste Water Management - Avoid and Minimise** • Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or from the mineralised overburden stockpile will be captured and transferred to the process plant or evaporation ponds. • Runoff will drain to sedimentation and stormwater ponds which will be designed to retain runoff from a 1-in-20 year ARI event. The surface water retention bund will be capable of retaining runoff within the mine area from a 1-in-1,000 year ARI event. • Waste water from washdown areas and cleanup water would also be captured for treatment and evaporation. **General Waste - Avoid and Minimise** • A system of separate collection of potentially contaminated wastes from operational areas will be implemented. • All equipment will be tested for contamination. Where recycling is practicable, items will be decontaminated to approved radiation levels before leaving site. Items that cannot be properly decontaminated, or where recycling is impracticable, will be buried in an approved manner. **Transport - Avoid and Minimise** • The dried UOC product would be top-loaded into 205-litre steel drums and sealed with lids and ring-clamps. The drum-filling station would be located in an airlock that maintains negative pressure to prevent uranium entering the work areas. The outside of the drums would be subsequently washed to remove any residual product from the lids and surfaces before labelling and loading into shipping containers for transport and export. • All consignments would have extensive safety, operational, emergency response and security arrangements in place.

Key Environmental Factors	
	Rehabilitate • All mineralised material will be backfilled to the pit with an engineered cover (refer to Environmental Factor 12). • The post-closure landform will be monitored in accordance with the Mine Closure and Rehabilitation Plan to ensure that it meets surface contamination criteria. • Radiation exposure to members of the public on the rehabilitated landform is expected to be low as the engineered cover will provide an effective barrier to radon by increasing the diffusion time of radon through the cover. • As per Environmental Factor 12 (Rehabilitation and Decommissioning).
Commitments:	• Develop and implement a Radiation Management Plan. • Develop and implement a Transport Radiation Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Human Health (Radiation).

Environmental Factor: 7	Amenity (Noise)
EPA Objective:	To ensure that impacts to amenity are reduced as low as reasonably practicable.
Potential Impacts:	• Noise modelling undertaken for the BHP Billiton Yeelirrie defined project indicated that the impacts on the nearest sensitive receptors were expected to comply with the Environmental Protection (Noise) Regulations 1997 and be very low to zero due to the remoteness of the Yeelirrie Project. As the noise impacts of Cameco's Project are expected to be similar no further modelling was undertaken. • Noise impacts from increased traffic movements at residences located along the transport route are expected to increase by 0.4 dB(A) which is considered negligible. Therefore noise impacts along the transport route were not required to be assessed in detail in accordance with State Planning Policy (SPP) 5.4
Management Measures:	**Avoid and Minimise** • Cameco will minimise noise emissions from the Project by operating and maintaining equipment in accordance with the manufacturers requirements. • Cameco will require its transport contractors to regularly maintain and operate vehicles in accordance with manufacturers requirements to minimise noise emissions.
Commitments:	• Comply with the Environmental Protection (Noise) Regulations 1997.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Amenity (Noise).

Key Environmental Factors

Environmental Factor: 8	Air Quality
EPA Objective:	To maintain air quality for the protection of the environment and human health and amenity.

Potential Impacts:	• Generation of dust (including dust containing radioactive material) resulting from mining, stockpiling, transporting, processing, crushing and milling resulting in impacts at sensitive receptors.
	• Atmospheric emissions from the on-site diesel power generators may impact on the air quality at the sensitive receptors.
	• The results of the dispersion modelling indicate that:
	  • fugitive dust emissions from the Project are not likely to result in unacceptable air quality impacts at any of the sensitive receptors; and
	  • emissions from the on-site diesel power generators will not result in unacceptable air quality impacts at any of the sensitive receptors.

Management Measures:	General – Avoid and Minimise • The Project has been designed to minimise atmospheric emissions as a result of its operation and comply with all relevant air quality standards and guidelines. • The process plant uses wet processing and the plant has been designed to minimise particulate emissions. • Tailings will be deposited to the in-pit TSF as a slurry and kept moist throughout operations to prevent dust generation at the surface. • The power station will be maintained to operate efficiently. • A Dust Management Plan will be prepared for the Project. The plan will include ambient monitoring of PM_{10} concentrations and dust deposition rates. In the unlikely event that the monitoring results show exceedances of the standards, they will be used to develop management targets for PM_{10} concentrations to allow adequate response time for Cameco to apply mitigation measures (e.g. additional water application) to reduce the risk of exceeding the NEPM standard. • Within the mining and stockpile areas conventional dust management techniques, including the use of water sprays, dust suppressants and progressive rehabilitation, will be used to manage dust emissions. Rehabilitate • Disturbed areas that are no longer required will be progressively rehabilitated over the life of the mine to reduce the potential for fugitive dust generation. • The pit will be progressively backfilled and rehabilitated from year 11. • As per Environmental Factor 12 (Rehabilitation and Decommissioning).
Commitments:	• Develop and implement the Dust Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Air Quality.

Key Environmental Factors

Environmental Factor: 9	Air Quality (Greenhouse Gas Emissions)
EPA Objective:	To minimise the emission of greenhouse and other atmospheric gases through the application of best practice.
Potential Impacts:	• Greenhouse gas emissions (GHG) from land clearing, fuel combustion, desorption from the TSF, breakdown of wastes and leakage of synthetic gases. • Total gross emissions are predicted to be approximately 3.76 x 10^6 t CO_2-e across the Project life of 22 years. When sequestration due to rehabilitation of the site is included into the calculated emissions, the net GHG emissions are estimated to be 3.73 x 10^6 t CO_2-e.
Management Measures:	Avoid and Minimise • Optimisation of the mining fleet size in order to best meet the targets of the mine plan and minimise diesel demand for the mining fleet. • Optimisation of the metallurgical process to reduce the electricity and steam requirements, including the capture and use of waste heat where possible, to reduce the site diesel demand. • Incorporation of energy efficiency measures for the accommodation and administration facilities. • Solar hot water systems and solar photovoltaic systems for the site administration and accommodation facilities. • Solar photovoltaic power systems for powering the remote groundwater wells and associated pumping stations. • Cameco will continue to investigate GHG emission abatement projects throughput the life of the Project as technologies improve. Rehabilitate • Disturbed areas that are no longer required for the operation of the Project will be progressively rehabilitated over the life of the mine to offset GHG emissions from clearing.
Commitments:	• Develop a GHG and Energy Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Air Quality (Greenhouse Gas Emissions).

Environmental Factor: 10	Terrestrial Environmental Quality
EPA Objective:	To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.
Potential Impacts:	• Mineralised material being deposited outside of the mining areas during hauling process. • Erosion and sedimentation (refer to Environmental Factor 4). • Flooding and overtopping of water storage facilities (refer to Environmental Factor 4). • Accidental spills (refer to Environmental Factor 4). • Seepage from TSF and waste storage (refer to Environmental Factor 5). • Dust deposition (refer to Environmental Factor 8).
Management Measures:	Avoid and Minimise • Vehicle and equipment hygiene measures will be implemented in accordance with the Radiation Management Plan to ensure that contaminated material is not transported off-site. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation will be kept within the contaminated area (refer to Environmental Factor 6).

Key Environmental Factors	
	• Minimise dust impacts in accordance with the Dust Management Plan (refer to Environmental Factor 8). • Implement surface water management measures in accordance with the Surface Water Management Plan to prevent release of contaminated runoff (refer to Environmental Factor 4). • Implement spill control procedures as required. Rehabilitate • Prior to commencement of construction, Cameco will have ascertained the availability and volumes of key materials required for rehabilitation. The results of these investigations will be presented in a revised version of the Mine Closure and Rehabilitation Plan to be submitted prior to the commencement of construction (refer to Environmental Factor 12). • Topsoils will be mapped and preferentially stockpiled for use in rehabilitation and revegetation. Topsoil will be stored in low stockpiles to retain seed viability and will be protected from erosion. Topsoil will not be handled when wet to avoid damaging soil structure. Soils that are not suitable for use in rehabilitation or construction (e.g. dispersive, saline soils) will be buried within the final landforms. • Cameco will ensure that all ore or mineralised waste is either processed through the processing plant, or buried in-pit at the end of mine life.
Commitments:	• Develop and implement surface water management measures as outlined in the Surface Water Management Plan. • Develop and implement a Radiation Management Plan. • Develop and implement a Dust Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Terrestrial Environmental Quality.

Environmental Factor: 11	Heritage
EPA Objective:	To ensure that historical and cultural associations, and natural heritage, are not adversely affected.
Potential Impacts:	• The Project will not have an impact on any Registered Aboriginal Sites. • The Project will impact a number of places where archaeological material and culturally modified trees have been identified. Disturbance to some of these places will be unavoidable during development of the Project.
Management Measures:	General • Cameco will consult with the Department of Aboriginal Affairs (DAA) regarding the status and management of archaeological sites across the Development Envelope. • Cameco will undertake consultation with members of the Tjiwarl Native Title claimants and with other Aboriginal groups with an interest in the area about the archaeological material and sites. General – Avoid and Minimise • **Cameco will u**ndertake investigations for archaeological sites on land that has not been previously surveyed. • Cameco will minimise ground disturbance and clearing activities in accordance with a Cultural Heritage Management Plan to be developed for the Project. This will include a pre-disturbance protocol to check for areas of significance.
Commitments:	• Cameco will develop and implement a Cultural Heritage Management Plan.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Heritage.

Key Environmental Factors

Environmental Factor: 12	Rehabilitation and Decommissioning
EPA Objective:	To ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner.
Potential Impacts:	• Residual soil or groundwater contamination and radon exhalation from the final landform. • Groundwater levels fail to recover following closure. • Backfilled soil profiles may restrict surface water channel and cause increased fluvial erosion and sediment transport (refer to Environmental Factor 4). • Erosion of final rehabilitated landform. • Inundation of the backfilled pits during peak rainfall events. • Spread of weed species inhibiting local species re-establishment. • Visual impacts from closed Project. • Post-mine radiation assessment has shown that ambient radiation doses will comply with relevant guidelines and be similar to the pre-mine environment (refer to Environmental Factor 6). • Post-closure modelling of seepage from the in-pit TSF carrying uranium, vanadium, arsenic and molybdenum may travel several hundred metres longitudinally along the valley, but typically not beyond the eastern boundary of the pit. Seepage may extend up to 600 m north and 200 m south of the in-pit TSF (refer to Environmental Factor 5). • Groundwater levels are expected to recover significantly within 50 years following cessation of dewatering and to baseline levels within 100 years. No discernible change in groundwater flow is expected at the catchment scale (refer to Environmental Factor 5). • Landform evolution modelling has shown that the final landform will be stable for at least 10,000 years. • On closure the backfilled pit is not expected to be inundated except under 1:1,000 year ARI or Probable Maximum Precipitation (PMP) events, where surface water could infiltrate the closed landform.
Management Measures:	General • Review and implementation of the Mine Closure Plan prior to commencement of operations. This will include establishment of rehabilitation objectives and completion criteria in consultation with key stakeholders. Rehabilitate • All plant and associated infrastructure will be demolished and removed at the conclusion of operations, subject to negotiations with key stakeholders. • Conduct progressive rehabilitation in accordance with the Mine Closure and Rehabilitation Plan. Commencement of rehabilitation during operations will enable rehabilitation methods to be refined throughout the LOM. • The backfilled pit will be constructed with an engineered cover as determined by geotechnical modelling. • The surface of the backfilled pit will be raised above the surrounding topography similar to the pre-mining topography and surface water flows will be reinstated around the final landform. • As no surface mining features (other than the slightly-raised backfilled pit) will be present post-closure, there are not expected to be any significant visual impacts from the Project following closure.
	• Ongoing weed management throughout operations and weed monitoring and control post-closure until completion criteria are achieved. • Implementation of the monitoring programs outlined in the Mine Closure and Rehabilitation Plan, until agreed completion criteria are achieved.

Key Environmental Factors	
Commitments:	• Develop, review and implement the Mine Closure and Rehabilitation Plan.
Outcomes:	Construction of a safe, stable, non-polluting post-mine landform that is capable of sustaining agreed post operational land use, and does not impact on surrounding environmental values or uses. Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Rehabilitation and Decommissioning.

Other Factors	
Environmental Factor: 13	Amenity
EPA Objectives:	To ensure impacts to amenity are reduced to as low as reasonably practical.
Potential Impacts:	• Some road works would be required to upgrade the existing road infrastructure for use by heavy vehicles and to construct the proposed borefield water supply pipeline. The result of such work would be improved access for road users and short term amenity impacts will be managed. • The Project is expected to moderately increase daily traffic along the public roads, which would also have the effect of making Yeelirrie and its surrounds more accessible and decreasing its 'remoteness'. • Given the distances to nearby occupied homesteads and the number of anticipated daily flights, the impact on amenity from air traffic and operation of the Project is expected to be low. • Refer to Environmental Factors 7 for Amenity (Noise) and 8 for Air Quality and Atmospheric Gases.
Management Measures:	Avoid and Minimise • Road upgrades and maintenance would be undertaken in consultation with road owners and landholders and in a manner that minimises disruption to traffic movements. • The intersection of the Albion Downs–Yeelirrie Road and the Goldfields Highway will be upgraded to provide appropriate traffic measures, such as slip lanes and turning lanes, for vehicles entering or leaving the Goldfields Highway at this intersection.
Outcomes:	Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Amenity.

Table E-4: Summary of potential impacts, proposed management and commitments - (*Commonwealth Environment Protection and Biodiversity Conservation Act 1999*)

Matters of National Environmental Significance (MNES)	
Environmental Factor: 13	Listed Threatened and Migratory Fauna
Potential Impacts:	Refer to Environmental Factor 3. • Habitat loss (leading to population decline and fragmentation). • Habitat degradation due to weed invasion or changes to hydroecology. • Habitat change due to altered fire regimes. • Ongoing mortality (leading to population decline). • Species interactions (feral or overabundant native species). • Dust impacts. • Radiation exposure and bioaccumulation. • Potential impacts on conservation significant vertebrate fauna as a result of the Project are expected to be negligible or minor. • Potential impacts on the conservation significant Shield-backed Trapdoor Spider are expected to be minor.
Management Measures:	Refer to Environmental Factor 3. • The evaporation pond will be inspected daily for fauna and bird access. Should fauna visitations to the facilities be considered significant, measures will be taken to deter fauna. • Training on the identification and reporting of conservation-significant fauna species will be included in the Cameco site induction. • The ground disturbance protocol will ensure that areas to be cleared are first inspected by qualified environmental personnel to determine if there are any significant habitats or signs of significant fauna activity. Training on vegetation clearing procedures will be included in the environmental induction. • Dust suppression will be undertaken in accordance with the Dust Management Plan. • Work with DPaW and local indigenous groups to assist in the implementation of a landscape scale fire management program.
Commitments:	• Develop and implement a Fauna Management Plan.
Outcomes:	No significant impacts to listed Threatened or Migratory Fauna.

Environmental Factor: 14	Nuclear Actions
Potential Impacts:	Refer to Environmental Factor 6. • Estimated radiation doses to Cameco's Yeelirrie workforce are expected to easily comply with the guideline dose limits. • Radiation exposure of the general public will easily comply with the guideline dose limit of 1 mSv/y (+ background). • Radiation exposure to members of the public on the rehabilitated landform is expected to be low as the engineered cover will provide an effective barrier to radon by increasing the diffusion time of radon through the cover. • ERICA modelling indicated that the expected dose rate for all groups of fauna as a result of the Project was below the screening level of 10 µGy/h. Therefore no significant radiation impacts on terrestrial fauna are expected to occur as a result of the Project.

Matters of National Environmental Significance (MNES)	
	• ERICA modelling indicated the expected dose rate for all plant groups expected to be less than the screening level of 10 µGy/h, with the exception of lichen and bryophytes. These organisms derive most of their nutrients from dust falling on them. However, lichen and bryophytes are known to be particularly radio-resistant and a threshold no-effect dose rate has been estimated to be 125,000 µGy/h, with some diversity reduction observed at 1.1 Gy/h (UNSCEAR 1996). Consequently no effect on lichens and bryophytes is expected from dust emissions from the Project.
Management Measures:	Refer to Environmental Factor 6. • Design, construct and operate the proposed Yeelirrie operation to ensure that human and ecological radiation exposures are ALARA and comply with Australian standards, codes of practice and guidelines. • Develop a Radiation Management Plan and obtain approval to implement the Plan prior to commencement of the Project. This will ensure compliance with the radiation dose limits for workers outlined in the Radiation Safety (General) Regulations 1983 and limit radiation exposure to members of the public to less than 1 mSv per year over and above background. • Development and implementation of a Transport Radiation Management Plan which includes an Emergency Response Assistance Plan (ERAP). • Closure and rehabilitation of the Project in accordance with the Mine Closure and Rehabilitation Plan (refer to Environmental Factor 12).
Commitments:	• Develop and implement a Radiation Management Plan. • Develop and implement a Transport Radiation Management Plan.
Outcomes:	No significant radiological impacts on human health or the environment.

Section 1

Introduction

Figure 1-1: Location of the proposed Yeelirrie Uranium Project

1. Introduction

1.1 Purpose and Scope

Cameco Australia Pty Ltd (Cameco), a wholly owned subsidiary of Cameco Corporation, one of the world's largest uranium producers, is proposing to develop the Yeelirrie Uranium Project (the Project) located approximately 660 km north east of Perth in the Shire of Wiluna of Western Australia (WA) (Figure 1-1).

This Public Environmental Review (PER) has been prepared as part of the process to seek State and Federal approval for the Project under the State *Environmental Protection Act 1986* (EP Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This PER is the key document for joint environmental assessment of the Project by the:

- Western Australian Environmental Protection Authority (EPA) and the Minister for Environment under the EP Act; and
- Commonwealth Department of the Environment (DoE) and the Minister for the Environment under the EPBC Act.

The purpose of the PER is to provide a description and environmental review of the principal elements of the Project, including an environmental impact assessment and description of the proposed environmental management measures for the key environmental factors in accordance with the Environmental Scoping Document (ESD) prepared by the EPA in consultation with the DoE (Appendix A1).

The PER is also made available to the public to review the Project. Comments received from the public, government agencies and other stakeholders during the public review period are reviewed by Cameco. Cameco's responses to these comments will assist the EPA in preparing an assessment report in which it will make recommendations to the State Government.

1.2 Document Structure

This document provides:

- an overview of the Project;
- information on Cameco;
- discussion of the legislative and administrative framework that will apply to the approval of the Project;
- stakeholder consultation and engagement;
- project benefits and evaluation of alternatives;
- a detailed project description;
- impact assessment methodology;
- a description of the existing environment;
- an assessment of environmental and social effects;
- proposed management measures; and
- proposed rehabilitation and closure of the site.

Technical appendices to the PER are provided on data stick with this document. The PER and technical appendices are also available on Cameco's website (www.cameco.com/australia/yeelirrie/community_information/). Hard copies of the PER can be ordered from Cameco's Perth office on +61 (8) 9318 6600.

Section 2

Project Background

2. Project Background

2.1 Project History

Cameco is proposing to develop the Project in the Shire of Wiluna, Western Australia (WA), located approximately 660 km north east of Perth and 420 km north of Kalgoorlie (Figure 1-1).

The Yeelirrie deposit was discovered by Western Mining Corporation (WMC) in 1972. In the decade that followed, WMC undertook further exploration leading to trial mining and the operation of a pilot processing plant. Environmental studies were undertaken and a draft Environmental Impact Statement (EIS) and an Environmental Review and Management Programme (ERMP) were submitted to the WA EPA and the Federal Environmental Agency in 1978 (Needham 2009). The Project was approved for mining by both the Australian and Western Australian governments in 1979 (EPA 1979).

Trial mining commenced and ore was extracted from three excavation pits. Between 1980 and 1982, ore was sent to the Kalgoorlie Research Plant (pilot metallurgical plant) for processing test work. The Project was placed on monitored care and maintenance in 1984, after the newly elected Australian Labor Government implemented its three mines policy in 1983 and the Western Australian Government assumed an anti-uranium position in the same year. Monitored care and maintenance allowed for WMC to undertake, inspect and maintain rehabilitation of already disturbed areas. From 2001, a closure plan was implemented with the objective of leaving the site in a safe and stable condition.

The project remained inactive until the purchase of WMC by a subsidiary of BHP Billiton Limited (BHP Billiton) in 2005. At the time, both Australian and Western Australian government uranium policies were not favourable to uranium mine development, with the Australian 'no new (uranium) mines' policy still in place and the Western Australian Government having an administrative ban on uranium mining in the State. These bans were lifted in 2007 and 2008 respectively.

In May 2009, BHP Billiton referred the proposed Yeelirrie development to the WA EPA under Section 38 of the EP Act and the Australian Environment Minister under the EPBC Act. In June 2009, the WA EPA set the level of assessment as an ERMP with a 10 week public review period. In response to appeals received during the public consultation period, the public review period for the ERMP was increased from 10 weeks to 14 weeks.

In June 2009, the Federal Environment Minister also determined that the proposed Project was a Controlled Action under the EPBC Act on the basis that it was a nuclear action and had the potential to have an impact on listed threatened species and communities, and listed migratory species.

From 2008 to 2011, BHP Billiton undertook extensive environmental and mine planning studies, including flora and fauna surveys, hydrogeological investigations, mine planning and ore processing studies. This work was finalised and documented in a draft ERMP, however in early 2011, BHP Billiton decided not to proceed with the Project and the document was not submitted to government for review.

In December 2012, Cameco Australia purchased the Project, including the Yeelirrie pastoral lease, from BHP Billiton.

In November 2014, Cameco decided to vary the Project. Cameco agreed with the EPA to terminate the previous referral lodged by BHP Billiton and make a new referral. This was because the EPA had adopted new administrative guidelines in 2012. In December 2014, the EPA determined the Project would be assessed as a PER.

Cameco also advised the Federal DoE of the change of proponent and proposed variation to the Project. In December 2014, the DoE accepted the proposed variation to the Project under section 156B of the EPBC Act.

Since purchasing the Project, Cameco has undertaken a comprehensive review of the work completed by both WMC and BHP Billiton. A gap analysis identified a number of areas where Cameco considered further work was required and additional studies have since been undertaken.

In preparing this PER, Cameco has considered and referenced much of the work undertaken by BHP Billiton and its consultants. The work undertaken by BHP Billiton and its consultants provides valuable historical reference material, much of which is relevant to the establishment of a current and contemporary baseline.

As part of this PER, Cameco and its consultants have assessed the extent to which historical studies and assessments remain both correct and contemporary (when compared to current guidelines). This has led to Cameco's consultants conducting further work, where required, to address current guidelines.

The PER applies current guidelines and current information.

2.2 Project Overview

Cameco is proposing to develop the Project, which comprises a uranium mine and associated treatment facilities. Ore would be mined from shallow open pits by open cut techniques. The ore would be processed using alkaline leaching, including the following steps: comminution via semi-autogenous grinding (SAG) milling, atmospheric alkaline leaching, counter current decantation (CCD), followed by direct precipitation of uranium oxide concentrate (UOC), product drying and packaging.

The mineral resource estimate, reported in accordance to NI 43-101[1] (and JORC Code[2]) is 127.3 million pounds (Mlbs) (57,742 tonnes) measured and indicated with an average grade of U_3O_8 of 0.16% or 1,600 ppm.

Over the anticipated 22 year life of the Project, it will produce an estimated 106 Mlbs (48,081 tonnes) of U_3O_8-equivalent UOC for export.

The UOC would be transported by road from the mine site to the Port of Adelaide, South Australia, via the Goldfields Highway, and the Eyre Highway.

This environmental assessment covers all transport within Western Australia. Transport within South Australia will be the subject of separate assessment and approvals processes.

2.3 Project Objectives

The objectives for the Yeelirrie Uranium Project are to:

- design, construct, operate and decommission an operation that minimises environmental impact and maximises benefits to the community;
- maximise the value of the deposit for the stakeholders, community and nation;
- enhance the current employment and lifestyle opportunities of local and regional communities;
- strengthen the relationship and communication with traditional claimant groups; and
- continuously improve the safety and environmental performance of the operation.

1. NI 43-101: National Instrument 43-101 is a Canadian mineral resource classification scheme used for the public disclosure of information relating to mineral properties.
2. JORC Code: Joint Ore Reserves Committee Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves.

2.4 Project Proponent

The proponent for the Project is Cameco Australia Ltd, a wholly owned subsidiary of Canadian based uranium miner, Cameco Corporation.

Proponent details are:

Cameco Australia Pty Ltd

ABN: 65 001 513 088
Office address: 24 Hasler Road, Osborne Park, WA 6017, Australia
Postal address: PO Box 748, Osborne Park, BC, WA 6196, Australia

Telephone: +61 8 9318 6600
Facsimile: +61 8 9318 6606

The contact for the Project for the approval process is:

Mr Simon Williamson, Environmental Manager.

2.4.1 Company History

Cameco is one of the world's largest uranium producers with uranium assets on three continents, including Australia. Cameco's head office is located in Saskatoon, Saskatchewan, Canada (Plate 2-1).

Plate 2-1: Cameco's head office in Saskatoon, Saskatchewan

Cameco Corporation was created from the merging of two government corporations, one owned by the province of Saskatchewan and the other owned by the Canadian Federal Government. Cameco was incorporated in Canada in June 1987 and began operating as the new combined entity a year later. Both of the predecessor companies, Saskatchewan Mining Development Corporation and Eldorado Nuclear Limited (the Canadian Federal Government company), had mining and milling assets in Saskatchewan. Eldorado Nuclear also owned uranium refining and conversion operations in the province of Ontario. Over time, the provincial government of Saskatchewan and the Canadian Federal Government divested all their common shares in Cameco. Cameco is now the world's largest publicly traded uranium company.

Cameco's shares are traded on both the Toronto Stock Exchange (CCO) and the New York Stock Exchange (CCJ).

2.4.2 Company Profile

Cameco is one of the world's largest uranium producers, accounting for about 16% of world production in 2014. Cameco holds approximately 429 Mlbs (194,500 tonnes) of proven and probable reserves, extensive resources and has exploration programs on three continents with land holdings that total approximately 1.7 million hectares (Figure 2-1).

Cameco employs more than 3,300 people worldwide, engaged in uranium mining, refining and conversion. Cameco's vision is to be a dominant nuclear energy company producing uranium fuel. Its goal is to be the supplier, partner, investment and employer of choice in the nuclear industry.

2.4.2.1 Operating Properties

McArthur River-Key Lake

Cameco is the operator and 70% owner of the McArthur River mine, the world's largest high-grade uranium mine. It is located in the Athabasca Basin of northern Saskatchewan, Canada.

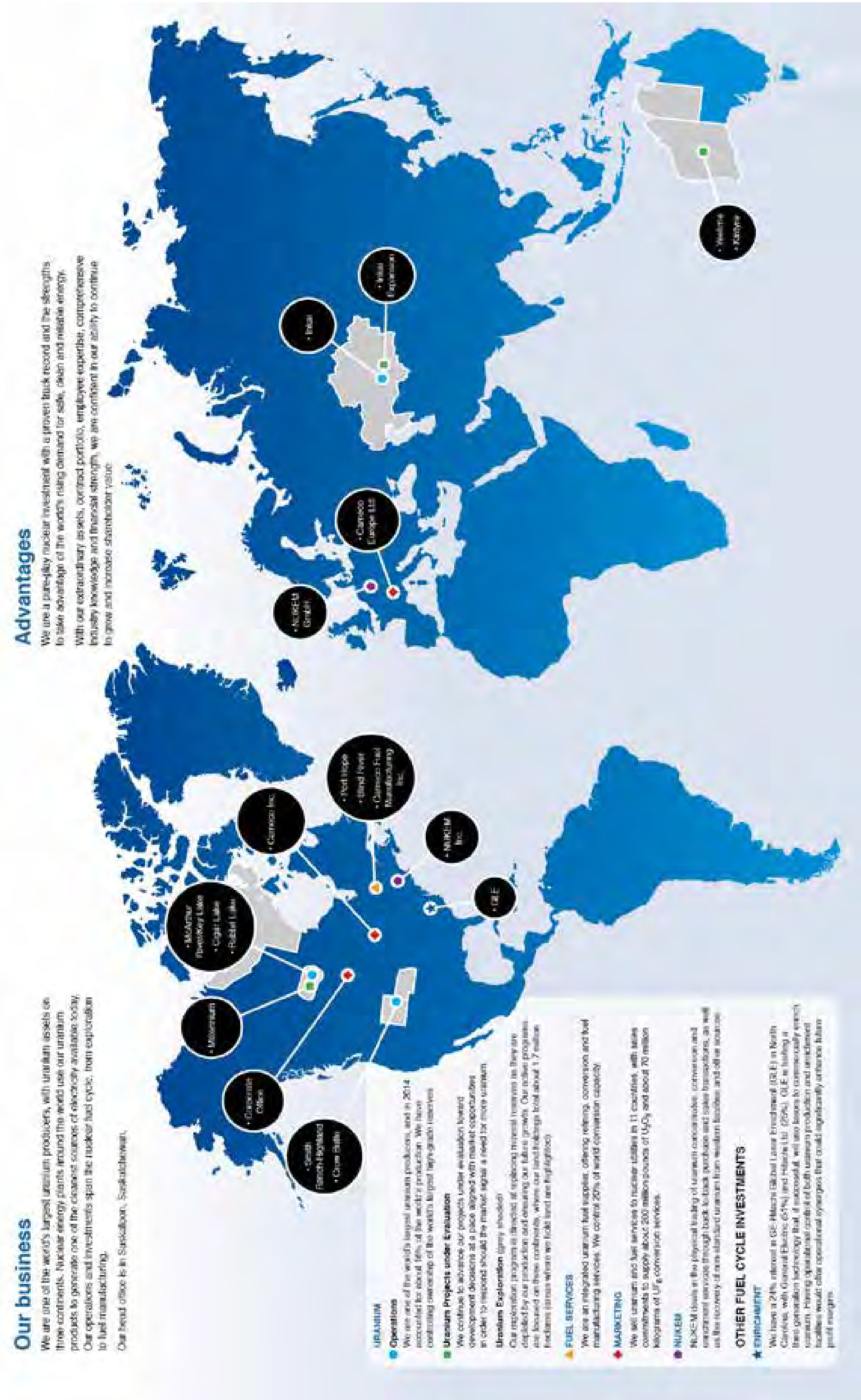


Figure 2-1: Worldwide operations - Cameco Corporation

Since 2000, the mine has produced 263.9 Mlbs (119,703 tonnes) of uranium for world markets. The uranium produced by McArthur River each year produces enough energy to meet about 8% of total electricity demand in the United States.

The McArthur River mine uses a number of innovative methods to safely mine the high-grade ore, including ground freezing to control groundwater and non-entry raise bore mining, which limits radiation exposure. The mine has twice been recognised by the Canadian Mining Institute for safety among Canadian metal mines by awarding it the prestigious John T. Ryan award.

McArthur River ore is processed underground into a slurry, pumped to the surface and then trucked 80 km to the Key Lake mill where the ore is processed into uranium oxide (U_3O_8).

Key Lake was the site of two former open cut uranium operations. One of the two Key Lake pits was converted into a specially engineered facility to ensure secure, long term containment of tailings.

Rabbit Lake

Rabbit Lake is the longest operating uranium production facility in North America. More than 1,904 Mlbs (863,640 tonnes) of uranium has been mined there since 1975, first in a series of open cut operations. For more than a decade, the high-capacity mill has processed ore from the Eagle Point underground mine, which is on the same surface mining lease. The mine life at Eagle Point has been continuously extended through discovery of new underground ore zones. The ore is lower grade than McArthur River, but is still relatively high grade by world standards.

Cigar Lake

The Cigar Lake mine is located in northern Saskatchewan. The mine plan for Cigar Lake, similar to McArthur River, incorporates extensive freezing of the ground around the orebody which is located within water-bearing sandstone about 460 m below the surface. This freezing is one of the tools used to prevent water penetration into the underground workings. The high-grade ore is safely mined using a remote mining method known as jet boring. It is an innovative system that uses pressurised water to remove the ore.

United States – In-Situ Recovery Mines

Cameco has two operations in the Western United States (US) that use the in-situ recovery (ISR) method of recovering uranium from water-bearing sandstone formations. The Smith Ranch-Highland operation in Wyoming and the nearby Crow Butte facility in north-eastern Nebraska make Cameco the largest uranium miner in the US.

Cameco has further leases near both operations where it is seeking approval to build satellite ***in-situ*** operations.

Joint Venture Inkai – Kazakhstan

Cameco produces uranium in Kazakhstan through a joint venture with state-owned Kazatomprom. The Inkai Joint Venture operates ISR mining and processing facilities in central Kazakhstan.

2.4.2.2 Projects Under Evaluation

In addition to the Project, Cameco has a number of other uranium projects under evaluation, including the Millennium Project in northern Saskatchewan and the Kintyre Project in Western Australia.

Exploration in Australia

In Australia, Cameco has active exploration projects in Western Australia and the Northern Territory.

2.4.2.3 Fuel Services

Cameco is an integrated uranium fuel supplier, offering refining, conversion and fuel manufacturing services from operations located in Ontario, Canada.

The refining of uranium oxide (U_3O_8 to UO_3) takes place at Blind River which provides uranium refining for producers from other parts of the world.

The Port Hope conversion facility in Ontario converts UO_3 to UF_6 which is the gas form of uranium required by companies which enrich uranium for light water reactors. The Port Hope conversion facility also has a plant producing natural UO_2, the form of uranium used in Canadian heavy water reactors.

Cameco Fuel Manufacturing, located in Port Hope, turns the natural UO_2 powder into fuel bundles. A satellite plant in nearby Cobourg produces zirconium-based metal components for reactors and fuel bundles.

2.4.3 Cameco's Safety, Health, Environment and Quality (SHEQ) Performance

Cameco measures its safety, environmental, social and financial performance using key performance indicators based around the following four measures of success:

- a safe, healthy and rewarding workplace;
- a clean environment;
- supportive communities; and
- outstanding financial performance.

The overall governance of safety, health, environment and quality at Cameco begins with the Safety Health Environment and Quality (SHEQ) policy, which states the commitment of the senior management of Cameco to the following principles:

- keeping risks at levels as low as reasonably achievable;
- prevention of pollution;
- complying with, and moving beyond legal and other requirements;
- ensuring quality of processes, products and services; and
- continually improving our overall performance.

Cameco's results in achieving its key performance indicators are available in Cameco's 2014 Sustainable Development Report at www.cameco.com/sustainable_development/2014/

Cameco has established risk-informed targets to reduce potential effects on air, water and land, optimise energy consumption, and manage waste. To ensure an effective approach to environmental performance, all operating sites have environmental management systems that are certified under the ISO-14001 standard.

Water: Cameco employs water treatment technologies that have improved the quality of the treated water released from Saskatchewan uranium mining and milling operations. For example, the amount of molybdenum, uranium and selenium in effluent at these operations has been dramatically reduced. For example, molybdenum discharged reduced by 87% from 14,908 kgs in 2009 to 1,985 kgs in 2013; and Selenium discharges were reduced by 35% from 70.8 kgs in 2009 to 45.7 kgs in 2013. Cameco continues to look at how to improve these treatment circuits and increase the efficiency of water use to achieve even better results at all operations.

Waste: Projects to reduce waste, improve the reclamation process and manage waste rock more effectively are continually underway. For example, at the Rabbit Lake operation, reclamation of over 8 million tonnes of waste rock in the B-Zone waste rock pile was completed during 2013.

Air: Cameco continues to revitalise facilities to extend the lifespan of operating sites. Although emissions have always met all regulatory requirements, they have been further improved by replacing some existing facilities. For example, replacement and upgrades to the sulphuric acid plants at Key Lake and Rabbit Lake have significantly reduced emissions of sulphur dioxide at those sites. Work to replace the calciner at Key Lake is also underway, which is expected to reduce emissions to air from the drying and packaging of the mill's final product.

2.4.4 Cameco's Radiation Management Performance

The corporate Radiation Protection Programme (RPP), operating within the governance of the SHEQ Policy, defines the minimum requirements for a radiation protection program at Cameco's sites and explains corporate management and oversight of the RPP. Because radiation protection is essentially a specialised occupational safety and health issue, Cameco has elected to base the corporate RPP on the general principals of the British occupational health and safety management standards, BSI 18000 series and subsequent BSI updates to these standards.

The RPP outlines requirements for site programs, including the areas of risk assessment, regulatory compliance, training, operational controls, emergency response, monitoring and measurement, non-conformance and corrective/preventive actions, audits and management review among others. This program also operates within the broader context of the Quality Management Programme and in conjunction with the other corporate level programs; specifically, the Safety and Health Management, Environment Management, Emergency Preparedness and Response, Contractor Safety and Environment and Management Systems Audit Programmes. Some of the specific requirements of the corporate RPP are discussed below.

Cameco is committed to complying with legal and other requirements relating to managing radiation protection issues. In some jurisdictions, the regulations are not prescriptive in all technical aspects. For example, internal dosimetry[3] requires the use of a number of models. In such cases, internationally accepted methods or standards are used. As most national regulations are based upon the scientific recommendations of the International Commission on Radiological Protection (ICRP) and standards of the International Atomic Energy Agency (IAEA), the publications of these two organisations are used as the primary source of guidance for technical issues.

As stated in the corporate RPP, each site is required to provide training in radiation protection. This training must include, at a minimum, orientation and supervisor training and is expected to address, among other aspects, the specific radiation risks found at a site, the protection measures to be followed, discussion of dose limits and health effects. Additional or specific training programs may be developed, as required by sites, for groups such as engineers and technical staff. Cameco has adopted the systematic approach to training and radiation training is developed and documented in line with this process.

Monitoring and measurement of individual doses and radiological conditions is a key aspect of a RPP and it provides both guidance and specific instruction in the monitoring and dose measurement. The RPP addresses expectations for measurement of gamma radiation, long lived radioactive dust and radon progeny doses. In addition, the program requires sites to develop engineering monitoring schedules for the appropriate types of radiation of concern. Engineering monitoring is a term used to describe types of monitoring not used for official dosimetry purposes. Most types of engineering monitoring are focussed on the workplace environment to control specific radiation parameters.

The corporate RPP also requires that several operational controls be in place at each site. Specifically, sites must have a program or process for ensuring doses are as low as reasonably achievable (ALARA) and consider social and economic factors. As low as reasonably achievable or the ALARA

3. Dosimetry is the measurement of doses received by individuals, in this case doses of ionising radiation.

Principle refers to the principle of optimisation of radiation protection, and is the key driver for ensuring that radiation doses are maintained at the lowest feasible level throughout the life cycle of a practice involving radioactive materials (DMP 2010). The ALARA Principle originally defined by the International Commission on Radiological Protection in 1977 (ICRP, 1977) takes into account economic and social factors and recognises that infinite resources could be spent on reducing radiation risks, but may result in minimal additional benefit. ALARA demonstrates a recognition that the health and safety of employees is of foremost importance. A site ALARA program includes a commitment by senior management to the ALARA program, responsibilities, control over work practices, qualifications and training, consideration of emergency or upset conditions, a review of monitoring results, and a communications plan.

The corporate RPP also requires sites to have a process, typically referred to as a radiation work permit, for setting of job-specific controls to help manage radiation doses in known high radiation conditions or high risk tasks. Finally, the corporate RPP states that each site must have a "code of practice" (or equivalent) which is a series of standard required actions in response to predetermined radiation levels. The actions are progressive in nature with an increasing management response as radiation levels increase. A code of practice helps to ensure a consistent response to unexpected radiation conditions.

How well sites conform to the requirements of the corporate RPP is assessed in many ways, from informal assessments to formal audits, and significant findings are reported to the Cameco Board of Directors. Corporate assistance is available to all sites to help overcome obstacles and achieve compliance with corporate requirements and regulations.

In addition to assisting with compliance, Cameco uses new science and technologies to aid sites in improving the accuracy of dosimetry results and dose reduction. Some specific examples include:

- dust particulate studies and the use of simulated lung fluid experiments, performed by Cameco at its in-house laboratory, to determine site specific solubility parameters for all of its uranium products to better assess doses from internal exposure;
- operational techniques to reduce dust in underground operations; and
- techniques to locate and manage sources of radon gas entering mine workings and mill workplaces.

Significant effort has been put into development of a company-wide database tool for collection of radiation information, calculation of doses, management of sampling compliance, management of equipment calibration and efficiency checks, and reporting of dosimetry and workplace radiological monitoring. This tool has been adapted for use in Canada, the US and Kazakhstan to date, and would be used at Yeelirrie. In addition, the corporate office has several technical experts to provide support to the sites.

Cameco has a strong commitment to radiation protection. As a minimum, the status of the RPP across the company is reported to senior management annually, and company-wide dose statistics are provided to senior management and the Board of Directors quarterly. Internal audit findings related to non-conformance or noncompliance with corporate programs, standards and applicable regulations are also presented to the Board of Directors, ensuring these matters receive prompt attention of senior management.

2.4.5 Cameco's Transport Management Performance

Cameco has significant experience with the transport of radioactive materials. The Cameco Canadian mills alone ship approximately 600 container loads of UOC by road annually with a total distance travelled at just under 2 million km. Using experience gained from many years of operation, Cameco has put into place a number of controls and initiatives to improve both the safety of transport as well as emergency preparedness and response to transport incidents. These include:

- Cameco Transport Standards;
- Emergency Preparedness and Response Program; and
- Emergency Response Assistance Plan.

The Cameco Transport Standards are mandatory corporate standards put in place to ensure Cameco operations worldwide comply with relevant regulations and additional Cameco specific requirements with respect to transport of radioactive materials. Packaging is a key focus of the standards, which puts in place minimum requirements to which each operation must adhere.

The Emergency Preparedness and Response Programme (EPRP), is a corporate program aimed at ensuring Cameco operations are ready and able to respond to the variety of incidents that may occur at Cameco operations. The EPRP is a broad program that encompasses all emergencies including transport. The effectiveness of the site programs is measured by a series of metrics reported annually by the sites and assessed by Cameco's corporate office.

The Cameco Emergency Response Assistance Plan (ERAP) has been in place for a number of years. The overall purpose of the ERAP is to ensure preparedness and response to incidents that may occur during transport of products. While the establishment and ongoing maintenance of the ERAP is a Canadian regulatory requirement, Cameco has extended the principles and methods of the ERAP to its worldwide operations. The ERAP includes a broad list of initiatives:

- Cameco emergency response teams;
- contracted emergency response networks;
- mutual aid agreements;
- First Responder Outreach Program;
- annual emergency response exercises;
- controls placed on Cameco carriers and freight-forwarders; and
- Cameco SHEQ audit program.

Cameco maintains emergency response teams at each operation. These teams train and practice on a regular basis and are equipped to respond to a variety of site specific surface and underground emergencies. Additionally, a corporate team attends all activations of the EPRP. These teams are typically composed of a hazardous materials/safety specialist, radiation specialists and an environmental specialist. Cameco radiation specialists being present during actual transport emergencies have proven to be most valuable over the years by providing a high level of technical oversight and effective communication to first responders.

Contracted emergency response networks have been established in North America in order to support the Cameco teams. The transport of Cameco products typically involves very long distances and a variety of transport modes. As a result, trained teams fully equipped and prepared to respond to Cameco events have been retained across the continent. These teams are trained by Cameco on a recurring schedule. Many of these contracted teams also participate in full-scale and table-top exercises conducted by Cameco.

In addition to the contracted commercial firms used by Cameco to support internal teams during a response, there are also mutual aid agreements set up with others in the nuclear fuel cycle. Cameco currently has an agreement with AREVA Resources whereby Cameco will respond with or on behalf of each other for transport incidents. Mutual aid partners are also included in applicable full-scale and table-top exercises.

Cameco has established a successful outreach program for first responders whereby representatives from Cameco conduct awareness sessions at strategic locations. The first response agencies targeted in Canada typically consist of full-time and volunteer fire departments because they are normally in charge of a transport incident occurring on Canadian public roads. These sessions, which include radiation safety and hazardous materials response advice specific to Cameco products, have been well received over the 12 years of the program. These awareness sessions are conducted on a three year recurring schedule. In addition to first responders, Cameco also conducts outreach training for shipping port representatives, emergency management agencies, and routinely speaks at hazardous materials conferences in Canada.

Cameco will use the experience gained from years of operation in Canada to establish similar support arrangements with commercial emergency response organisations, other uranium companies, and professional and volunteer first responder organisations.

While not specifically required as part of the ERAP, Cameco places conditions and controls within contractual agreements with all carriers and freight-forwarders that transport its products. Specific conditions can include parking and route restrictions, reporting of any incidents, driver qualification and emergency instructions in the event of an accident.

All carriers and freight-forwarders transporting radioactive materials for Cameco undergo a regular SHEQ audit every two years. These audits, conducted by trained Cameco and third-party auditors, are a valuable tool to evaluate and keep in direct contact with transport vendors.

The controls that Cameco has placed on transport of its products have resulted in a dependable, safe and effective transport system. The core values of the company are reflected in the transport of its products worldwide.

2.4.6 Cameco's Corporate Social Responsibility Performance

Cameco is committed to earn the trust and support of local communities and stakeholders wherever it operates. In addition to maintaining safe, clean operations, Cameco pursues initiatives to ensure that local communities benefit from its activities. These initiatives, led by Cameco's corporate social responsibility group, are developed around five pillars:

- business development;
- community engagement;
- community investment;
- environmental stewardship; and
- workforce development.

In Canada, these initiatives have established Cameco as the nation's largest industrial employer of Aboriginal peoples. Due to preferential hiring policies, about half of the employees and contractors at its mining operations in northern Saskatchewan are residents of the remote, primarily Aboriginal region where mining operations are located. Cameco also favours local Aboriginal-owned business in contracting for services at its operations. During 2013, 67% of the services required to support Cameco's Saskatchewan operations were provided by Aboriginal-owned businesses. These policies build capacity and create opportunity for the Indigenous peoples of northern Saskatchewan. Cameco also conducts extensive stakeholder engagement activities to ensure that people are aware of and understand its activities. These efforts are complemented by community investment, workforce development, and direct support for education to ensure people can benefit from opportunities related to mining in their region. Cameco's efforts to build and sustain the trust and support of local communities have been rewarded with consistently high levels of public support confirmed through annual polling in Canada.

Cameco has achieved Gold level certification in the Progressive Aboriginal Relations Programme with the Canadian Council for Aboriginal Business four times for "innovative programs and engagement of Aboriginal Peoples that have made an enduring impact on the business and Aboriginal communities, and demonstrate best practice for those companies beginning their journey".

Moving into new global regions such as Australia, Cameco will adapt this successful model and implement location-specific programs and initiatives based on ongoing engagement with local communities.

Cameco supports indigenous communities in the Wiluna and Leonora regions through participation in the Murlpirrmarra Connection which assists and supports Aboriginal youth, improving opportunities in the areas of education, educational options, sporting pathways, health, rehabilitation, discipline, self-confidence and employment prospects for young Wiluna and Murchison based Aboriginal men and women. Cameco has also supported a range of community events in Wiluna.

2.5 The Nuclear Energy Industry

The following section has been presented to provide some background information on the global nuclear energy industry and uranium demand.

The long term outlook for the uranium industry continues to be very positive, despite the uncertainty that exists today. Against the backdrop of the world's growing need for safe, clean, reliable and large-scale sources of energy, nuclear energy continues to play a significant role in the global energy mix. The challenge for the industry is the pathway and timing of the transition from today's stagnant, over-supplied short-term market to the promise of nuclear growth and positive uranium market conditions in the long term.

Market conditions deteriorated following the events at the Fukushima power plant in 2011, and Cameco believes the uncertainty could continue, depending on how events unfold. In particular, the slower than expected pace of Japanese reactor restarts, unexpected reactor shutdowns in the United States and temporary shutdowns in South Korea have led to a reduction in demand, while supply has remained steady. The impact of these conditions has been an increase in inventory and downward price pressure.

This market dynamic has also led to a reduction in market contracting activity. Utilities are well covered under long term supply contracts for the time being and are not under pressure to buy. Similarly, existing suppliers appear reluctant to enter into meaningful contract volumes at current prices. The result has been very low levels of long term contracting, highlighting a stalemate between buyers and sellers. How this stalemate is resolved will be a key factor influencing the pace of market recovery.

2.5.1 Long-term Outlook

Electricity is essential to maintaining and improving the standard of living for people around the world. Demand for safe, clean, reliable, affordable energy continues to grow and the need for nuclear as part of the world's energy mix remains compelling.

Looking beyond the current market challenges, there have been several positive indications for the long term. In Japan, more clarity has been gained around the process for reactor restarts: the Nuclear Regulatory Authority (NRA) implemented measures that improved regulatory stability; restart applications have been submitted by 11 utilities covering 21 reactors; and, there has been observable confidence from Japanese utilities who are spending billions of dollars on plant upgrades in anticipation of a positive restart environment.

In other regions, China's remarkable nuclear growth program remains on track. The UK has also garnered positive attention as a result of a government-backed revenue arrangement with Électricité de France, designed to support new the construction of new plants in the UK.

The 2013 World Energy Outlook predicts that by 2035 electricity consumption will have grown by about 70% from current levels (Figure 2-2), driven mainly by growth in the developing world as it

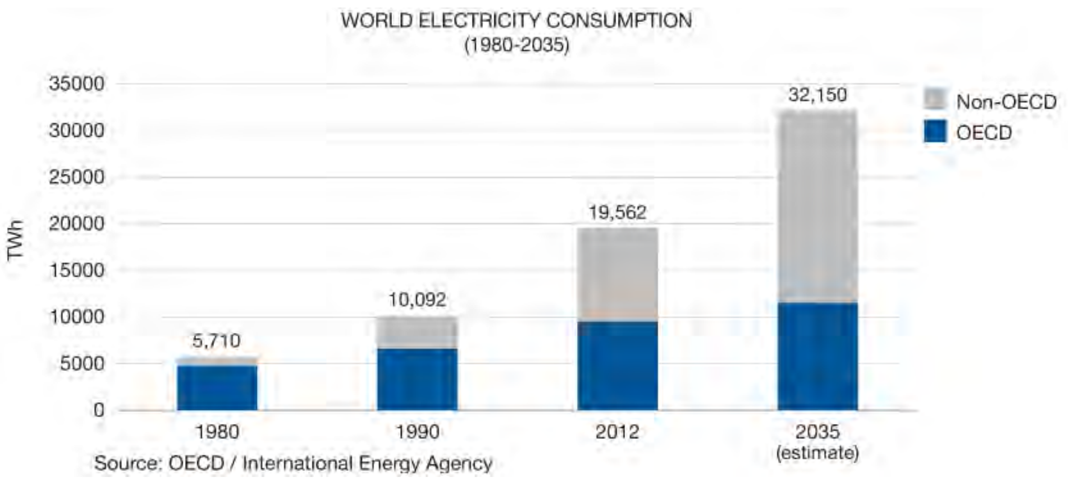


Figure 2-2: World electricity consumption 1980-2035

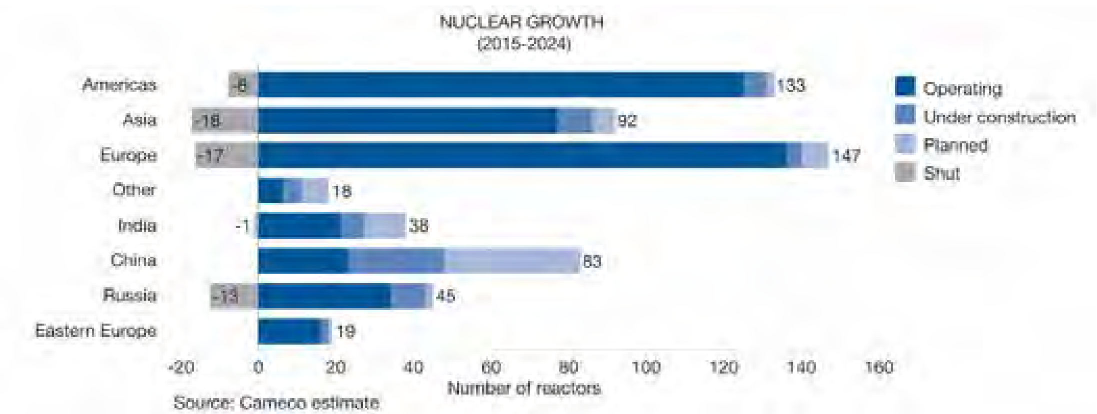


Figure 2-3: World nuclear growth 2015-2024

seeks to diversify sources of energy and provide security of supply (OECD/IEA, 2013). In January 2015, there were 437 operable commercial nuclear power reactors in 30 countries (World Nuclear Association, 2015), and by 2024, Cameco expects that to grow to 518 reactors (Figure 2-3). Most of this new build is being driven by rapidly developing countries like China and India, which have severe energy deficits and want clean sources of electricity to improve their environment and sustain economic growth.

It is clear that this growth will require new sources of uranium supply at a time when secondary supplies (uranium from sources other than mining, such as down-blended weapons material) are diminishing and current market conditions have resulted in deferrals and cancellations of several uranium projects.

Current prices are insufficient to drive new production. The end of the Russian Highly Enriched Uranium (HEU) commercial agreement in 2013, removing 24 Mlbs (10,886 tonnes) of annual secondary supply from the market, highlights the need for increasing reliance on primary uranium supply in the future. The timing of this required supply may well be muted in the near term due to the extension of the over-supply situation, but new supply will be required this decade. The development and execution of new uranium supply projects, as well as continued performance of existing supply, will also play a significant role in determining the timing and pace of market recovery.

Given Cameco's extensive base of mineral reserves and resources, diversified sources of supply and global exploration program, the company is well positioned to meet the growing demand for uranium.

Section 3

Legislative Framework and Impact Assessment Process

3. Legislative Framework and Impact Assessment Process

3.1 Key Legislative Requirements

The Project requires environmental approval from:

- the Western Australian (WA) Minister for Environment under the provisions of the *Environmental Protection Act 1986* (EP Act); and
- the Australian Minister for the Environment under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The EP Act and its associated regulations are the principal statute in WA that provides for environmental protection in the State. Part IV – (Environmental Impact Assessment) of the EP Act allows for referral, environmental assessment and implementation of proposals. Part V – (Environmental Regulation) of the EP Act outlines mechanisms for control of pollution through the licensing system. The EP Act is administered by the State Office of the Environmental Protection Authority (OEPA) and the Department of Environment Regulation (DER). An overview of the Part IV environmental assessment process as it applies to this PER is outlined in Section 3.1.1.

The EPBC Act provides a legal framework to manage environmental issues of national significance including nuclear actions (such as uranium mines) and the protection of nationally and internationally important flora, fauna, ecological communities and heritage places. The EPBC Act is administered by the DoE and a summary of the Federal assessment process is outlined in Section 3.1.2.

This document has been prepared to meet both State and Federal requirements.

3.1.1 Western Australian Environmental Assessment Process

The environmental assessment process under the WA EP Act is commenced with referral of the Project to the EPA. The referral document enables the EPA to determine if a proposal requires assessment under Part IV of the EP Act, and if so, what level of assessment is appropriate.

Cameco withdrew the original assessment and submitted a new referral to the EPA on 12 November 2014 due to changes to the project and amendments to the EPA administrative procedures. The Western Australian EPA advertised the level of assessment for the Project as a PER on 15 December 2014. The ESD for the Project was released on 10th April 2015 (Appendix A1).

Cameco has prepared the PER (this document) in accordance with the scope of works documented in the ESD. When the EPA is satisfied that the PER document has addressed all of the environmental factors and studies identified in the ESD, the proponent is required to release the PER for a public review period normally between 4 and 12 weeks. In the case of the Yeelirrie Uranium Project, the EPA has set a 12 week public review period.

Public submissions on the PER document that are received by the EPA are provided to the proponent. The EPA prepares a summary of the issues raised and the proponent is required to respond to these issues to the satisfaction of the EPA. The EPA will then assess the PER document, submissions received, proponent's response to submissions, and obtain advice from any other persons it considers appropriate and submit its report and recommendations to the WA Minister for Environment. Any person may lodge an appeal with the Minister against the contents and/or recommendations of the EPA's Report. The Minister will then consider the appeals before making a decision on whether a proposal can be implemented and if so, the conditions attached to the project.

3.1.2 Federal Environmental Assessment Process

The EPBC Act provides for the protection of Matters of National Environmental Significance (MNES). The Act lists eight Matters of National Environmental Significance as follows:

- World Heritage properties;
- National Heritage places;
- wetlands of International Importance (listed under the Ramsar Convention);
- listed threatened species and ecological communities;
- migratory species protected under international agreements;
- Commonwealth marine areas;
- The Great Barrier Reef Marine Park; and
- nuclear actions (including uranium mines). A nuclear action is defined by the EPBC Act as:
  a) establishing or significantly modifying a nuclear installation;
  b) transporting spent nuclear fuel or radioactive waste products arising from reprocessing;
  c) establishing or significantly modifying a facility for storing radioactive waste products arising from reprocessing;
  d) mining or milling uranium ore;
  e) establishing or significantly modifying a large-scale disposal facility for radioactive waste;
  f) decommissioning or rehabilitating any facility or area in which an activity described in paragraph (a), (b), (c), (d) or (e) has been undertaken; or
  g) any other action prescribed by the regulations.

As the Project proposal triggers three of the above Matters: listed threatened species and ecological communities; migratory species protected under international agreements; and nuclear actions, the Project will also be assessed under the EPBC Act.

Assessment under the EPBC Act commences with referral of the Project to the Federal Environment Minister. The Minister has 20 business days to decide whether the proposed action will require assessment and approval under the EPBC Act. This includes ten business days for public comment on the proposed action. If the Minister decides that the proposed action is likely to have a significant impact on one or more Matters protected by the EPBC Act, then the proposal is deemed a controlled action.

The Minister may assess a proposal using one of the following assessment methods:

- accredited assessment;
- assessment on referral information;
- assessment on preliminary documentation (referral form plus any other relevant material identified by the minister);
- assessment by EIS or Public Environment Report; and
- assessment by Public Inquiry.

The Project has been determined to be a controlled action in respect of nuclear action, listed threatened species and communities, and listed migratory species.

Cameco advised the DoE of the change of proponent for the Project on 19 December 2012, and formally requested a variation for the Project under the EPBC Act on 12 November 2014. This was granted by the Federal Minister for the Environment on 5 December 2014.

The Project is not being assessed under the current Bilateral Agreement, which exists between the Australian Government and the Western Australian Government. This is because the Project was determined to be a controlled action prior to the commencement of the current Bilateral Agreement.

Rather the assessment process for the Project was determined by the Federal Minister on 12 March 2015 to be "assessment by an accredited assessment process". Pursuant to the Federal Minister's assessment decision, the Project will be assessed by the WA EPA in a manner similar to the process under the current Bilateral Agreement. This means that the Project can be assessed under both the EP Act and the EPBC Act concurrently, using the same documentation prepared to meet the requirements of both Acts. This concurrent assessment will be coordinated by the WA EPA.

The Federal Environment Minister will make a separate decision on the proposal to the State Environmental Minister.

3.1.3 Yeelirrie State Agreement

State Agreements specify the rights, obligations, terms and conditions for development of a project and establish a framework for ongoing relations and cooperation between the State and the Project proponent.

The Yeelirrie State Agreement (*Uranium (Yeelirrie) Agreement Act 1978*) was established between the State Government and the original proponent of the Project, Western Mining Corporation Limited, in 1978. This agreement facilitates the exploration, mining and treatment of certain uranium ores and associated minerals from mining areas that form the subject of the agreement, and allows for associated infrastructure to mine and process such ores.

The Yeelirrie State Agreement addresses matters that include the provisions for the supply of water to the Project and investigation and research for environmental management.

The Yeelirrie State Agreement also requires the proponent to submit a Development Proposal on the Project to provide detailed information on operational plans, plant and equipment, workforce, workforce accommodation, project specific infrastructure, social infrastructure, impact on public infrastructure and services, land requirements and environmental management. The Development Proposal is submitted to the Minister for State Development and must be approved before the Project can proceed.

The Minister cannot approve the Development Proposal until all primary approvals (including environmental approval under Part IV of the WA EP Act) have been granted.

3.1.4 Other Approvals

Prior to commencement of construction and operation a number of other approvals are required for the Project as outlined in Table 3-1. Key approvals in WA are as follows:

- Environmental approvals under:
  - Part V of the EP Act;
  - *Mining Act 1978* (Mining Act);
  - *Rights in Water and Irrigation Act 1914* (RIWI Act);
- Heritage approvals under the *Aboriginal Heritage Act 1972* (Aboriginal Heritage Act); and
- Radiation safety approvals under the *Radiation Safety Act 1975* (Radiation Safety Act) and associated regulations.

Environmental Protection Act 1986

Under Part V of the EP Act, Cameco will be required to obtain a Works Approval prior to construction of the Project. The plant will also require a Licence to Operate prior to commencement of operations. Supporting documentation for these approvals will address project detail/description, assessment of potential impacts and proposed management measures. The supporting documentation will be submitted to the DER for assessment.

Further approvals or reporting requirements during operation may be necessary under the Environmental Protection Regulations 1987 and subsidiary legislation.

Mining Act 1978

Cameco will need to submit a Mining Proposal to the Department of Mines and Petroleum (DMP) for approval under the Mining Act, prior to commencement of construction. The Mining Proposal will provide details of the Project including design of the tailings facility, mine pit, waste rock landform and plant site and an assessment of potential impacts and proposed management.

The Mining Proposal will be accompanied by the Radiation Management Plan and the Mine Closure and Rehabilitation Plan, which also require approval from DMP before construction and operations can commence.

Rights in Water and Irrigation Act 1914

Cameco will be abstracting groundwater for water supply and also for pit dewatering to allow mining to be undertaken safely. Cameco will obtain the necessary groundwater licences and permits to construct and operate wells under the RIWI Act (Section 5C and 26D respectively) which is administered by the Department of Water (DoW).

Aboriginal Heritage Act 1972

The Aboriginal Heritage Act provides protection for all places and objects in Western Australia that are important to Aboriginal people because of connections to their cultural heritage.

Cameco's position is that disturbance to Aboriginal heritage sites and the values associated with these sites will be avoided where possible. However, in some cases it may not be possible to avoid disturbance to all Aboriginal heritage sites if the Project is to proceed. In this case Cameco will consult with Aboriginal people with an interest in the land, including Native Title claimants, undertake formal heritage surveys and apply for a permit or consent under Section 18 of the Aboriginal Heritage Act.

Radiation Safety Act 1975

Under the Radiation Safety Act, the Yeelirrie site must be licensed by the Radiological Council. The owner of any premises in which any radioactive substance is manufactured, used or stored also requires registration under the Radiation Safety Act.

As part of the licensing process, Cameco must prepare a Radiation Management Plan for construction and operation of the Project. The Radiation Management Plan must be approved by the Radiological Council.

The licensing of the Project will also require a Radioactive Waste Management Plan, a Transport Management Plan and a Mine Closure and Rehabilitation Plan to be prepared by Cameco and approved by the Radiological Council.

Exploration at Yeelirrie is currently being undertaken under the approved Exploration Radiation Management Plan. Requirements under the Radiation Safety Act subsidiary legislation include:

- a licence for any premises in which a radioactive substance is manufactured, used or stored under the Radiation Safety (General) Regulations 1983;
- a licence to transport radioactive substances under the Radiation Safety (Transport of Radioactive Substances) Regulations 2002; and
- an approved radiation protection program for transport of radioactive substances.

Other legislation

In addition, there may be requirements under the following legislation which may apply to the Project:

State Legislation

- *Agriculture and Related Resources Protection Act 1976;*
- *Bush Fires Act 1954;*
- *Contaminated Sites Act 2003* and Regulations;
- *Land Administration Act 1997* and Regulations 1998;
- *Local Government Act 1995;*
- *Main Roads Act 1930;*
- *Nuclear Activities Regulation Act 1978;*
- *Nuclear Waste Storage and Transportation (Prohibition) Act 1999;*
- *Occupational Health and Safety Act 1984;*
- *Poisons Act 1964*; and
- *Soil and Land Conservation Act 1945.*

Commonwealth Legislation

- *Australian Heritage Council Act 2003;*
- *National Greenhouse and Energy Reporting Act 2007;*
- *National Environmental Protection Measures Implementation Act 1998;*
- *Aboriginal and Torres Strait Islander Act 2005;*
- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984;* and
- *Energy Efficiency Opportunities Act 2006.*

Table 3-1: Approvals Required

Legislation	Approval	Agency/Department
State Legislation		
Uranium (Yeelirrie) Agreement Act 1978	Development Proposal	DSD
Part IV of *Environmental Protection Act 1986*	Formal environmental approval	EPA
Part V of *Environmental Protection Act 1986*	Works Approval	DER
	Licence to Operate	DER
Mining Act 1978 and Regulations 1981	Mining Leases	DMP
	Miscellaneous Licences	DMP
	Mining Proposal	DMP
	Approval of closure and site rehabilitation plans	DMP
Mines Safety and Inspection Act 1994 and Regulations 1995	Project Management Plan	DMP
	Radiation Management Plan	DMP
	Radioactive Waste Management Plan	DMP
	Transport Management Plan (for transport of uranium oxide)	DMP

Legislation	Approval	Agency/Department
Radiation Safety Act 1975 and Radiation Safety (Qualifications) Regulations (1980)	Radiation Management Plan	Radiological Council
	Radioactive Waste Management Plan	Radiological Council
	Approval of a nominated Radiation Safety Officer to be holder of licence for mining and milling of radioactive ores	Radiological Council
	Registration of owners of premises	Radiological Council
	Approval of closure and site rehabilitation plans	Radiological Council
Radiation Safety (General) Regulations (1983)	Licence of premises	Radiological Council
Radiation Safety (Transport of Radioactive Substances) Regulations 2002	Licence to transport radioactive substances	Radiological Council
	Radiation Protection Programme for transport	Radiological Council
Dangerous Goods Safety Act 2004 Dangerous Goods Safety (Storage and Handling) Regulations 2007 Dangerous Goods Safety (Security Risk Substances) Regulations 2007 Dangerous Goods Safety (Explosives) Regulations 2007 Dangerous Goods Safety (Non-Explosives) Regulations 2007	Dangerous Goods Licences	DMP
Aboriginal Heritage Act 1972	Ministerial Consent under Section 18 to disturb heritage sites (if required)	Department of Aboriginal Affairs (DAA)
Rights in Water and Irrigation Act 1914	Groundwater licences for construction of wells and abstraction of groundwater	Department of Water (DoW)
Wildlife Conservation Act 1950	Flora and fauna licensing Approval to disturb threatened flora or fauna (if required)	Department of Parks and Wildlife (DPaW) WA Minister for Environment
Building Act 2011	Building permit for worker accommodation	Shire of Wiluna
Planning and Development Act 2005	Planning approval for worker accommodation	Shire of Wiluna
Health Act 1911 and Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974	Notice of Completion	Shire of Wiluna
	Sewage treatment permit	Department of Health (DoH)
Commonwealth Legislation		
Environment Protection and Biodiversity Conservation Act 1999	Formal environmental approval	Federal Minister for the Environment DoE
Australian Radiation Protection and Nuclear Safety Act 1998	Facility licence	Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

Legislation	Approval	Agency/Department
Nuclear Non-Proliferation (Safeguards) Act 1987 and *Nuclear Safeguards (Producers of Uranium Concentrates) Charge Act 1993*	Permit to possess nuclear material (Section 13)	Australian Safeguards and Non-Proliferation Office (ASNO)
	Permit to establish a uranium mining facility	ASNO
Regulation 9 of Customs (Prohibited Exports) Regulations under the *Customs Act 1901*	Permit to export uranium ore concentrates	Department of Industry (DoI)
Native Title Act 1993	Land Access (Negotiation Notification Section 29 and State Deed; or Consultation Notification)	National Native Title Tribunal

Cameco has not yet obtained the approvals listed in Table 3-1.

3.2 International Agreements

Table 3-2 lists the international agreements that are relevant to the assessment of the Project under the EPBC Act or other approvals that are required under Commonwealth Legislation.

Table 3-2: Relevant international agreements on uranium and the environment

Agreement	Description
Treaty on the Non-Proliferation of Nuclear Weapons 1968 (NPT)	The NPT's objective is to prevent the spread of nuclear weapons and weapons technology, to promote co-operation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament. The Treaty represents the only binding commitment in a multilateral treaty to the goal of disarmament by the nuclear-weapon States and entered into force in 1970. A total of 187 parties have joined the Treaty, including the five nuclear-weapon States. Australia ratified the Treaty in 1973.
Australian Nuclear Safeguards Agreements	Australia only exports uranium for peaceful purposes to countries and parties with which Australia has a bilateral safeguards Agreement. Australia currently has 22 bilateral safeguards Agreements in force covering 39 countries.
International Convention on Biological Diversity 1992	This Convention applies to the conservation of biological diversity, the sustainable use of biological components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding. Australia ratified the Convention in 1993.
Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	The Convention on the Conservation of Migratory Species of Wild Animals aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Programme, concerned with the conservation of wildlife and habitats on a global scale. Australia has been a party to the Convention since 1991.
Japan Australia Migratory Birds Agreement (JAMBA) 1974	An agreement between the Governments of Australia and Japan for the protection of migratory birds and birds in danger of extinction and their environment. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.

Agreement	Description
China Australia Migratory Birds Agreement (CAMBA) 1986	Agreement between the Governments of Australia and The People's Republic of China for the protection of migratory birds and their environment. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.
Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) 2006	Agreement between the Governments of Australia and The Republic of Korea on the protection of migratory birds. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.
United Nations Framework Convention on Climate Change and the Kyoto Protocol 1997	The Kyoto Protocol is an international agreement created under the United Nations Framework Convention on Climate Change (UNFCCC). The Convention establishes legally binding commitments to reduce four greenhouse gases (carbon dioxide, methane, nitrous oxide and sulphur hexafluoride), and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by industrialised nations, as well as general commitments for all member countries. The Kyoto Protocol includes mechanisms for greenhouse gas emission trading between nations. Australia's ratification of the Kyoto Protocol came into effect on 11 March 2008.

3.3 Guidelines, Policies and Standards

There are a large number of policies, guidelines, standards and codes that are applicable to the environmental management of mining projects. Policies and guidelines relevant to the Project are summarised in Appendix B. Where applicable these guidelines have been referenced within the PER.

The key guidelines applicable to this Project are the EPA Environmental Assessment Guidelines 8 and 9 (EAG8 and EAG9) which form the basis of guidance for the State environmental assessment process and the EPBC Act Significant Impact Guidelines 1.1.

EAG8 defines environmental factors and associated environmental objectives used by the EPA for assessing projects; describes the EPA's framework for environmental factors and objectives and how they link to other EPA guidance; and outlines the EPA's expectations for applying environmental factors, objectives and guidance through the environmental impact assessment process (EPA 2013a). The key environmental factors and objectives outlined in Section 9 of this PER are based on EAG8.

EAG9 describes how the EPA makes decisions, throughout the environmental impact assessment process, on the likely significance of impacts of a proposal, using a risk based approach (EPA 2013b). This risk-based approach has formed the basis of the risk assessment undertaken by Cameco for the Project (Section 8).

Section 4

Stakeholder Consultation

4. Stakeholder Consultation

4.1 Stakeholder Consultation Overview

Cameco has undertaken a comprehensive stakeholder and local community consultation process as part of the Project's PER. Foremost, this engagement strategy is aligned with Cameco's Five Pillars of Corporate Social Responsibility, which are endorsed on all of Cameco's operations. These pillars are:

- Workforce development: We are committed to train, educate and employ local people. In consultation with local communities, Cameco develops action plans to ensure effective education and training is available to allow local people to make the most of employment opportunities at our operations.
- Business development: We seek to build capacity in local stakeholder communities by assisting them in developing sustainable businesses to provide goods and services to our operations.
- Community investment: We invest in charitable projects that support community development, education and literacy, youth, and health and wellness initiatives.
- Community engagement: We build and sustain strong relationships with local community and government groups through open and direct communication. Cameco focuses on indigenous communication by listening to elders and youth and working to overcome cultural and language barriers.
- Government and regulatory relations: We seek positive, open relationships and partnerships with important stakeholders including governments and regulatory agencies.

4.2 Stakeholder Consultation Objectives

The objectives of undertaking a comprehensive consultation program with key stakeholders for the Project's PER were to:

- Provide an opportunity for stakeholders to participate and contribute in discussions and provide suggestions and advice on the Project, transport proposals and heritage management.
- Provide opportunity for input and feedback through the environmental impact assessment process into the decision process.
- Capture and respond to stakeholder issues and concerns during the development of the Project and the formal reporting phases.
- Provide an opportunity to educate stakeholders on aspects of uranium mining, processing, the final product and transport and radiation.
- Provide an opportunity to inform people about Cameco and the Project, including, for example, Cameco's experience as one of the world's leading uranium miners and one of Canada's leading employers of Aboriginal people.

In developing the stakeholder consultation program, Cameco was conscious that significant work had been completed by BHP Billiton. In discussion with key stakeholders it became obvious that some stakeholders considered they had been adequately consulted and informed, while others, in particular some Aboriginal community and family groups, were keen to hear more from Cameco. Based on this early feedback, Cameco has attempted to undertake a targeted consultation to serve three purposes; firstly, to provide some education and build awareness about uranium mining and related matters (such as radiation, dust, implications for bush tucker and transport, second, to inform stakeholders about the proposed development and to gain feedback on it, and third, to inform people about Cameco, including for example, our experience as one of the world's leading uranium miners and one of Canada's leading employers of Aboriginal people.

4.3 Key Stakeholders

To help identify stakeholders and their issues, BHP Billiton established a Community Reference Group comprising local government and community representatives from Wiluna, Leonora, Menzies, Kalgoorlie-Boulder and Sandstone in June 2009. Stakeholder identification and analysis of issues included the feedback from this group in addition to a variety of other sources, including:

- outcomes of stakeholder meetings conducted from February 2009;
- prevailing stakeholder perceptions identified by quantitative and qualitative research regarding attitudes towards uranium mining;
- desktop research on a number of topics, including community profiles, industry bodies, regional organisations and service providers;
- media analysis;
- advice from industry groups, relevant associations and government bodies;
- liaison with, and advice from, Central Desert Native Title Services (CDNTS), as the native title representative body; and
- discussions and research undertaken for other sections of the ERMP, including social, land use and economic investigations.

Following the acquisition of the Project by Cameco and supported by feedback from early communications with stakeholders about their needs and interests, the stakeholders were grouped into categories, given a rating regarding future needs and importance and consideration was given as to how best to engage each group.

In continuing consultation, priority was given to those groups who have a direct interest in the Project and those who are more likely to be interested in the content of the PER. Cameco recognises that there are other groups that haven't been provided priority at this time, and commits to ongoing consultation during and after the approval process. Refer to Table 4-1.

Table 4-1: Priority for consultation as part of the approval process

Group	Priority	Process
Functional Groups – industry bodies and resource service providers. Local businesses and service providers in the wider catchments of the transport routes (e.g.education, employment, accommodation, health and emergency services).	Low	Consult more widely post approval
Non-Government - Special interest – local, state and national organisations with a special interest in the proposed development, in particular those with environmental, health and anti-nuclear interests, eg, Conservation Council of WA.	Medium	Face to face meetings Open day presentation
State and Federal Government - Key decision making agencies, eg, EPA, DRD, DER, DPaW, DMP, DoE.	High	Related topic presentations, face to face meetings, written correspondence
Local community, including local government, Shire of Wiluna and Shire of Leonora.	High (most local government agencies were represented on the Community Reference Group) and have advised Cameco they are well informed.	Meetings, field days

Group	Priority	Process
Local Aboriginal community members.	High	Meetings, field days, face to face meetings with small groups
Wider local community – residents in the nearby local government areas, such as the shires of Menzies and Sandstone, the City of Kalgoorlie-Boulder, and along the transport route.	Medium	Meetings and presentations
Media – print, radio, television and online media at local, regional, metropolitan and national levels.	Low	Interviews

4.4 Engagement and Communication Mechanisms

Engagement and communications mechanisms will vary depending on the stakeholder. In the first instance, in general, Cameco has met all key stakeholders at least once with a face to face meeting. Where necessary the initial contact has been followed up by more specific meetings and briefings.

In meeting the needs of the local indigenous community and family groups, Cameco has attempted to modify the message, the delivery and the setting to maximise the opportunity for people to engage and understand the scope of the Project and to discuss issues they raise.

Cameco has met with many local indigenous family groups in their communities and homes or other preferred meeting places in Leonora and Wiluna to maximise engagement.

More face to face local meetings are planned once the PER is publically available to provide further opportunity for people to become aware of the impact of the Project and proposed management plans.

A register of stakeholder consultation is included in Appendix C.

4.5 Stakeholders' Perceived Project Issues and Impacts

Regulatory Stakeholders

The concerns of regulatory stakeholders are primarily captured in the ESD (Appendix A1) and are addressed in the PER. A table listing the required work from the ESD and referencing the sections of the PER where the work is addressed is included in Appendix A2.

Local Aboriginal community

Local Aboriginal community members raised concerns across a range of topics, including:

- radiation and the proliferation of nuclear arms with specific reference to Maralinga, Chernobyl and Fukushima;
- radiation and the impact on bush food and the environment;
- protection of heritage places; and
- employment and community and business development opportunities.

Cameco has attempted to address these issues through presentations and discussions in forums arranged by the CDNTS and in meetings with individual family groups. Discussion on the impacts of radiation and the protection of heritage will continue throughout the approval period and the life of the Project.

The desire to maximise the potential employment and community development opportunities that can come from development is also a very high priority for the local community and this will also be a topic for further discussion.

Local Government Authorities

Local Government Authorities have also expressed interest in the Project and any implications for local and regional services and service delivery. The transport of radioactive product from the Project (and the industry generally, given there are several other Projects in the region approved or seeking approval) is a key topic and has been the subject of numerous presentations by Cameco and other companies.

4.6 Ongoing Engagement

Cameco is committed to continuing engagement with stakeholders throughout each phase of the Project to ensure that key issues and relevant impacts and benefits are identified, monitored and appropriately managed. Regular meetings and project briefings with the stakeholder groups listed above will continue.

All interested parties will have a formal opportunity to comment on the PER during the 12 week public review period. During this period, Cameco will continue to meet with local community groups and visit towns along the transport corridor to discuss the proposal.

Section 5

Project Justification and Alternatives

5. Project Justification and Alternatives

5.1 Project Rationale and Benefits

The Project is a key step in Cameco Corporation's plans to expand its global operations into Australia. The development of the Project will result in economic and social benefits for local communities and the WA and Australian economies. The Project will contribute directly through:

- royalties and taxation payments;
- capital investment in the north eastern Goldfields region;
- increased direct and indirect employment and contracting opportunities in the region and across the state;
- increased demand for goods and services, which will support local communities and economies; and
- increased opportunities in education, training, employment, contracting and business and community development in the region through implementation of Cameco's Five Pillars program.

5.1.1 Global Demand for Uranium

The fundamental driver of growth in the demand for uranium is the generation of electricity from nuclear power reactors. Other important applications include the production of radioisotopes used extensively in medical applications, industry and scientific research. The primary driver of increasing electricity demand is the continued growth in global population and improvements in the standard of living in many countries. The United States Census Bureau (www.census.gov) estimates the global population is currently around 7.2 billion; this is predicted to increase to over 9 billion by 2050 (United Nations Population Fund).

Uranium is used in nuclear reactors around the world. There are currently 437 nuclear reactors operating (primarily on the East Coast of the United States and in Western Europe, South Korea and Japan) with a combined electricity output of around 2,360 billion kWh per annum. These reactors consume around 65,600 tonnes per annum (tpa) of UOC (World Nuclear Association 2015). The US is the world's largest market, while France is the most reliant on uranium supplies, with more than 75% of its electricity generated by nuclear power.

Nuclear power has high up-front capital costs and low operating costs. It is therefore, cost-effective to keep existing nuclear power stations operating at high capacities, with changes in load to meet local electricity demand largely met by fossil fuel electricity generators. As a result, the demand for uranium is largely isolated from economic variations, and more dependent on installed capacity. There are currently 70 nuclear reactors under construction, 183 ordered or planned and 311 proposed (World Nuclear Association 2015).

Growth of global uranium consumption has slowed over the last few years with nuclear reactors in Japan being offline following the events at the Fukushima-Daiichi nuclear power plant in March 2011. However, the long term future for the industry looks positive as Japan gradually returns to nuclear power and demand for nuclear-generated electricity increases around the world. By 2024, Cameco expects over 100 gigawatts of nuclear power, or about 80 net new reactors, to be added to the world's grids, with even more growth expected outside that timeframe. Of the reactors under construction today, if startups occur as planned, 45 of those units (about 46 gigawatts) could be online over the next 3 years. The potential growth in the number of nuclear reactors is mainly concentrated in Asia.

Approximately 85% of the demand for uranium is supplied from mines, with the remainder supplied from uranium stockpiles or other secondary sources, including recycled uranium and plutonium from spent nuclear fuel, re-enriched uranium tails, and decommissioned weapons-grade uranium

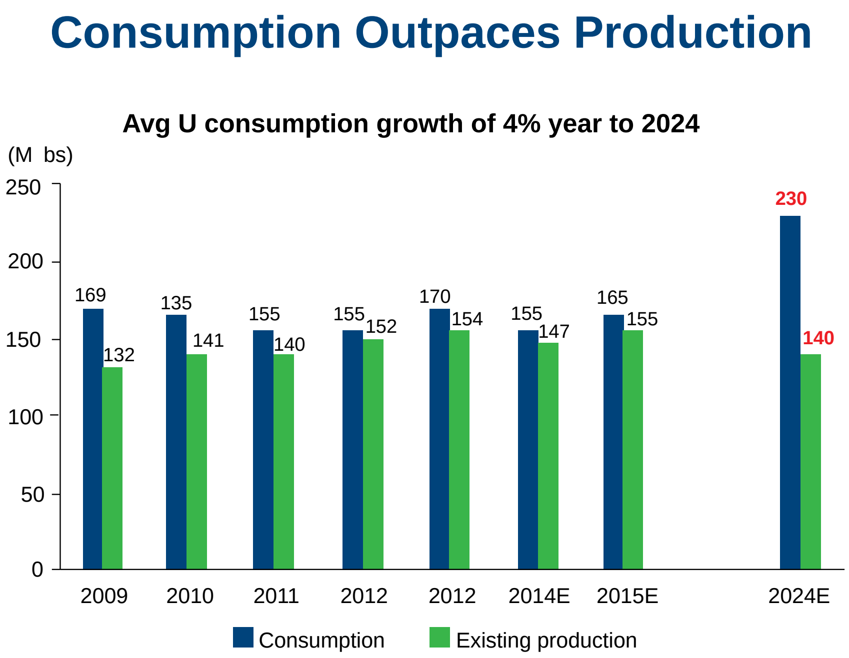


Figure 5-1: Uranium oxide demand and supply

and plutonium. These stockpiles are being drawn down and are expected to contribute less over time, which means that more primary production will be needed from uranium mines. Cameco estimates about 15% of total supply required over the next decade will need to come from new mines not yet in development.

Figure 5-1 illustrates the predicted shortfall between current uranium production and future demand to 2030. This shortfall will need to be met by current prospective and future deposits becoming operational, or by increasing production from existing operations.

5.1.2 Uranium Mining in Western Australia

Mining is an important contributor to the economic and social fabric of WA, as indicated by the following information provided by the DMP (2014): During 2013/2014, the WA mineral and petroleum industry was valued at $121.6 billion, with iron ore accounting for $73.7 billion (78%). Gold was the second most valuable mineral sector with total sales of $8.8 billion (9%). This was followed by alumina, nickel and base metals (copper, lead and zinc). As at September 2014, WA had an estimated $160 billion worth of resource projects under construction or in the committed stage of development. A further $108 billion has been identified as being allocated to planned or possible projects in coming years.

While Australia has the largest known resources of uranium in the world, it is not the largest supplier. There are currently three operating mines: Ranger in the Northern Territory, Olympic Dam and Four Mile mine in South Australia. The Beverley and Honeymoon mines (also in South Australia) were shut down in 2013/2014 due to the low uranium price. Uranium mining was banned in WA from 1983 until 2008. While Western Australia does not have a commercially productive uranium mine in operation, several projects have either obtained or are seeking environmental approval and are being advanced. As of June 2012, WA has known deposits of about 211,000 tonnes of uranium (DMP 2013). Development of the uranium sector in WA will provide further diversity to the WA mining industry.

The Yeelirrie deposit is the largest known uranium deposit in WA. The proposed Project, which proposes to produce up to 7,500 tpa UOC, is well placed to take advantage of the current and expected growth in demand.

5.2 Evaluation of Project Alternatives

Cameco has investigated numerous alternatives for the various environmental and socially significant aspects of the proposed Yeelirrie development. The design of a successful project is an iterative process, and the decision to select particular alternatives over other options took into account environmental best practice in combination with economic and social factors.

This section outlines the evaluation of the key alternatives and modifications to the Project after the evaluation of historical information gathered during previous assessments undertaken by WMC in 1978 and by BHP Billiton in 2010.

The assessment of options has also been informed by the results of stakeholder engagement and findings of environmental surveys conducted by both BHP Billiton and Cameco. Government and non-government stakeholders contributed to this process, raising a number of options considered for the Project. These considerations ensure that the proposed development is practicable and provides an appropriate level of protection for the environmental, social and cultural values of the Project Area.

The major Project alternatives investigated and discussed here include:

- mining method and equipment;
- tailings management;
- dewatering and water supply;
- processing capacity and production rate;
- energy supply;
- site services;
- transport of product to Port Adelaide; and
- consequences of not proceeding with the Project.

5.2.1 Mining Method and Equipment

The key Project value driver for mining at Yeelirrie is the availability of high grade ore to feed the mill early in the mine life and the control of smectite grades. In order to minimise ore loss and dilution, and effectively separate high smectite materials, a highly selective mining method is required. The other key characteristics affecting the mining method are the near surface location of the orebody, high value and high processing cost of the ore, vertical variability of the orebody, presence of high grade ore zones and general low strength of the material being mined, meaning relatively easy digging.

While a range of mining methods and mining equipment options were considered, the best option to achieve the value drivers and the required mining selectivity were the use of small scale hydraulic excavators and standard off-highway rear dump trucks for the prime movement of both ore and waste materials. Rehandle activities will be performed primarily by front end loaders. Due to the general low strength of the material, free digging of materials will be possible with the exception of limited areas which may require bulldozer ripping before digging. Explosives will not be required.

5.2.2 Tailings Management

The major consideration for tailings management was whether to use in-pit storage or above ground storage. The key design objectives that informed the final decision for the tailings storage facility were:

- to provide safe and economic storage of tailings to minimise environmental impacts and risks;
- to provide an erosion-resistant and non-polluting structure that is stable in the long term;

- to minimise seepage from the facility; and
- to minimise ground disturbance.

The following factors were considered when determining the preferred tailings management option:

- location and layout with particular attention to maximising operational efficiency and reducing net ground disturbance;
- hydrological and hydraulic factors;
- geotechnical, geochemical (geomorphological) and radiological factors;
- availability and properties of construction materials;
- embankment design and stability; and
- operational factors and availability of material for closure.

Above ground tailings storage was not selected because it would have required extensive additional environmental impact from ground disturbance and would not be as stable over the long term as in-pit storage.

With the design intent stated above, storage of tailings in the mine pit was selected as the preferred option.

The deposition of tailings in the pit minimises the net environmental impact of the Project as it reduces the Project disturbance area. The in-pit solution would also isolate the tailings from the groundwater because of the underlying 60 m layer of very low permeability clay/quartz and the effective encapsulation of the tailings within the pit voids using constructed clay embankments (Section 6.5). As mining progresses, additional capacity for tailings storage will be available within the pit void. The overburden removed from the developing mining operation would provide suitable material to cap the tailings storage cells for progressive decommissioning, rehabilitation and closure. This tailings management option also has the significant benefit of being able to provide a stable final landform similar to that of the pre-mining landform.

The deposition of tailings into the open pit void presents some timing issues. The pit has to be dewatered and mined before tailings can be deposited. Similarly, there has to be sufficient area mined and open to receive tailings to allow tailings deposition at a rate to allow adequate drying and consolidation. To achieve this, mine dewatering will precede mining which will also be advanced several years before the commencement of milling.

As a result of the staggered schedule, a larger ore stockpile will be established adjacent to the plant before the commencement of milling.

The proposed schedule for dewatering, mining and deposition of tailings is discussed in detail in Section 6.3.

5.2.3 Dewatering of the Open Pit

Dewatering of the mine open pit prior to the commencement of mining is required to provide safe and dry conditions for mining and tailings operations. To meet these conditions, it is expected that dewatering would commence up to one year before the commencement of mining. In the first year of dewatering, up to approximately 4.0 ML/d of groundwater would be abstracted, peaking in year four at up to approximately 13.0 ML/d for a short period. In the first few years of operation, some water from mine dewatering is likely to exceed Project requirements, and as such would require disposal. In order to ‘preserve’ the water for future use Cameco proposes to reinject the water upstream of the mining area, so that it can be abstracted for future use later in the mine life. The Project water balance model suggests there will be a requirement to reinject groundwater for the first four years, with maximum reinjection occurring in year three at the rate of up to approximately 6.5 ML/d.

This proposal has the environmental benefit of reducing the volume of water needed to be abstracted elsewhere.

The initial excess water would be reinjected into the groundwater aquifer within the open pit boundary and 'upstream' of the active mining area so that it can be re-abstracted for use in the coming years. After the initial years, there is a net water demand and all water abstracted from dewatering would be used on-site.

A system consisting of in-pit trenches and pumps has been selected as the best dewatering option. This system was demonstrated to be effective during work completed by WMC when a series of trial mining open pits were developed in the early 1980's. This would be a dynamic/transient system close to active mining and tailings storage facility areas. To provide safe dry mining conditions, the aquifer would be locally dewatered by trenches and sump pumping systems that would extend 1 to 3 m below the active pit floors and begin pumping up to three months before mining of the relevant area to allow enough time for dewatering to meet the scheduled rate of advance. Dewatering trenches would be maintained at the perimeter of the final pit footprint to manage the longer-term inflows from groundwater outside the pit.

The elevated salinity of the water abstracted from dewatering (about 10,000 to 50,000 mg/L) makes this water suitable for use in dust suppression and as raw process water for the metallurgical plant. This would in turn reduce the amount of Project water required from other sources (and potential impacts arising from this) and is consistent with regulatory preferences for use of mine water.

The process of dewatering and reinjection and the environmental implications are further discussed in Section 9.5.

5.2.4 Water Supply

The Project requires water of various qualities and quantities for different uses during the construction and operation phases. The biggest single demand is for raw process water in the grinding and leaching circuits. The second biggest use of water is for dust suppression. Both uses can accommodate poor water quality from saline sources. The total annualised average operational water demand is estimated at around 8.7 ML/d, with about 4.8 ML/d required for metallurgical processing and the remainder used as required for dust suppression and the reverse osmosis plant within the mining operation.

A much smaller demand for water during construction and operation is for feed water to a reverse osmosis (RO) desalination plant to produce low-salinity water (about 500 mg/L). This water will be used for steam generation and other parts of the process circuit (2.2 ML/d), as well as for producing potable water for the accommodation village and on-site workforce. This feed water supply would preferably be lower-salinity water than the expected pit dewatering discharge and therefore would be provided from higher-quality groundwater sources.

Further details of the water demand and supply source for the construction and operation of the proposed development are provided in Section 6.6.

Pit dewatering will provide a valuable water supply for the first four years of the Project. To meet the need for increasing make-up water supplies, a series of wellfields surrounding the Project has been identified and assessed to be the best option. Water supply infrastructure would be constructed to link the Project to these wellfields situated within the State Agreement area, hereafter referred to as the Yeelirrie Wellfield and bores.

In deciding an appropriate groundwater production strategy, Cameco's philosophy is to utilise poorer quality (higher salinity) groundwater where possible within the demand requirements. This reduces the demand for better quality water and potentially minimises the impact of groundwater drawdown on groundwater dependant ecosystems.

The selected wellfield option for make-up water supplies represents a combination of two aquifer types:

- The deeper palaeochannel aquifer that occurs as a largely confined strip aquifer about 40 to 70 m below the State Agreement area. This is the same aquifer from which the down-gradient Albion Downs Borefield abstracts most of its groundwater and is poorer quality than the shallower aquifers.
- The shallower aquifer intervals comprising sandy alluvium and weathered bedrock profiles, which are typically located away from the central axis of the catchment and lie within 30 km of the proposed metallurgical plant site.

The location, design pumping rates, and durations of pumping for the selected option has been determined based on many factors including:

- physical capacity of the aquifers to sustain pumping rates over the required timeframes;
- the potential impact on groundwater-dependent ecosystems from possible drawdowns of the watertable; either directly from pumping of the shallow unconfined aquifer system, or indirectly by inducing vertical leakage from the shallow aquifer through the confining layers when pumping from the deeper aquifer;
- the locations of existing groundwater users' abstraction points (bores and wells);
- land access and tenure; and
- groundwater salinity.

The 1978 WMC EIS identified six distinct wellfield areas for the Project water supplies. The 1978 requirements were for larger volumes of groundwater at much lower salinities (6.5 ML/d at less than 3,000 mg/L TDS for process water and 4 ML/d at less than 1,000 mg/L TDS for potable water) than the current proposed Project, principally because of different ore processing requirements and the fact that desalination was not a technical solution practically available in 1978.

Cameco does not consider that the plans proposed by previous proponents are viable. The water supply wellfields proposed by WMC for development in 1978 were to be located in the Lake Way catchment, at distances of about 15 to 45 km north and north east of the proposed metallurgical plant site. These areas were rejected by the current study for numerous reasons, including:

- land access and tenure;
- costs;
- likely potential environmental impacts (from pumping a shallow aquifer hosted by calcrete and likely to support groundwater-dependent ecosystems);
- located outside the Mining Areas specified in the State Agreement for water search; and
- the much-reduced reliance on low-salinity groundwater within the proposed process.

Parts of areas proposed by WMC in the 1978 study as alternative or back-up water supplies have been incorporated into the proposed Yeelirrie Wellfield, primarily for their closer proximity to the metallurgical plant (2 to 20 km) and the diminished potential for hosting groundwater-dependent ecosystems.

5.2.5 Processing Capacity and Production Rate

Uranium would be extracted from the ore in a series of agitated and heated alkali leaching tanks operating under atmospheric pressure. Pressure leaching could have been used which would have reduced the footprint of the Process Plant marginally but the high capital intensity and operating complexity of a pressure leach circuit, coupled with the requirement for enhanced skill levels to operate and maintain the production autoclaves, favoured the selection of the agitated tank leach option. To optimise uranium extraction, the feed material would be ground to reduce the particle size before leaching. The leach residue would be separated from the uranium solution (termed 'pregnant leach solution' or PLS) and washed in a counter-current decantation (CCD) circuit. The use of filtration to separate the leach residue from the PLS is less effective than CCD due to low filtration rates associated with fine clay particles in the ore. Uranium would be precipitated from the PLS as an impure sodium diuranate (SDU), and subsequently dissolved and purified before being precipitated a second time as uranium peroxide ($UO_4.2H_2O$). This would be dewatered, dried and packed as uranium oxide concentrate (UOC) with the option to calcine through to yellowcake (U_3O_8) available given the flexibility in design of the drying and packaging equipment proposed. The metallurgical plant would be commissioned about two years after mining begins, and would operate continuously thereafter.

The alkali leaching and direct precipitation process was considered optimal given the chemistry and mineralogy of the ore and the relatively poor quality of groundwater available to the Project. Acid leaching was not a viable option due to the carbonate content of the ore and the consequent high acid consumption and CO_2 emissions in the leaching stage. The alternative to direct precipitation is to use ion exchange (IX) to pre-concentrate the dissolved uranium following the leaching stage.

The efficiency of uranium transfer to a resin (IX) would not be acceptable considering the quality of water available to the Project. Specifically, the chloride ion concentration in the ground water far exceeds the minimum level required for effective IX. The option to treat the entire process water volume through a reverse osmosis facility to improve the water quality to an acceptable level would consume significant additional energy and not be cost effective. The ore contains significant quantities of inorganic salts, such as sodium and magnesium chloride that dissolve upon contact with the process water and this would reduce the quality of the process water even if the process water was purified initially via reverse osmosis prior to its contact with the ore. The dissolved salts in solution actually play an important role in assisting to settle the solid residue in the CCD circuit, so to purify the process water would negatively impact the CCD circuit. Solvent extraction (SX) was not considered as there is no commercial SX process that is effective under alkaline conditions. Given the practical constraints associated with improving the process water quality, direct precipitation of SDU using sodium hydroxide was the selected option to recover and concentrate the uranium from the PLS.

Beneficiation, a process of pre-concentrating the uranium containing minerals within the ore prior to leaching, was also tested but the mineralogy of the ore is not suited to conventional ore pre-concentration techniques. The primary uranium containing mineral (carnotite) is finely disseminated within the clay minerals but also finely disseminated within the harder calcrete and dolomite minerals (and in similar proportions). As a result, a mineralogical deportment constraint renders preliminary wet scrubbing and screening, which is the first and most important step in a potential ore beneficiation process, ineffective at recovering and concentrating the majority of the uranium bearing minerals into one process stream. A complex beneficiation process would be required to ensure acceptable uranium recovery and the beneficiation process would likely consume significantly higher quantities of water overall relative to the selected process path. The potential to apply beneficiation techniques was discounted based on poor results obtained from preliminary scrubbing, screening and attrition test work.

Vanadium recovery was evaluated and rejected due to the uneconomic nature and potential environmental impacts of the identified recovery process.

5.2.6 Energy Supply

Peak electricity demand for the proposed development is estimated at 20 MW to meet an average annual electricity consumption of 150,000 MWh. Most of this power would be required to operate the grinding mill and pump process slurries within the metallurgical plant. The power would also be used to operate the Yeelirrie Wellfield and associated water transport and treatment infrastructure.

Electricity requirements would be met by installing a series of on-site diesel (or gas fired) generators and local transmission infrastructure. Installing multiple diesel generators would provide contingency in the event of planned and unplanned generator outages and would also allow the operation of the generators to be optimised, minimising fuel consumption.

Should the option of gas-fired generators become viable, (both on economic and gas availability grounds) a new gas pipeline lateral of approximately 50 km length would be required for a connection to the Goldfields gas pipeline. The gas option remains under consideration and will be progressed during the definitive feasibility stage of Project planning. If it is determined to be a viable alternative to diesel, an environmental impact assessment of establishing the pipeline corridor will be completed and appropriate approvals sought. For the purposes of this approval, however, it is assumed that power will be generated using diesel fuel.

A diesel-fired steam generator would be installed, with sufficient capacity to provide about 25 t/h of high-grade steam at a pressure of around 1,000 kPa. A boiler would also be constructed to capture waste heat associated with the exhaust gases of both the diesel-fired electrical generators and the steam generators.

The requirement for steam generation would be minimised through the use of heat exchangers within the metallurgical process to transfer heat between process streams where the nature of the precipitation process demands significant differences in heat. Up to 70 % of the carbon dioxide (CO_2) would be captured from the power station for use in the metallurgical process.

Other than the decision between diesel and gas, there are limited options for the power supply for the Project.

5.2.7 Site Services

Workforce Accommodation

With regard to the residential alternative, the original State Agreement Act required WMC to establish a town for its estimated workforce. The town, including suitable commercial, educational, recreational, sporting, religious and medical facilities, was to have been located 13 km north of the proposed open cut mine.

Cameco has decided not to establish a town at this stage because the small size of the operation would not support it. The operational phase would employ approximately 250 people and only half of them would be in the area at any time. The proposed WMC township would have required additional land disturbance and the proposed location was close to known Aboriginal cultural heritage sites.

Cameco will establish a fly-in/fly-out (FIFO) and drive-in/drive-out (DIDO) operation and an accommodation village close to the Project.

Location of Accommodation Village

A number of options were reviewed to determine the best location for the accommodation village at Yeelirrie taking into account factors such as travel distances, dust, aesthetics and natural background radiation level. The site located approximately 20 km south east of the mine site was determined to be the most appropriate place for the accommodation village for several reasons: it is well located for road access to Mount Keith for air services and it is sufficiently distant from the mine site to eliminate any concerns regarding radiation.

Air Services

Cameco proposes to utilise the airport facilities at the nearby Mount Keith operation, coupled with a proposed bus service between Mount Keith and Yeelirrie, for the movement of a FIFO workforce as approved under the terms of the sale agreement of the Yeelirrie Project with BHP Billiton. In the event the Mount Keith option is not acceptable to either party, Cameco would construct an onsite airport adjacent to the existing Yeelirrie air field. In this case, Cameco would seek separate environmental approval for this facility.

5.2.8 Transport of Product to Port Adelaide

The proposed Yeelirrie development would produce up to 7,500 tpa uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), with peak production in the early years of the Project. The product is proposed to be exported from Australia from the Port of Adelaide.

Packaging and transportation of UOC is regulated by Commonwealth, State and Territory government agencies in accordance with the Code of Practice for the Safe Transport of Radioactive Material published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Details of regulatory controls, transportation and packaging are discussed in more detail in Section 9.6 and Appendix J1.

In developing a transport solution for UOC, numerous options based on road, rail and a combination of road and rail were identified and assessed. The assessment considered social, political and environmental factors, as well as emergency response and operational considerations.

In February 2009, BHP Billiton undertook community consultations in the Goldfields region and presented several road/rail options for the transport of UOC from the proposed Yeelirrie development to the Western Australia/South Australia border. The options proposed were (see Figure 5-2):

- road to Leonora, then rail to South Australia;
- road to Kalgoorlie-Boulder (via Kalgoorlie Research Plant), then rail to South Australia;
- road to Kalgoorlie-Boulder (via West Parkeston), then rail to South Australia; and
- road to Parkeston, then rail to South Australia (identified as an emerging opportunity).

Feedback from those community sessions, coupled with discussions with state and local governments, indicated that the proposed Parkeston road to rail intermodal facility would be the most acceptable transport solution, and BHP Billiton agreed to use such a facility if it was established and licensed by third parties for UOC transport, as part of an intermodal facility handing all cargoes at Parkeston.

Cameco was also party to the discussions on the proposed Parkeston facility and agreed to use such a facility if it were established.

In the event that the facility is not established by the time production at Yeelirrie commences, Cameco proposes to transport the product by road from Yeelirrie along the Goldfields and Eyre highways to Port Adelaide for direct export. Port Adelaide is an approved UOC export port and the Project would use the established facilities and processes (see the following section on the export of uranium consignments).

Figure 5-2: Transport options and major transport routes for uranium oxide concentrate

The following considerations and benefits arise from the selected transport option:

- The use of the Goldfields Highway (eastern bypass), which is already a major transport route, reduces the interaction with Kalgoorlie-Boulder communities.
- Benchmarking of transport solutions from existing Australian uranium mines and international organisations identified no transport incidents where the UOC cargo presented a hazard to the community or environment because of road transport operations. Those operations, which include BHP Billiton's Olympic Dam, have successfully used road transport over similar distances as the proposed Yeelirrie mine site to Adelaide (approximately 2,230 km).
- The use of the Parkeston intermodal facility, depending on its development, location, road access and location east of KCGM's super pit, could further reduce road transport through Kalgoorlie-Boulder communities.

Export Ports for Uranium Consignments

Shipments of UOC would be transported by Australian Safeguards and Non-Proliferation Office (ASNO) approved carriers, which hold permits allowing the transport of radioactive material by approved vessels operating along approved routes from the Australian point of export through to the final overseas discharge port.

Western Australian and interstate ports were considered for the export of UOC consignments from Yeelirrie. However, the use of a Western Australian port was rejected because these ports are not currently licensed by either the Australian or Western Australian governments to export UOC. If the regulations change and Western Australian ports become licensed to export UOC, their suitability would be considered by Cameco and be subject to a separate approval process.

Port Adelaide is currently used to export shipments of UOC from BHP Billiton's Olympic Dam operation and other Australian producers. Darwin is the only other port in Australia that is currently approved to export UOC.

5.2.9 Consequences of Not Proceeding with the Project

Not proceeding with the Project will typically result in the loss of the benefits outlined in Section 5.1. However, if the Project does not proceed as planned, then it may well remain as a development option for the future. In other words, the costs and benefits may just be deferred.

Nonetheless, the consequences of the forgone benefits and impacts do have some immediacy:

- the time value of money means that collateral benefits to the State and regional communities are preferable now rather than later;
- a new development adds to the critical mass of the industry, from which a number of broader benefits flow beyond the Project itself; and
- diversification of the resources sector.

5.3 Optimisation Initiatives

The above sections identified the selected alternatives for the proposed Yeelirrie development and the reasons for rejecting other options. The following lists the key design elements that will be the focus of optimisation initiatives investigated during the detailed design phase:

- improve energy efficiency and reduce greenhouse gas emissions;
- improve process efficiency to reduce reagent requirements;
- improve water efficiency;
- review at-source and operational controls for dust;
- further minimise the Project's footprint and its impact; and
- minimise the net area of disturbance at any given time through refinements to the mining and processing schedules, with regard to progressive development and rehabilitation of the open pit and tailings storage cells.

Section 6

The Project

Figure 6-1: Location of the proposed Yeelirrie development in a regional context

6. The Project

6.1 Project Overview

Cameco proposes to develop an open pit mine and associated processing facilities at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie-Boulder, 65 km west of Mount Keith, 70 km south west of Wiluna and 110 km north west of Leinster (Figure 6-1).

The proposed development would produce up to 7,500 tonnes or 16.5 Mlbs per year of uranium oxide concentrate (UOC) as $UO_4.2H_2O$. Production will peak at this level in the second year of ore processing and steadily decline as the grade of the ore reduces over the 15 year ore processing period. The average annual production over the 15 year ore processing period will be approximately 3,850 tonnes or 8.48 Mlbs of UOC as $UO_4.2H_2O$.

The open pit mine would be about 9 km long, up to 1.5 km wide and about 15 m deep. Up to 14 million tonnes (Mt) of overburden and ore would be mined annually during the mining pre-production pre-strip phase, with an average extraction rate of around 8 Mtpa. Ore would be stockpiled and subsequently treated in the proposed metallurgical plant. The mined material would be stockpiled near the open pit before being processed within the metallurgical plant, or backfilled into the pit, if it is not economic to process.

The metallurgical plant would use an alkali tank leaching process, followed by direct precipitation, to produce UOC for containerised export from Port Adelaide. All tailings generated during the metallurgical processing of the ore would be returned to the tailings storage facility (TSF) constructed within the two open pits.

The proposed development would necessitate the construction and operation of infrastructure required to support mining and processing, including the supply of water and electricity, workforce accommodation and infrastructure to transport the product. The main components of the infrastructure are as follows:

- on-site quarry to provide raw construction materials;
- pit dewatering system consisting of trenches, sump drains and pumps to lower the groundwater level within the pit to allow safe access to the ore body and to provide a primary process water supply;
- water supply wellfield and associated infrastructure to supplement the water obtained from pit dewatering;
- surface water diversion system to exclude water from the mining area, the tailings and the stockpiled ore;
- electricity supply network powered by a series of on-site diesel (or gas fired) generators;
- buildings, including workshops, offices and warehouses;
- accommodation village catering for a peak on-site construction workforce of up to 1,200; and
- associated infrastructure including potable water and sewage treatment plants.

At the completion of operations, the development infrastructure would be decommissioned and removed and the site rehabilitated. In addition to the tailings, any remaining low-grade ore stockpiles and potentially radioactive materials, including processing facilities, would be buried in the pit and then covered with original mined materials (e.g. overburden) and topsoils. The cover for the mine would be designed to be safe, stable and non-polluting. Disturbed areas would be recontoured and rehabilitated as far as practicable with endemic, self-sustaining vegetation.

The proposed development would also use, where practicable, existing regional and national infrastructure, including:

- the road and rail network between Perth, Esperance, and Kalgoorlie-Boulder for the import of materials;
- facilities at the port of Adelaide for the export of UOC; and
- airport facilities at the BHP Billiton Nickel West Pty Ltd Mount Keith operation, coupled to a proposed bus service between Mount Keith and Yeelirrie for the movement of a fly-in/fly-out (FIFO) workforce.

The key characteristics of the proposed development are summarised in Table 6-1 and 6-2 and are shown on Figures 6-2 and 6-3.

Table 6-1: Proposal summary and key characteristics of the proposed development

Proposal Title:		Yeelirrie Uranium Project
Proponent Name:		Cameco Australia Pty Ltd
Short Description:		The proposal is to mine uranium ore from the Yeelirrie deposit, approximately 70 km south west of Wiluna, and the construction of associated mine infrastructure, including ore processing facilities, water abstraction and reinjection infrastructure, roads, accommodation, offices and workshops, stockpile and laydown areas and evaporation pond. Tailings will be discharged back into the mine open pit.
Physical Elements		
Element	**Location**	**Proposed Extent**
Mine Open Pit	See Figure 6.3	Clearing of approximately 725.9 ha within a 4,874.6 ha development envelope and no deeper than 15 m below ground level.
Associated Infrastructure	See Figure 6.3	Clearing of approximately 1,695.9 ha within a 4,874.6 ha development envelope.
Operational Elements		
Element	**Location**	**Proposed Extent**
Mining Rate	Mining with conventional equipment	Up to 14 Mtpa of mineralised ore and non-mineralised material (annual average of approximately 8 Mt).
Ore Processing (waste)	All tailings deposited in open pit	Deposition of up to approximately 3.0 Mtpa.
Water Abstraction	Dewatering of pits and production from borefield. See Figure 6.2	Extraction of up to approximately 4.9 GL/a.
Water Reinjection		Reinjection of up to approximately 1.3 Gl/a. [(1)]
GL/a – gigalitres per annum		Ha – hectares
m – metres		Mtpa – million tonnes per annum
Notes:		
1 In the early phase of the project, pit dewatering volumes exceed water demands. The surplus water would be re-injected into the local calcrete aquifer within the confines of the mine footprint.		

Table 6-2: Other project characteristics

Non-spatial elements	Description
Development operating life	An operational life of 22 years, including 3 years of pre-production dewatering, mining and construction followed by a further 12 years of mining and 15 years of processing. The conclusion of processing would be followed by an estimated 4 years of decommissioning and rehabilitation.
Nature of mineralisation	Shallow-depth alluvial deposit with mineralisation starting from surface to about 15 m below ground level, with a thickness between about 1 to7 m.
Operations summary	Open pit mining and on-site processing of uranium mineralised ore to produce uranium oxide concentrate.
Mining method	Open pit mining using conventional equipment such as excavators, front-end loaders and haul trucks.
Processing method	Alkali leach and direct precipitation.
Production rate	Up to 7,500 tpa of uranium oxide concentrate produced at peak production in the second year of ore processing. The average annual production over the 15 year ore processing period will be approximately 3,850 tonnes or 8.48 Mlbs of UOC as $UO_4.2H_2O$.
Tailings management	In-pit disposal to an engineered tailings storage facility.
Quarry	A quarry supplying approximately 500,000 tonnes of crushed rock material would be located about 8 km north of the processing plant.
Waste management facility	A waste management facility would be established on the mining lease, approximately 4 km south east of the metallurgical plant.
Water supply	The development's primary water supply would be sourced from the initial dewatering of the open pit mine and then, as dewatering rates decreased, water would be piped from a network of groundwater wells. Obtaining water from this source would require the construction of pipeline and associated pumping infrastructure.
Annualised (over the 15 year process plant life) average water demand (ML/d)	8.7 ML/d (3.2 GL/a)
Maximum electricity demand (MW)	20
Average electricity consumption (MWh/a)	150,000
Maximum diesel demand (KL/a)	80,000 (excluding product transport diesel)
Accommodation village	A village would be constructed about 20 km east of the processing plant, with sufficient accommodation for up to 1,200 people, which would be downsized after construction.
Peak construction workforce	1,200
Average construction workforce	500
Peak operational workforce	300
Average operational workforce	225

6.1.1 Project Timeline

This section provides an indication of proposed timing. The commencement of the development schedule will ultimately depend on the timing and nature of government approvals and the final investment decision by the Cameco Board.

The Yeelirrie Uranium Project has a construction, operation, decommissioning and closure timeline of 22 years. If the Project were approved, Cameco would complete planning activities, including a Definitive Feasibility Study (DFS) and detailed project design, before the proposed timeline would commence.

Cameco plans to mine the deposit through a number of staged phases of dewatering and mining, which are summarised below.

The Project would start with the dewatering of Stage 1 of the open pit. Mining Block 1 would be pre-stripped down to the ore body and the material stockpiled. Ore would then be mined down to the water table then stockpiled. Once the water table has been reached, dewatering trenches would be established and the mining block would be dewatered by pumping water from the trenches. This would continue for about 12 months before the commencement of mining of ore from below the water table. During this time, site infrastructure construction would also commence. Once Stage 1 of the open pit is safely dewatered, mining would continue. Mining and stockpiling would continue for a further 12 months to establish a cell within the open pit void suitable to receive and store tailings. During that period the metallurgical plant would be constructed and commissioned.

Initial mining would target areas of higher-grade ore. Mining of the open pit is expected to take 15 years to exhaust the ore. The metallurgical plant would continue to treat ore from stockpiles for another two years. The open pit would be progressively rehabilitated as the pit void is filled with tailings from the metallurgical plant and capped with stockpiled mined materials. At the completion of ore processing, the plant would be disassembled and disposed of into the pit void before being covered and capped with mined material. Backfilling, mine closure and rehabilitation are expected to take a further four years.

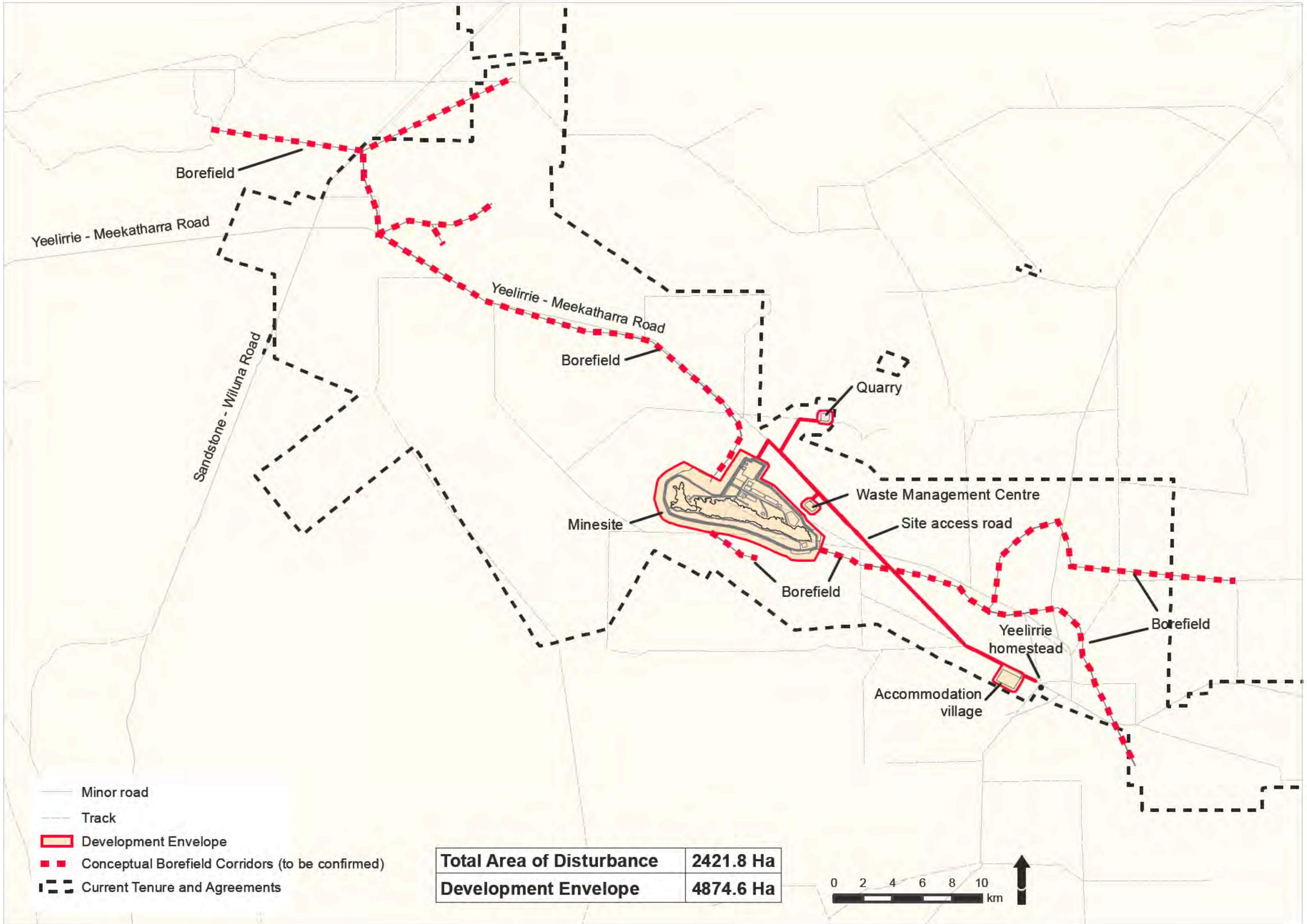
Figure 6-4 shows the Project timeline and Figures 6-5 and 6-6 show a conceptual layout of the Project at approximately Year 2 and Year 10.

6.2 The Resource

The Yeelirrie uranium deposit is the largest known uranium deposit in Western Australia. It occurs in calcrete hosted material in the central drainage channel of a wide, flat and long valley which is flanked by granitic breakaways of low topographic relief with elevations between 490 m AHD and 610 m AHD (see Figure 6-7).

The mineralisation extends from the surface to an approximate depth of 10 m, with the main concentration centred about 4 m below the surface, with a thickness ranging from 1 to 7 m (see Figure 6-8). The surface extent of the identified resource is 9 km long and an average of 1 km wide, with a maximum width of about 1.5 km.

The resource is sufficient to provide approximately 15 years of ore to the metallurgical processing plant at a nominal processing rate of 2.4 Mtpa.



Total Area of Disturbance	2421.8 Ha
Development Envelope	4874.6 Ha

Figure 6-2: Proposed Yeelirrie minesite elements regional setting

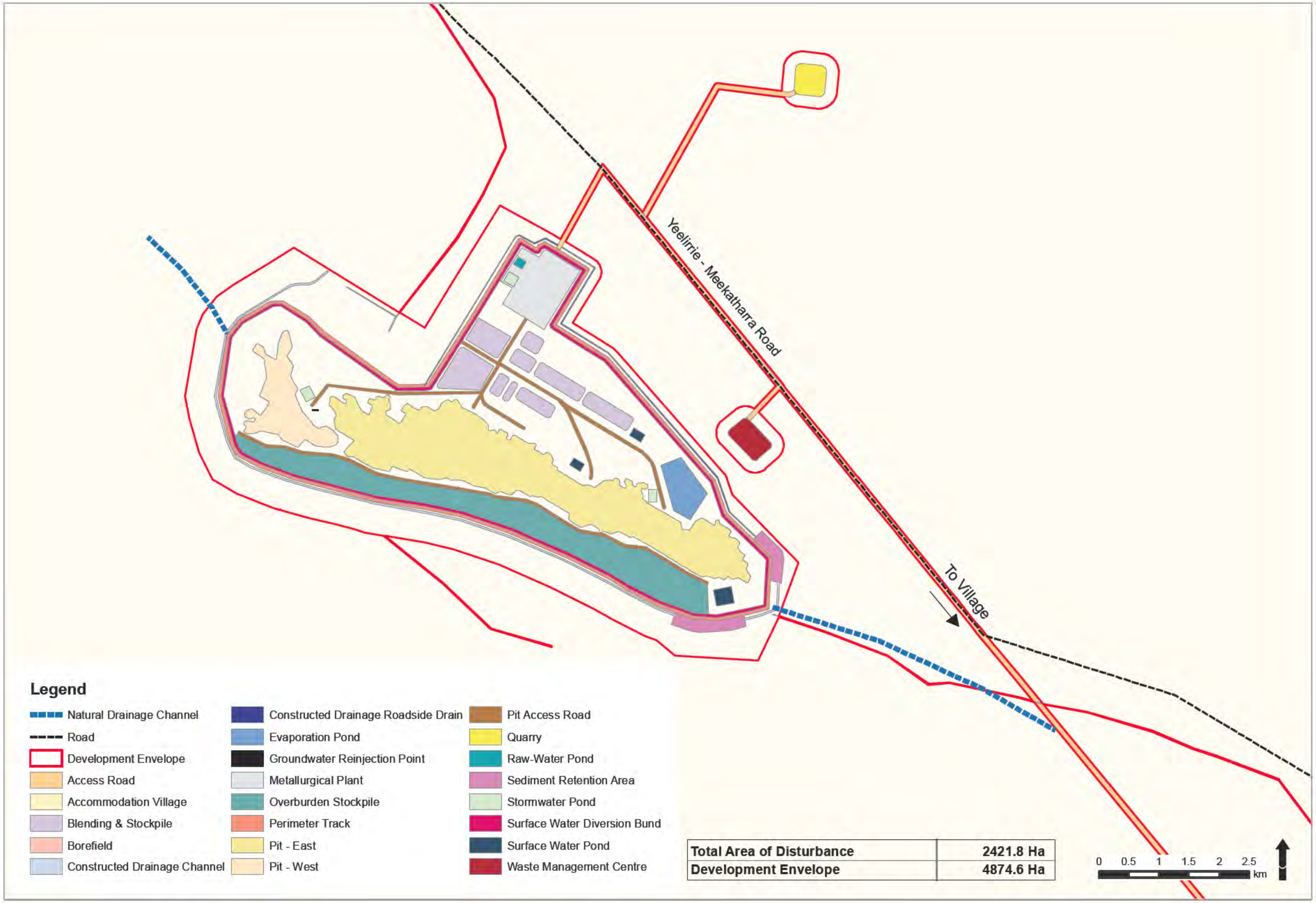


Figure 6-3: Proposed Yeelirrie minesite elements

YEAR	DEWATERING SCHEDULE		MINING SCHEDULE	MILLING SCHEDULE	TAILINGS DEPOSITION SCHEDULE	COVER
1		**Dewatering Block 1** Strip Dewatering Block 1 to above the water table, construct trenches, start dewatering				
2	Construction camp and plant	**Dewatering Block 2** Strip Dewatering Block 2 to above the water table, construct trenches, start dewatering	**Mine Block 1** MB1 dewatered and mined			
3		**Dewatering Block 3** Covers Mining Block 3 and part of MB4 Strip Dewatering Block 3 to above the water table, construct trenches, start dewatering	**Mine Block 2** MB2 dewatered and mined			
4		**Dewatering Block 4** Covers part of Mining Block 4, MB5 and MB6 and part of MB7 Strip Dewatering Block 4 to above the water table, construct trenches, start dewatering	**Mine Block 3** MB3 dewatered and mined	**Start of milling**	**Pond 1** Five (5) cells used on a rotating schedule	
5			**Mine Block 4** MB4 dewatered and mined			
6			**Mine Block 5** MB5 dewatered and mined			
7		**Dewatering Block 5** Covers part of Mining Block 7, MB8 and part of MB9 Strip Dewatering Block 5 to above the water table, construct trenches, start dewatering	**Mine Block 6** MB6 dewatered and mined			
8			**Mine Block 7** MB7 dewatered and mined			
9		**Dewatering Block 6** Covers part of Mining Block 9, MB10 and part of MB11 Strip Dewatering Block 6 to above the water table, construct trenches, start dewatering	**Mine Block 8** MB8 dewatered and mined			
10			**Mine Block 9** MB9 dewatered and mined			
11		**Dewatering Block 7** Covers part of Mining Block 11, and MB12 and MB13 Strip Dewatering Block 7 to above the water table, construct trenches, start dewatering	**Mine Block 10** MB10 dewatered and mined		**Pond 2** Five (5) cells used on a rotating schedule	Placing of cover, starting with the cells of Pond 1
12			**Mine Block 11** MB11 dewatered and mined			
13			**Mine Block 12** MB12 dewatered and mined			
14		**Dewatering Block 8** Covers part of Mining Block 14 and MB15 Strip Dewatering Block 8 to above the water table, construct trenches, start dewatering	**Mine Block 13** MB13 dewatered and mined			
15			**Mine Block 14&15** MB14&15 dewatered and mined			
16	End of mining		**Mine Block 14&15** MB14&15 dewatered and mined			
17						
18	End of milling			**End of milling**		
19					**Decommissioning:** Placing of wastes in mining blocks 8 - 15	
20						
21						
22	Cover completed					

Figure 6-4: Indicative project timeline

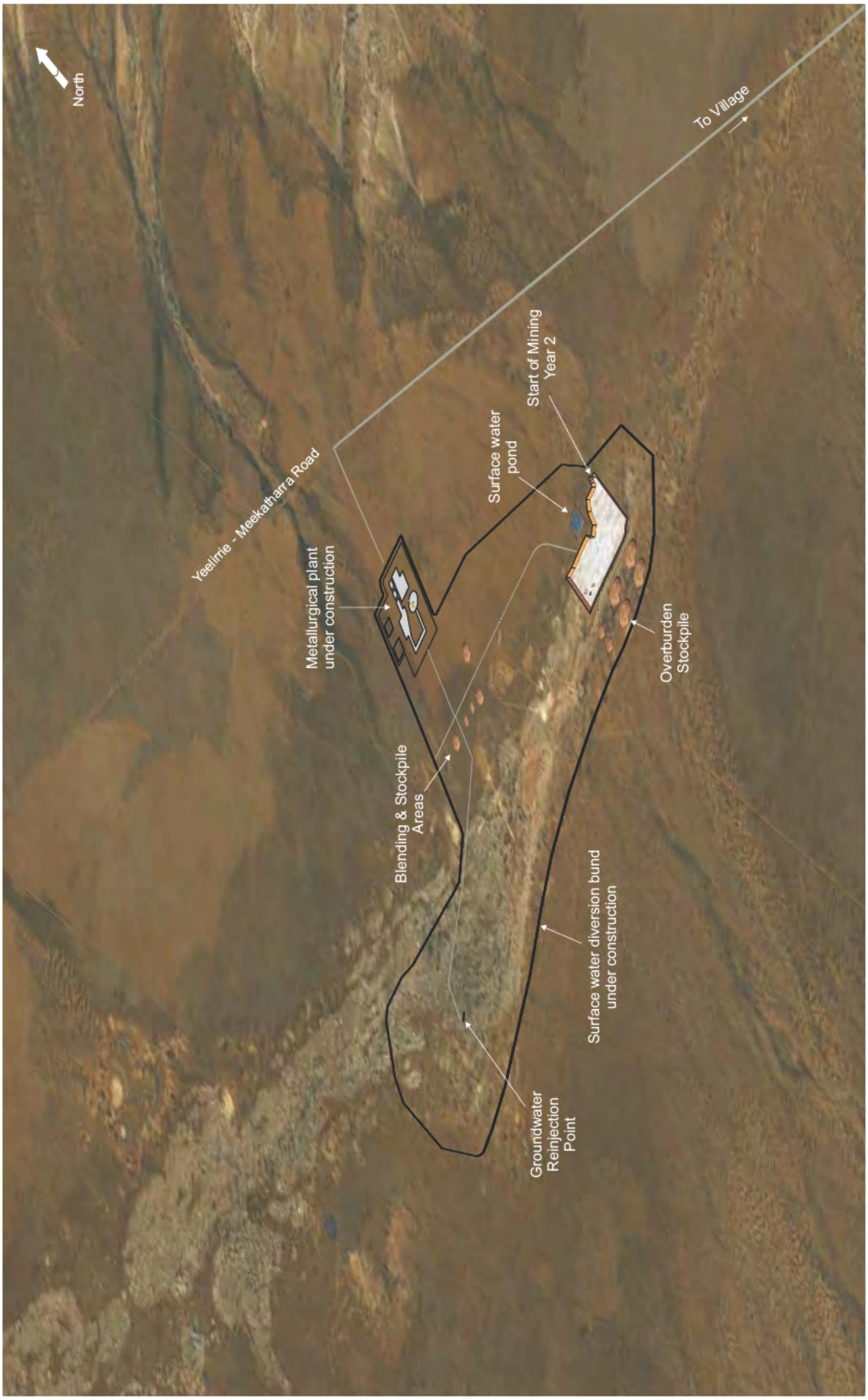


Figure 6-5: Mine site development at year 2

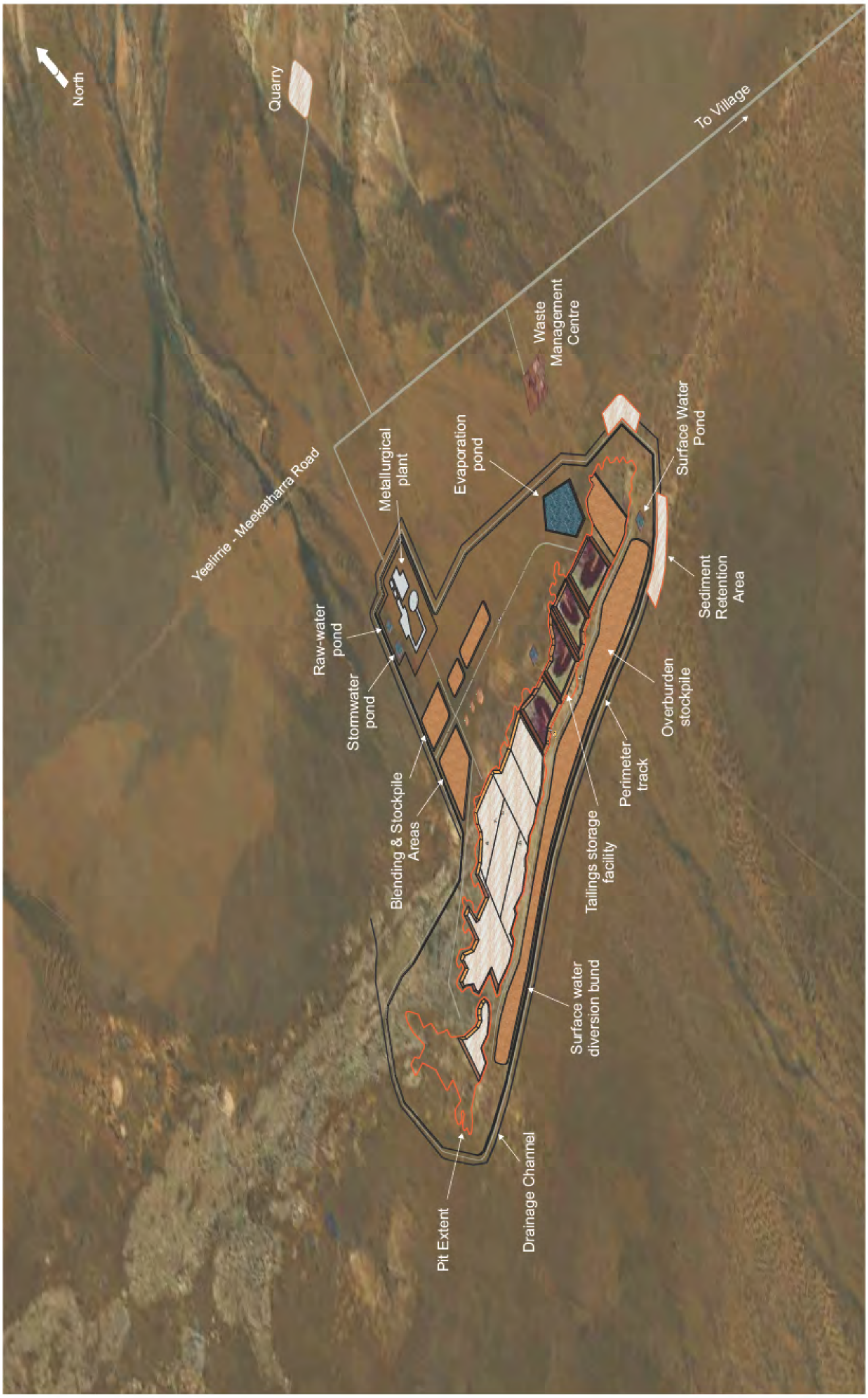


Figure 6-6: Mine site development at year 10

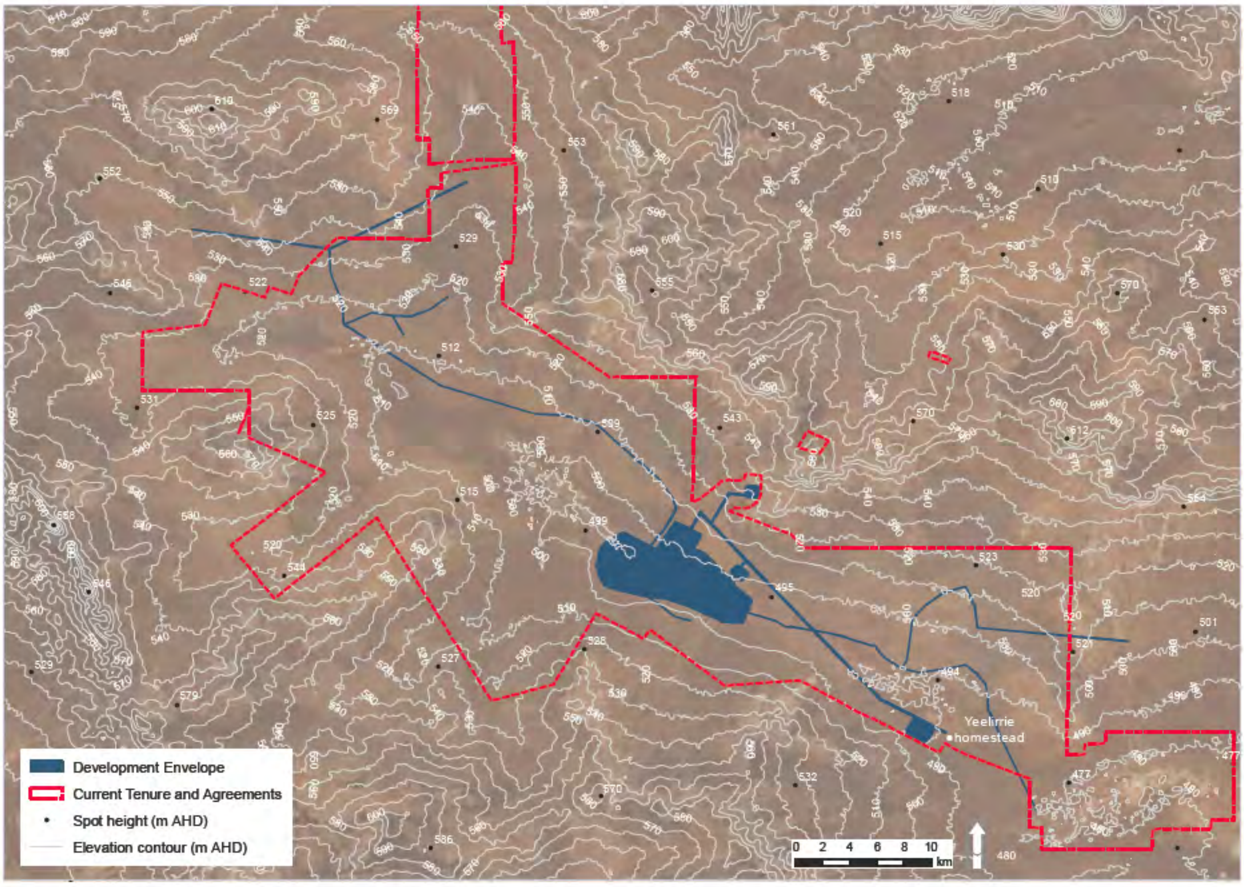


Figure 6-7: Yeelirrie orebody in a local context

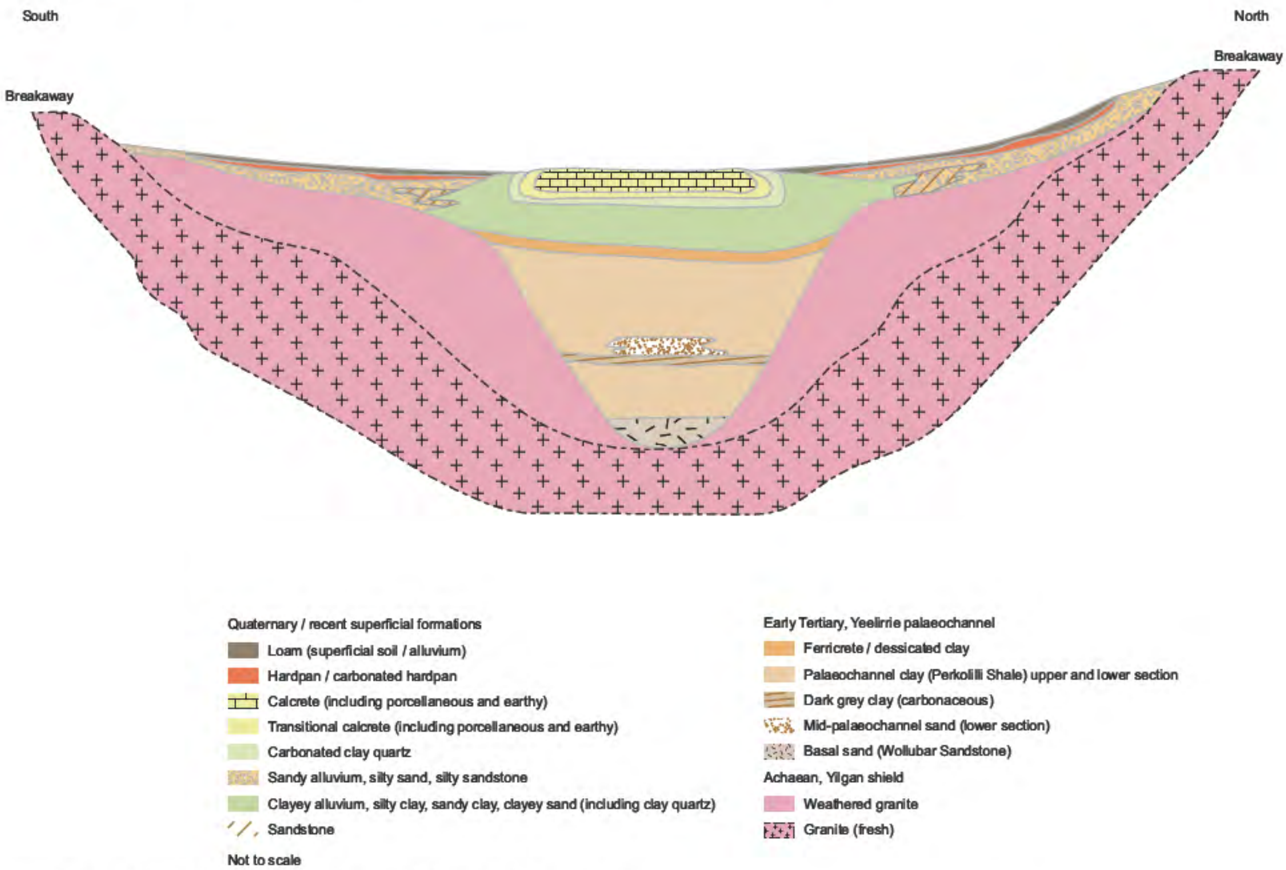


Figure 6-8: Conceptual cross-section of the Yeelirrie orebody

6.2.1 Lithology and Mineralogy

Lithological and mineralogical studies conducted in the Yeelirrie valley (WMC 1975, and studies conducted for this PER) show that there are four principal lithological units at the proposed development site:

1. Overburden: consisting of a combination of sandy loam, siliceous and ferruginous cemented hard-pan and carbonated loam, which is probably a weathered calcrete.

2. Calcrete: a calcite and/or dolomite replacement of the clay-quartz, although relics of partially replaced clay-quartz are common throughout the calcrete. The upper portion of the calcrete comprises friable 'earthy calcrete', a continuous layer grading upwards into the overlying soils. Nodular porcellanous calcrete represents the lower layer of the calcrete and consists of up to 70% carbonate (McKay and Miezitis 2001).

3. Clay-quartz: a kaolinitic clay-quartz alluvial fill material. Bands of quartz grit and arkose are randomly scattered through the clay-quartz as horizontal beds. Upper clays are predominantly montmerillonite, with kaolinite becoming more abundant at depth.

4. Archaean granitic basement complex: generally seen in drill holes at depths of around 30 m below the surface near the ore body.

Uranium mineralisation occurs as carnotite, a potassium uranyl vanadate ($K_2(UO_2)_2(VO_4)_2.3H_20$), which is found in the overburden and clay quartz unit. However, mineralisation is richest within the calcrete and transitional calcrete material. It typically fills fractures and voids, occurring as a coating on surfaces and as a very fine-grained dispersion through the mineralised units. Although found throughout the 'earthy calcrete' and the nodular porcellanous calcrete, approximately 90% of the ore is in the clay-rich carbonated rocks of the transition zone at the base of the calcrete unit.

Uranium mineralisation in the (mainly) calcrete is related to groundwater levels and chemistry. Key processes involved in the precipitation of uranium mineralisation can be summarised as:

- oxidation of mildly reducing uranium, potassium and vanadium-bearing waters, either by direct contact with air, or by mixing with more oxidised surface water; and
- evaporation concentration of water during drier climate cycles or along the flow path towards salt lakes.

The majority of the uranium mineralisation occurs beneath the water table due to the leaching of uranium by carbon dioxide in rainfall infiltrating from the surface.

6.2.2 Geochemistry

The geological database, derived from drill cores from the deposit, provides the following general observations about the distribution and variability of key elements within the different lithological units:

- Many metals (e.g. vanadium, copper, nickel and lead) are present at low concentrations in all units, with median concentrations below crustal averages. Concentrations are lowest in calcrete, and highest in the deeper clay-quartz lithologies. There appears to be some correlation between these metals and aluminium and silicon content, suggesting clays may be important as sorption sites (e.g. ion exchange).
- Median arsenic and molybdenum contents are generally less than 20 ppm and 5 ppm, respectively. Crustal average values for arsenic and molybdenum are 1.5 ppm. Highest median contents are found in the deeper clay-quartz lithologies.

6.3 Mining

Mining of the pit would use standard surface mining equipment, such as excavators and front-end loaders in conjunction with haul trucks and scrapers, to remove the ore and overburden. Due to the typically high friability of the ore and overburden material, minimal drilling and blasting would be required, although this technique may be needed in areas of the open pit if hard rock was encountered. For the purpose of the impact assessment presented in this document, a realistic worst-case scenario has been adopted, whereby 16 blasts are undertaken each year, using a total of about 70 tonnes of explosives and emulsion product.

Given the shallow nature and relatively small footprint of the area being mined at any time, the total mining fleet would consist of 3 to 6 excavators, or similar surface mining equipment, feeding about 12 haul trucks. Standard surface mining support fleet would include water trucks, graders, drill rigs and bulldozers. The major features of the proposed open pit are summarised in Table 6-3. From the open pit, ore will be trucked to various stockpile areas based on grade and other geochemical characteristics.

Table 6-3: Features of the open pit development

Features	Proposed Development
Mining method	Open pit
Nominal mine life (years)	Up to 15
Maximum mining rate (Mtpa)	Up to 14
Average mining rate (Mtpa)	8
Length of ore body (km)	9
Average/maximum width of the ore body (km)	1 to 1.5
Average pit depth (m)	10

6.3.1 Construction Phase

The construction activities associated with the development of the open pit are discussed in the following sections.

6.3.1.1 Site Preparation

Site preparation activities would be conducted before, and concurrently with, the progressive mining activities across the Project Area. Areas to be disturbed, and 'no-go areas' to be retained (e.g. areas that support significant flora species that would be retained within the perimeter bund), would be outlined by survey and with survey pegs and flagging tape before ground disturbance commenced. Vegetation would be cleared and topsoil stripped and stockpiled for reuse as the mine was progressively developed. The topsoil would be placed in specific stockpiles and managed to maintain the ecological viability of the seed-stock contained within it.

Internal roads would be established for hauling ore and waste, linking the open pit to the metallurgical plant and stockpiles of ore and mined material. Where possible, haul roads would be established within the ultimate footprint of the open pit to reduce the extent of vegetation disturbance. Service roads for light vehicles would be constructed to a smaller footprint to minimise the extent of vegetation disturbance.

6.3.1.2 Quarry

A quarry would be required to provide materials for the construction of internal roads, laydown and sealed hardstand areas and other civil works. It is expected that about 500,000 t of material would be extracted from the quarry, requiring a site of around 10 ha to be excavated to an average depth of 5 m. The quarried material would be crushed on-site to produce aggregate.

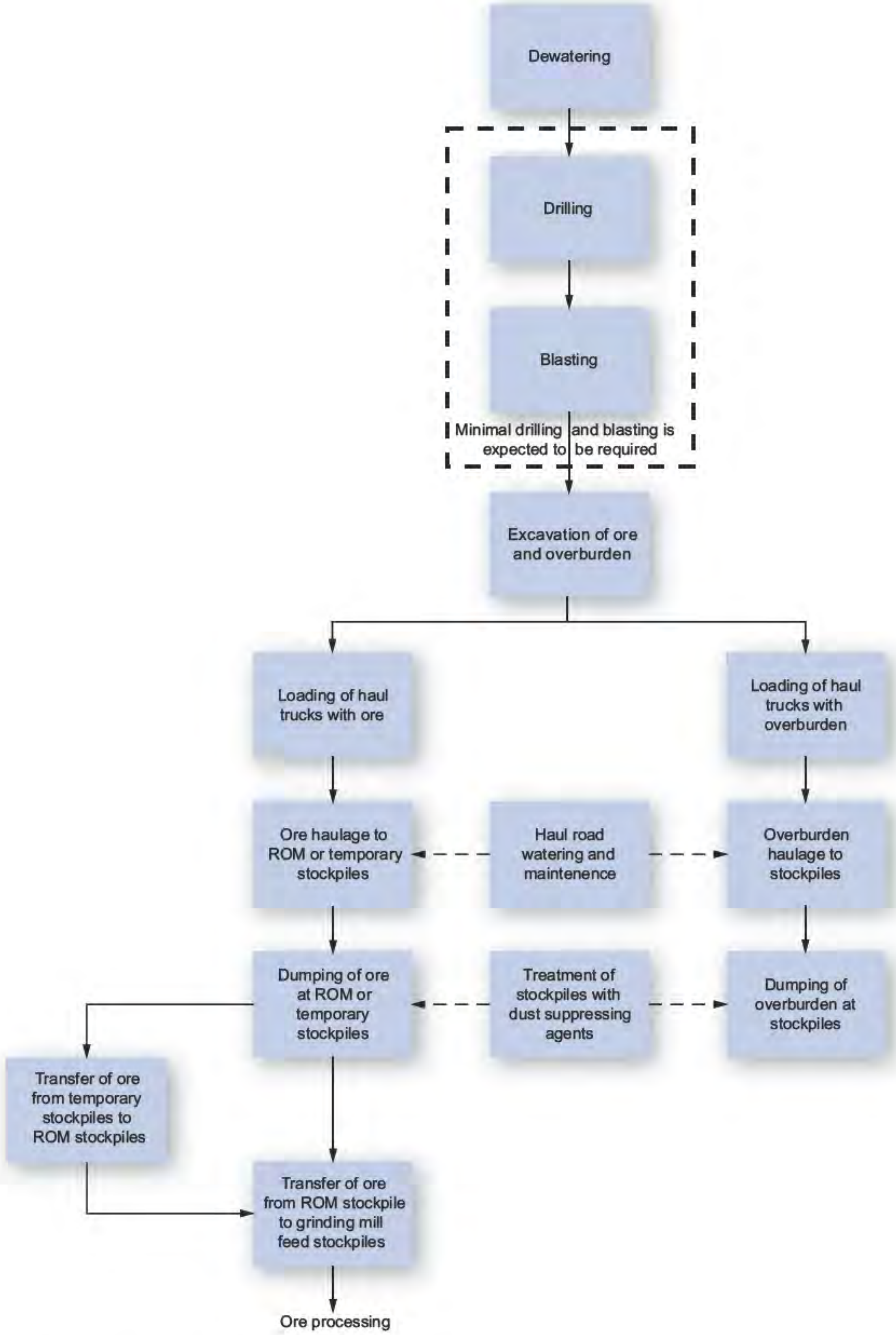


Figure 6-9: Proposed mining process flow diagram

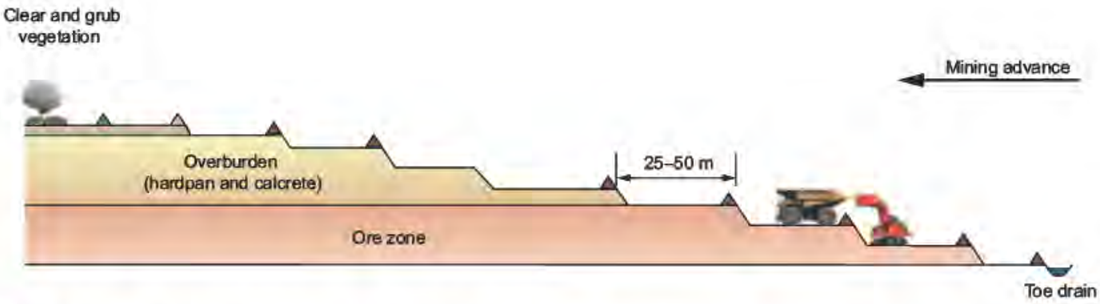


Figure 6-10: Conceptual mining operation cross-section

The quarry would primarily operate during the construction phase of the proposed Yeelirrie development, and then periodically as required for site maintenance purposes. The quarry would be located within the existing quarry lease area and would be sited to avoid identified surface water drainage channels and sites of Aboriginal cultural heritage significance.

6.3.1.3 Pit Dewatering

Pit dewatering would commence before and continue during the ongoing mining operation, details of which are provided in Section 6.6.1.

6.3.2 Operational Phase

6.3.2.1 Mining Operation

The operation of the proposed open pit would use conventional bulk mining techniques, as shown on a flow chart in Figure 6-9 and illustrated conceptually in Figure 6-10.

The open pit would be mined via a series of horizontal benches, called flitches, until the bottom of the ore body was reached. Each flitch would be divided into zones based on grade and geological classifications, and the mined material would be delivered to stockpiles or final landform destinations. Ore-grade material mined from the open pit would either be sent directly to the metallurgical plant run-of-mine (ROM) stockpile, or be stockpiled according to ore grade and geological ranges at locations accessible for subsequent handling. This approach allows for the blending of materials to ensure a consistent ore grade and geological classification feed to the metallurgical plant, which maximises processing efficiency. Stockpile foundations would be compacted before the placement of mined materials and water run-off traps would be constructed to assist in stormwater management, allowing captured water to be reused within the metallurgical plant or for dust suppression.

If dewatering using trenches, as described in Section 6.1.1, is not successful in lowering the water table below the mining level and it was necessary to excavate ore from below the water table, this ore would be placed on higher benches to drain inside the pit before being stockpiled outside the pit perimeter. This would be a precautionary measure to minimise the potential for seepage of contaminants from stockpiles to the groundwater.

Pre-stripping and mining would commence about two years before the commissioning (i.e. testing) of the metallurgical plant. The proposed mining sequence would preferentially target the highest-grade ore within the ore body, as shown conceptually as Block #1 in Figure 6-11, and would then progress east and west as Block #1 was mined out. Once mining had begun within a block required for tailings storage, it would continue to be mined to its full depth (nominally 8 to 10 m). The Block #1 void would be used to dispose of the initial tailings generated from the metallurgical plant. The pit would advance from east to west, at a rate at least sufficient to allow for the disposal of tailings throughout the life-of-mine. Section 6.5 describes the construction, operation and closure of the

Figure 6-11: Indicative plan for excavation

proposed tailings storage facility. Ore material from the open pit operation would be extracted to balance the feed requirements of the metallurgical plant. Non-economic material would be extracted as required to uncover the economic ore and to meet the requirement for material to construct and extend the surface water diversion bund infrastructure.

6.3.2.2 Stockpile Rehandling Operations

Each stockpile of ore would be no higher than 20 m, with the stockpile locations optimised within the Project footprint. Stockpiles would be managed so that stocks of high-grade material would be stockpiled for no more than 36 months and medium-grade materials for no more than 12 years. Low-grade and non-economic materials may be stockpiled for the life of the operation, depending on the progress of rehabilitation activities and the economics associated with the processing of the lower-grade ore.

A dust suppressing material such as hydromulch may be applied to stockpiles to reduce the potential for wind erosion and reduce the demand for dust suppression water.

Stockpiled ores would be loaded by excavators or loaders into haul trucks and relocated to a blended ore stockpile near the grinding mills, from which it would be fed via front-end loader through a sizing grate and onto a feed conveyor for delivery to the grinding mill. The blended ore stockpile would be used to ensure the material feed to the metallurgical plant was of uniform grade, enabling the plant to operate more consistently and with greater recovery of uranium.

6.4 Ore Processing

A metallurgical plant would be established to treat ore extracted from the open pit at a nominal rate of 2.4 Mtpa and producing up to 7,500 tpa of UOC, and over the 15 year ore processing period averaging approximately 3,850 tonnes of UOC, depending on the uranium grade of the ore.

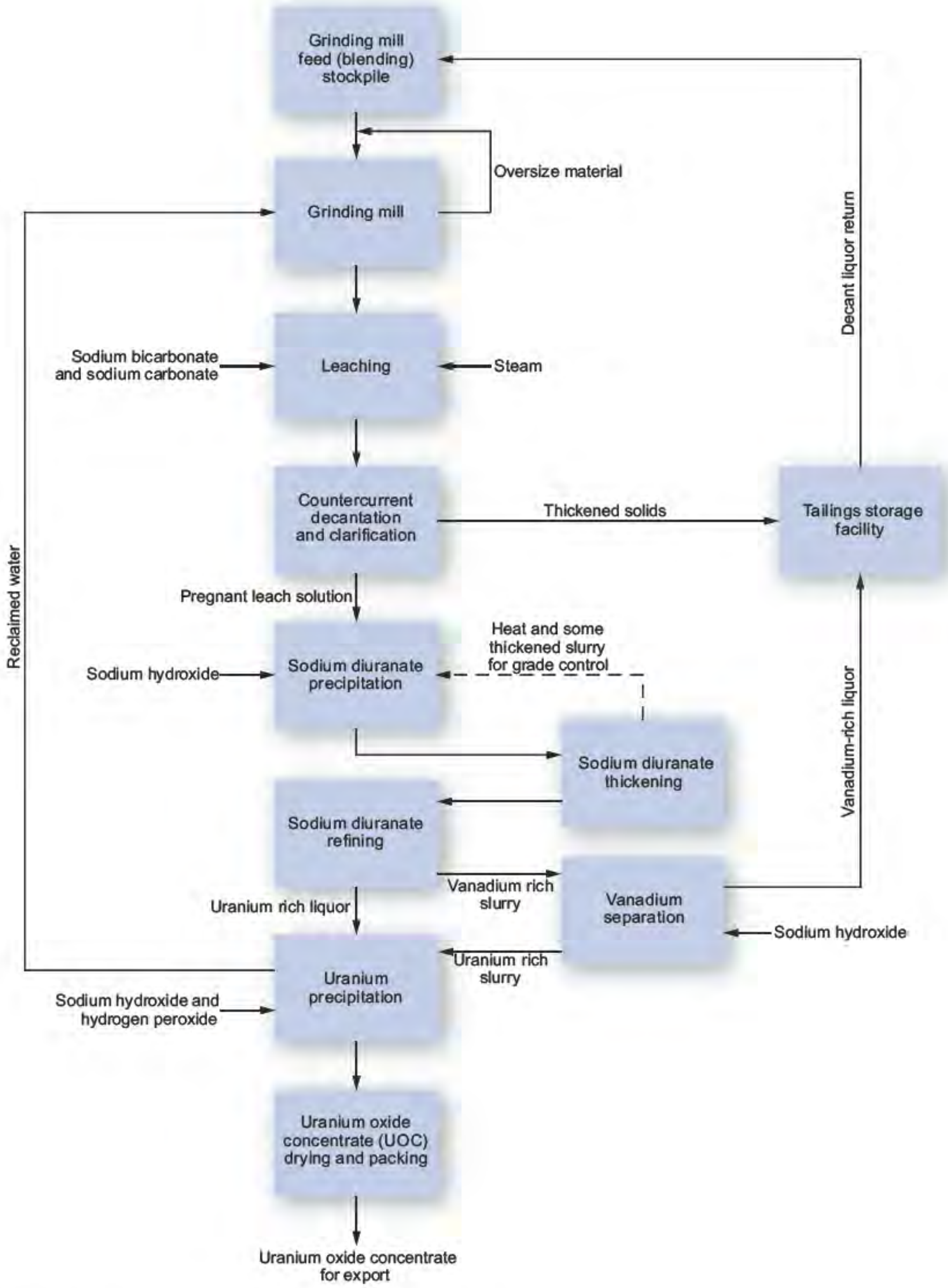


Figure 6-12: Proposed metallurgical process flow diagram

Uranium would be extracted from the ore in a series of agitated and heated alkali leaching tanks. To optimise uranium extraction, the feed material from the grinding mill feed (or blending) stockpiles would be ground to reduce the particle size before leaching. The leach residue would be separated from the uranium solution (termed pregnant leach solution, PLS) and washed in a counter-current decantation (CCD) circuit. Uranium would be precipitated from the PLS as an impure sodium diuranate (SDU), and subsequently dissolved and purified before being precipitated a second time as uranium peroxide ($UO_4.2H_2O$). This would then be dewatered, dried and packed as UOC.

A summary of the major features of the proposed metallurgical plant is provided in Table 6-4.

Table 6-4: Features of the metallurgical plant

Features	Proposed Development
Nominal metallurgical plant life (years)	15
Uranium oxide concentrate production (tpa)	Up to 7,500
Summary of uranium extraction process	Alkali leach
Summary of uranium purification process	Direct precipitation

6.4.1 Construction Phase

The completion of construction of the metallurgical plant would be timed to coincide with the completion of construction of the first tailings storage facility cell in mining Block #1.

Construction of the metallurgical plant would begin with ground preparation for foundations. Where feasible, suitable non-mineralised material (i.e. overburden) from the initial mining activities would be used for foundations. This would be supplemented, if necessary, with material extracted from the proposed quarry. Vegetation would be cleared and topsoil removed and stockpiled for reuse in progressive rehabilitation or landscaping. Graders, front-end loaders and bulldozers would be used for site preparation, levelling and grading. The selection of appropriate foundations for the metallurgical plant would not be finalised until the detailed design stage but, normally, concrete foundations would be installed over a rock or compacted soil base. The fabrication and erection of buildings would follow, including the installation of pre-assembled modules that had been delivered to site, in addition to the mechanical, piping, electrical and instrumentation components of the plant. Containment bunding would be established around all process material vessels and reagent storage areas in accordance with relevant legislative requirements.

6.4.2 Operational Phase

The proposed metallurgical plant would operate continuously (24 hours a day, 7 days a week) for approximately 15 years. The metallurgical process is illustrated in Figure 6-12, and detailed in the following sections.

6.4.2.1 Ore Storage and Milling

Run-of-mine (ROM) ore would be delivered to a number of blending stockpiles with a combined storage equivalent of up to ten days of metallurgical plant throughput. Ore would be loaded by a front-end loader into an ore bin fitted with a sizing grate, from where it would be fed directly to the milling circuit via a feeder conveyor to the mill. The design may include a system to mix the ore with water, allowing finer materials to be pumped directly to the mill as a slurry. Oversized material that was too large to pass through the sizing grate would be allowed to accumulate and would be crushed on a campaign basis using mobile crushing equipment or a rock breaker. Alternatively, a mineral sizer may be used as a primary crusher to crush oversize material on a continuous basis, negating the need for campaign crushing of the oversize material.

A single-stage Semi Autogenous Grinding (SAG) mill, or a SAG mill and Ball mill configuration, would be used to grind the ore to a fine particle size. The mill discharge slurry would be classified through screens or cyclones, with the oversized material being directed back to the grinding mill. Water reclaimed from the tailings storage facility (TSF) and other recycled process streams would be added to the resultant fine material to create a slurry of around 30 to 55% solids density.

6.4.2.2 Leaching

Slurry from the grinding mill would be mixed with sodium carbonate and sodium bicarbonate to facilitate uranium extraction during the leaching stage. The slurry would be preheated via a series of heat exchangers that would reclaim the heat from the discharge slurry generated in the hot leach stage, minimising the requirement for additional raw steam originating from the boilers.

Leaching would be done at elevated temperatures in a series of six agitated tanks. Steam would be used to increase the temperature of the pre-heated slurry to around 95°C, at which temperature the uranium within the ore would be dissolved into solution. The slurry discharge from the leach tanks would pass through the heat exchangers before the counter-current decantation (CCD) stage.

6.4.2.3 Counter-current Decantation and Clarification

A number of thickeners would be operated in series using a solution of water and carbonated barren solution, with the addition of flocculant to facilitate the separation of the uranium-bearing PLS from the solid material. The thickened solids would be pumped to a residue tank before disposal in the TSF, and the PLS would progress to a clarifier, where additional flocculent and coagulant would be added to extract the last of the solid material from the PLS.

6.4.2.4 Sodium Diuranate Precipitation

Clarified PLS would be pre-heated using residual heat from the sodium diuranate (SDU) thickening stage before mixing with some of the thickened SDU slurry to ensure the PLS uranium grade was consistent. The resultant slurry would be mixed with sodium hydroxide to precipitate SDU. The SDU thickener would separate the precipitated solids from the barren solution. The solids would be thickened. The barren solution would be cleaned by a series of sand filters before being recarbonated using exhaust gases from the power station generators and boilers and recycled to the CCD circuit as a wash solution.

6.4.2.5 Sodium Diuranate Refining

The temperature of the thickened SDU slurry would be lowered and its pH lowered through contact with sulphuric acid, to dissolve the uranium and vanadium from the precipitated SDU slurry into a solution. This solution would then be transferred by gravity to a series of tanks, where the temperature would be raised to precipitate out some of the vanadium and leave most of the uranium in solution. The uranium-rich liquor would be directed to the uranium precipitation stage and the vanadium-rich slurry would be filtered, repulped with water and mixed with sodium hydroxide. This causes the remaining uranium within the slurry to dissolve and then precipitate out (as SDU), leaving the vanadium, which also dissolves but does not precipitate, to be filtered and subsequently pumped to the TSF. The filter solids, containing residual uranium, would be returned to the SDU thickener.

6.4.2.6 Uranium Precipitation and Packing

The uranium-rich solution generated from the SDU refining stage would be cooled and mixed with sodium hydroxide and hydrogen peroxide, resulting in the precipitation of uranium peroxide. The resultant slurry would be thickened and the solids separated from the solution.

The solids would be directed to a uranium storage tank before dewatering and packing, and the solution pumped back to the mill water tank would be used as make-up water in the milling circuit.

A centrifuge would be used to dewater the uranium slurry before drying, and an electrically heated indirect oil dryer would reduce the moisture content of the UOC to less than 1%. The dried product would be top-loaded into 205-litre steel drums and sealed with lids and ring- clamps. The drum-filling station would be located in an airlock that maintained negative pressure to prevent uranium entering the work areas. The outside of the drums would be subsequently washed to remove any residual product from the lids and surfaces before labelling and loading into shipping containers for transport and export.

6.5 Tailings Management

The tailings material discharged from the metallurgical plant following extraction of the uranium would be disposed of in previously mined voids within the proposed open pit. Approximately 36 Mt of tailings would be disposed to the open pit during the proposed life of the operation.

The in-pit tailings facility would comprise a series of cells constructed sequentially as the pit was mined. Each cell would be around 200,000 to 300,000 m^2 in area and would take about five to six years to fill to an average height of about 2 m below ground level (1 m at the crest, to 3 m at the decant pond). After filling, the cells would be allowed to consolidate for some time (estimated at around 1 year) before capping with previously mined material and topsoil. Up to 22 cells would be built within the pit void over the life of the operation, with 3 to 5 cells active at any one time. Cameco has undertaken a detailed study for the design and operational aspects of the TSF. The report is presented in Appendix D. A summary of the major features of the proposed tailings storage facility is provided in Table 6-5.

Table 6-5: Indicative features of the proposed tailings storage facility

Features	Proposed Development
Storage method	In-pit storage
Total disposal of tailings (Mt)	36
Average annual tailings production rate (Mtpa)	2.4
Number of TSF cells	Up to 22
Number of TSF cells active at any one time	3 to 5
Area of each TSF cells (m^2)	200,000 to 300,000
Years to fill each TSF cell	5 to 6
Average rate-of-rise of tailings (m/a)	1.2 to 1.4
Average solids concentration (%)	40

6.5.1 Tailings Properties

Indicative properties of the tailings are provided in Table 6-6. The geochemical and radiological properties of the tailings are described in Tables 6-7 to 6-10. As these have been derived from specific ore blends, the final tailings properties may differ.

Table 6-6: Indicative tailings material properties

Parameter	Value
Plasticity (LL[1])	59 to 71%
Plasticity (PL[2])	21 to 30%
Plasticity (PI[3])	38 to 41%
Particle specific gravity (SG)	2.61 to 2.8

Parameter	Value
Initial settled density	50 to 53% (dry density of 0.73 to 0.81 t/m³)
Average dry density	1.2 to 1.4 t/m³
Tailings permeability	1×10^{-9} m/sec
Beach slope	1%
Coefficient of consolidation	1 to16 m²/a
Shear strength (Su/σv)	0.29
Rheology yield shear stress	20 N/m²
Plastic viscosity	0.014 N/m²/sec

[1] Liquid limit.
[2] Plastic limit.
[3] Plasticity index.

Table 6-7: Indicative geochemical constituents of tailings solids

Constituent	Unit	Concentration
Aluminium	wt%	3.8
Antimony	ppm	<0.5
Arsenic	ppm	14
Calcium	wt%	10.6
Carbon	wt%	5.6
Copper	ppm	18
Iron	wt%	1.8
Lead	ppm	130
Magnesium	wt%	4.2
Molybdenum	ppm	27
Potassium	ppm	7,480
Selenium	ppm	0.2
Silicon	wt%	20.9
Sodium	ppm	40
Uranium	ppm	150
Vanadium	ppm	260

Table 6-8: Indicative geochemical constituents of tailings liquor (µg/L unless indicated)

Constituent	Concentration	Constituent	Concentration
pH	9.6 to 9.7	Cadmium	<5
Total alkalinity	75,300 mg $CaCO_3$/L	Cobalt	<5
Aluminium	780	Chromium	350
Calcium	500	Copper	80

Constituent	Concentration	Constituent	Concentration
Iron	450	Mercury	<0.1
Potassium	1,590,000	Lithium	6
Magnesium	350	Manganese	<5
Sodium	44,800,000	Molybdenum	2,400
Silicon	13,000	Nickel	<5
Bromine	43,000	Phosphorus	<100
Chlorine	15,000,000	Lead	<5
Fluoride	<500	Antimony	<5
Nitrate	610,000	Selenium	490
Sulfate	8,800,000	Tin	10
Silver	<5	Strontium	60
Arsenic	7,900	Titanium	<5
Boron	30,000	Uranium	50,000 to 100,000
Barium	10	Vanadium	35,000
Beryllium	<5	Zinc	130
Bismuth	<5	Salinity	>15,000 mg/L TDS

Table 6-9: Indicative radiological constituents of tailings solids

Radionuclide	Activity (Bq/kg)
Uranium-238	940 to1,140
Thorium-230	9,540 to 17,800
Radium-226	9,220 to 14,300
Lead-210	10,200 to 15,700
Polonium-210	n/a
Uranium-235	<40 to 110
Actinium-227	390 to 610
Thorium-232	n/a
Radium-228	47 to 120
Thorium-228	47 to 79
Potassium-40	290 to 470

Table 6-10: Indicative radiological constituents of tailings liquor

Radionuclide	Activity (Bq/L)
Uranium-238	2,190 to 4,840
Thorium-230	<110 to 450
Radium-226	13 to 67
Lead-210	<7 to 37
Polonium-210	n/a
Uranium-235	110 to 220
Actinium-227	<2 to 4.1
Thorium-232	<4
Radionuclide	Activity (Bq/L)
Radium-228	<1
Thorium-228	<0.5 to1.5
Potassium-40	42 to 48

Design Intent

The proposed TSF has been designed to provide safe and economic permanent storage of tailings in a way that minimises potential environmental impacts and risks. The intent of the closure design is to provide an erosion-resistant and non-polluting facility that is stable in the long term. In addition, the proposed TSF design aims to:

- minimise the overall project disturbance footprint;
- maximise the volume of tailings liquor and water than can be reclaimed to the metallurgical plant; and
- minimise the volume of seepage.

To meet the design intent, the proposed facility design has been based on standards and guidelines set by the Australian National Committee on Large Dams (ANCOLD) and the Western Australian DMP. The major design and operational aspects considered during the design of the TSF were:

- TSF location and layout;
- hydrological and hydraulic factors;
- geotechnical, geochemical (geomorphological) and radiological factors;
- availability and properties of construction materials;
- embankment design and stability;
- operational factors; and
- post-closure land use and landform.

6.5.2 TSF Location and Layout

Tailings from the metallurgical plant would be discharged to a series of cells created within the open pit void following mining. Each mining block (see Section 6.3.2 for further information) would be converted for use as TSF cells following the completion of mining within that block. Each block would nominally be divided into one to three TSF cells, depending on the size of the mined block, with a target TSF cell area of about 200,000 to 300,000 m^2. Figure 6-12 shows the proposed metallurgical process flow diagram and Figure 6-13 illustrates the overall TSF cell layout, with an inset showing a conceptual plan and elevation view of an individual TSF cell.

To avoid the need for an initial external (above-ground) TSF cell, mining Block #1 and part of mining Block #2 would be excavated and stockpiled prior to the commencement of processing, to permit in-pit disposal of tailings from the commencement of metallurgical operations.

6.5.3 Hydrological and Hydraulic Factors

6.5.3.1 Surface Water Management

The design of the TSF would include establishing embankments (designed as water-retaining structures constructed with clay material from the bottom of the open pit) to safely separate the active mining areas and the pit wall from the tailings (see Figure 6-13). The drain between the pit wall and the TSF embankment would help direct any groundwater or surface water inflow to the pit dewatering system. At closure, the area between the pit wall and the TSF cell embankment would be backfilled with a higher-permeability material sourced from waste rock to allow it to continue to function as a higher groundwater flow zone post-closure (and thus avoid groundwater flows through the tailings material).

6.5.3.2 Freeboard

The internal TSF cell embankments, and embankments separating the TSF from active mining areas, constructed of either consolidated tailings or compacted clay would be built to a height of around 1 m below ground level. The cell would be filled with tailings so the tailings surface was an average of about 2 m below the original ground level. The beach freeboard, the basin formed by the tailings beach and the storage capacity provided by unfilled tailings cells (as the embankments are constructed to full height), would ensure there was sufficient freeboard and storage capacity at all times to contain a probable maximum precipitation (PMP) event.

6.5.4 Geotechnical, Geochemical and Radiological Factors

6.5.4.1 Tailings Characterisation

Golder Associates (1982) investigated and characterised the proposed Yeelirrie tailings through laboratory testing and studies on an experimental tailings pond and two tanks of tailings at the Kalgoorlie-Boulder Research Station. Further laboratory testing and analysis has been conducted as part of studies undertaken to support the PER.

6.5.4.2 Construction Materials

TSF embankments close to the pit walls would be constructed of clay-based materials originating from the development of the pit. Some materials from the on-site quarry may be required (e.g. for surfacing temporary roadways), subject to meeting the required construction material properties. TSF embankments that are not near the pit walls, including intra-cell embankments, would be constructed of either compacted clay or consolidated tailings.

6.5.4.3 Embankment Design and Stability

The proposed in-pit TSF embankment would be designed to meet or exceed the Australian National Committee on Large Dams (ANCOLD) Factor of Safety requirements (see Table 6-11) using the seismic coefficients stability criteria as listed in Table 6-12. The high pool case assumes that water is ponded against the embankment and the embankments are designed as water-retaining structures.

Table 6-11: Factor of safety for the proposed in-pit TSF cells

Loading condition	Factor of safety
Normal operation	1.5
Steady state seepage (high pool)	1.3
Earthquake	1.1

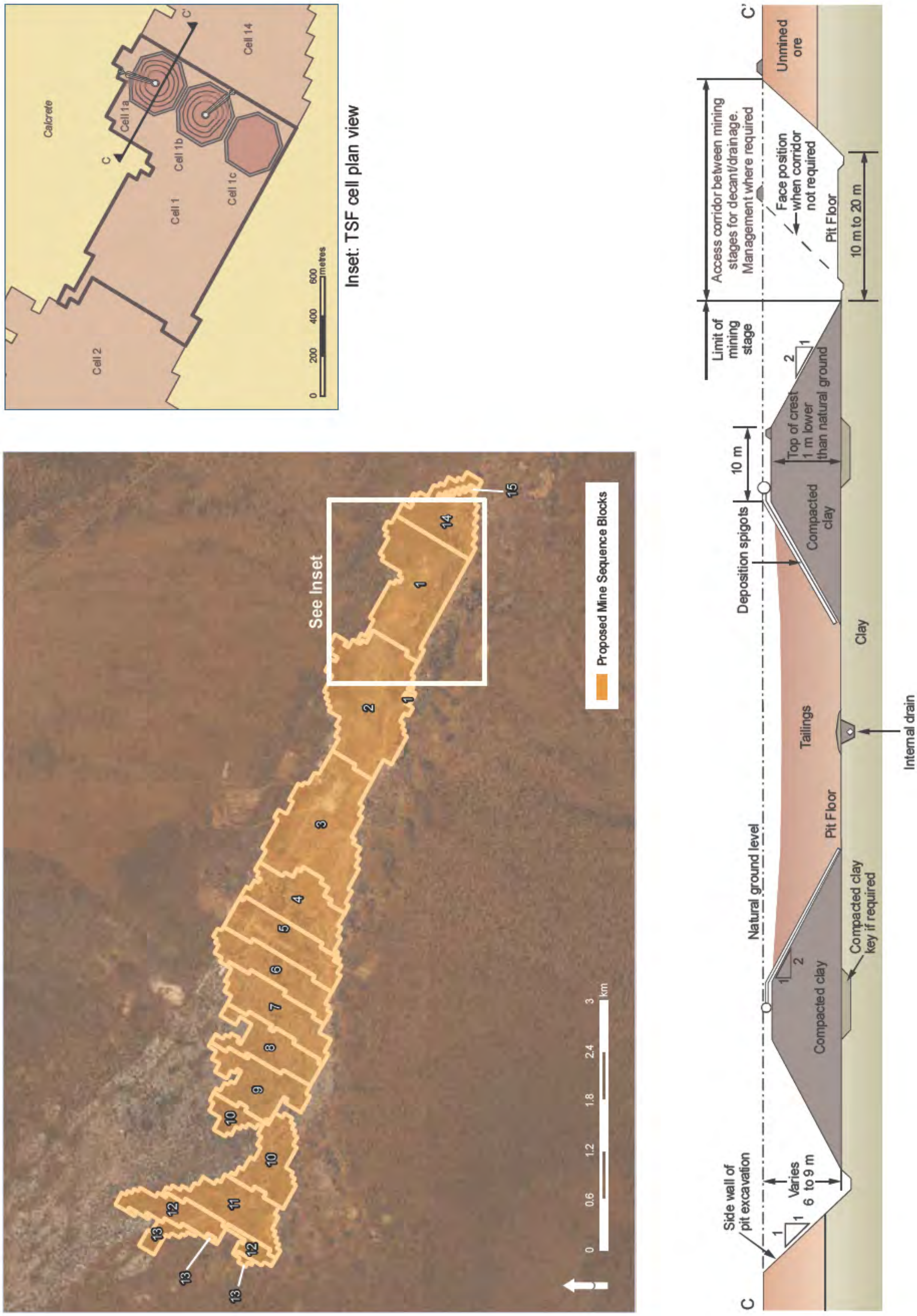


Figure 6-13: Conceptual tailings storage facility cell layout

Table 6-12: Seismic coefficients for the proposed TSF design

Earthquake	Return period	Pseudostatic seismic coefficient
Operating basis earthquake (OBE)	1,000 years	0.036
Design basis earthquake (DBE)	5,000 years	0.06
Maximum credible earthquake (MCE)	>10,000 years	0.13

Operational Factors

6.5.4.4 Tailings Construction and Commissioning

Mining Block #1 and part of mining Block #2 would be mined to allow for the disposal of tailings from the metallurgical plant following commissioning. After the pit was established, an embankment would be constructed along the proposed TSF cell internal perimeter wall to a height about 1 m lower than the natural ground level. Embankments would separate the active TSF cells from the active mining works, the open pit walls and the previously filled TSF cells to assist with water management and ensure TSF cell stability. Before deposition, each TSF cell would be prepared by ensuring there were no defects in the clay floor materials, and the embankment foundations would be constructed down to the low-permeability materials making up the cell floor.

Deposition infrastructure in the form of a tailings pipeline would encircle the TSF cell, and deposition spigots would be installed down into the cell to allow for tailings dispersion near the tailings surface to minimise the potential for erosion of the beach. Approximately three to five TSF cells would be constructed and operated initially, with additional cells constructed as required and as pit voids became available and operating TSF cells were filled to design.

The TSF cells are underlain by up to 60 m of very low-permeability clay, which would reduce the potential for seepage. The TSF start-up plan would minimise the ponding of water on bare ground by capturing and returning free water to the metallurgical plant. The TSF schedule allows for the early start-up of each cell to establish a consolidated tailings layer that would effectively act as a low-permeability liner. The permeability of the pit floor and the TSF cell embankments would be very low, with an estimated permeability of 1×10^{-9} m/sec, similar to the permeability of a geosynthetic liner.

Additionally, the underdrains established to dewater the pit floor before mining may be used as underdrainage within each cell to help collect and return leachate to the metallurgical plant. Initial trials in the early cells may show that the very low permeability of the consolidated and dewatered tailings may reduce seepage to the extent that the underdrains did not collect any leachate, in which case they would not continue to be used in later cells. Seepage from the TSF has been modelled and the results and discussion is presented in Section 9.5.

The average rate-of-rise of the TSF cells to efficiently dry the tailings and minimise seepage would be around 1.2 to 1.4 m a year. Each cell would take between five and six years to fill, to a maximum height of around 2 to 3 m below ground level before the deposition of tailings ceased (see Figure 6-13). The 'bowl' of the cell may be filled using central decant techniques before decommissioning of the cell. Tailings would be allowed to consolidate for around one year before the start of closure and rehabilitation activities (see Section 6.13).

6.5.4.5 Tailings Discharge, Reclaim and Surface Water Management

Layers of tailings would be deposited via a peripheral header, with spigots placed about 25 m apart. Tailings would be deposited around the facility in thin layers of around 100 mm, allowing approximately 30 days drying between each layer. The thin-layer deposition would promote evaporation of tailings liquors and increase the rate of consolidation and strength of the tailings. Excess liquor would pond at the centre of each TSF cell and be reclaimed through a central decant system.

Reclaimed liquor and stormwater would be pumped to the metallurgical plant for reuse as raw water make-up. Maximising the collection of water within each TSF cell for return to the metallurgical plant would reduce the head pressure that may otherwise encourage seepage in the central decant area. During operation, the tailings surface would be kept moist by the thin-layer deposition to minimise radon exhalation.

Very little seepage from the TSF is anticipated because of the proposed tailings drying cycle, which locks the solutes into the tailings matrix. As discussed above, underdrainage would initially be established within each TSF cell as a precautionary measure to help collect and return leachate to the metallurgical plant. The TSF cells would be covered (capped) as soon as possible after filling to prevent rainfall and stormwater infiltration.

6.5.4.6 Evaporation Pond

Under some circumstances there will be excess water in the site water balance. For example, not all of the reclaimed tailings liquor will be able to be reused in processing, and in other scenarios it may be necessary to store storm water captured within the disturbed area. Water from these sources would be stored and evaporated from the proposed Evaporation Pond. Water balance modelling has determined that a pond of approximately 50 hectares and up to 5 m deep would be required to store and evaporate water. The pond is likely to be constructed with multiple cells to provide the opportunity for the removal of sediment and evaporites. In order to maintain the effectiveness of the evaporation dam, the cells will require routine cleaning which would involve removal of sludge and sediment. The removed material will be placed into the TSF.

While there are a number of surface water bodies (salt lakes and claypans that fill and hold water for extended periods after rain) in the north eastern goldfields region, the presence of a large permanent water body is likely to attract some bird and animal life. The design, construction and operation of the facility will be aimed at reducing the attractiveness of the facility to fauna. The internal and external wall slopes will be steep to remove the potential for beaches to form and the facility would be fenced to exclude native and feral fauna. Bird scare devices such as rotating beacons with intermittent beams and noise generating gas guns would also be installed if necessary.

Cameco has modelled the quality of the water being stored in the facility, which will change over time as water of differing quality is added to the dam, to understand the potential impact on birds that might land on and consume the water. These results and a discussion is presented in Section 9.3.5.2.

6.6 Water Demand and Supply

The proposed development would require water of varying quality for different uses during both the construction and operational phases, the most significant of which would be non-potable saline water for use within the processing plant and for dust suppression associated with the mining operation. The construction of infrastructure associated with the proposed development would also require water, specifically for use in compaction activities, concrete manufacture, dust suppression and water-testing of pipelines and water supply infrastructure.

Where possible, saline water would be used to reduce the demand for better-quality water. In general, better-quality water (less than 10,000 mg/L total dissolved solids (TDS)) will be used as feed water for the reverse osmosis (RO) desalination plant (see Section 6.6.3 for details). Average quality water (between about 10,000 to 30,000 mg/L TDS) would be used within the majority of the metallurgical processes. Lower-quality water (greater than about 30,000 mg/L TDS) would be used to suppress dust.

A summary of the water demand and supply source for the construction and operation of the proposed development is presented in Table 6-13. The total annualised average operational raw

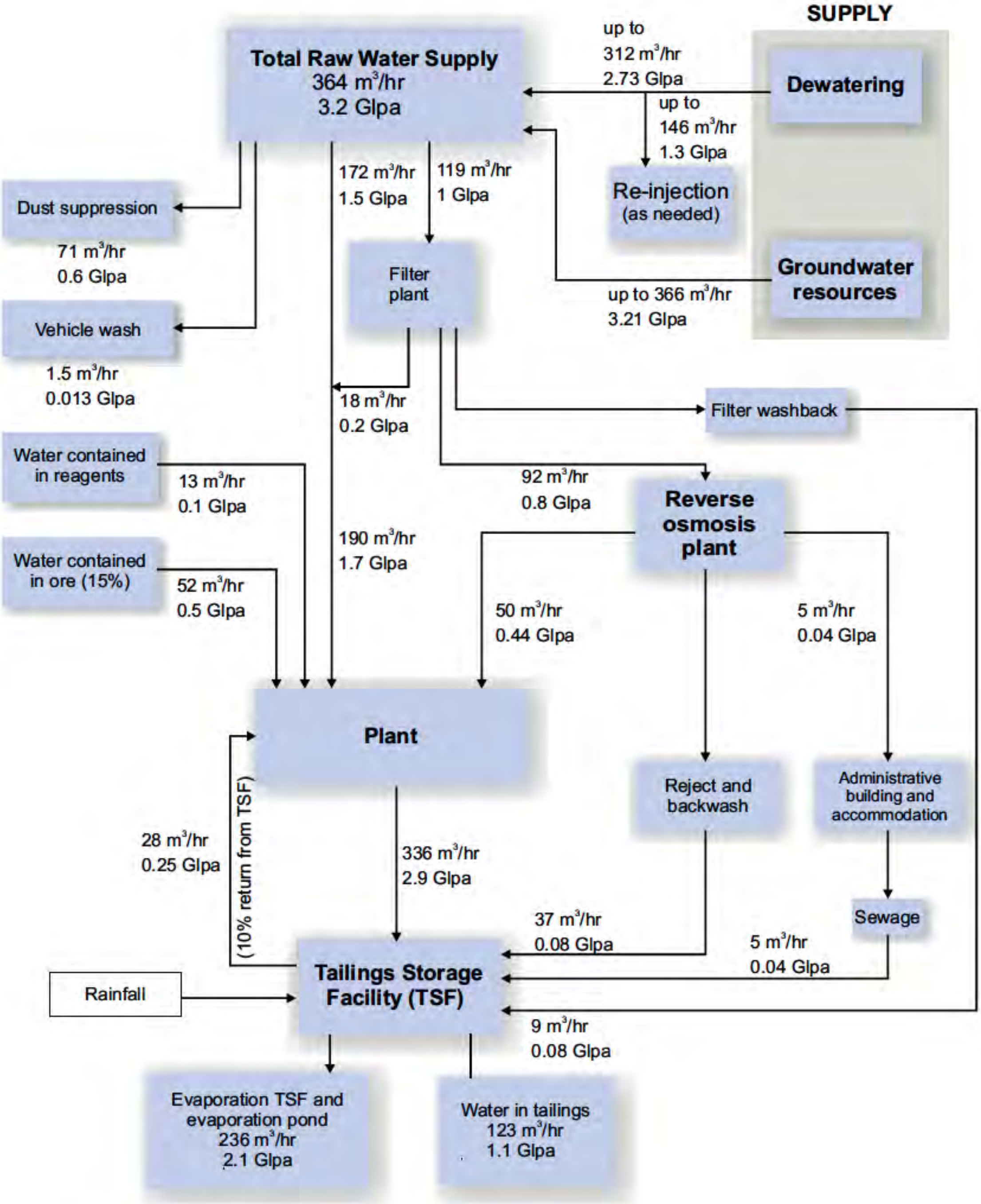


Figure 6-14: Conceptual water balance

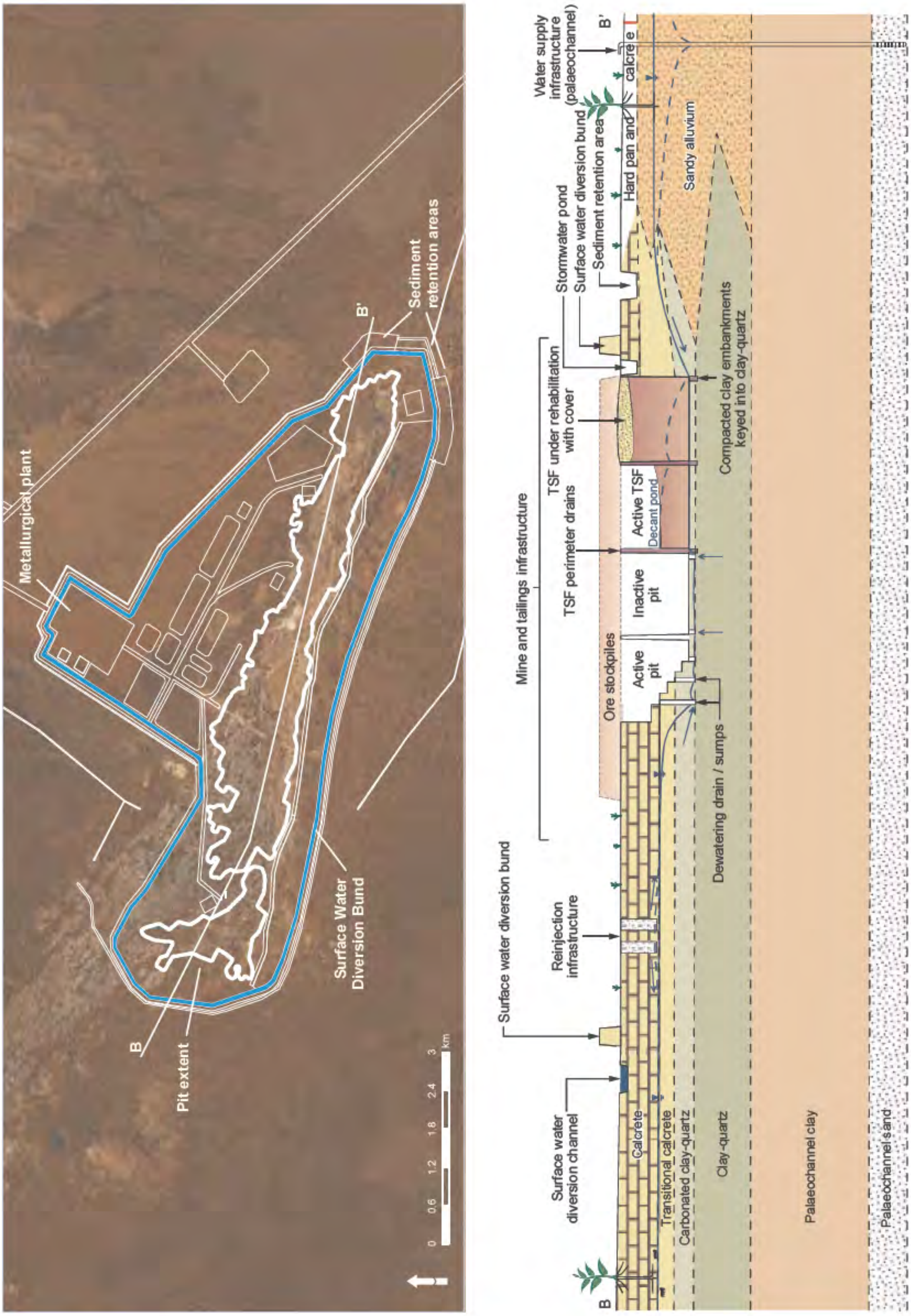


Figure 6-15: Conceptual open pit dewatering cross-section

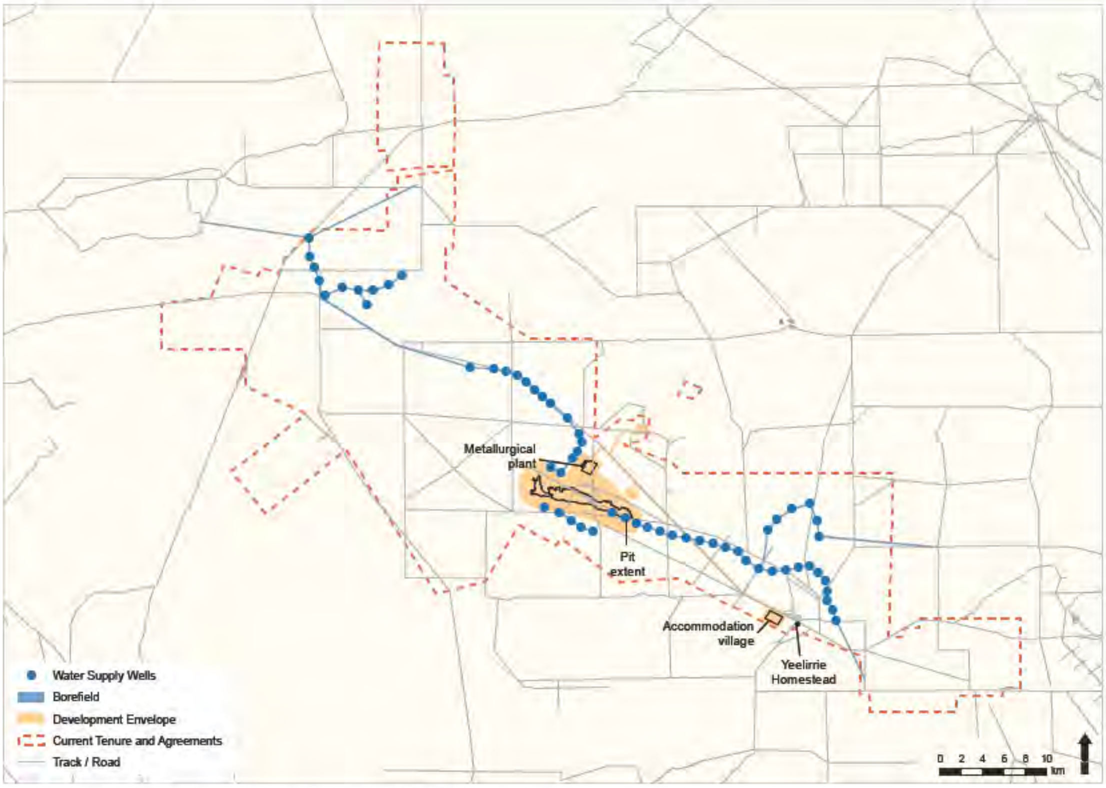


Figure 6-16: Indicative Yeelirrie wellfield infrastructure layout

water demand during the period when mining and processing are both in operation is estimated at around 8.7 ML/d.

Table 6-13: Indicative water demand for the proposed development

Demand Ml/d	Use
4.8	In the metallurgical plant for the treatment of ore
2.2	Reverse Osmosis plant for use on-site as drinking water in the accommodation village and administration facilities and in the boiler for steam production.
1.7	Dust suppression within the open pit mining operations
0.03	Vehicle washdown

A conceptual water balance for the proposed development is illustrated in Figure 6-14.

The following sections outline the proposed water supply infrastructure.

6.6.1 Water supply

6.6.1.1 Pit Dewatering Supply

The proposed open pit would be up to 15 m deep and would intersect the groundwater table, which occurs 3.5 to 5 m below the surface. To facilitate the mining operation, the open pit would be dewatered to control inflows of groundwater and to reduce the amount of water on the active pit floor to provide a safe working environment.

To facilitate dewatering, a system of slots, trenches or wells that intersect the groundwater would be excavated in advance of the active mining areas. The low-quality water collected in the slots or trenches would be directed to a series of sumps, from where it would be pumped to a water storage pond before use within the metallurgical plant, or for dust suppression activities within the open pit and surrounding stockpiles (see Figure 6-15). The initial rates of groundwater extraction from mine dewatering could be up to about 7.5 ML/d in year 4, decreasing over the life of the proposed mining operation to approximately 2 to 3 ML/d from years 5 to 18 as groundwater levels within the mine footprint decrease.

A series of mobile transfer pumps would be established within the open pit to manage rainfall that fell directly into the pit. Once the surface water diversion bund had been established, stormwater that accumulated within the flood protection bund during rainfall events would be directed to water storage infrastructure or the pit for temporary storage. The proposed facility would be managed as far as practicable to segregate and separately manage stormwater falling within the flood protection bund, depending on both its quantity and quality for use on site.

It is expected that pit dewatering would form the primary water supply for the proposed development for the first 4 years, after which production from a borefield would be required to supplement operational demand.

6.6.1.2 Wellfield Supply

Water supply infrastructure would be constructed, linking the development to a series of wellfields located near the Ministerial Temporary Reserve and within the defined Project Area (see Figure 6-16).

The Yeelirrie Wellfield would be developed with the capacity to supply the entire water demand of the proposed Yeelirrie development, providing a supply network with redundant (i.e. additional) capacity.

In planning the water supply to meet the required demand, Cameco's philosophy has been to target more saline sources, to minimise the demand on sources of better quality water. The additional capacity confirmed through modelling provides Cameco with some flexibility to manage extraction from each source to meet environmental aspects.

Dust suppression water would continue to be supplied via pit dewatering. The infrastructure for the Wellfield would include electrically pumped wells connected to the metallurgical plant via a buried pipe.

Power would be supplied to each well via an overhead line from the generators. Tracks would be established to provide access to the wells and the pipeline and power corridor. The water supply pipeline would pass beneath public roads surrounding the Project Area, with road crossings kept to a minimum.

6.6.2 Water Treatment

The proposed development would require water of various qualities to be generated from the raw water obtained from the primary supply (either pit dewatering or the saline Wellfield supply). To facilitate this, two package water treatment plants would be installed on-site.

6.6.2.1 Reverse Osmosis (RO) Desalination Plant

The proposed RO unit would treat about 2 ML/d of raw water from the wellfield, to produce about 1 ML/d of RO water and 0.1 ML/d of potable water from feed water containing less than 10,000 mg/L TDS. The RO water would be used within the metallurgical plant in the leaching and precipitation stages and the 0.1 ML/d of potable water would be further treated before use within the administration and village facilities (see Section 6.12).

The RO unit would generate about 1 ML/d of brine and filter backwash solution containing residual quantities of coagulants and other conditioning chemicals. The reject stream would be directed to the TSF.

6.6.2.2 Potable Water Treatment

The potable water generated by the RO plant would be further treated in a package water treatment plant to produce drinking-quality (potable) water. The treatment would consist of calcite filtration and chlorination. There is expected to be little, if any, waste associated with the operation of this water treatment plant. The plant would be used to meet the demand for potable water within the on-site administration infrastructure and the accommodation village.

6.6.3 Water Recycling

Extensive water reuse and recycling systems would be developed for the proposed development to minimise the demand for raw water from the local and regional systems. Examples include:

- directing most wastewater streams to the metallurgical plant grinding circuit;
- recirculating and treating liquors within the metallurgical plant, in particular the precipitation stages, to both reduce raw and RO water demand and ensure the recovery of a greater proportion of the contained uranium;
- capturing stormwater within mining-disturbed areas and treating and using it in place of groundwater, reducing groundwater abstractions and also reducing the energy necessary to operate the RO plant as a result of the higher quality of stormwater over groundwater; and
- the extensive use of heat exchangers to reuse the heat capacity of some of the precipitation stages to reduce the steam (hence water) demand in other stages.

6.7 Site Infrastructure

A range of site infrastructure would be required to support the proposed mine and metallurgical plant, including the following:

- accommodation village;
- quarry;
- internal access roads;
- metallurgical plant and associated infrastructure in preparation for processing;
- mine infrastructure in preparation for the mining development;
- installation of pit dewatering infrastructure;
- water management infrastructure;
- an administration building;
- operations stores and warehouse facilities;
- maintenance workshops;
- sand blasting and painting facilities, including a decontamination area for the removal of surface radiation before clearance from site;
- laundry and employee change and washing facilities;
- a sewage treatment plant;
- a process control room;
- security and emergency response facilities, including the provision of a fire tender and ambulance; and
- a vehicle wash-down, drive-through vehicle wheel wash and weighbridge facility fitted with sediment capture and oil separators.

These infrastructure elements would be constructed and operating before the metallurgical plant was commissioned.

6.7.1 Site Security

A number of levels of site security would be provided:

- The mining area would be fenced with a ring lock fence.
- The process facilities and mine workshops would have secured area barrier fencing with primary access via a security gate with swipe card entry.
- The packaging and drying facility would be a fully monitored and secured area within the process area, with restricted swipe card entry.

6.8 Energy Supply

The current Project design is based on a diesel fired power station. An alternate option under consideration would use a gas fired power station, subject to finalising the availability of gas and viability of that option. The gas fired option may bring minor environmental benefits but would require a gas supply pipeline (approximately 50 km long) to be installed. The viability of the gas line extension and the impact on other gas users in the region is currently under review. Should the gas fired power plant become the preferred option, separate approval would be sought for the construction of the gas pipeline.

Based on an assumption to implement the diesel fired power station as the base case, most of the energy demand for the proposed development will be associated with diesel-fired electricity generators, diesel-fired steam generation and diesel-fuelled heavy and light vehicles. The estimated demand for diesel and electricity is summarised in Table 6-14 and detailed in the following sections.

Table 6-14: Indicative energy demand for the Project

Energy source	Proposed annual demand (kL/a)
Diesel – on-site vehicles	6190
Peak/average diesel – materials transport	24,000/4,000
Diesel – electricity generation	34,000
Diesel – steam generation	28,000
Electricity[1]	150,000 MWh/a

Notes:

[1] Electricity demand is internal to the site. Demand is met through the on-site generation of electricity from diesel and no external connections are required

6.8.1 Vehicle Fleet Diesel

Approximately 6,190 kL/a of diesel would be required to operate the heavy and light vehicles associated with the proposed development; most of this fuel would be used to supply the heavy vehicle mining fleet. A fuel unloading and storage facility complying with the relevant Australian Standards would be constructed close to the proposed vehicle maintenance area and the steam and electricity generators to minimise the length of pipework. This facility would provide dispensing facilities for heavy and light vehicles. A conventional mains fire protection system, using RO water, would be installed in accordance with relevant standards and legislation.

6.8.2 Electricity Generation

The peak electricity demand for the proposed development would be around 20 MW to meet an average annual consumption of around 150,000 MWh. Most of this power would be required to operate the grinding mill and pump process slurries within the metallurgical plant.

The electricity requirements would be met by installing a series of diesel fired electricity generators (or an alternate gas fired option) and local electricity transmission infrastructure. Installing multiple generators would provide contingency in the event of planned and unplanned generator outages and also allow the operation of the generators to be optimised, minimising power station fuel consumption.

Exhaust gases from the diesel generators would pass through a waste heat boiler to supplement the steam supply, and then be directed into the barren solution stage of the metallurgical process, where some of the carbon dioxide would recarbonate the solution before it was used as a wash solution within the CCD stage of the metallurgical process.

6.8.3 Steam Generation

A diesel fired steam generator (or co-generation from a gas fired power station) would be installed, with sufficient capacity to provide about 25 tonnes per hour (t/h) of high-grade steam at a pressure of around 1,000 kPa. A boiler would also be constructed to capture waste heat associated with the exhaust gases of both the electrical generators and the steam generators.

The requirement for steam generation would be minimised through the use of heat exchangers within the metallurgical process to transfer heat between process streams, where significant differences in heat are demanded by the nature of the precipitation process.

6.9 Chemical Storage and Use

Table 6-15 lists the indicative volumes of reagents and methods of storage that would be required for the proposed development. The nominal reagent site storage capacity has been set at five to ten days, but this is subject to identifying suppliers and agreeing to supply arrangements, which would be determined during detailed design.

Table 6-15: Indicative annual metallurgical plant requirements and storage methods

Bulk chemicals and reagents	Annual consumption (tpa)	Storage method
Sodium hydroxide (liquid 50% w/w)	200,000	Bunded storage tank
Sodium carbonate (dry, bulk dense)	15,500	Bunded storage tank
Sodium bicarbonate (dry, general purpose)	9,500	Bunded reagents area, stored in the as-transported bulk bags (1,000 kg each)
Sulphuric acid (liquid, 98% w/w)	4,500	Bunded storage tank
Hydrogen peroxide (liquid, 70% w/w)	2,000	Bunded storage tank
Flocculants and coagulants (liquid, bulk)	1,200	Flocculent is stored in the as-transported bulk bags. Coagulant is stored in the as-transported standard liquid containers. Both are stored within the bunded reagents area
Operating consumables	**Annual consumption (tpa)**	**Storage method**
Grinding media	660 t	Stored in a hardstand area near the milling circuit. Mill lubricants including oils and greases would be stored in a bunded hydrocarbon area
Mill liners	2 sets	
Mill lubricants	50 drums	
Wedge wire screen	32 panels	
Filtration media	1 change every three years	
Final product drums	33,000 drums	

6.10 General Waste Management

Due to the isolated nature of the site and the absence of waste management infrastructure, Project-specific waste recycling, treatment and/or disposal facilities would be required for the construction, operation and decommissioning phases. Although the volumes are likely to vary from phase to phase, general wastes arising from the development can be broadly categorised into four types, as set out below:

- non-process solids wastes;
- non-process liquid wastes;
- low-level radioactive wastes; and
- controlled wastes.

Each of these categories is discussed in greater detail in the following section. The waste types discussed exclude mined materials, tailings and process water, which have been previously discussed.

6.10.1 Waste Management Facility

The primary segregation and management of non-process wastes would be undertaken within a waste management facility constructed to the east of the metallurgical plant (refer Figure 6.3), on a fully fenced and gated area of around 15 ha. This facility would be operated for the life-of- mine, at the predicted waste generation rates outlined in the following paragraphs. The waste management facility would consist of:

- collection bays for the temporary stockpiling of waste streams pending transport off-site to third-party treatment and disposal facilities;
- a transfer station for the segregation of waste materials;
- a category 89 putrescible and clinical waste landfill, which would not intercept the water table and would not exceed a final height of 1.5 m above surrounding grade (category as per WA Department of Environment and Conservation (DEC) Landfill Waste Classification and Waste Definitions 1996 (as amended December 2009)); and
- a general inert cover material laydown area (buffer zone), including firebreak.

Cover would be provided on a monthly basis, with the waste cells constructed according to the DER guidelines for landfills.

6.10.1.1 Non-process Solid Wastes

Non-process solid wastes that would be generated by the proposed development include reagent and spare parts (consumables) packaging, construction and maintenance wastes and general office and administration wastes such as cardboard, paper, plastics, timber and concrete.

6.10.1.2 Non-process Liquid Wastes

Non-process liquid wastes, including vehicle wash-down water (following oil/water separation), stormwater and desalination brine, would be collected and directed to the TSF for reclaiming and reuse within the metallurgical process or as needed for dust mitigation.

Water associated with the generation of sewage wastes would be treated in one of two package wastewater treatment plants (one for the site office, and a larger facility for the proposed accommodation village) with sufficient capacity to accommodate the staffing numbers. After leaving the treatment plants, the water would be used for dust suppression or general site irrigation or removed from site by licensed operators.

6.10.1.3 Low-level Radioactive Wastes

Small quantities of low-level radioactive wastes (LLRW) would be produced by the proposed development. These would comprise laboratory wastes (about 4 to 6 m^3/a) and used personal protective equipment (about 20 m^3/a). In addition, some used items of plant and equipment that were found not to meet the radiation activity criteria for off-site disposal would be stored within the site boundary in a suitable facility before disposal. LLRW material would ultimately be disposed of within the TSF cells in discrete campaigns – typically, in excavated trenches which would be immediately backfilled.

Radiation source equipment would be used on-site including wellhole logging (Cf-252), automatic weighing and gauging equipment (Ce-144) and smoke detectors (Am-241). Radiation source equipment would be returned to the supplier at the end of its productive service.

6.10.1.4 Controlled Wastes

Controlled wastes are waste materials as defined in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004. Some controlled wastes for which there are no favourable recycling option would be collected and forwarded to off-site licensed facilities for treatment and disposal. The management practices for the controlled wastes arising from the proposed development are summarised in Table 6-16.

Table 6-16: Indicative controlled waste generation rates and proposed management

Waste type	Indicative management practice	Generation rate (tpa)
Chemical drums/aerosols/cans	Rinse and recycled	45
Oily rags/absorbents	Bagged and sent to third-party service provider	1
Diesel ash	Encapsulate or inert landfill disposal on site	5
Waste oil/solvents/coolants	Forwarded to third-party service provider for recycling	28
Tyres	Stockpiled and disposed in tailings or mine void	14
Batteries	Forwarded to third party service provider for recycling	10
Conveyor belt rubber	Disposed of in tailings or mine void	20
Fluorescent globes	Disposed of in tailings or mine void	0.25
Reagent bags	Disposed of in tailings or mine void	0.1
Kitchen oil/grease	Forwarded to third party service provider for recycling	10
Paint	On-site evaporation pad	3
Hydrocarbon contaminated soil	Treatment in bioremediation land farm	1
Reagent delivery/transfer hoses	Rinse and disposed in tailings or mine void	5
Total		142

6.11 Transport

The construction and operation of the proposed development would necessitate materials being transported to and from Yeelirrie. The logistics associated with this requires different strategies during the construction and operational phases of the Project (see Figure 6-17). The transport and logistics operation would comply with all relevant state and Australian transport requirements.

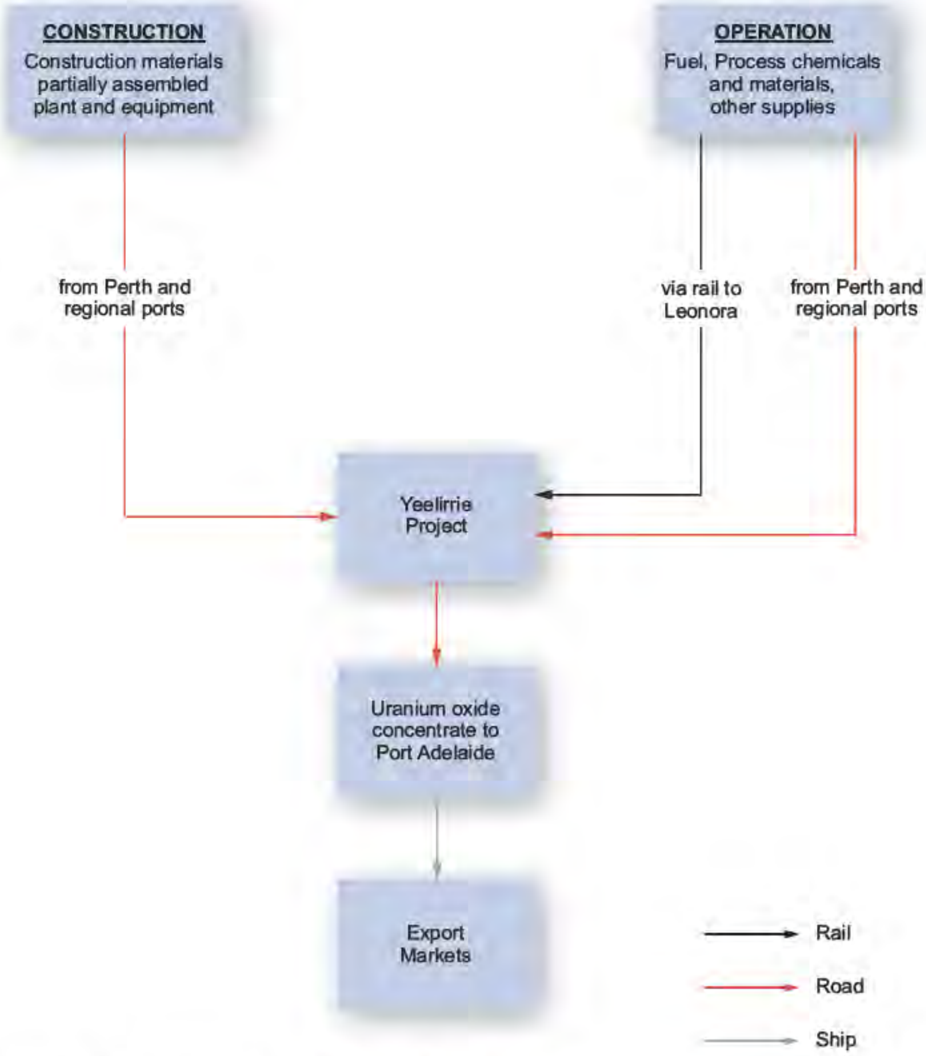


Figure 6-17: Indicative transport and logistics flow diagram

6.11.1 Site Access

As part of the early construction activities, a site access road would be built to connect the quarry to the metallurgical plant, crossing the existing Yeelirrie – Meekatharra Road (see Figure 6-18).

The main access to the proposed development would be from the Goldfields Highway, along the existing Albion Downs – Yeelirrie Road to the accommodation village (see Figure 6-18). Traffic between the village and the metallurgical plant would travel via the existing Yeelirrie - Meekatharra Road and would enter the site through a main gate to be established at the entrance to the metallurgical plant.

Some upgrading and modification of the existing road infrastructure would be required to enable heavy vehicle (e.g. triple road train) use and to minimise the risk associated with additional heavy vehicle traffic. These upgrades and modifications include:

- modification of road alignments to improve vehicle line-of-sight issues;
- upgrading of the Goldfields Highway and Albion Downs – Yeelirrie Road intersection with slip lanes and turning lanes to facilitate heavy vehicle movements;
- redesigning of some cattle grids;
- upgrading of the existing road dips;

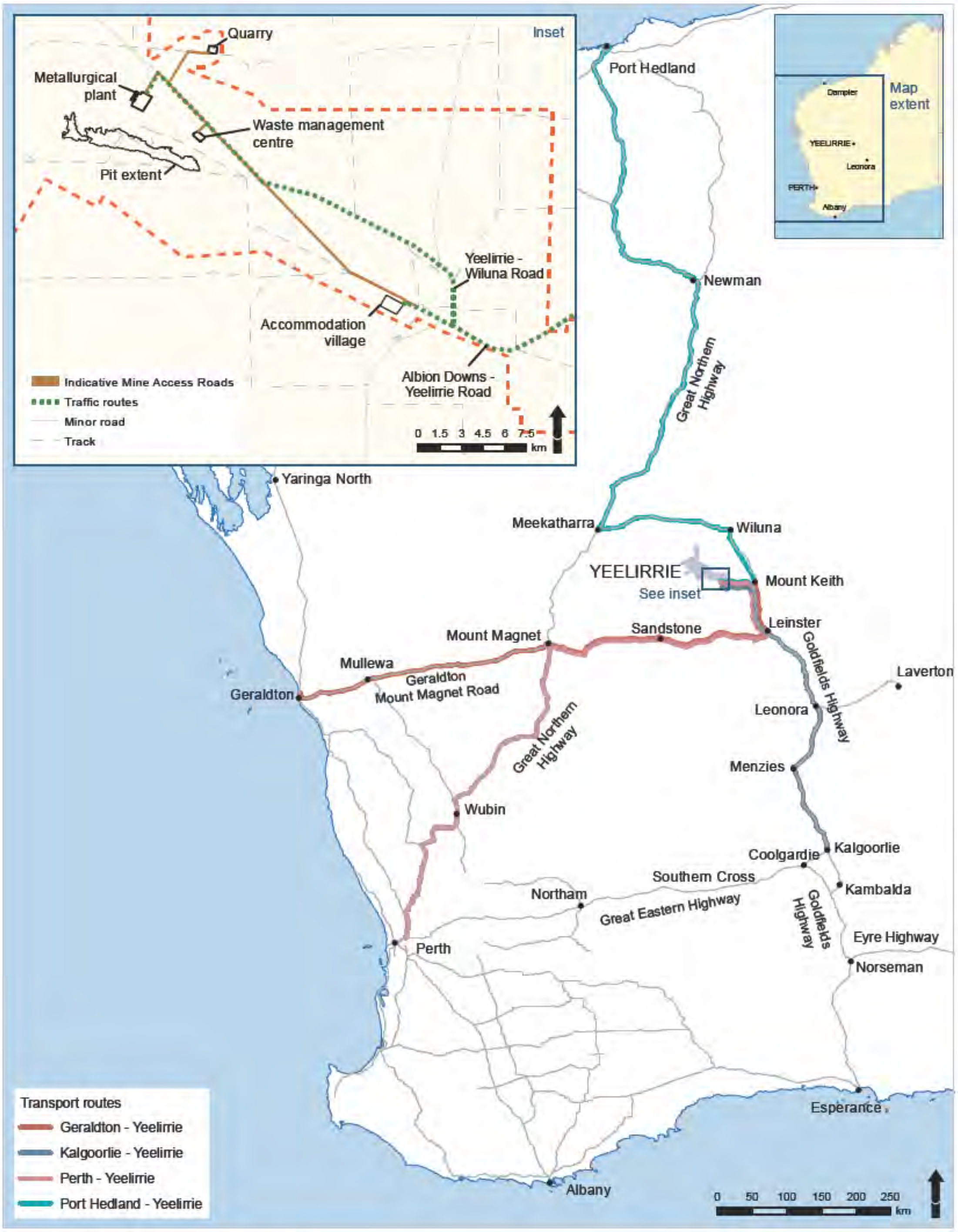


Figure 6-18: Transport and logistics

- the addition of an inspection bay to ensure that heavy vehicles transitioning from unpaved to paved road surfaces did not introduce debris to the roadways; and
- upgrading of existing road signs and installing additional signs where required.

Cameco would work with Main Roads Western Australia and the local shires of Leonora and Wiluna to facilitate the delivery of a regular and ongoing road maintenance program.

6.11.2 Construction Phase

The major construction, mining and workforce estimates are summarised in Table 6-17.

Table 6-17: Major construction, mining and workforce transport estimate

Item	Unit	Quantity to be transported
Construction items	Freight tonnes	50,000
Cement	Tonnes	10,000
Construction steel	Tonnes	7,000
Village facilities	Freight tonnes	600
Workforce bus movements (from Mount Keith Airport)	Annual trips	520
Mining equipment fleet	Road deliveries from Perth	72

The majority of the on-site infrastructure would be constructed on-site, necessitating road movements for the delivery of construction materials including cement, steel, machinery, pipework, pumps and valves. Other indivisible loads, consisting of partially assembled mining equipment and pre-assembled and prefabricated materials, will also be trucked to site. The transport of materials to and from site during the two-year construction phase would use around 24,000 kL of diesel annually. It is anticipated that partially assembled mining equipment would originate from Perth and/or Kwinana, and pre-assembled and prefabricated materials would be delivered from Kalgoorlie-Boulder, Geraldton and/or Port Hedland (see Figure 6-18).

6.11.3 Operational Phase

Details of the diesel consumption and likely annual reagent use associated with the proposed development were provided in Table 6-14 and Table 6-15, respectively. The estimated total transport volume (covering inbound raw materials and consumables along with outbound finished goods for the ongoing production and operational phase) is 344,000 tpa. The transport of materials to and from site during the operational phase would use around 4,000 kL of diesel annually.

6.11.3.1 Import of Materials

During the operational phase, some imported materials and supplies would be transported by rail from Perth and/or the east coast to the existing West Kalgoorlie-Boulder intermodal terminal, before being transported to Yeelirrie by road; other materials would be transported solely by road (see Figure 6-18). Wherever feasible, the transport of materials and supplies by road would use double and triple road train vehicles due to their freight efficiency. The Yeelirrie State Agreement nominates the import of caustic soda and diesel through the port of Esperance, then transport via rail to Leonora followed by haulage by road from Leonora to Yeelirrie. The Project will retain the option to import these commodities through Esperance as nominated in the State Agreement. The final transport solution for caustic and diesel will be decided after detailed negotiations have been finalised with potential suppliers.

Figure 6-19: Proposed uranium oxide transport routes

6.11.3.2 Transport of Uranium Oxide Concentrate (UOC)

After processing the uranium ore into UOC, it would be securely stored on the mine site before being transported by road to the existing port facilities in South Australia for direct export. The transportation of UOC is regulated by State and Australian agencies in accordance with the Code of Practice for the Safe Transport of Radioactive Material (current edition 2009), published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Cameco would adapt the extensive transport management systems, processes and procedures applied at its Canadian operations for the proposed Yeelirrie development. The packed drums of UOC would be sealed, braced and locked in shipping containers in preparation for transport to Adelaide.

Shipments of UOC would be transported from Yeelirrie along the Goldfields Highway to Norseman, along the Eyre Highway to Port Augusta and then the Princes Highway to Adelaide (see Figure 6-19). All consignments would have extensive safety, operational, emergency response and security arrangements in place.

6.12 Workforce and Accommodation

6.12.1 Workforce

The construction and operation of the proposed development would require the employment of a workforce of up to approximately 225 people.

The proposed operational workforce would operate on a rotating shift roster on a fly-in/fly-out (FIFO) basis. The workforce would fly into Mount Keith Airport (subject to availability) and travel by bus to the mine site. In addition, and as deemed necessary, a bus service would be provided between Wiluna and the mine site for workers residing in this area. Private vehicles would not be able to access the mine site, but there would be a small number of private vehicle parking spaces at the accommodation village.

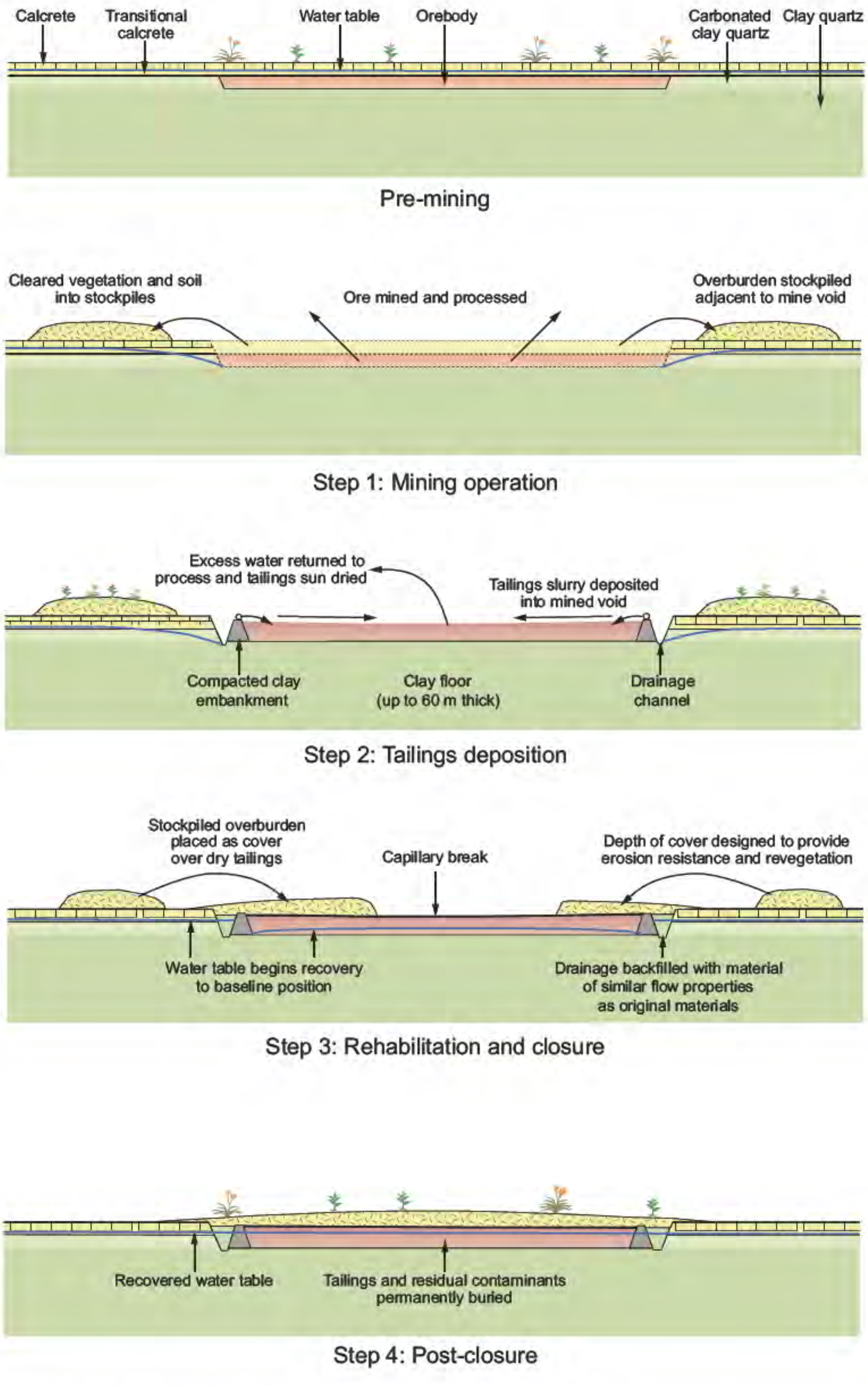


Figure 6-20: Conceptual final - post rehabilitation - landform cross-sections

6.12.2 Accommodation

An accommodation village would be established approximately 20 km south east of the metallurgical plant. At its peak, the facility would be designed to accommodate up to 1,200 people simultaneously, with separate accommodation areas for construction and operational phase workers. Following the completion of construction activities, a proportion of the accommodation units would be decommissioned and removed, subject to demand.

The accommodation units would comprise single-bed ensuite rooms, fitted with air-conditioners and refrigerators. Services at the village would include a laundry, gym, sports hall, mess facilities, a tavern and other entertainment infrastructure. Communications would be provided via a microwave link that connects into the national network, and the site would have mobile phone coverage.

The accommodation village would be supplied with electricity from generators, and with water from the on-site package water treatment plant. Sewage wastes would be treated in a package wastewater treatment plant.

6.13 Rehabilitation and Closure

6.13.1 Preliminary Closure Plan

A preliminary Mine Closure Plan for the proposed Project has been developed. The key objectives for the closure include:

- protecting the health and safety of the public and the workforce during closure activities and post-closure;
- minimising off-site impacts by controlling erosion and sedimentation and by minimising changes to background infiltration rates, and water levels and quality, upstream, downstream and close to the proposed development;
- returning the topography, soils, drainage and vegetation of disturbed areas, other than the TSF, to as close to pre-mining conditions as practicable;
- employing rehabilitation and closure methods to establish self-sustaining ecosystems that do not require ongoing maintenance;
- developing and implementing an appropriate post-closure monitoring and contingency plan to assess the performance of the closure and rehabilitation against agreed criteria; and
- developing a long term management plan for the Yeelirrie pastoral lease that ensures rehabilitation and conservation areas are protected from disturbances such as grazing.

An indicative flow diagram for rehabilitation and closure is presented in Figure 6-20. To achieve these outcomes, indicative closure methods have been developed for each of the key infrastructure elements. These are summarised in Table 6-18.

Table 6-18: Preliminary closure methodologies for key infrastructure elements

Infrastructure Element	Preliminary Closure Method
Open pit and associated infrastructure	Bury all tailings and materials that do not meet the surface activity criteria for off-site disposal (from other mine site areas and from stockpile footprints) in the pit void retained for this purpose. Back fill the mine void, first with low-level radioactivity waste material, followed by non-economic material. Rehabilitate the stockpile footprints and the various mine roads and infrastructure with the original surface cover material appropriately stockpiled during construction and mining operations. Revegetate with appropriate native plants. The cover to the mining area would be designed and constructed to be safe, stable and non-polluting. The cover would safely and securely contain the tailings and disposed infrastructure and minimise radiation exposure. Provide appropriate contouring and surface water management features to return mine-scale surface water flows to pre-mining systems, and locally to ensure that concentrated flow does not erode or damage rehabilitated areas. Where required, provide appropriate sediment catchment features to minimise sediment carry on to other areas. Divert groundwater flows around the contained tailings to minimise the release of contaminants into the groundwater.
Metallurgical plant	Demolish and remove all plant, structures, pipes, power lines and concrete footings down to a depth of at least 1.0 m below natural ground level. Remove all contaminated pipes and tanks. Recycle materials that are below contamination limits and dispose of the remainder in pits. Remove all contaminated soils and bury with all other contaminated material in the pit void reserved for this purpose. Dispose of all uncontaminated material by sale or in appropriate landfill. Remove pond liners and dispose of in pit. Demolish walls and either reuse embankment material for shaping and contouring or dispose of in pit. Rehabilitate entire area with the original surface cover material stripped and stockpiled during construction and operations, and revegetate with appropriate native plants. Provide appropriate contouring and surface water management features to ensure that concentrated flow does not erode or damage rehabilitated areas. Provide appropriate sediment capture features to minimise sediment carry on to other areas.

Infrastructure Element	Preliminary Closure Method
General infrastructure	Demolish and remove all plant, structures, pipes, power lines, and concrete footings down to a depth of at least 1.0 m below natural ground level. Remove all contaminated pipes and tanks buried at any level. Dispose of demolished and removed items in pit. Remove wellfield and surface water management infrastructure. Dispose of all uncontaminated material by sale or in appropriate landfill where it cannot be recycled. Remove all contaminated soils and bury with all other contaminated material in the pit void reserved for this purpose. Dispose of all uncontaminated material by sale or in appropriate landfill where it cannot be recycled. Rehabilitate entire area with the original surface cover material stripped and stockpiled during operations, and revegetate with appropriate native plants. Provide appropriate contouring and surface water management features to ensure that concentrated flow does not erode or damage rehabilitated areas. Provide appropriate sediment capture features to minimise sediment carry on to other areas.
Accommodation village	Remove all buildings and infrastructure and dispose of either by sale, or to an appropriate off-site landfill where it cannot be recycled, given that the accommodation village would not be contaminated, or in an appropriately constructed and rehabilitated on-site landfill. Remove all contaminated soils and bury with all other contaminated material in the pit void reserved for this purpose. Dispose of all uncontaminated material by sale or in appropriate landfill where it cannot be recycled. Rehabilitate the entire area with the original surface cover material stripped and stockpiled during construction and operations, and revegetate with appropriate native plants. Provide appropriate contouring and surface water management features to ensure that concentrated flow does not erode or damage rehabilitated areas. Provide appropriate sediment capture features to minimise sediment carry onto other areas.
Tailings storage facility	Following the completion of tailings deposition within a given cell, the tailings surface would dry, forming a salt-enhanced crust. After about one year after deposition ceased, the tailings cell would be covered with a 3 m layer of non-economic material and topsoil, minimising the release of radon, and would subsequently be allowed to revegetate. Higher-permeability materials would be used as backfill between the outer clay embankments and the open pit perimeter to act as a groundwater diversion channel to help exclude groundwater from the tailings mass, and maintain the long term integrity of the TSF cells.

Section 7

Regional Overview

Figure 7-1: The Eastern Murchision subregion of the WA bioregions.

7. Regional Overview

7.1 Regional Setting

The Project is located approximately 660 km north east of Perth and 420 km (or 500 km by road) north of Kalgoorlie-Boulder. The Project Area is located in the Murchison bioregion, and in the Eastern Murchison (MUR1) subregion as described in the Interim Biogeographic Regionalisation for Australia (IBRA) (Figure 7-1).

The Murchison bioregion is characterised by low hills and mesas separated by flat colluvium and alluvial plains. Vegetation is predominantly low mulga woodlands. The bioregion is one of the main pastoral (sheep and cattle) areas in Western Australia, although mining (gold, iron ore and nickel) is the greatest income generator of its economy. Major population centres are Cue, Laverton, Leinster, Leonora, Meekatharra, Sandstone, Mount Magnet and Wiluna.

The Eastern Murchison subregion is characterised by its internal drainage, and extensive areas of elevated red desert sandplains with minimal dune development. It contains salt lake systems associated with the occluded Palaeodrainage system, red sandplains and broad plains of red-brown soils and breakaway complexes. Vegetation contains Mulga Woodlands which are often rich in ephemeral species, saltbush shrublands, *Halosarcia* shrublands and hummock grasslands. The subregion has an arid climate with rainfall mostly in winter (Cowan 2001).

7.2 Social Setting

The Project is located in the Shire of Wiluna in the Mid West region of WA. A summary of the baseline socio-economic profile and demographic trends for the communities in proximity to the Project is provided below.

7.2.1 Mid West

The Mid West region includes the Batavia Coast, North Midlands and the Murchison subregions. The East Murchison is the largest subregion covering more than 423,000 km^2, and incorporates the shires of Cue, Meekatharra, Mount Magnet, Murchison, Sandstone, Wiluna and Yalgoo. The Murchison has strong mining and pastoral industries and an emerging outback tourism sector. It has also been selected as one of the locations for the international Square Kilometre Array radio telescope (SKA) (Mid West Development Commission 2014).

The Mid West region includes the regional centre of Geraldton (635 km west of the Project by road) with an urban population of around 36,000. Outside of the Mid West, but located closer to the Project Area, is the city of Kalgoorlie-Boulder (500 km south by road) which has an urban population of around 31,000. These regional centres could provide skilled workforces for the Project, although the majority of the workforce is expected to commute on a fly-in fly-out (FIFO) basis from Perth.

Until December 2012, the Mid West region's unemployment rate was lower than the State average at 4.2%. However, like other areas of WA, the Mid West unemployment rate has increased since early 2013 and spiked in September 2013 to 8.3%. Unemployment figures for the region in December 2013 decreased to 6.8%. The increases may reflect a recent decline in major project activity experienced in the region and contraction in the regional economy generally (Mid West Development Commission 2014).

The Mid West region is considered socio-economically disadvantaged when compared with WA residents overall, with the Shire of Wiluna ranking within the top 10% of the most socio-economically disadvantaged areas within WA (Mid West Development Commission 2014). The region's Australian Early Development Index (AEDI) results also indicate similar disadvantage of children in these areas with up to 65% of children considered developmentally vulnerable in the Meekatharra/Wiluna community (AEDC 2012).

The Mid West is considered to have efficient strategic infrastructure networks including the Great Northern, North West Coastal and Goldfields highways; and the Goldfields, Dampier to Bunbury and Mid West gas pipelines.

The nearest towns to the Project Area are Wiluna (approximately 90 km north, residential population 200), Leinster and Leonora in the Shire of Leonora (115 km south east, residential population 700) and Sandstone in the Shire of Sandstone (135 km south west, residential population 130) (Figure 7-1).

7.2.2 Shire of Wiluna

The Shire of Wiluna covers an area of 182,155 km^2 and has an estimated population of approximately 1,279 (in 2013; Mid West Development Commission 2014).

The Shire of Wiluna has a large transient population with approximately 45% of the people counted during the 2011 census listed as usually resident outside of the Shire. Employment data collected during the census indicates the majority of the workforce in the Shire was employed in mining or manufacturing. These industries are supported by a large FIFO workforce, which would account for the significant transient population (ABS 2012a).

Aboriginal people, living in the local townships, communities and homesteads, comprise approximately 25% of the resident population in the Shire of Wiluna (ABS 2012a).

The percentage of secondary school children attending an educational institution in the Shire of Wiluna was 5.5%, a figure well below the State average (17%) (ABS 2012a, 2012b). This may be due to working families with older children moving out of the region and relocating to areas with more comprehensive secondary educational facilities and regional students attending boarding schools.

Unemployment for the Shire of Wiluna at the time of the 2011 census was 4.7% compared with the unemployment rate for Western Australia of 4.4% (ABS 2012a, 2012b). Unemployment figures are expected to have increased since this time, in line with the regional trend[1].

7.3 Land Use

Land use in the area surrounding the proposed Project site is typical to the Northern Goldfields area of WA and consists predominantly of mining activities, pastoral stations and conservation reserves. Some hunting and bush food collection by Aboriginal people occurs throughout the region.

7.3.1 Pastoralism

The Project Area occurs within the Yeelirrie pastoral station which is owned by Cameco. Historically, the property has been used for pastoral purposes; however, it is currently de-stocked. Pastoral stations in the region have experienced low profitability in recent years as a result of low commodity prices, climate change, deteriorating pastoral conditions and predation of stock by wild dogs.

The Yeelirrie pastoral station (pastoral lease LA3114/620 CL449-1966) covers approximately 246,000 ha. Following its initial development in 1925, Yeelirrie was operated continuously as a sheep station until its purchase by Western Mining Corporation (WMC) in 1972. WMC de-stocked the station in anticipation of project approvals, but following the Australian Government's decision in the early 1980s to prevent further development of uranium mining projects, the Yeelirrie pastoral station was re-stocked (this time with cattle) and operated by WMC. WMC also operated the neighbouring properties of Albion Downs, Yakabindie, Mount Keith and Leinster Downs. The Yeelirrie pastoral lease, and the surrounding leases noted above, were acquired by BHP Billiton in 2005. Cameco acquired the Yeelirrie pastoral lease in 2012 as part of the purchase of the Project.

[1] Recent unemployment data for the Shire of Wiluna not available.

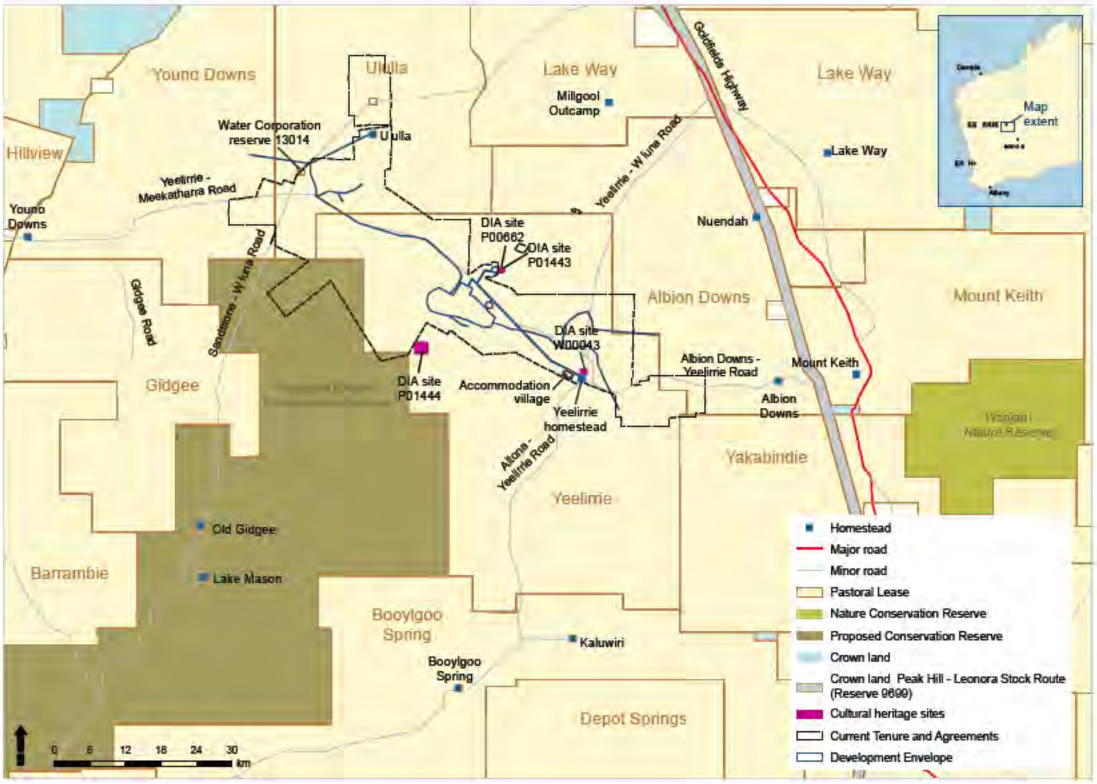


Figure 7-2: Land use near the proposed Yeelirrie development

Pastoralism remains the dominant land use on the properties surrounding the Yeelirrie pastoral station. Ululla and Kaluwiri stations are currently de-stocked and Yuono Downs, Yakabindie and Albion Downs leases continue to operate as active pastoral stations (Figure 7-2).

7.3.2 Conservation

There are no World Heritage Properties, National Heritage Places, Wetlands of International Significance, Commonwealth Lands, Commonwealth Heritage Places or State Reserves within 20 km of the Project Area. The closest existing conservation reserve is the Wanjarri Nature Reserve, located about 60 km east south east of the proposed Project Area. The proposed Kaluwiri, Lake Mason and Black Range conservation reserves lie about 10 km, 55 km and 100 km respectively south west of the Project (Figure 7-2). The Yeelirrie State Agreement Area overlaps the boundary of the proposed Kaluwiri conservation reserve, but no disturbance is planned within the proposed reserve.

7.3.3 Traditional use

As with many pastoral properties throughout the region, the advent of the Yeelirrie Pastoral Station (in 1925) and the inception of large-scale pastoral activities significantly affected traditional Aboriginal hunting and gathering activities. The Yeelirrie pastoral station continues to be accessed occasionally by Aboriginal people for hunting and collecting bush food.

There are four heritage sites registered with the WA Department of Aboriginal Affairs (DAA) that are within the Project Area, but not within the areas proposed to be disturbed by the Project and, therefore, are not expected to be impacted (see Figure 7-2). These sites may be visited intermittently; however, the remote location of Yeelirrie makes site access difficult.

7.3.4 Historic mining activities at Yeelirrie

Between 1972 and 1980 WMC undertook several phases of exploration and three trial mining programs at the site of the proposed Yeelirrie development. As part of metallurgical testing programs, 220,000 m^3 of material was mined from three locations referred to as 'slots'. The majority of 'mine overburden' (material containing sub-economic concentrations of uranium) was placed in stockpiles while the rest was used to form roads and temporary access tracks. A series of ore stockpiles, of various uranium grades, was also created.

Detailed metallurgical studies were undertaken between 1980 and 1982 at a purpose-built pilot plant located north of Kalgoorlie (Kalgoorlie Research Plant (KRP)) and a selection of the various ore grades mined at Yeelirrie were transported to the KRP for processing.

For a period of about 20 years after 1982, no mining operations occurred at Yeelirrie. In 2004, substantive rehabilitation works commenced. The rehabilitation earthworks included backfilling the slots first with stockpiled ore materials and then non-mineralised road base from haul roads and access tracks, demolished concrete, excavated materials from the Gamma Calibration Pit, and removed infrastructure. Roads were then ripped and graded, mounds were created over backfilled mine slots, and disturbed areas were profiled to natural grades and deep ripped to promote revegetation.

The progress of revegetation was monitored for five years following the completion of rehabilitation works in 2004.

As a result of WMC's exploration and trial mining activities, a total area of 586 ha was disturbed within the Project Area. The areas affected by the WMC trial mining and exploration are within the planned mine area as presented in this PER. Some areas of the proposed project footprint have, therefore, already been cleared of native vegetation.

7.4 Climate

A detailed analysis of climatic conditions is presented in Appendix L1. The weather of the Yeelirrie region is influenced by its inland location (~ 600 km from the coast) and generally displays two modes: spring/summer and autumn/winter.

Spring/summer conditions generally bring higher temperatures and lower mean sea level pressure as the climate is influenced by the Australian monsoon season in northern Australia. This results in higher rainfall and more variable weather in summer. During this period, the winds are predominantly from the east and the southwest. The autumn/winter mode consists of lower temperatures, higher mean sea level pressure and lower rainfall with winds predominantly from the east.

Finer detailed weather analysis for the Project Area identified four main weather types (Table 7-1). Types 1 and 2 are dominant in summer and spring due to the generation of tropical lows associated with the Australian cyclone season and the passage of fronts. Types 2 and 3 take precedence in autumn and winter as the cyclone season expires and the procession of low-pressure systems off the southern coast of Australia shifts further north. Type 3 is a result of the high-pressure system moving inland under Type 2 conditions. As the system approaches the centre of the continent, the daily heating and cooling of the large land mass causes the eastward movement of the system to slow and at times stall, becoming a stationary (blocking) high. Without the procession of fronts generated by tropical depressions (Type 1) to force eastward movement of the system, the high can remain stationary for several days, generating calm and settled weather. These conditions (Type 2 and 3) generally lead to the stratification of the nocturnal atmosphere, with warmer air held close to the ground under higher colder air (commonly referred to as inversion layers). At night the ground cools resulting in a cold layer of air covered by warmer air. This causes stable conditions as the colder air stays closer to the ground and the warmer air continues to rise, and is commonly referred to as an inversion layer.

Table 7-1: Weather types identified at the synoptic, regional and local scale

Weather Type	Synoptic Situation	General Description
1	Monsoonal low off the north-west coast, trough moving inland, high-pressure system to the south	Hot, dry north easterly winds
2	Ridge of high pressure pushing in behind front	Temperatures in the low 20s, 30–40% humidity, light easterlies tending south westerly along the coast
3	High-pressure system over central Australia with associated fronts along the coast	Wide range of temperatures from below zero at night to above 30°C during the day, more moderate temperatures along the coast. Humidity stable around 50–70%, very light winds inland from the north east to south east with more moderate winds from the south east to south west along the coast
4	Similar to Type 3 only high-pressure system is further south over the Great Australian Bight	Wide range of temperatures from below zero at night to above 30°C during the day, more moderate temperatures along the coast. High humidity 70–90%, very light winds inland from the south east to north west with more moderate winds from the south east changing to north east along the coast

The Yeelirrie climate typically exhibits wide temperature ranges with very hot days in summer, and mild days and cold nights in winter. The average maximum temperature is 37.9°C (January) and the average minimum is 3.5°C (July) (Table 7-2).

The average annual rainfall for Yeelirrie (Bureau of Meteorology (BoM) Station No. 012090, 1928 to 2014) is 239 mm, with recorded minimum and maximum annual rainfalls of 43 mm (1950) and 507 mm (1975), respectively. The rainfall frequency and total annual rainfall are widely variable. Yeelirrie receives 61% of its mean annual rainfall from November to April (Table 7-2). The highest recorded monthly rainfall of 211 mm occurred in April 1992 and the highest daily rainfall of 99.1 mm occurred in March 1931.

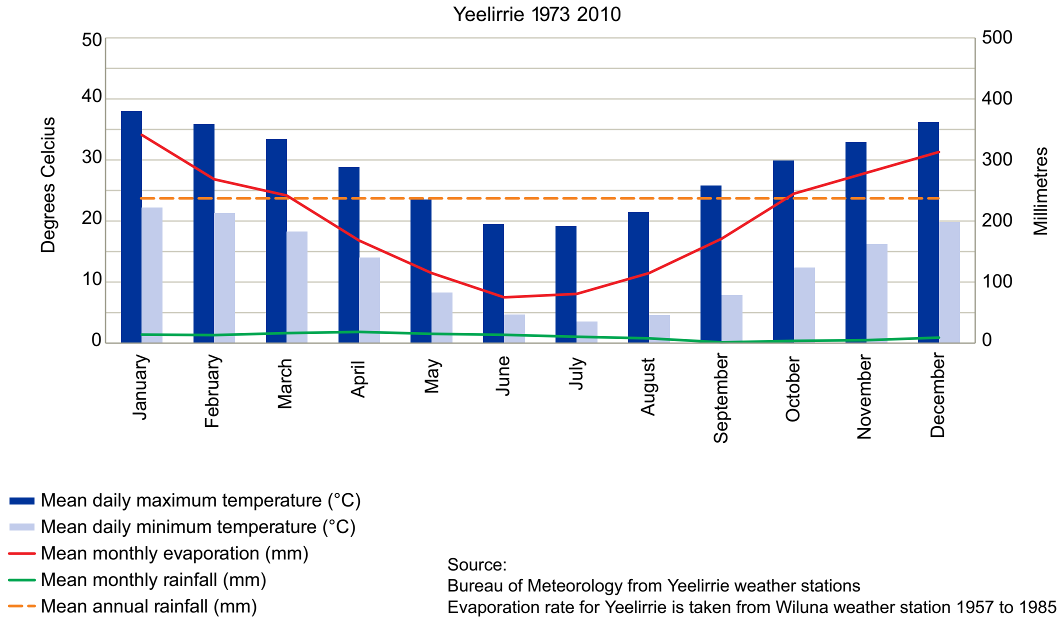
Summer rains are normally of high intensity, caused by localised thunderstorm activity or much larger weather systems associated with cyclones and tropical lows. On average, there are 42 rain days per year at Yeelirrie.

Rainfall is overwhelmed by the large evaporation rates that exist in the area (Figure 7-3). The Wiluna BoM Station (No. 013012, 1957 to 1985) recorded an average pan evaporation rate of 2,412 mm a year. The next closest meteorological station, Meekatharra Airport (BoM Station No 007045), recorded a mean annual pan evaporation rate of 3,548 mm. In the absence of evaporation data at Yeelirrie, long term (1889 to 2014) BoM SILO (Scientific Information for Land Owners) database, synthetic rainfall and evaporation data were generated for the Yeelirrie catchment, with an average annual pan evaporation rate of 2,918 mm predicted.

In the lower-lying valley floor areas of the Yeelirrie catchment (at the proposed mine site), evapotranspiration from the shallow water table is significant. Evapotranspiration would occur as evaporation from bare soils above the shallow water table and as transpiration by phreatophytic vegetation (groundwater-dependent vegetation) in areas where water table depths and groundwater salinity accommodated such vegetation. This natural phenomenon and its implications for seepage from the open pit, tailings storage areas and stockpiles are discussed further in Section 9.5.5.

Table 7-2: Summary of monitoring data from Bureau of Meteorology monitoring station at Yeelirrie

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Rainfall (mm) (1928 – 2014)													
Ave. rainfall	29.7	31	31.4	24.4	25.3	22.8	17.4	12.4	4.8	9.7	10.1	20.4	239
Temperature (°C) (1973 – 2014)													
Mean max	37.9	35.9	33.2	29.0	23.5	19.5	19.3	21.7	25.8	30.1	33.0	36.1	28.8
Mean min	22.2	21.3	18.2	13.9	8.3	4.7	3.5	4.7	7.9	12.6	16.3	19.9	12.8
Max	47.9	46.0	44.0	38.5	36.8	29.9	28.6	33.4	37.5	41.5	43.2	45.4	47.9
Min	12.0	10.0	6.0	3.0	-2.8	-5.0	-5.1	-4.8	-2.2	-0.4	1.9	7.6	-5.1
Solar Exposure (MJ/m^2) (1990 – 2010)													
Mean daily	27.8	24.5	21.6	17.3	14.3	12.3	13.5	17.4	21.8	25.4	28.0	28.8	21.1
Relative Humidity (%) (1973 – 2010)													
Mean 9am	34	42	43	52	59	68	66	56	44	36	33	32	47
Mean 3pm	21	27	27	34	37	42	41	33	26	20	19	19	29



Source:
Bureau of Meteorology from Yeelirrie weather stations
Evaporation rate for Yeelirrie is taken from Wiluna weather station 1957 to 1985

Figure 7-3: Climatic averages

7.4.1 Climate Change

The report by CSIRO and the BoM regarding climate change in Australia (CSIRO, BoM 2007) suggests that Australia is likely to experience higher mean temperatures and more frequent spells of dry days but more intense rainfall. Australian mean temperatures have increased by 0.9°C since 1950, accompanied by an increase in the frequency of heatwaves and a decrease in the number of frosts and cold days. Across Western Australia, temperatures have increased by about 0.8°C since 1910. Most of this warming has occurred since 1950 at an average increase of 0.14°C per decade (IPCC 2007).

Yeelirrie is located in the Rangelands South subdivision as defined by CSIRO and BoM (2007). In this region, natural variability in rainfall is projected to predominate over trends due to global warming in the future. Changes to summer rainfall are possible but unclear and winter rainfall is expected to decrease with high confidence under both intermediate and high greenhouse gas emission scenarios. An increase in the intensity of extreme rainfall events is predicted with high confidence (CSIRO, BoM 2007).

The report indicates there is very high confidence that average temperatures will continue to increase in all seasons. By 2030, there is expected to be an increase in annually averaged temperatures of between 0.6 and 1.4°C under all emission scenarios. There is very high confidence that extreme (hot) temperatures will increase at a similar rate to mean temperatures (CSIRO, BoM 2007).

These estimates correspond well with those of the Intergovernmental Panel on Climate Change (IPCC 2007), namely that for an area such as Yeelirrie, the temperature by 2020 is likely to increase by between 0.1 and 1.3°C above 1990 levels. It further forecasted that the temperature increase would range from 0.3 to 3.4°C by 2050 and from 0.4 to 6.7°C by 2080.

These predictions suggest that groundwater levels and groundwater available in storage may reduce as a longer-term response to lesser groundwater recharge and higher groundwater discharge by evapotranspiration.

Changes to rainfall intensities due to global warming would affect the peak (flood) flows within the Yeelirrie valley. For example, an increase in rainfall intensity of 2% would be expected to increase 20-year ARI (average recurrence interval) flows by 16%. As changes such as these would affect the management of storm-related aspects of the Yeelirrie project, flood modelling for a range of different climate change scenarios has been undertaken (Section 9.4.5).

7.5 Geology

The Northern Goldfields area, in which the Project Area is located, is underlain by weathered and fractured Archaean bedrock, which forms the northern portion of the 'Fractured-Rock Groundwater Province' of the Yilgarn Goldfields (Johnson *et al.* 1999).

A deeply incised palaeodrainage system traverses the region, including a palaeochannel system traversing the length of the Yeelirrie catchment (see Figure 7-4), which forms part of the Carey Palaeodrainage. The Yeelirrie palaeochannel consists of fractured rock, palaeochannel sand and alluvium that has washed down from the top and sides of the catchment basin, as well as surficial calcrete bodies that have formed since in the central portion of the valley (see Figure 7-5). It is within these calcrete bodies that the uranium mineralisation is localised.

7.5.1 Archaean Stratigraphy

The Yilgarn Craton is of Archaean origin and comprises metamorphic, igneous and sedimentary rocks (greenstone belts), and intrusive granitoids (Johnson *et al*. 1999). It forms a plateau surface varying between 200 and 600 m above sea level, known as the Old Plateau or Yilgarn Plateau (Beard 1998).

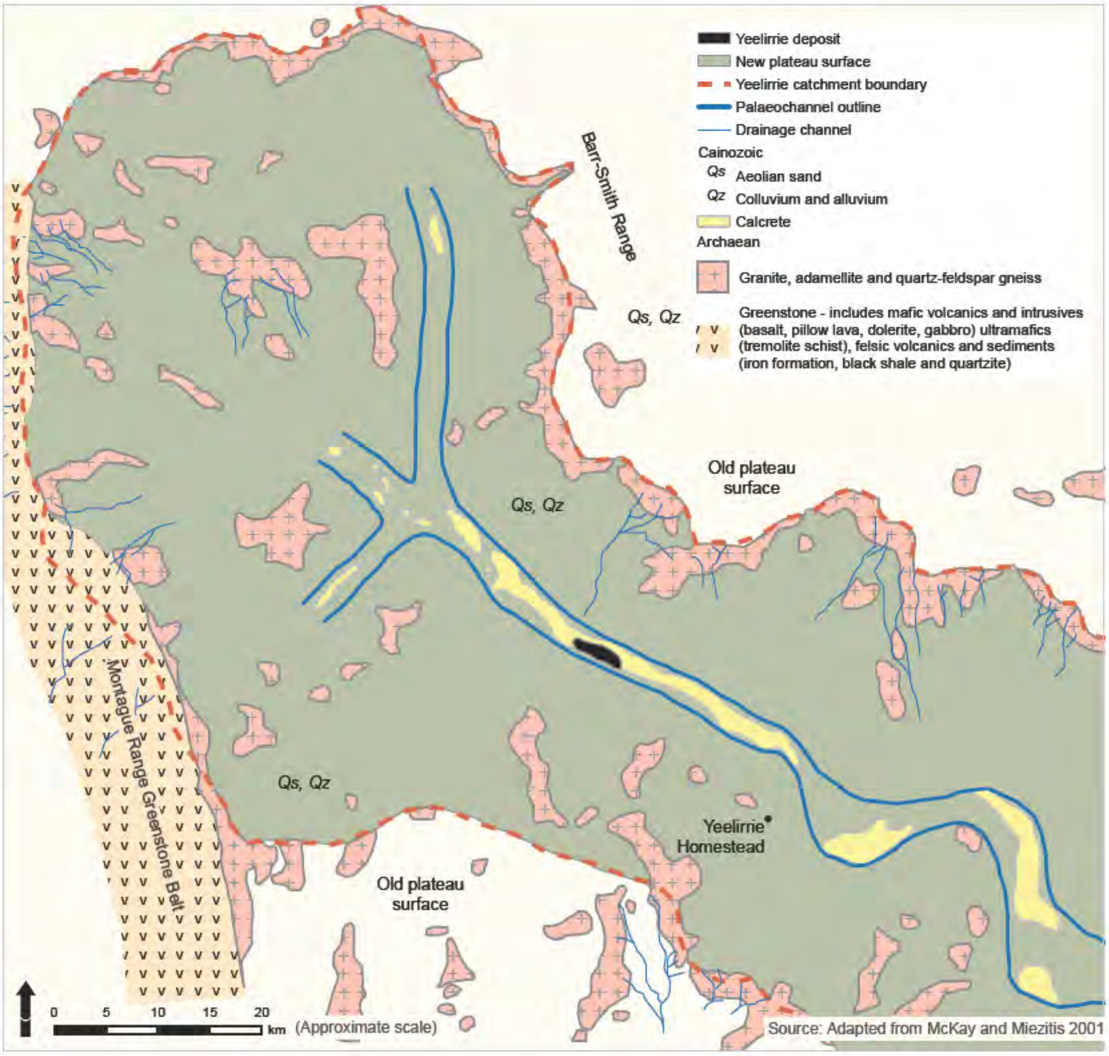


Figure 7-4: Yeelirrie deposit showing north west trending palaeochannel

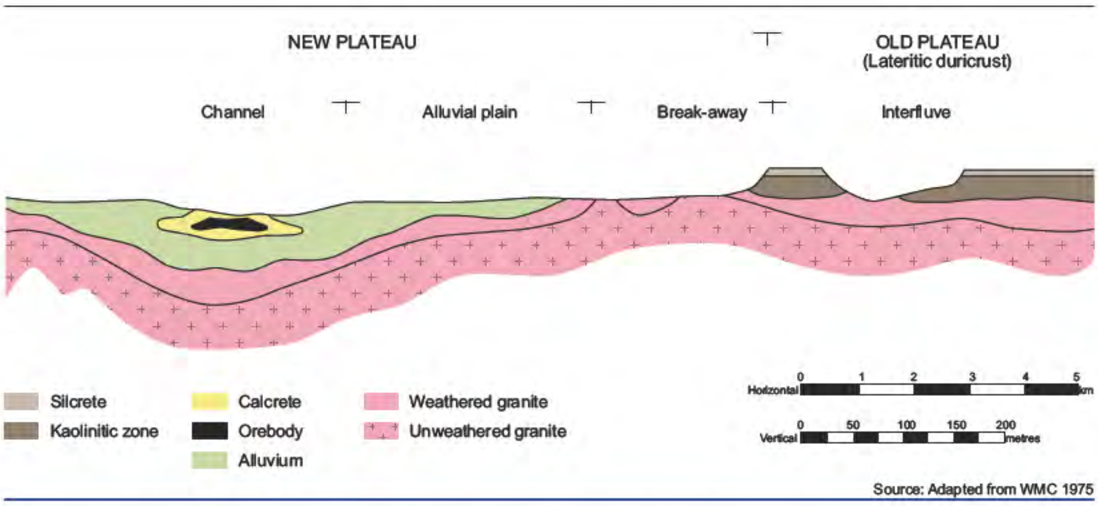


Figure 7-5: Diagrammatic geomorphic profile of the Yeelirrie deposit

Most of the Archaean rocks in the northern and eastern Goldfields have a weathered profile resulting from chemical breakdown of the crystalline bedrock. The depth of weathering in the greenstones generally extends to about 50 m below the surface but in some areas may exceed 100 m. Weathering of the granitoid rocks is generally less than 40 m deep, although deeper sections have been observed along shear zones and below the palaeodrainages.

The weathering profiles on the greenstones and granitoids generally comprise a Permian lateritic duricrust at the surface underlain by a variable thickness of dense, kaolinitic clay. In such instances, the clay grades downward into a zone of weathered and fractured bedrock with fracturing enhanced by secondary chemical dissolution and joints commonly in-filled with clay. Below the weathering zone, there is a sharp contact with fresh, sparsely fractured bedrock with fracturing decreasing with depth.

7.5.2 Mesozoic Stratigraphy

During the late Mesozoic (Cretaceous Period), the Yilgarn Craton and associated land masses experienced very humid (high rainfall) conditions when the area was drained by extensive river systems flowing south east towards a shoreline considerably more inland than current.

The palaeodrainage valleys, which were eroded into the Old Plateau during this time form a well-integrated, contributory pattern, are typically subrectangular to rectangular in shape, 20 to 100 km wide, and are of very low gradient and relief (de Broekert and Sandiford 2005). The bedrock floor of these valleys is described as the New Plateau and lies 10 to 100 m below the Old Plateau, sometimes outcropping through the younger sediments.

7.5.3 Cenozoic

Cenozoic sedimentary deposits have long-since in-filled the palaeovalleys. The sediments typically comprise a basal fluvial sand overlain by lacustrine clay, with inter-fingering sequences of alluvium and minor colluvium that is locally replaced or displaced by calcrete. Outwash fans on the flanks of the trunk valleys overlie these sediments. The thickness of the alluvial fill is highly variable, ranging from a thin veneer (Johnson *et al*. 1999) to 85 m thick in terminating salt lakes downstream.

Investigations into the age of the sediments that fill these palaeovalleys indicate that they began to fill quite rapidly in the middle to late Eocene (de Broekert and Sandiford 2005). This is thought to correspond with the separation of Australia and Antarctica and increasing aridity (Magee 2009). The arid conditions have given rise to hydrologic stagnation, landscape salinisation and deposition of evaporite sediments, such as calcrete and gypsum (Magee 2009).

7.5.4 Palaeosands

The basal fluvial sand occurs as a sinuous stringer sand unit, bounded by relatively steep topography, on the underlying Archaean bedrock surface and may be up to 40 m thick and 100 to 1,000 m wide (Johnson *et al.* 1999). These palaeosands are often sought after as they often contain a useable groundwater resource and are highly transmissive. Section 9.5.4 provides a more detailed description of the basal palaeosand aquifer that underlies the Yeelirrie deposit.

7.5.5 Calcrete

In Australia, surficial (on or near Earth's surface) uranium deposits, such as the Yeelirrie deposit, are typically found in calcrete. The other main uranium-bearing calcrete deposits are Lake Way, Lake Maitland and Centipede in the Yilgarn Craton in Western Australia.

Calcrete is a carbonate rock formed by the in situ replacement or displacement of the alluvial and colluvial deposits by magnesium and calcium carbonate precipitated from percolating carbonate-saturated groundwater. The source of the carbonate-rich groundwater is believed to be related to the alteration and decomposition of ultramafic minerals in greenstone rocks, and the precipitated carbonate mineral is generally calcite rather than dolomite.

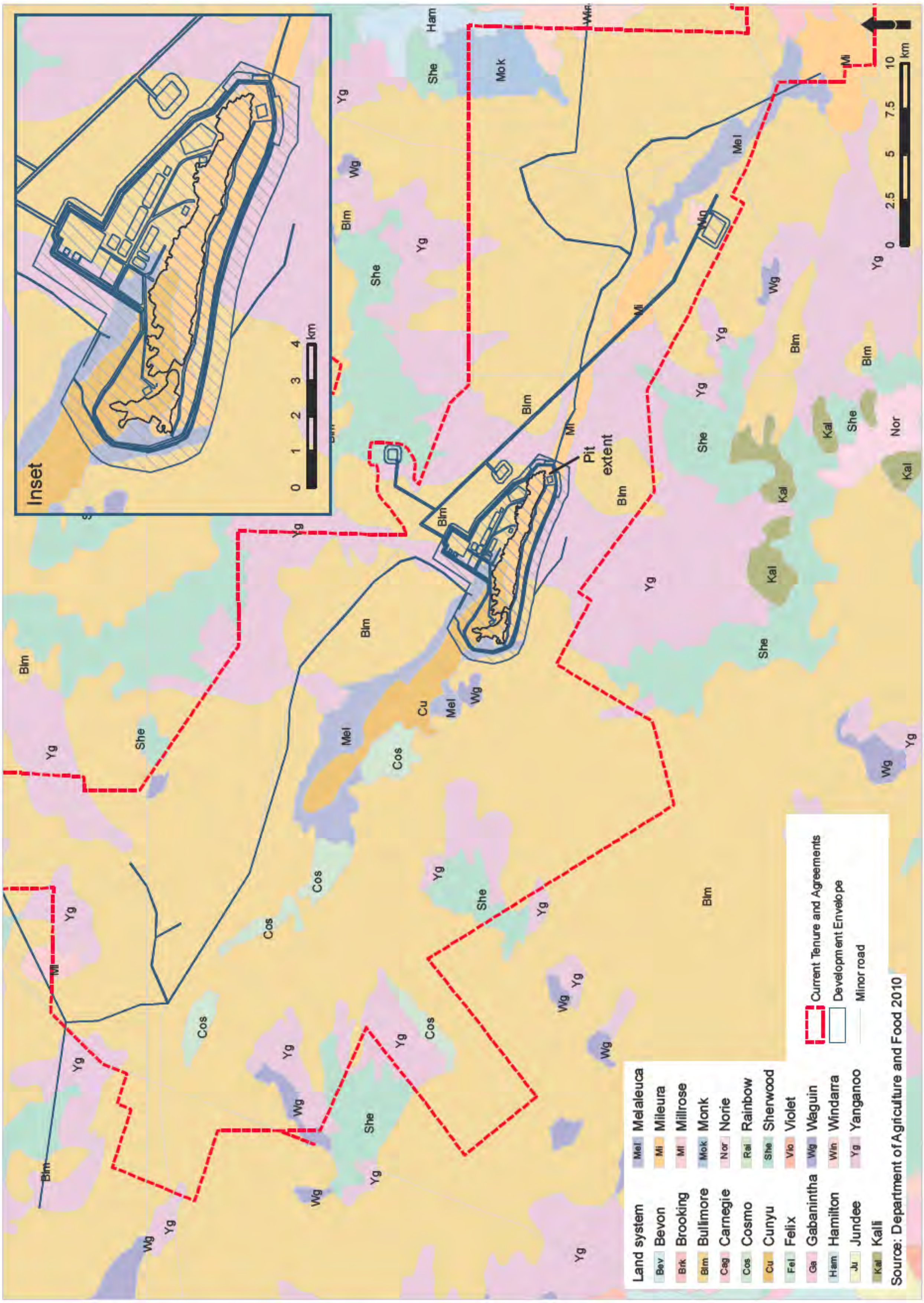


Figure 7-6: Land systems of the Yeelirrie region

The calcrete also contains uranium, vanadium, potassium and iron, which were leached into the groundwater from the surrounding granitic rocks of the Yilgarn Block over millions of years and then precipitated along with the carbonates as the calcrete slowly formed (Needham 2009).

Bodies of calcrete generally occur at the margins of present-day salt lakes, and locally in some of the main tributaries in the palaeochannels (see Figure 7-4). Owing to their porous and/or fractured nature and their location in the landscape, calcrete bodies often have quite high potential to store groundwater and are often used as groundwater resources.

Within the central part of the Yeelirrie drainage valley, calcrete has formed over extensive areas, occasionally up to 6.5 km long and 20 m thick, with the latter appearing to vary in response to the depth of the Achaean basement.

7.5.6 Surface Alluvium and Evaporites

In addition to calcrete deposits and outcrops, the valley floor areas of the Yeelirrie palaeovalley are commonly characterised by clay pans, hardpan and comparatively small-scale playas, such as the Yeelirrie Playa. Gypsum is relatively abundant in the upper soils. The surface alluvium may be of either aeolian or fluviatile origin and is discussed in more detail in Section 9.10.4.

7.6 Land Systems, Landforms and Soils

Mapping of the Soil-Landscape Systems of Western Australia's rangelands and arid interior was conducted by the Department of Agriculture during the 1980's and 90's. The mapping has been recently updated with the methodology and changes outlined by Tille (2006) (Figure 7-6). The Land Systems present in the area surrounding the Proposal are:

- Sherwood System – Breakaways, kaolinitic footslopes and extensive gently sloping plains on granite supporting mulga shrublands and minor halophytic shrublands.
- Bullimore System – Gently undulating sand plain with occasional linear dunes and stripped surfaces supporting spinifex grasslands with mallee and acacia shrubs.
- Yanganoo System – Almost flat hardpan wash plains, with or without small wanderrie banks; supporting mulga shrublands and wanderrie grasses on banks.
- Melaleuca System – Sandy-surfaced plains and calcareous plains supporting spinifex or mulga shrublands with wanderrie grasses.
- Cunyu System – Calcrete platforms, intervening drainage floors and channels and minor alluvial plains, supporting acacia shrublands, occasional casuarina woodlands and minor halophytic shrublands.
- Mileura System – Saline and non-saline calcretised river plains with flood plains and calcrete platforms supporting variable tall shrublands, mixed halophytic shrublands and shrubby grasslands.
- Cosmo System – Calcretised drainage tracts through sand plain with spinifex hummock grasslands and occasional mulga open woodlands.
- Waguin System – Sand plains and stripped granite or laterite surfaces with low fringing breakaways and lower plains; supports bowgada and mulga shrublands with wanderrie grasses and minor halophytic shrublands.
- Hamilton System – Hardpan plains, stony plains and incised drainage lines supporting mulga tall shrublands.
- Kalli System – Elevated gently undulating red sand plains edged by stripped surfaces on laterite and granite, supporting acacia tall shrublands with wanderrie grass understoreys.
- Windarra System – Gently undulating stony plains and low rises with quartz mantles on granite, supporting acacia-eremophila shrublands.

- Monk System – Hardpan plains with occasional sandy banks supporting mulga tall shrublands and wanderrie grasses.

The dominant Soil-Landscape Systems within the Project Area are the Cunyu, Mileura, Melaleuca, Bullimore and Yanganoo Systems. These five systems are defined by the wide, flat and long drainage valley of sand plains and calcrete platforms, the central axis of which hosts the uranium deposit, and the flanking granitic breakaways which bound the valley system. The gradients present within the valley system are uniformly low, with overall slopes of the sand plains perpendicular to the drainage axis up to the granite breakaways < 5%, the central valley floor < 1 % and the gradient along the drainage axis < 0.1%.

The palaeovalley has been in filled by Tertiary and Quaternary aged alluvium, generally of aeolian and/or fluvial origin. Typical stratigraphy across the valley area consists of clay loams overlying calcrete and transitional calcrete which are underlain by Cainozoic aged variously compacted clayey to silty sands/sandstones. The upper profile soil materials comprise a mixture of loamy clays, silty sands and hard pan clays with occasionally outcropping calcrete which form clay pans, hardpans and small-scale playas respectively.

7.7 Natural Hazards

7.7.1 Fire

Fire is a natural part of the Australian landscape with many of the fires in remote areas such as the Murchison started by lightning strikes. The Aboriginal people have also used fire for thousands of years as part of their traditional land management practices. However, with the arrival of Europeans the patterns, frequency and intensity of fires has changed, resulting in changes to floristic and faunal characteristics (DEC *et al*. 2011). Fires, whether naturally occurring or as a result of human activities, can also pose a threat to human life and property.

Some vegetation communities such as mulga (*Acacia aneura*) shrublands are considered to be "fire sensitive" where adult plants are killed if the entire canopy is burnt during very hot fires (Latz 1995). However, many Acacia species regenerate from seed following fire. In spinifex-dominated communities, fire management aimed at providing a mosaic of fuel ages and vegetation structure is considered important to enhance and maintain species diversity (DEC *et al*. 2011).

Official fire records in the Yeelirrie area are limited, although a recent history has been obtained from the Landgate FireWatch Program (Landgate 2010). The last recorded fire in the Project Area was in December 2007, when 54 km^2 was burnt.

7.7.2 Drought

Drought is a natural hazard common to many parts of Australia, including the area of the proposed Yeelirrie development. However, as outlined in Section 7.4 the area has experienced a general trend of increasing rainfall since the 1950s.

The BoM defines a period of drought as when rainfall for three consecutive months or more lies in the lowest 10% of values recorded for that area. Using this definition it can be calculated that in the past 60 years there have been 13 periods of drought according to rainfall data collected by the Yeelirrie BoM Station (No. 012090). These droughts occurred during the following periods:

- June – September 2014
- July – September 2012
- May – July 2006
- January – March 2005
- October 1993 – January 1994

- December 1990 – February 1991
- September – December 1985
- February – April 1977
- June – August 1969
- September 1961 – January 1962
- January – March 1959
- November 1955 – February 1956
- July – September 1950.

While these droughts are distributed throughout the year, the majority occur from December to February.

Water supplies for the Project will be from groundwater sources including dewatering, although an extensive system of water recycling will be incorporated into the metallurgical plant design to conserve water (Section 6.6.3).

7.7.3 Dust Storms

Dust and dust storms are a common feature of the region in which the Project Area is located. In extreme events, they can persist for many hours and mobilise significant quantities of soil and debris. There is a clear relationship between dust storms and both drought condition and fire. However, the frequency of such events is highly variable, while the intensity is more predictable.

In Australia, the intensity of dust storms is classified by means of a Dust Storm Index (DSI) (current version referred to as DSI3; McTainsh and Tews 2007). This has been developed to evaluate the occurrence and severity of dust storms. DSI values have been related to droughts and fire events. The Murchison bioregion has a mean DSI value (1992–2005) of 1.43, which is considered low relative to arid areas or areas in which soil erosion is extensive.

The management of dust emissions from the Project is an important aspect from a radiation management and health and safety perspective (Section 9.6.5).

7.7.4 Tropical Cyclones and Storm Events

Tropical cyclones are low pressure systems that form over warm tropical waters and produce sustained gale force winds of at least 63 km/ hr and gusts in excess of 90 km/hr. Severe tropical cyclones produce sustained hurricane force winds of at least 118 km/hr and gusts can exceed 280 km/hr. During the cyclone season (typically November to April), an average of 13 tropical cyclones develop over Australian waters, mostly over the northwest of Western Australia and northeast Queensland. Of these, approximately 25% cross the coast in the western and eastern basins, whilst around 80% of those cyclones in the northern basin make landfall. However, there may be considerable variability in cyclone numbers from year to year (http://www.bom.gov.au/cyclone/about/ accessed 7 January 2015).

The National Climate Centre of the Bureau of Meteorology has collated a southern hemisphere tropical cyclone archive consisting of cyclone track data for a 36 year period from 1969/70 to 2005/06 (http://reg.bom.gov.au/jsp/ncc/climate_averages/tropical-cyclones/index.jsp?period=eln#maps accessed 7 January 2015). This dataset shows the average number of cyclones per cyclone season in El Niño years, La Niña years, neutral years and all years. The Project Area is located in a region which experiences an average of 0.1 to 0.2 cyclones (or tropical depressions) per year when considering data from all years (i.e. up to one cyclone every five years). However, this frequency may increase to 0.2 to 0.4 cyclones per year in years that experience a La Niña event. BoM data indicates that between 1970 and 2000, 13 cyclones have passed within 200 km of Yeelirrie.

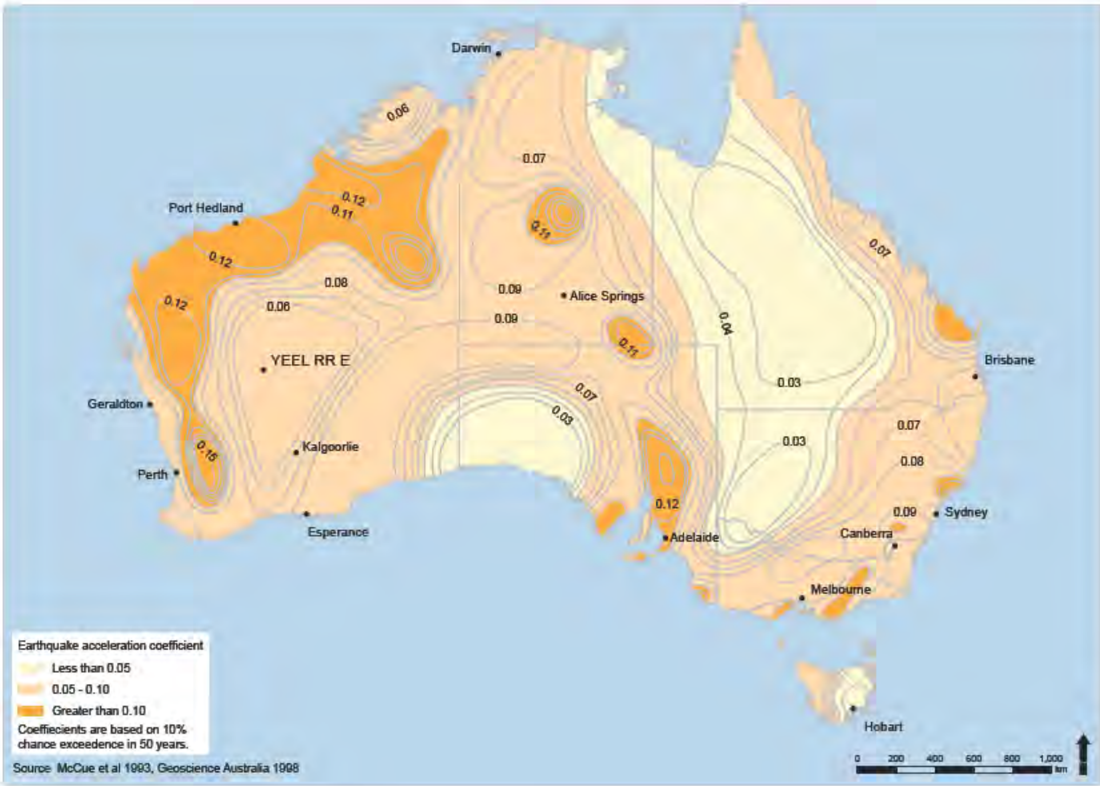


Figure 7-7: Earthquake risk

Severe thunderstorms can occur anywhere in Australia and are more common between September and March in the northern part of Australia. A severe thunderstorm is defined by the Bureau of Meteorology as one which produces hail greater than 2 cm in diameter, wind gusts of 90 km/h or greater, flash flooding and/or tornadoes (http://www.bom.gov.au/info/thunder/ accessed 7 January 2015).

Cameco has taken the risk of cyclonic weather and severe storms into consideration in the design of stormwater management structures (Section 9.4.5) and will ensure buildings and other structures are designed and built to withstand extreme climatic conditions. Under the *Mines Safety and Inspection Act 1994*, Cameco will also be required to prepare emergency plans and procedures that include actions to be undertaken in the threat of cyclonic or storm activity.

7.7.5 Seismic Activity

The effects of an earthquake will depend on its magnitude and on physical factors such as geology. Acceleration coefficients, which relate to the level of ground shaking that occurs following a seismic event, are used in engineering calculations to estimate the force exerted on a built structure. At an acceleration coefficient of 0.1, poor-quality buildings would be damaged, but appropriately designed and constructed buildings would not be affected (Standards Australia 1993).

The Project is located in a part of Western Australia that experiences low seismic activity. Contours of acceleration coefficients for Australia (see Figure 7-7) indicate that seismic events with acceleration coefficients of 0.05 could be experienced at Yeelirrie (Gaull *et al.* 1990). The probability that these figures would be exceeded is low, with a 10% chance of an event occurring in 50 years.

The only significant earthquake in the Murchison bioregion since 1950 was a magnitude 5.7 event, which occurred on 18 June 1969, with the epicentre located approximately 380 km north west of Yeelirrie and 300 km east of Carnarvon (Geoscience Australia, 2015).

The seismicity of the region has been taken into account in the design of key structures such as the pit and the tailings storage facility.

Section 8

Assessment Framework

8. Assessment Framework

8.1 EPA Guidelines for Environmental Assessment

Under the Western Australian EP Act, the EPA is required to identify, in its report to the Minister for Environment, what it considers to be the key environmental factors identified in the course of an assessment. The EPA uses environmental factors and associated objectives as the basis for assessing whether a proposal or scheme's impact on the environment is acceptable. Environmental Assessment Guideline No. 8 (EAG8) (EPA 2015a) sets out the EPA's environmental principles, policies, factors and associated objectives for the purposes of assessing environmental impacts.

Environmental Assessment Guideline No. 9 (EAG9) (EPA 2015b) outlines the EPA's 'Significance Framework' to determine the likely significance of a proposal and to inform decisions throughout the environmental impact assessment (EIA) process – from the EPA's decision on whether or not to assess a proposal, through to its recommendations to the Minister for Environment on whether or not a proposal should be implemented, and the recommended implementation conditions. The EPA has determined that the Yeelirrie Uranium Project will be assessed as a PER.

Cameco has applied these two guidelines to identify the key environmental factors for the Project and determine where mitigation measures will be required to minimise potential impacts.

The Environmental Scoping Document (ESD) for the Project was prepared by the OEPA in consultation with the key regulators (notably DPaW, DMP, DoW and DER) and was finalised on 10 April 2015. For this assessment, the EPA has identified the following key environmental factors that require assessment (Table 8-1, Appendix A1):

- Flora and vegetation
- Human health
- Subterranean fauna
- Terrestrial fauna
- Hydrological processes / Inland waters environmental quality
- Air quality and atmospheric gases
- Terrestrial environmental quality
- Heritage
- Rehabilitation and decommissioning
- Offsets.

The ESD outlines the required Scope of Works (Appendix A1). This PER has been prepared in accordance with this Scope of Works.

The 'Hydrological Processes' and 'Inland Waters Environmental Quality' factors address both surface water and groundwater impacts. As the impacts of the Project on surface water and groundwater are quite different, these have been discussed in separate sections Section 9.4, (Surface water) and Section 9.5 (Groundwater).

Key factors are addressed in Section 9, with the exception of Offsets which is addressed in Section 12. During assessment of proposals, other factors may be identified that are relevant to a proposal, but not of significance to warrant further assessment by the EPA, or impacts can be regulated by other statutory processes. For this assessment, the EPA has identified the other factor of 'Amenity' in relation to noise and access to roads. The potential impacts of the Project on local and regional amenity are discussed in Section 11.

Table 8-1: Environmental factors (EPA 2015a)

Theme	Factor	Objective	Applicability/ Significance to Project
Land	Flora and Vegetation	To maintain representation, diversity, viability and ecological function at the species, population and community level.	Key factor
	Landforms	To maintain the variety, integrity, ecological functions and environmental values of landforms and soils.	Other factor
	Subterranean Fauna	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.	Key factor
	Terrestrial Environmental Quality	To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.	Key factor
	Terrestrial Fauna	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.	Key factor
Water	Hydrological Processes	To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.	Key factor
	Inland Waters Environmental Quality	To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.	Key factor
Air	Air Quality	To maintain air quality for the protection of the environment and human health and amenity.	Key factor
People	Amenity	To ensure that impacts to amenity are reduced as low as reasonably practicable.	Other factor
	Heritage	To ensure that historical and cultural associations are not adversely affected.	Key factor
	Human Health	To ensure that human health is not adversely affected.	Key factor
Integrating Factors	Offsets	To counterbalance any significant residual environmental impacts or uncertainty through the application of offsets.	Key factor
	Rehabilitation and Decommissioning	To ensure that premises are closed, decommissioned and rehabilitated in an ecologically sustainable manner, consistent with agreed outcomes and land uses, and without unacceptable liability to the State.	Key factor

8.2 Matters of National Environmental Significance

Under the Commonwealth EPBC Act, the Federal DoE is required to assess proposals which are likely to have a significant impact on matters of national environmental significance protected under the Act. These matters are:

- world heritage properties;
- national heritage places;
- wetlands of international importance (listed under the Ramsar Convention);
- listed threatened species and ecological communities;
- migratory species protected under international agreements;
- Commonwealth marine areas;
- the Great Barrier Reef Marine Park;
- nuclear actions (including uranium mines); and
- a water resource, in relation to coal seam gas development and large coal mining development

The matters of national environmental significance that are relevant to this Project are 'listed threatened species and ecological communities', 'migratory species protected under international agreements' and 'nuclear actions'. These are discussed in detail in Section 10.

8.3 Hazard and Risk Assessment Approach

BHP Billiton undertook a qualitative risk assessment for developing the Project. The risk assessment followed the methodology and processes outlined in Australian and New Zealand Standard AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. The risk assessment was used to complement the EIA process and looked at the risks of potential failures of unplanned events.

The risk assessment process involved establishing the context, risk identification, risk analysis, risk evaluation and risk treatment. A set of Consequence[1] and Frequency[2] look-up tables were used during the risk assessment workshops to provide consistency throughout the process. Risks were categorised as:

- Extreme - considered unacceptable, immediate action required to reduce risk to a tolerable level;
- High - considered unacceptable, action required to reduce risk in accordance with the principles of ALARP;
- Medium - risk is tolerable, action is desirable to reduce risk in accordance with the principles of ALARP;
- Low - risk is acceptable, managed by routine processes.

Key Project risks identified by BHP Billiton related to water management, flora and vegetation, cultural heritage, terrestrial fauna, rehabilitation and closure, stakeholder engagement, radiation management and emergency response (e.g. in relation to a transport incident). There was considered insufficient information (at the time of BHP Billiton's assessment) to complete the risk assessment for impacts to subterranean fauna, invertebrate fauna and groundwater dependent ecosystems.

Cameco has reviewed the outcomes of BHP Billiton's risk assessment, and undertaken further work on significant flora, subterranean fauna and invertebrate fauna, to identify the following key risks for the revised Project (Table 8-2).

Detail of the impact assessment and proposed management measures for these key risks are discussed in detail in Section 9.

1 Consequence is defined as a measure of the magnitude of the impact from a risk event, should it occur.

2 Frequency (or likelihood) describes how often an event might occur.

Table 8-2: Key risks identified by Cameco for the Yeelirrie Project

Aspect	Inherent Risk	Management	Residual Risk
Atriplex sp. Yeelirrie Station (Threatened) (Section 9.1)	Loss of genetic diversity of the species by the removal of one population of *Atriplex* sp. Yeelirrie Station on the orebody.	Permanent protection of the other population of *Atriplex* sp. Yeelirrie Station. Ongoing research on all aspects of the plant eco-physiology to inform a translocation plan. Develop and implement a threatened species recovery plan	Medium to Low Sufficient work has been completed to indicate, with a reasonable level of confidence, that sustainable replacement populations can be estalished to maintain long term genetic diversity.
Subterranean fauna (Section 9.2)	That mining and groundwater production will have a significant impact on stygofauna.	Extensive sampling has been conducted. 115 subterranean species in total have been recorded in the Yeelirrie study area, which approximately matches the extent of Cameco's tenements at Yeelirrie. 10 species of stygofauna and five species of troglofauna are currently known only from areas where the extent of habitat will be reduced by development of the Yeelirrie Project. Moderately robust inferences may be drawn from the distribution patterns of related species and proximity of recorded species occurrences to the boundary of disturbance areas that eight of the 15 species may occur beyond the areas impacted by mining and groundwater abstraction. Management of groundwater abstraction to minimise the drawdown across the Project Area and therefore reduce the overall impact on the vertical habitat.	Medium Seven species out of the 109 species recorded may be restricted to the impact zone.
Yeelirrie Calcrete Priority Ecological Community (PEC) (Section 9.2)	That groundwater production will have an impact on the Yeelirrie Calcrete PEC. Approximately 37% of the calcrete habitat within the PEC will experience groundwater drawdown of >0.5 m as a result of groundwater production.	Management of groundwater abstraction to minimise the drawdown across the Project Area and therefore reduce the overall impact on the vertical habitat.	Medium

Aspect	Inherent Risk	Management	Residual Risk
Radiation (Radon gas) (Sections 9.6 and 9.8)	That levels of radon gas in the atmosphere might build up to unsafe levels in the open pit during periods of temperature inversions.	Modelling of radon gas in the open pit under stable atmospheric conditions (as would occur under an inversion) was conducted under worst case conditions (maximum hours in the pit under the worst case inversion) and showed that the maximum worker dose from Radon gas would be 4mSv/yr. Real time radon monitors would be established to confirm radon gas levels in the open pit and workers rotated or removed as required to minimise dose.	Low Radiation dose calculations suggest that radon gas would form about half of the overall dose to workers. Dose calculations are based on first principles and are extremely conservative. Real doses are expected to be less than half of the calculated dose.
Radiation contamination of public roads (Section 9.6)	Radioactive contaminated soil may be transferred out of the mine site onto public areas on the tyres and wheels of trucks and light vehicles.	Implementation of management measures to separate "clean" vehicles from "dirty" vehicles limiting each classification to the designated areas. Contaminated vehicles (vehicles that traffic on radioactive material) will not be allowed to enter "clean" areas or leave the site without decontamination.	Low Radiation levels are inherently low. Properly implemented procedures will ensure contaminated vehicles remain within contaminated areas.
Radiation contamination of soils, surface water and groundwater (Section 9.6)	Contamination of soils, surface water runoff and groundwater from active mine areas.	Implementation of radiation, dust and surface water management measures.	Low Project has been designed to minimise radiation risk.
Terrestrial fauna (Sections 9.3 and 10.1)	Terrestrial and avian fauna may consume contaminated water from tailings storage facilities and evaporation ponds resulting in the death of wildlife.	The input water quality is generally poor with initial salinities approaching sea water quality. Evaporation will result in salinity levels two to three times higher than discharge levels is making the water unpalatable. Implementation of management measures including fencing the facilities, bird scare horns and mirrors will also act as a physical deterrent.	Low

Aspect	Inherent Risk	Management	Residual Risk
Safe long term closure of the tailings storage facility (Sections 6.13, 9.5, 9.10 and 9.12)	That the closure and rehabilitation of the TSF will be unsuccessful, resulting in releases of radioactive tailings to groundwater and the environment.	Cameco has designed the mine plan to allow for in pit storage of tailings. Extensive studies have confirmed the hydrogeology is suitable for construction of an in-pit TSF. The TSF has been designed with low permeability floor and walls, with an under-draingage system to capture seepage. Suitable cover materials is also available to cover and rehabilitate the TSF. Surface water hydrology studies and landform evolution modelling have been completed confirming that in pit disposal provides long term security and integrity of the TSF.	Low

9. Environmental Factors

9.1 Flora and Vegetation

9.1.1 EPA Objective

The EPA's objective for flora and vegetation is:

- To maintain representation, diversity, viability and ecological function at the species, population and community level.

9.1.2 Relevant Legislation and Policy

Relevant legislation and policies to the Project are:

Wildlife Conservation Act 1950

All native plants in WA are protected under the WA *Wildlife Conservation Act 1950* (WC Act). Any activity which involves taking part of or the whole of a native plant may require a licence or permit to do so. Little known or threatened flora are given special protection under this Act and the following conservation categories may be applied to certain species:

> T: Threatened flora - Specially protected under the WC Act, listed under Schedule 1 Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora). Species which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.
>
> X: Presumed extinct flora - Specially protected under the WC Act, listed under Schedule 2 of the Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora. Species which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such

Threatened Flora are further recognised by DPaW according to their level of threat using IUCN Red List[1] criteria as follows:

> Critically Endangered (CR): Considered to be facing an extremely high risk of extinction in the wild.
>
> Endangered (EN): Considered to be facing a very high risk of extinction in the wild.
>
> Vulnerable (VU): Considered to be facing a high risk of extinction in the wild.
>
> Extinct (EX): There is no reasonable doubt that the last individual has died.

One species of Threatened Flora *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) is present within the Study Area and is listed as Vulnerable – D2[2] (Section 9.1.4). This species has also been nominated for listing under the EPBC Act. Taking of Threatened Flora cannot occur without special permission from the WA Minister for the Environment.

DPaW also produces a list of Priority species under the WC Act. Priority flora categories are as follows:

> **Priority One:** Poorly-known taxa. Taxa that are known from one or a few collections or sight records (generally less than five), all on lands not managed for conservation and under threat of habitat destruction or degradation. Taxa may be included if they are comparatively well known

1. International Union for Conservation of Nature (IUCN) Red List of Threatened Species is a global program that evaluates the conservation status of plant and animal species. The Red List identifies particular species at risk of extinction (see http://www.iucnredlist.org/technical-documents/categories-and-criteria).
2. Population with a very restricted area of occupancy (typically less than 20 km^2) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period.

from one or more localities but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes.

Priority Two: Poorly-known taxa. Taxa that are known from one or a few collections or sight records, some of which are on lands not under imminent threat of habitat destruction or degradation (e.g. national parks, conservation parks, nature reserves, State forest, vacant Crown land, water reserves, etc.). Taxa may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes.

Priority Three: Poorly-known taxa. Taxa that are known from collections or sight records from several localities not under imminent threat, or from few but widespread localities with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Taxa may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and known threatening processes exist that could affect them.

Priority Four: Rare, Near Threatened and other taxa in need of monitoring. (a) Rare: Taxa that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands; (b) Near Threatened: Taxa that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable; (c) Other: Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

Priority Five: Conservation Dependent taxa. Taxa that are not threatened but are subject to a specific conservation program, the cessation of which would result in the taxa becoming threatened within five years.

Proponents that intend to disturb Priority flora should first consult with DPaW regarding the impact of the proposal on the species' conservation status. There are a number of Priority flora species present within the Project Development Envelope that are discussed below.

Environmental Protection (Clearing of Native Vegetation) Regulations 2004

The WA Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (hereafter referred to as Clearing Regulations) regulate the clearing of native vegetation in the State. Low impact mineral and petroleum activities as defined in the Clearing Regulations, and clearing of up to 10 ha per financial year per 'authority area' regulated under the *Mining Act 1978* (Mining Act), may be exempt from obtaining a clearing permit. However, these exemptions do not apply to environmentally sensitive areas (ESAs) or within non-permitted areas such as wetlands or riparian vegetation. There are no ESAs within or near the development envelope.

A Clearing Permit is not required if the impacts of the proposed clearing have already been assessed by the EPA under Part IV of the EP Act.

EPA Policies

The EPA has produced Position Statement No. 2 (EPA 2000) for the environmental protection of native vegetation in WA specific to the clearing of native vegetation. This document outlines the EPA's position on clearing in agricultural areas and clearing in other areas of WA. It also outlines the elements the EPA will take into consideration when assessing a proposal. Proponents are required to demonstrate in their proposals that all reasonable measures have been undertaken to avoid impacts on biodiversity. Where some impact on biodiversity cannot be avoided, it is for the proponent to demonstrate that the impact will not result in unacceptable loss.

The EPA Position Statement No. 3 (EPA 2002b) outlines the use of terrestrial biological surveys as an element of biodiversity protection in Western Australia. Proponents are expected to undertake field surveys that meet the standards, requirements and protocols as determined and published by the EPA. Further detail on the requirements for flora and vegetation surveys is provided in EPA Guidance Statement No. 51 (EPA 2004b). The vegetation in the study area was surveyed using the methods set out in accordance with this guidance statement and outlined below.

The EPA also provides guidance on the rehabilitation of terrestrial ecosystems (EPA 2006). The Mine Closure Plan has been prepared in accordance with this guidance (Appendix O1).

9.1.3 Studies and Investigations

The flora and vegetation of the development envelope and the regional surrounds have been extensively surveyed. A summary of botanical surveys that are relevant to the Project are presented in Table 9-1. In addition to those listed in the table, there are other surveys of nearby projects that contribute to the botanical knowledge of the area. Reports of other related work, including for example, site specific soil surveys are also listed. These are listed in Western Botanical (2015a, Appendix E2).

Table 9-1: Summary of previous botanical and related work relevant to the Project

Reference	Scale	Summary Description
Historic Surveys		
Gardner (1942)	Regional	Broad scale regional flora surveys and general account of vegetation for the Murchison
Mabutt *et al.* (1963)	Regional	Descriptions of land systems and vegetation of the Austin Botanical District (Wiluna and Glengarry)
Specht (1970)	Regional	National scale structural vegetation classification and mapping
Beard (1976)	Regional	Broad scale regional vegetation mapping (1:1,000,000) of the Murchison including vegetation unit descriptions.
Western Mining Corporation Ltd (1978)	Local	Vegetation and flora survey of the Yeelirrie Project for draft EIS and ERMP
Pringle *et al.* (1994)	Regional (land systems). Local (vegetation)	Description of broad land systems and local vegetation units of the North-eastern Goldfields. Mapping at 1: 250,000.
Payne *et al.* (1998)	Regional	Floristic inventory, condition assessment, and mapping of the Sandstone, Yalgoo, Paynes Find Area. Mapping at 1:250,000.
Recent Work		
Western Botanical (2011)	Local	Baseline flora and vegetation survey of the Yeelirrie Project. Mapping at 1:10,000. Significant flora and vegetation units of Yeelirrie (Appendix E1)
D.C. Blandford & Associates (2011)	Local	Soil landscapes assessments of the Yeelirrie Project including soils profile descriptions and some soil chemistry (Appendix M1)
Meissner (2011) (Draft)	Regional	Flora and vegetation survey of calcrete palaeodrainage channels in the north-eastern Goldfields.
Clarke *et al.* (2012)	Local	Assessment of genetic variance within *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) to help determine taxonomic and conservation status.
Shepherd *et al.* (unpublished)	Local	Taxonomic resolution of *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) utilising morphological and molecular methods (Appendix E4)

Reference	Scale	Summary Description
Western Botanical (2014)	Local	Review of *Atriplex* sp. Yeelirrie Station population within rehabilitated former stockpile and initial demography assessment of the Western population (Appendix E8)
Western Botanical (2015a)	Local	Reviewing and updating results of Western Botanical (2011) (Appendix E2)
Western Botanical (2015b)	Local	Demography assessment Phase 1, *Atriplex* sp. Yeelirrie Station Eastern, Western and Rehabilitation populations. (Appendix E7)
Western Botanical (2015c)	Local and Regional	Potential Translocation trial site assessment, Lake Mason (Appendix E9)
Soilwater Consultants (2015b)	Local and Regional	Potential Translocation trial site assessment, Lake Mason (Appendix E5)

9.1.3.1 Recent Survey Work

Western Botanical was commissioned in 2008 to undertake a flora and vegetation assessment of the proposed BHP Billiton Project. The outcome of the survey was the Yeelirrie Project Flora and Vegetation Survey Baseline Report, February 2011 (WB653) (Western Botanical, 2011; Appendix E1). The field survey included 16 study areas. Study Areas 1, 2, and 3 are collectively referred to as the Local Study Area and cover the Development Envelope, while areas 4 to 16 are collectively referred to as the Regional Study Area. These areas are shown on Figure 9-1.

A level 2 survey of Study Area 1 was performed in accordance with EPA Position Statement No. 3 (EPA 2002b) and Guidance Statement No. 51 (EPA 2004b), including quadrat based assessment of flora and the mapping of vegetation at a scale of 1:10,000. Study Area 1 includes the pit extent, metallurgical plant, surface water diversion bund and the majority of vegetation within the potential groundwater drawdown zone. Areas of vegetation potentially indrectly affected by the Project are also included withi Study Area 1. Study Area 2, comprising five areas adjacent to and contiguous with Study Area 1 and including the majority of the proposed bore fields, quarry, and buffers around Study Area 1. A level 1 survey of Study Area 2 was performed and focussed on mapping of vegetation units and known Priority Flora populations. Areas proposed to be disturbed such as the quarry and infrastructure corridors will have pre-clearance surveys undertaken as part of ground disturbance procedures. A level 1 survey of Study Area 3 was performed and focussed on mapping of vegetation units, known Priority Flora populations and definition of the extent and size of the Eastern Population of *Atriplex* sp. Yeelirrie Station.

Figure 9-1 shows that the Level 2 survey conducted by BHP Billiton does not cover all of the borefield corridors. Cameco did not undertake further flora surveys over these areas as the layout of the corridors is conceptual and subject to change following further groundwater investigations during future development phases of the Project.

Once the location of the groundwater bores and access corridors have been finalised, further flora surveys will be carried in accordance with the requirements of the Guidance Statement for Level 2 surveys.

Regional study areas 4 through to 16 were areas of palaeodrainage channels and lake systems which contained similar landforms to Study Area 1 and 3. The purpose of the regional study areas was primarily to search for additional populations of *Atriplex* sp. Yeelirrie Station whilst providing a regional context for the distribution of flora species with conservation interest that were recorded within Study Area 1.

In 2014, Cameco commissioned a review of the 2011 report to confirm that the work was undertaken in accordance with current guidance and to update any species name changes, species

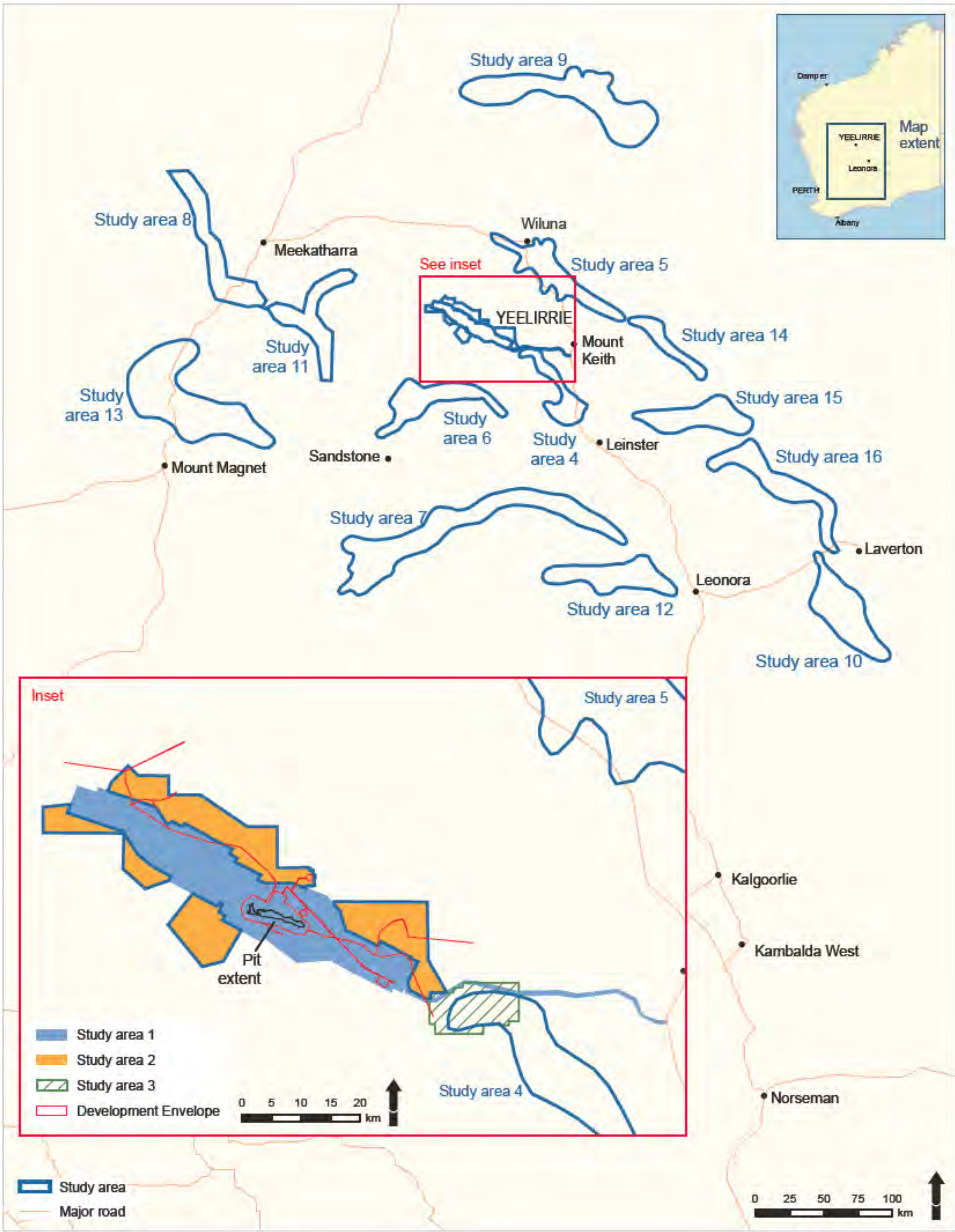


Figure 9-1: Regional and local Study Areas

identification corrections, conservation status, naturalised status, and conformity to known range, that may have occurred since the 2011 report. The review report (Western Botanical 2015a) is attached as Appendix E2. The review determined that the conservation status of four species within the Local Study Areas have changed, notably *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) which has been upgraded from Priority 1 to Threatened.

An independent research project, commissioned by BHP Billiton, investigating the genetic structure of *Atriplex* sp. Yeelirrie Station was undertaken in 2011 (Shepherd *et al.* unpublished). The study assessed genetic variation within the two major populations of *Atriplex* sp. Yeelirrie Station to determine its taxonomic and conservation status. This research project led to the release of a journal paper titled 'Significant population genetic structure detected for a new and highly restricted species of *Atriplex* (Chenopodiaceae) from Western Australia, and implications for conservation management' (Clarke *et al*. 2012).

In August 2014, Western Botanical was commissioned by Cameco to assess the Western population of *Atriplex* sp. Yeelirrie Station located on the Yeelirrie orebody, and also the rehabilitation population noted in the former southern stockpile area (Western Botanical 2014).

In 2015, further investigations were commissioned by Cameco to increase the understanding of the conservation significant species *Atriplex* sp. Yeelirrie Station. These investigations included:

- a study by DPaW to determine the taxonomy of the species comparing both genetic and morphological information (yet to be published);
- life cycle, population dynamics (sex ratios, age structure, seedling recruitment) forming the basis of a population viability analysis (Western Botanical 2015b);
- soil type, structure, moisture and chemistry; hydrological requirements; surrounding vegetation; scale (area of occupancy); slope, aspect and altitude (Western Botanical 2015b, Soilwater Consultants 2015b);
- seed viability and germination (Western Botanical 2015d); and
- potential translocation sites for *Atriplex* sp. Yeelirrie Station outside the current known locations were investigated and the potential short and long term impacts on the ecology of the potential recipient sites were assessed (Western Botanical 2015c).

9.1.4 Existing Environment

9.1.4.1 Land Systems and Vegetation Condition

Land systems of the Yeelirrie area have been described and mapped as part of two rangeland conditions surveys undertaken by the WA Department of Agriculture (now Department of Agriculture and Food) (Pringle *et al*. 1994; Payne *et al*. 1998). Sixteen land systems representing ten land types have been mapped at a scale of 1:500,000 within the Local Study Area. The proportion of each land system which occurs in the Local Study Area is presented in Table 9-2 and illustrated in Figure 9-64 in Section 9.10.

Table 9-2: Land system extent within the local Study Area and regional representation

Land system	Sandston-Yalgoo-Paynes Find area (ha)[1]	North-eastern Goldfields area (ha)[2]	Total area mapped (ha)	Within Local Study Area (ha)	Proportion within Local Study Area (%)
Millrose	n/a	n/a	53,500 [3]	13	0.02
Sherwood	345,800	387,500	733,300	921	0.13
Waguin	124,900	74,500	199,400	254	0.13
Gransal	80,000	274,100	354,100	440	0.12

Land system	Sandston-Yalgoo-Paynes Find area (ha)[1]	North-eastern Goldfields area (ha)[2]	Total area mapped (ha)	Within Local Study Area (ha)	Proportion within Local Study Area (%)
Windarra	37,000	193,800	230,800	99	0.04
Bullimore	624,900	2,401,300	3,026,200	71,530	2.36
Hamilton	32,500	113,000	145,500	46	0.03
Ranch	29,800	65,500	95,300	11	0.01
Monk	182,200	816,200	998,400	247	0.02
Yanganoo	327,600	87,500	415,100	11,202	2.70
Desdemona	4,000	252,400	256,400	141	0.06
Cosmos	5,000	14,100	19,100	1,797	9.41
Cunyu	35,800	31,000	66,800	2,857	4.28
Melaleuca	12,900	26,700	39,600	3,008	7.60
Mileura	70,000	55,000	125,000	3,796	3.04
Carnegie	864,900	550,600	1,415,500	3,525	0.25

Notes:

1. Pringle *et al*. (1994)
2. Payne *et al.* (1998)
3. Millrose land system is not present within either Technical Bulletin No. 87 or Technical Bulletin No. 90. Total mapped area comes from the Millrose land system's presence within Technical Bulletin No. 84.

As evident in Table 9-2 many of the land systems found within the Local Study Area are well represented in the wider biogeographic region. However, there is a considerable representation of land type 18 (Calcrete drainage plains with mixed halophytic and non-halophytic shrublands) and its four component land systems (Cosmos, Cunyu, Melaleuca and Mileura) within the Local Study Area. These land systems are associated with margins of salt lakes and occluded palaeodrainage channels, and are considered an uncommon and geographically isolated series of land systems and vegetation communities within the broader region (Western Botanical 2011).

In addition to the WA Department of Agriculture mapping, broad scale vegetation mapping of the region by Beard (1976) indicates five vegetation units are present within the Local Study Area as follows:

1. Mulga (*Acacia aneura sens. lat*.), Mallee (*Eucalyptus kingsmillii*) and Spinifex (*Triodia basedowii*) shrub steppe on sand plains.
2. Mulga (*Acacia aneura sens. lat*.) and Wattles (*Acacia* spp.) with Saltbush (*Atriplex* spp.) or Bluebush (*Maireana* spp.) succulent steppe.
3. Saltbush (*Atriplex* spp.), Bluebush (*Maireana* spp.) and Samphire (*Tecticornia* spp.) communities succulent steppe.
4. Mulga (*Acacia aneura sens. lat*.) low woodland.
5. Mulga (*Acacia aneura sens. lat*.) and *A. quadrimarginea* shrubland.

Vegetation condition mapping was undertaken within the Local Study Area, based on the Keighery (1994) scale (as presented in Government of Western Australia 2000). The results of this mapping are presented in Figure 9-2. Due to a history of pastoral management and de-stocking, the majority of the vegetation within the Local Study Area is of 'excellent' condition rather than 'pristine' condition. The area immediately surrounding the Yeelirrie homestead and the airstrip is considered

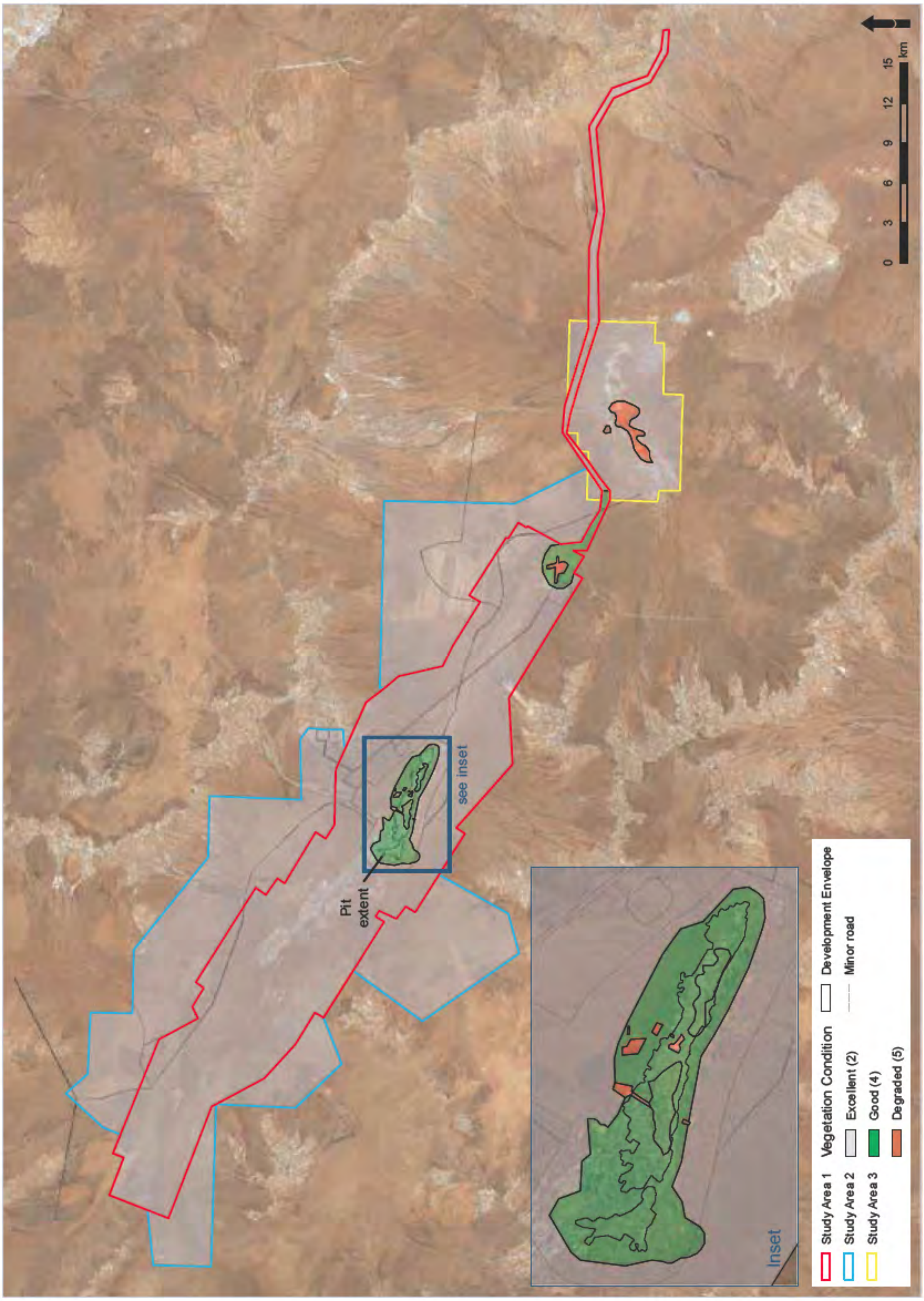


Figure 9-2: Vegetation condition within the local Study Area

'degraded', improving to 'good' with distance from the homestead. Within the mining footprint, exploration activities and some weed incursion have reduced the vegetation condition to 'good'. Exploration tracks, roads and some previously cleared areas were given a condition of 'degraded' (Not illustrated in Figure 9-2).

Atriplex sp. Yeelirrie Station (L. Trotter & A. Douglas 25025) is preferentially grazed (predominantly by cattle) when more palatable feed is unavailable. Correspondingly some areas supporting this species in the Eastern Population were classified as 'degraded-good' but overall the condition of the Eastern population is rated good (Western Botanical 2015a).

9.1.4.2 Vegetation associations and communities of conservation significance

Vegetation association mapping determined fifty-two vegetation associations (National Vegetation Information System [NVIS] Level 5), including one complex, within the Local Study Area, 39 of which were recorded in Study Area 1 by Western Botanical (2011) (Figure 9-3).

No flora-related Threatened Ecological Communities (TECs) listed under the EPBC Act 1999, or Priority Ecological Communities (PECs) listed under the WC Act 1950 were recorded within Study Area 1. Some vegetation communities present within the Calcrete System of Study Area 1, are of interest as they are considered to have a limited distribution. The vegetation communities of interest within Study Area 1 are:

- Communities recognised by Cowan (2001) as being of limited regional distribution and at risk:
  - CEgW *Eucalyptus gypsophila* Woodland on Calcrete, equivalent to Calcrete platform woodlands/shrublands of the north-east Goldfields (Pringle *et al.* 1994 - site type 8);
  - CCpW *Casuarina pauper* Woodland on Calcrete, equivalent to Calcyphytic casuarina acacia woodlands/shrublands of the north-east Goldfields (Pringle *et al.* 1994 - site type 7); and
  - CMxS *Melaleuca xerophila* Shrubland on Calcrete, equivalent to *Melaleuca* sp. nov. Low Closed to Open Forest Strand Community Near Wiluna.
- Communities described by Western Botanical as known from within the Local Study Area only:
  - CApS *Atriplex* sp. Yeelirrie Station Shrubland on Calcrete. A new community described by Western Botanical and is not documented elsewhere to date. CApS is dominated by *Atriplex* sp. Yeelirrie Station on clay in depressions and is confined to clay flats within the Calcrete System. Based on current information available the CApS community is limited in distribution; and
  - CRsS *Rhagodia* sp. Yeelirrie Station Shrubland on Calcrete. A new vegetation community described by Western Botanical and is not documented elsewhere to date. Based on current information available the CRsS community is limited in distribution.

Table 9-3: Summary descriptions of the vegetation communities within Study Area 1 and shown on Figure 9-3.

Code	Vegetation Community	Landform Description	Dominant, Defining Flora
SAES	Stony *Acacia galeata* and *Eremophila* spp. Shrubland	Foot slope deposits of granite breakaway	*Eremophila galeata*, *Acacia aneura*, *A. ayersiana*, *A. tetragonophylla*, *Ptilotus obovatus* (typical Goldfields form), *Eremophila compacta* subsp. *compacta*, *E. latrobei* subsp. *latrobei*, *Senna artemisioides* subsp. x *sturtii*, *S. artemisioides* subsp. *helmsii*, *Sida ectogama*, *Eragrostis eriopoda*
BCLS	Breakaway Chenopod Low Shrubland	Foot slope deposits and undulating alluvial plains at the base of granite breakaway	*Maireana triptera, Sclerolaena diacantha, Ptilotus obovatus* (typical Goldfields form), *Cymbopogon ambiguus*

Code	Vegetation Community	Landform Description	Dominant, Defining Flora
GFGr	Granite Foot Slope Grassland	Foot slope deposits of granite breakaway	*Aristida contorta, Cymbopogon ambiguus, Ptilotus obovatus* (typical Goldfields form), *Sclerolaena* spp., *Eremophila galeata, Senna artemisioides* ssp. *helmsii*
GPoS	*Ptilotus obovatus* Shrubland	Foot slope deposits of granite breakaway	*Ptilotus obovatus* (typical Goldfields form), *Maireana pyramidata, Eremophila compacta* subsp. *compacta, E. maculata* subsp. *brevifolia, Senna* spp., *Eragrostis* sp.
Qtz	Quartz Ridge	Hills and foot slopes associated with granite breakaway	*Acacia quadrimarginea, Acacia aneura, Callitris columellaris, Dodonaea petiolaris, Eremophila exilifolia and E. latrobei subsp. latrobei, Ptilotus obovatus* (typical Goldfields form), *Cymbopogon ambiguus*
GR	Granite Rise	Exfoliating granite outcrop	*Acacia quadrimarginea, Acacia aneura, Callitris columellaris, Dodonaea* spp., *Eremophila latrobei* subsp. *latrobei, Senna* spp., *Sida* spp., *Cymbopogon ambiguus*, various herbs
GRMS	Mulga Shrubland on Granite Rise	Plains with granite rise	*Acacia aneura, A. tetragonophylla, A. craspedocarpa, A. quadrimarginea, Ptilotus obovatus* (typical Goldfields form), *Eremophila* spp., *Sida ectogama, Senna* spp.
SASP	Sand plain Spinifex Hummock Grassland	Sand plain	*Triodia basedowii, Leptosema chambersii, Euryomyrtus inflata* P3, *Prostanthera wilkieana, Keraudrenia velutina, Acacia effusifolia, Grevillea acacioides*
SAWS	Sand plain Spinifex Hummock Grassland with Wattles	Sand plain	*Triodia basedowii, Acacia effusifolia, A. heteroneura* var. *prolixa, A. jamesiana, A. prainii, A. pachyacra*
SAMA	Sand plain Spinifex Hummock Grassland with Mallee	Sand plain	*Triodia basedowii, Eucalyptus leptopoda* ssp. *elevata, E. kingsmillii, E. trivalva, Acacia effusifolia, A. heteroneura* var. *prolixa, A. prainii, A. ligulata, Leptosema chambersii*
SAHS	Sand plain Spinifex Hummock Grassland with Heath	Sand plain	*Triodia basedowii, Enekbatus eremaeus, E. cryptandroides, Acacia effusifolia, A. heteroneura* var. *prolixa, A. jamesiana, Hakea francisiana*
SAGS	Sand plain Spinifex Hummock Grassland with *Eucalyptus gongylocarpa*	Sand plain	*Eucalyptus gongylocarpa, Acacia effusifolia, A. ligulata, A. prainii, A. heteroneura* var. *prolixa, Eremophila platythamnos* subsp. *platythamnos, Halgania cyanea* ssp. Allambi Stn (B.W. Strong 676), *Triodia basedowii*
SAMU	Sandplain Mulga Spinifex Hummock Grassland	Sand plain	*Acacia aneura, A. ayersiana, A. ramulosa* var. *linophylla, A. effusifolia, Melaleuca interioris, Triodia basedowii*

Code	Vegetation Community	Landform Description	Dominant, Defining Flora
WABS	Wanderrie Bank Grassy Shrubland	Sand plain	*Acacia aneura, A. ayersiana, Grevillea berryana, A. ramulosa* var. *linophylla, A. tetragonophylla, Eremophila forrestii* ssp. *forrestii, Ptilotus obovatus* (typical Goldfields form), *Eragrostis eriopoda*
SDSH	Sand Dune Shrubland	Sand dunes	*Callitris columellaris, Acacia aneura, Eucalyptus leptopoda* ssp. *elevata, Bertya dimerostigma, Micromyrtus flaviflora, Hakea lorea* ssp. *lorea, Triodia basedowii*
HPMS	Hardpan Plain Mulga Shrubland	Plains	*Acacia aneura, A. ayersiana, A. ramulosa* var. *linophylla, A. tetragonophylla, Melaleuca interioris, Grevillea berryana, Eremophila* spp.
DRMS	Drainage Tract Mulga Shrubland	Drainage lines on plains	*Acacia aneura, A. ayersiana, Eremophila* spp., *Pluchea dentex*, various herbs
DRES	Drainage Line *Eucalyptus camaldulensis* Woodland	Drainage lines on plains	*Eucalyptus camaldulensis* subsp. *obtusa, Acacia aneura, A. quadrimarginea, A. tetragonophylla, A. ramulosa* var. *linophylla, Cymbopogon ambiguus, Pluchea dentex*
GRMU	Mulga Groves on Hardpan Plain	Plains	*Acacia aneura, A. ayersiana, A. craspedocarpa, A. tetragonophylla, A. ramulosa* var. *linophylla, Eremophila hygrophana, Ptilotus obovatus* (typical Goldfields form)
PLAPoS	*Acacia* spp. and *Ptilotus obovatus* Shrubland	Flats in Playa System	*Acacia aneura, A. ayersiana, A. tetragonophylla, A. ramulosa* var. *linophylla, A. burkittii, Ptilotus obovatus* (typical Goldfields form)
PLAET	*Acacia* spp. and *Eremophila* spp. Thicket	Playas with sink holes	*Acacia aneura, A. tetragonophylla, Eremophila longifolia, Hakea lorea* ssp. *lorea, Eucalyptus lucasii, Grevillea berryana, Santalum lanceolatum, Ptilotus obovatus* (typical Goldfields form), *Senna artemisioides* ssp. *filifolia, Eragrostis setifolia, Eriachne helmsii*
PLAMi	*Acacia* spp. and *Melaleuca interioris* Shrubland	Fringes of playas in Playa System	*Acacia aneura, A. ayersiana, Melaleuca interioris, Ptilotus obovatus* (typical Goldfields form)
PLMf	*Muehlenbeckia florulenta* Shrubs	Playas	*Muehlenbeckia florulenta*
PLCsMp	*Cratystylis subspinescens* and *Maireana pyramidata* Shrubland	Playas	*Maireana pyramidata, M. georgei, Cratystylis subspinescens, Ptilotus obovatus* (typical Goldfields form), *Sclerolaena eriacantha, Solanum lasiophyllum, Frankenia laxiflora*
PLEmc	*Eremophila maculata* ssp. *brevifolia* Shrubland	Scalded areas in Playa System	*Eremophila maculata* ssp. *brevifolia*
PLEml	*Eremophila malacoides* Shrubland	Scalded areas in Playa System	*Eremophila malacoides*
PLEsp	*Eragrostis* sp. Grassland on Playa	Playas	*Eragrostis* sp. LCH26982, *Ophioglossum lusitanicum*

Code	Vegetation Community	Landform Description	Dominant, Defining Flora
PLCh	Chenopods on Scalded Areas	Scalded area in Playa System	*Maireana georgei, M. carnosa, M. triptera, Sclerolaena diacantha, Dissocarpus paradoxus*
CEgW	*Eucalyptus gypsophila* Woodland on Calcrete	Calcrete rises	*Eucalyptus gypsophila, Templetonia incrassata, Eremophila arachnoides* ssp. *arachnoides* P3, *Acacia burkittii, Senna artemisioides* ssp. *filifolia*
CCpW	*Casuarina pauper* Woodland on Calcrete	Calcrete rises	*Casuarina pauper, Acacia burkittii, Templetonia incrassata, Senna artemisioides* ssp. *filifolia, Eremophila arachnoides* ssp. *arachnoides* P3, *Ptilotus obovatus* (typical Goldfields form), *Sclerolaena fusiformis*
CMxS	*Melaleuca xerophila* Shrubland on Calcrete	Flats within Calcrete System	*Melaleuca xerophila, Acacia burkittii, Senna artemisioides* ssp. *filifolia, Lycium australe, Ptilotus obovatus* (typical Goldfields form), *Sclerolaena fusiformis, Dissocarpus paradoxus, Amyema microphylla*
CAbS	*Acacia burkittii* Shrubland on Calcrete	Calcrete rises	*Acacia burkittii, Grevillea berryana, Eremophila arachnoides* ssp. *arachnoides* P3, *Senna artemisioides* ssp. *filifolia, Ptilotus obovatus* (typical Goldfields form)
CMiS	*Melaleuca interioris* Shrubland	Depressions in Calcrete System	*Melaleuca interioris, Acacia ayersiana, A. aneura* and *A. tetragonophylla, Ptilotus obovatus* (typical Goldfields form), *Sclerolaena convexula*
CErG	*Eragrostis* sp. Yeelirrie Calcrete Grassland	Flats in Calcrete System	*Eragrostis* sp. Yeelirrie Calcrete (S. Regan LCH 26770), *Lycium australe, Ptilotus obovatus* (typical Goldfields form)
CApS	*Atriplex* sp. Yeelirrie Station Shrubland	Clay Flats in Calcrete System	*Atriplex* sp. Yeelirrie Station (L. Trotter and A. Douglas LCH25025) P1
CRsS	*Rhagodia* sp. Yeelirrie Station Shrubland	Clay Flats in Calcrete System	*Rhagodia* sp. Yeelirrie Station (K.A. Shepherd *et al.* KS1396) P1, *Teucrium racemosa*
CMpS	*Maireana pyramidata* Shrubland	Flats in Calcrete System	*Maireana pyramidata, M. georgei, Sclerolaena fusiformis, Ptilotus obovatus* (typical Goldfields form)
CLaS	*Lycium australe* Shrubland	Flats in Calcrete System	*Lycium australe, Eragrostis* sp. (S. Regan LCH 26770)
CMGbS	Mulga *Grevillea berryana* Shrubland	Outwash zone in Calcrete System	*Acacia aneura, Grevillea berryana, Senna artemisioides* spp. *filifolia, Acacia burkittii*

9.1.4.3 Phreatophytic vegetation

Cameco has undertaken an analysis of groundwater-dependent (phreatophytic) vegetation within the Local Study Area. The following vegetation communities are potentially groundwater dependent due to the specific species found within them:

- CMGbS: Mulga *Grevillea berryana* shrubland on outwash zone in calcrete system;
- CEgW: *Eucalyptus gypsophila* woodland on calcrete rises;
- CMxS: *Melaleuca xerophila* shrubland on calcrete Flats within calcrete system;
- CCpW: *Casuarina pauper* woodland on calcrete rises;

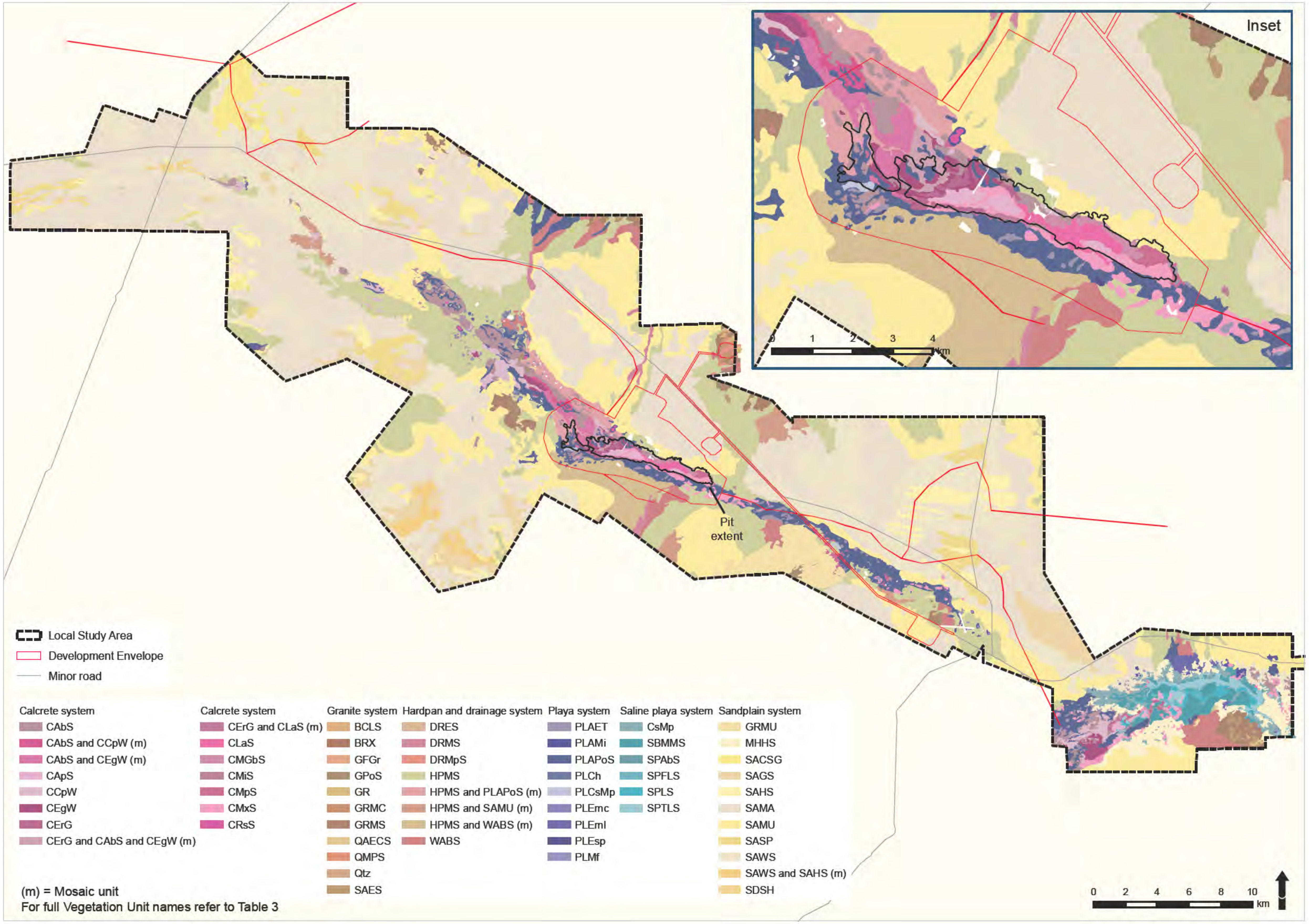


Figure 9-3: Vegetation communities within the local Study Area and development envelope

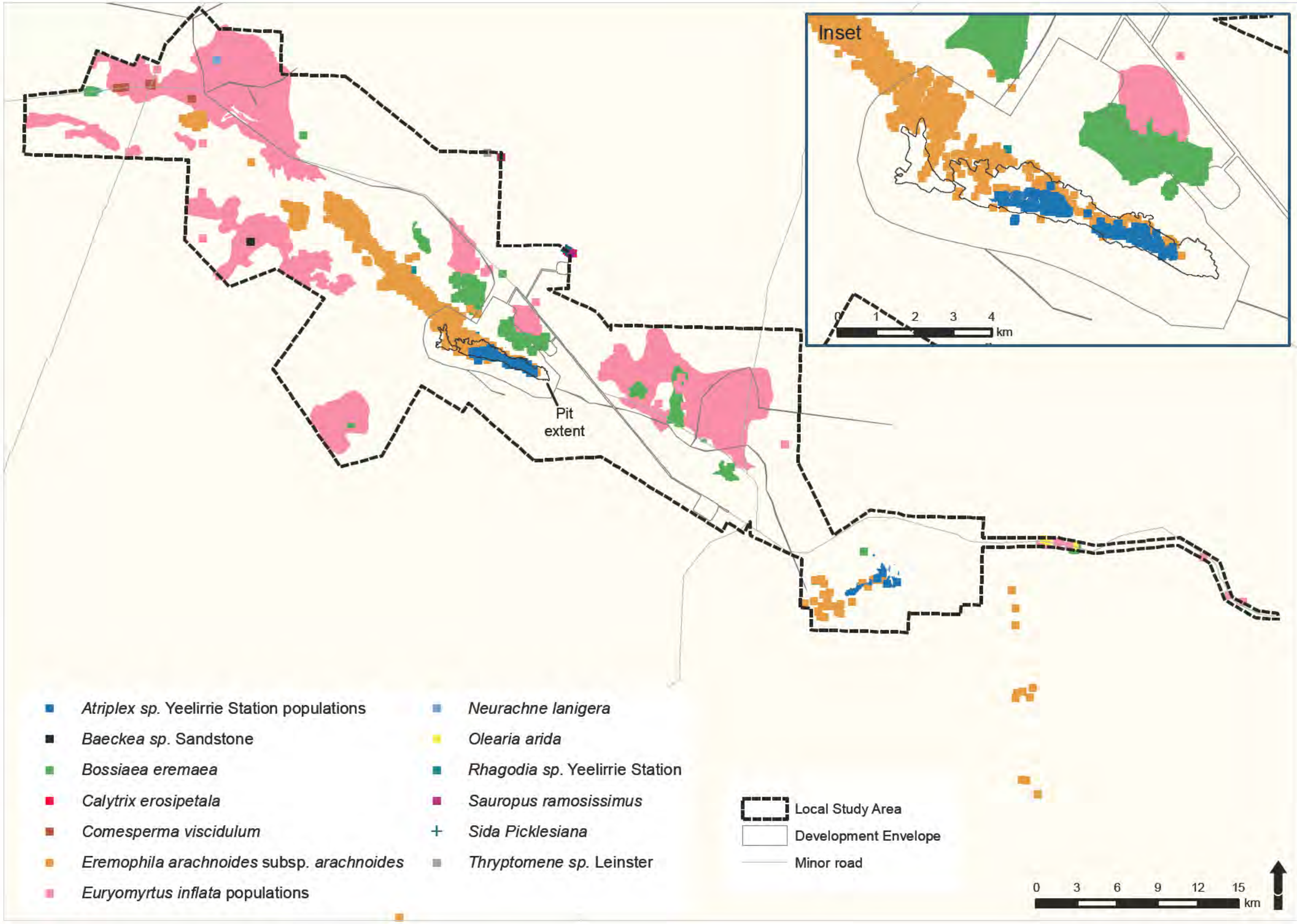


Figure 9-4: Priority species within the Local Study Area

- PLAET: *Acacia* spp. and *Eremophila* spp. thicket on playas with sink holes; and
- PLAMi: *Acacia* spp. and *Melaleuca interioris* shrubland on fringes of playas in playa system.

In addition to these communities, other potentially phreatophytic species are present throughout large expanses of the Sand Plain System and Hardpan and Drainage System. These species include *Melaleuca interioris, Grevillea berryana*, *Eucalyptus* and *Corymbia* species, which occur in the SAWS, SAMU, SAMA, SAGS, SACSG, SASP and / or HPMS vegetation communities (Appendix E1). Refer to Table 9-3 for descriptions of these vegetation communities.

9.1.4.4 Significant Flora

No flora species of conservation significance listed under the EPBC Act have been recorded in the Local or Regional Study Areas.

One flora species, *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025), that is listed as 'Threatened' under the WC Act has been recorded within the Local Study Area (Western Botanical 2015a). This species is discussed in detail below.

Other priority flora listed under the WC Act, that have been recorded within the Local Study Area are presented in Table 9-4 and shown on Figure 9-4. The conservation status of these species is discussed in detail in Western Botanical (2015a) and in the Conservation Species Management Plan (Cameco 2015b) (Appendix E3). In addition, there are a number of flora species of interest which are discussed in Western Botanical (2015a).

Table 9-4: Priority flora occurring within the local Study Area

Species Name	Conservation Status
Priority Flora	
Neurachne lanigera	P1
Rhagodia sp. Yeelirrie Station (K.A. Shepherd *et al*. KS1396)	P1
Baeckea sp. Sandstone (C.A. Gardner s.n. 26 Oct 1963)	P3
Bossiaea eremaea	P3
Calytrix uncinata	P3
Eremophila arachnoides subsp. *arachnoides*	P3
Euryomyrtus inflata	P3
Sauropus ramosissimus	P3
Sida picklesiana	P3
Thryptomene sp. Leinster (B.J. Lepschi & L.A. Craven 4362)	P3
Comesperma viscidulum	P4
Olearia arida	P4

Of the priority flora presented in Table 9-4, only three species, *Bossiaea eremaea* (P3), *Eremophila arachnoides* subsp. *arachnoides* (P3) and *Euryomyrtus inflata* (P3), will be impacted to a small degree by the Project (Section 9.1.5.2).

Atriplex sp. Yeelirrie Station

When discovered during the 2010 survey, *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) was reported as a Priority 1 species listed under the WC Act. The conservation status of the species was upgraded to Threatened on 17 February 2012 (Western Australian Government 2012, No 23). Photos of the species are presented in Plate 9-1 and Plate 9-2.

Plate 9-1: Photos of *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) showing growth habit and divaricate branching structure (in Western Botanical, 2015a)

Plate 9-2: Photos of *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) showing female flowers (top left), male flowers (top right), and two morphotypes of fruiting bracteoles; no appendages (bottom left), and with appendages (bottom right) (photos by Dr Kelly Shepherd; in Western Botanical, 2015a).

Atriplex sp. Yeelirrie Station has been recognised as a rare, new species of *Atriplex* (*Chenopodiaceae*) comprising two genetically distinct populations in arid Western Australia, described here as the Western and Eastern Populations. The Western and Eastern Populations were found to have similar levels of genetic diversity, but exhibited an unexpected level of genetic differentiation given their proximity (Clarke *et al.* 2012). The Western Population lies wholly within the economic orebody and encompasses two sub-populations that are located in close proximity to each other. The Eastern Population, some 30 km south east of the Western Population, encompasses ten sub-populations in close proximity to each other (Figure 9-5).

There is a small number of *Atriplex* sp. Yeelirrie Station plants within rehabilitated areas in close proximity to the orebody: 109 plants at the Southern Stockpile, six plants near the former communications tower site and a single plant has been recorded adjacent to a track leading to the rehabilitated Northern Stockpile Area (as at August 2014). In addition a single live *Atriplex* sp. Yeelirrie Station plant was observed in March 2015 within the *Rhagodia* sp. Yeelirrie shrubland 1.45 km north of the western subpopulation of the Western (orebody) population. All known locations of the species are located on both Cameco tenure and the Cameco operated Yeelirrie Pastoral Lease.

Western Population of *Atriplex* sp. Yeelirrie Station

The Western population lies wholly within the economic orebody as shown in Figure 9-5. *Atriplex* sp. Yeelirrie Station occurs on clay flats within the Calcrete System, which coincides with the central part of the proposed open pit mine and the drainage line within the palaeochannel. It was primarily recorded within the CApS vegetation unit with scattered individual plants also in surrounding CMxS and CLaS vegetation units. The densest populations were recorded in the central area of the proposed open pit mine.

An estimate of 80,542 plants being wholly within the orebody area is based on an assessment of plant density within quadrats and a measurement of the area of occupancy determined using GIS mapping. These plants occur in two marginally separated sub-populations. The total area of occupancy of *Atriplex* sp. Yeelirrie Station within the orebody area is 76 ha, inclusive of a 10 m buffer around the population (Western Botanical 2015a). The condition of the plants in the Western Population was rated as Good to Excellent.

Eastern Population of *Atriplex* sp. Yeelirrie Station within Study Area 3.

The Eastern population of *Atriplex* sp. Yeelirrie Station supports approximately 190,755 plants over ten sub-populations within an area of occupancy of 1.30 km^2 inclusive of a 10 m buffer around the populations. As in Study Area 1, *Atriplex* sp. Yeelirrie Station within Study Area 3 is restricted to clay flats. The plants in the Eastern Population were rated as being in Good condition.

Atriplex sp. Yeelirrie Station within rehabilitation at Yeelirrie

The baseline survey reported a minor population of *Atriplex* sp. Yeelirrie Station within a previously rehabilitated site at the southern end of the Central Baseline (< 50 individuals) and scattered individuals were also recorded within a rehabilitation site near the communications tower. An assessment in late August 2014 by Western Botanical and Cameco counted and tagged 109 live individual plants within the rehabilitated Southern Stockpile Area. An additional review by Cameco counted six live (and four dead) individuals in a clump in rehabilitation on a calcrete rise near the former Communications Tower and a further single male plant adjacent to a track leading to the rehabilitated Northern Stockpile Area (all within the development envelope). A total of 116 live plants were known within rehabilitation as at the end of August 2014 (Western Botanical 2014). The plants occurred over an area of approximately 1 ha within the 6 ha rehabilitated area.

Description

Atriplex sp. Yeelirrie Station is a long lived, single stemmed, semi-woody, sub-dioecious plant forming mounded shrubs 0.4 – 1 m high x 0.6 – 1.8 m wide. Male plants predominantly have terminal male flowers in dense short panicles and occasional axillary female flowers further down the flowering branch while female plants have sub-terminal axillary female flowers. Fruiting bracteoles, each containing one seed, are sessile and are held securely on the plant for many years. The species is most likely wind pollinated.

Taxonomy

In 2014, the Western Australian Herbarium (Shepherd *et al* 2015 unpublished) undertook a project to determine whether *Atriplex* sp. Yeelirrie Station was distinct from other known species by morphological and molecular evidence. Genetic analyses using Amplified Fragment Length Polymorphisms (AFLPs) showed significant genetic divergence between the two populations. In contrast, an ordination based on elliptic fourier descriptors for leaf and bracteole shape did not identify any consistent morphological differentiation.

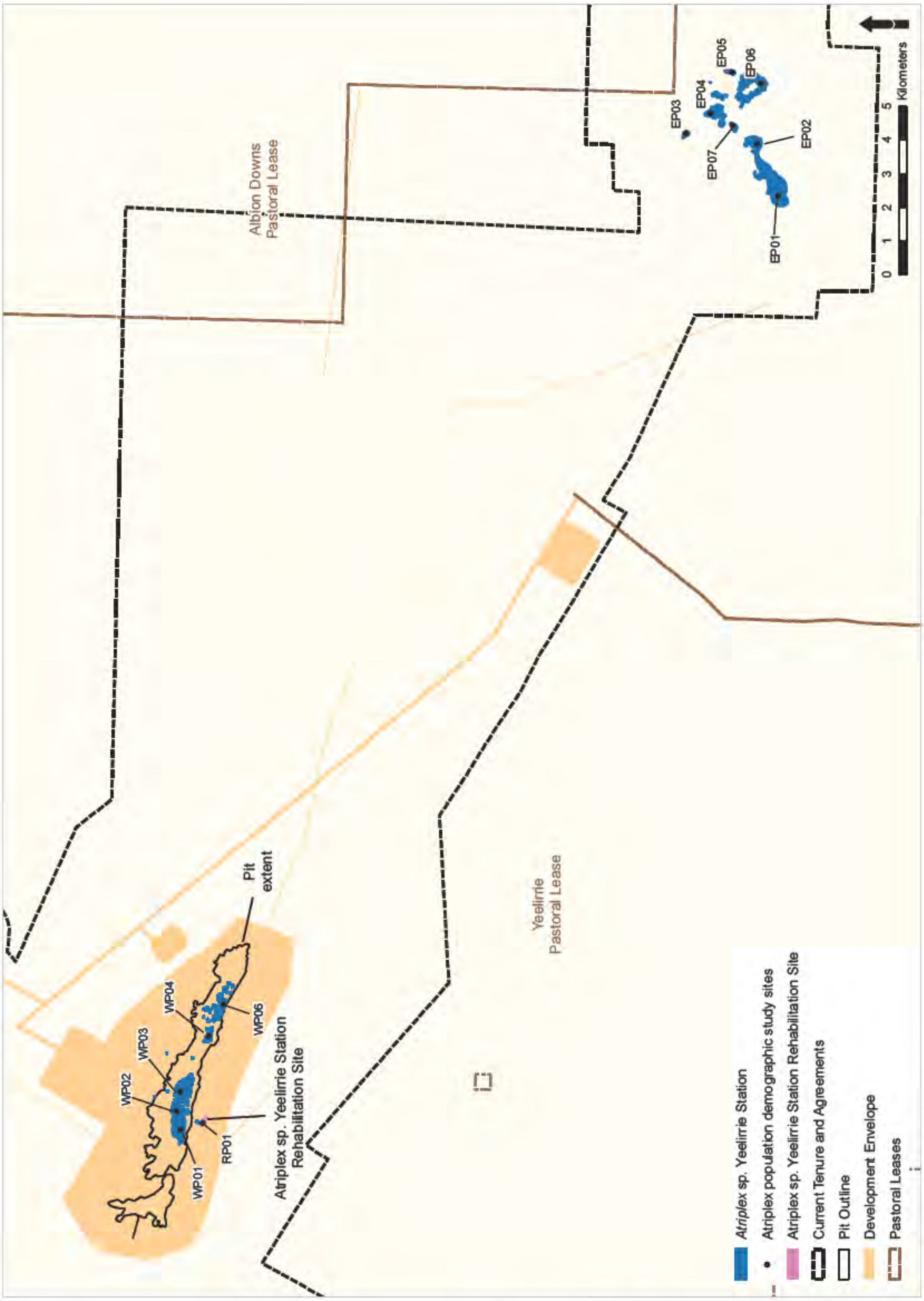


Figure 9-5: Locations of *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025)

Based on the review it was recommended that the new taxon be described as a single species, although the recommendation remains subject to peer review.

The review also recommended that the two populations of *Atriplex* sp. Yeelirrie Station should be managed as separate units for conservation to preserve the genetic diversity exhibited between the two populations.

Reproduction and Survival

Measures taken at both the Eastern and Western populations show a male:female sex ratio of around 50% with no significant differences between sites. While mature plants are long lived, and fruiting bracts containing viable and germinable seeds are held on the plants for many years, the presence of new season seedlings within both the Eastern and Western populations noted in August 2014 and again in March 2015, from two separate recruitment events, indicate that some seed is dispersed from bracts on occasion. Observed seedling numbers varied considerably between sample plots in March 2015 with an average of 22,800 seedlings per ha with a 95% confidence level and a range between 13,420 to 32,580 per ha (Western Botanical 2015b). However, the large numbers of newly germinated seedlings observed in August 2014 suffered a relatively high mortality rate (probably due to the lack of summer rain and were largely absent in the same areas observed at the Eastern population in March 2015. The mechanism triggering seed fall/dispersal from the enclosing bracts is not yet understood.

Population Statistics

Western Botanical (2011) reported an overall mature plant population estimate of ~275,297 across both populations where an average of 1,112 mature plants per ha were reported in the Western population (84,510 plants over 76 ha) and 1,467 mature plants per ha were reported in the Eastern population (190,646 plants over 130 ha).

The assessment of *Atriplex* sp. Yeelirrie Station undertaken in March 2015 established a baseline data set for future assessment of population dynamics and population viability analysis.

During the baseline field surveys, a third population of the species was assessed. This population of 109 individuals is growing in an area that was disturbed by exploration activities conducted in the 1980s and was subsequently rehabilitated in 1994. A further seven live plants have been noted in rehabilitation north of the deposits. It is believed that *Atriplex* sp. Yeelirrie Station seed was introduced to the site with soil. The population, described as the Rehabilitation Population, has been assessed and statistically compared with the Western Population in August 2014:

- There was no significant difference in the ratio of male to female plants between the populations.
- There was no significant difference in the proportion of plants scored as juvenile vs mature between the populations.
- Plants in the Rehabilitation Population were significantly larger in all dimensions, 24% taller, 99% wider and 75% broader than plants in the Western Population. Consequently, plants in rehabilitation had a larger overall plant volume (72%).
- Plants in the Rehabilitation Population also had large portions of their canopies that were dead. When this was taken into account and the live volumes of plants were assessed, plants in the Rehabilitation Population had live canopies that were 42% smaller than those in the Western Population.
- As no plants in either the Rehabilitation Population or Western Population were flowering, there was no difference in flowering rate between these two sites. However, the mature plants at the Eastern Population were noted as flowering (and growing) vigorously. This probably reflected the higher soil moisture noted in soil samples taken at the Eastern Population in August 2014.
- Plants holding fruiting bracteoles were scored on a scale of 0 to 3 (nil to large amounts of fruits on the plant). Plants in the Rehabilitation Population scored 239% higher for the number

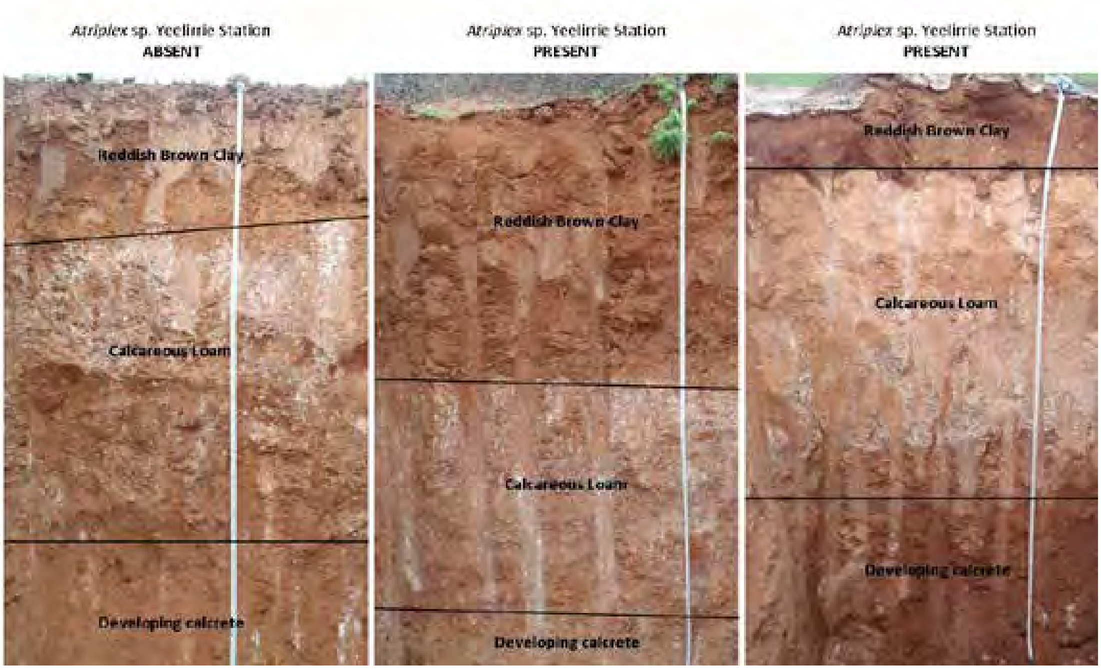


Plate 9-3: Soil profiles within the clay pans where *Atriplex* sp. Yeelirrie Station is absent and present

of plants holding fresh fruits on the plant and had a higher score (252%) for the amount of fresh fruits held on the plants compared to the Western Baseline Population. Some fruits were dissected in-situ at the Rehabilitation Population and were found to consistently have a firm, robust viable seed within. The fruits collected from plants under the DRF permits issued (35- 1415 and 162-1415) have not yet been assessed for seed fill, viability or germinability.

- There was no difference in the frequency of plants holding older fruits and no difference in the abundance of older fruits held on plants between populations.

Associated Species

In its preferred habitat at the Western population, *Atriplex* sp. Yeelirrie Station is the dominant perennial shrub species with occasional *Lycium australe* shrubs scattered within the population. It is associated with annuals *Lawrencia densiflora*, *Zygophyllum compressum* and *Salsola australis*. Small numbers of *Atriplex* sp. Yeelirrie Station may also be found as scattered individuals in fringing vegetation associations including under *Melaleuca xerophila* scrubland on calcrete and *Lycium australe* shrubland on the fringes of the clay flats at the Western population. At the Eastern population, *Atriplex* sp. Yeelirrie Station is associated with the perennial shrubs *Lycium australe*, *Frankenia* spp. and a range of annual herbs and grasses including *Eragrostis* spp. In some cases *Tecticornia* sp. LCH37319 and *Tecticornia* sp. LCH37320 (identifications still in progress) are also associated.

Soil Characteristics

The soil profile within the clay pans supporting the *Atriplex* sp. Yeelirrie Station within both the Eastern and Western Populations was investigated in detail by Soilwater Consultants (SWC 2015b) (Appendix E5). This work involved excavating shallow (i.e. maximum 2 m depth) soil trenches, using an 8 t backhoe, in clay pan areas where *Atriplex* Yeelirrie Station plants were present and where they were absent to elucidate potential differences that may facilitate understanding of their ecophysiological function and requirements.

Soil profiles within the clay pans supporting the existing Western and Eastern Populations were relatively uniform, and little observable difference existed between areas where *Atriplex* Yeelirrie Station plants were present and absent (Plate 9-3). All profiles generally comprised 10 – 80 cm of a reddish brown clay, overlying a brown loam trending to a calcareous loam at depth. These surficial

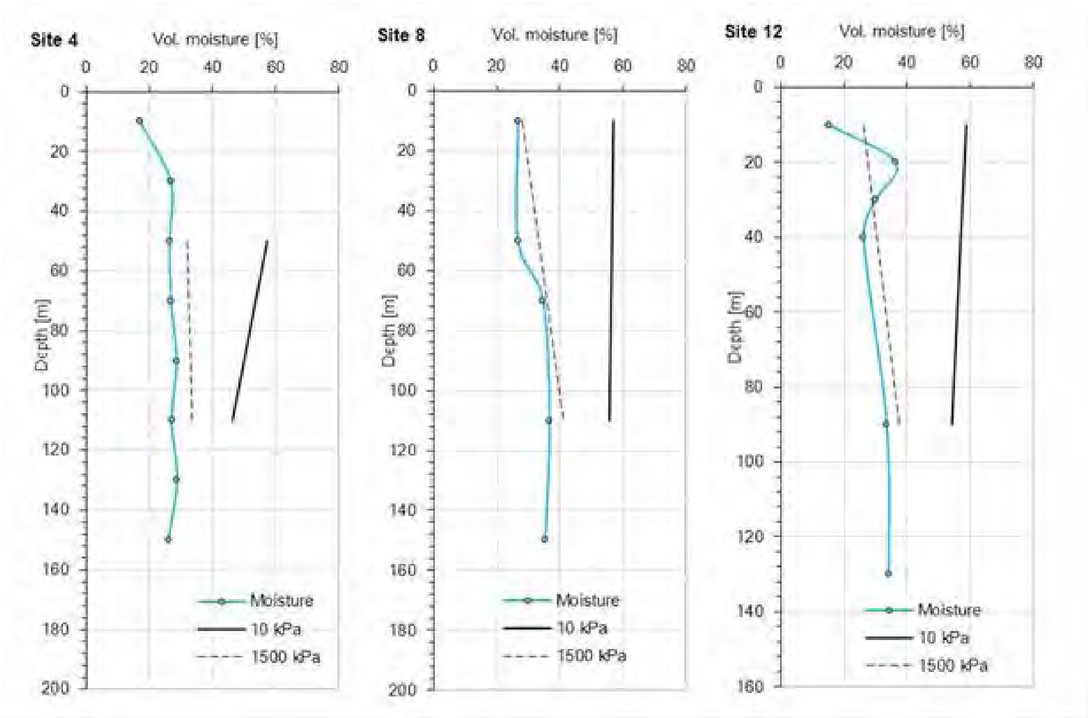


Plate 9-4: Soil moisture profiles for representative clay pan soil profile supporting *Atriplex* sp. Yeelirrie Station

earthy soils had been deposited directly onto the pre-existing calcrete (paleo) surface, resulting in an abrupt boundary at around 1.5 m depth. Although there was uniformity in the morphological structure of the profiles between sites and populations, internally there was appreciable complexity in the soils, such that within the surficial clay or loam horizon, a definite lens of coarse sand or a gravel layer were sometimes present.

The SWC (2015b) investigation analysed a full suite of physical and geochemical properties of the soils within the Western and Eastern Populations. This included particle size distribution, bulk density, field moisture, water retention properties, basic chemistry (i.e. pH and EC) and total and plant available (trace) metals and nutrients. In addition, exchangeable cations and corresponding Cation Exchange Capacity (CEC), and mineralogy were determined on representative materials from each soil horizon.

The results from this detailed analysis showed that no discernible difference in the majority of the physical, chemical or hydraulic properties exist within the clay pans between areas that support *Atriplex* sp. Yeelirrie Station and those areas that do not. At the time of sampling (mid – late April; where around 120 mm of rainfall occurred in the preceding six weeks – i.e. from the 1st March 2015) the soil profiles were effectively dry throughout, with field moisture contents at or just below Permanent Wilting Point (PWP, 1,500 kPa matric suction; Plate 9-4). Water retention results for the various soil types within the clay pan are provided in Table 9-5. These results highlight the clayey nature of all materials with PWPs > 24% (v/v).

Table 9-5: Average water retention results for the major soil types occurring within the clay pans

Soil material	Volumetric water content (%)					Plant Available Water (PAW) content
	0 kPa	10 kPa	33 kPa	100 kPa	1,500 kPa	
Clay	64.94	47.41	42.05	34.32	24.13	23.28
Loam	61.23	49.01	46.08	38.61	27.41	21.60
Calcareous Loam	70.63	52.48	49.96	41.39	31.51	20.98
Calcrete	73.33	46.29	53.55	43.36	33.57	12.72

There was no apparent difference in mineralogy between the various soils in the clay pan, and all were dominated by quartz and kaolinite, with minor smectite, trace mica and calcite and accessory iron oxides (goethite and hematite). The geochemical results for each of the soils types within the clay pan are provided in Table 9-6 to Table 9-8. These illustrate there is little variation in geochemical properties of the various soils that comprise the areas where *Atriplex* sp. Yeelirrie Station is both present and absent.

Table 9-6: Average multi-element composition of the dominant soil types within the clay pans

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Yeelirrie Sites						
Al	40,240	69,800	16,723	27,600	41,200	69,800
As	7	11	5	8	12	16
B	125	250	30	41	147	260
Ba	70	160	23	30	43	57
Ca	34,710	88,000	50,867	130,000	59,200	160,000
Cd	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Co	7.2	8.7	7.1	12.0	6.7	8.6
Cr	53	71	32	46	46	70
Cu	14	22	6.6	9.7	13	21
Fe	21,790	34,000	10,533	16,000	20,460	34,000
Mg	61,200	84,000	24,400	48,000	51,200	67,000
Mn	255	410	98	160	199	350
Mo	1.0	2.4	0.3	0.5	1.1	1.8
Na	5,670	28,000	513	1,200	5,448	11,000
Ni	15	23	7	11	14	23
Pb	4.5	8.1	2.9	3.5	4.7	7.9
V	89	110	55	71	100	150
Zn	38	61	14	24	33	56

Table 9-7: Average bioavailable trace element composition of the dominant soil types within the clay pans

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Yeelirrie Sites						
Al	348	>550	360	480	266	>550
As	0.4	0.7	0.8	1.7	1.1	2.1
B	46	100	4.4	6.6	56	100
Ca	>5,500	>5,500	4,400	>5,500	5,500	>5,500
Cd	0.01	0.02	0.01	0.01	0.01	0.01
Co	0.31	0.91	0.51	0.99	0.31	0.77
Cu	0.2	0.5	0.2	0.4	0.2	0.3
Fe	64	120	52	62	61	110
K	511	>550	283	>550	550	>550
Mg	500	500	643	930	500	500
Mn	29	74	23	33	18	38
Mo	0.04	0.15	0.01	0.02	0.13	0.30
Na	552	>1,000	347	960	810	>5,500
Ni	0.4	0.6	0.3	0.4	0.3	0.3
P	18	48	4	6	13	30
Pb	1.2	1.8	0.9	1.3	1.4	2.1
S	90	160	157	>250	0	>250
Se	0.3	0.6	0.1	0.2	0.2	0.3
Zn	0.2	0.3	0.2	0.3	0.1	0.2

Table 9-8: Average nutrient composition of the dominant soil types within the clay pans

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Yeelirrie Sites									
Total N	0.018	0.044	0.077	0.012	0.021	0.039	0.016	0.021	0.027
Total P	89	174	300	43	68	89	54	143	250
Colwell P	2	10	21	4	5	6	2	5	6
Total K	2,300	4,790	9,300	500	1,650	3,500	2,500	6,380	11,000
Colwell K	410	1,510	3,300	150	527	1,200	1,000	1,640	2,600
Total S	110	3,138	25,000	92	33,511	100,000	520	24,524	85,000
KCl ext. S	4	717	4,000	32	2,167	6,300	320	3,224	7,200

It was reported by SWC (2015b) that the *Atriplex* sp. Yeelirrie Station occurs within the same micro-topographic or geomorphic position within all clay pans. In all cases this species was positioned on a slight rise above the surrounding clay pan surface, such that it likely remained 'dry' when the clay pans became inundated following heavy rainfall or flooding. The slight rises that the *Atriplex* sp. Yeelirrie Station occupy only extend 10 – 20cm above the clay pan surface, and no *Atriplex* sp. Yeelirrie Station was observed occurring within the main clay pan. Detailed sampling and testing of the salinity of the soils within these rises and the adjacent clay pan highlighted that in areas where healthy *Atriplex* sp. Yeelirrie Station occurred, soil salinity was significantly lower (Table 9-9). It is likely that the clay soils within the slight rise have experienced more leaching than the surrounding soils, given their elevated nature above the surrounding plain, and are not (in most rainfall events) inundated, which has the potential to increase soil salt content.

Table 9-9: Summary of soil salinity results for the slight rises supporting the *Atriplex* sp. Yeelirrie Station and areas where it is absent

Environment	Mean (mS/m)	Median (mS/m)	High (mS/m)	Low (mS/m)
Clay Rise (*Atriplex* sp. Yeelirrie Station performing well)	520	331.5	1874	12.82
Clay Pan Surface (*Atriplex* sp. Yeelirrie Station performing poorly)	1676	1591	2605	918
Clay Pan Surface – No *Atriplex* sp. Yeelirrie Station	577	535.2	1135	102
Loam (*Atriplex* sp. Yeelirrie Station performing well)	511	505	1,122	10.31
Loam (*Atriplex* sp. Yeelirrie Station performing poorly)	693	709	793	517
Loam – No *Atriplex* sp. Yeelirrie Station	926	933	1,133	712

Based on field observations and physical, chemical and hydraulic properties of the soils it suggests that the *Atriplex* sp. Yeelirrie Station is susceptible to a combination of salinity and inundation, and therefore is occupying a niche habitat within clay pans. The results suggest that inundation is likely to be the dominant limiting factor, as even if the salinity is within the apparent tolerable range (i.e. around 500 mS/m) any inundation is expected to inhibit the establishment of this species.

The soils which appear to be associated with the *Atriplex* sp. Yeelirrie Station distribution have been classified as 'Self-mulching'. Based on laboratory work undertaken by Soilwater Consultants in 2015 (SWC 2015b) in accordance with the established procedure of Grant and Blackmore (1991), all surface clay soils sampled from the *Atriplex* sp. Yeelirrie Station areas are not classified as Self-mulching. The cracking clay surface is therefore incorrectly labelled as Self-mulching, and is simply a function of desiccation and shrinkage of the clays upon drying. It is important to note that whilst these clays exhibit surface desiccation cracks they are not cracking clays, and a more appropriate classification of them would be 'Red/Brown Clay' according to the Soil Groups of Western Australia (Schoknecht 2002).

9.1.5 Potential Impacts and Management

The potential impacts on flora and vegetation that have been identified are:

- clearing of up to 2,421.8 ha of native vegetation;
- indirect impacts on groundwater dependent vegetation due to groundwater abstraction and reinjection;
- indirect impacts to vegetation dependent of surface water due to alterations and disruptions to surface water flows;
- indirect impacts on flora and vegetation from dust;
- introduction of weeds and spread of weeds into mining areas and adjacent native vegetation through movement of vehicles and materials;

- impacts on plants from feral animals and introduction of plants from outside the local area;
- uptake of radionuclides or other contaminants;
- altered fire patterns; and
- introduction of plants from outside the local area.

9.1.5.1 Impacts on vegetation communities

Impacts of clearing

Approximately 726 ha of native vegetation will require clearing from the open pit area, and up to 1,695 ha will require clearing for associated infrastructure.

Land Systems

An assessment of impacts from clearing to vegetation at the Land System level within the Local Study Area is presented in the Table 9-10. As evident in Table 9-2, the majority of the Land Systems are well represented across the north-eastern Goldfields and therefore the overall regional impact each individual Land Systems is low. No management measures are required to reduce impact or protect the land systems within the local area.

Table 9-10: Impacted land systems within local Study Area

Land System (Pringle *et al*. 1994, Payne *et al*. 1998)	Total Area of Land System within Local Study Area (ha)	Total Area to be Cleared (ha)	Percentage to be Cleared (%)
Millrose	13	2.5	19.23
Sherwood	921	32.9	3.57
Waguin	254	0	0
Gransal	440	0	0
Windarra	99	11	11.1
Bullimore	71530	850	1.19
Hamilton	46	0	0
Ranch	11	0	0
Monk	247	1.4	0.57
Yanganoo	11202	157.2	1.40
Desdemona	141	0	0
Cosmo	1797	0	0
Cunyu	2857	316.6	11.08
Melaleuca	3008	98	3.26
Mileura	3796	940.5	24.78
Carnegie	3525	0	0

Vegetation Associations

The vegetation associations of the study area have been mapped at NVIS Level 5 Vegetation Association. This level of definition is only available within Study Areas 1, 2 and 3 and is not available on a wider local or regional scale. Figure 9-6 shows the mapped vegetation associations of the study area, the Project footprint that is proposed to be cleared, and the broader development envelope. Table 9-11 lists the proportion of the total mapped area of each vegetation association and how much of each association is proposed to be cleared.

Table 9-11: Vegetation associations within Local Study Area to be impacted by the proposal

Vegetation community code	Vegetation Community Name	Area of Community within Local Study Area (ha)	Total Area to be Cleared (ha)	Percentage to be Cleared (%)
SAES	Stony *Acacia galeata* and *Eremophila* spp. Shrubland	311.1	0	0%
BCLS	Breakaway Chenopod Low Shrubland	54.4	0	0%
GFGr	Granite Foot Slope Grassland	43.4	0	0%
GPoS	*Ptilotus obovatus* Shrubland	133.8	2.3	1.7%
Qtz	Quartz Ridge	15.8	0	0%
GR	Granite Rise	47.7	0	0%
GRMS	Mulga Shrubland on Granite Rise	1159.4	1.9	0.2%
SASP	Sand plain Spinifex Hummock Grassland	2052.1	7.3	0.4%
SAWS	Sand plain Spinifex Hummock Grassland with Wattles	16698.8	94	0.6%
SAMA	Sand plain Spinifex Hummock Grassland with Mallee	30112.2	429.9	1.4%
SAHS	Sand plain Spinifex Hummock Grassland with Heath	2258.5	11.2	0.5%
SAGS	Sand plain Spinifex Hummock Grassland with *Eucalyptus gongylocarpa*	2885.6	0	0%
SAMU	Sandplain Mulga Spinifex Hummock Grassland	14186.9	270.5	1.9%
WABS	Wanderrie Bank Grassy Shrubland	1684.5	5.2	0.3%
SDSH	Sand Dune Shrubland	164	0	0%
HPMS	Hardpan Plain Mulga Shrubland	11198.5	187.4	1.7%
DRMS	Drainage Tract Mulga Shrubland	283.3	1.9	0.7%
DRES	Drainage Line *Eucalyptus camaldulensis* Woodland	5	0	0%
GRMU	Mulga Groves on Hardpan Plain	1410	0	0%
PLAPoS	*Acacia* spp. and *Ptilotus obovatus* Shrubland	2798.6	343.8	12.3%
PLAET	*Acacia* spp. and *Eremophila* spp. Thicket	384.3	36.4	9.5%
PLAMi	*Acacia* spp. and *Melaleuca interioris* Shrubland	101.4	0	0%
PLMf	*Muehlenbeckia florulenta* Shrubs	17.7	0	0%
PLCsMp	*Cratystylis subspinescens* and *Maireana pyramidata* Shrubland	639.3	7.9	1.2%
PLEmc	*Eremophila maculata* ssp. *brevifolia* Shrubland	8.5	0	0%
PLEml	*Eremophila malacoides* Shrubland	197.8	0	0%
PLEsp	*Eragrostis* sp. Grassland on Playa	15.2	8.1	53.6%
PLCh	Chenopods on Scalded Areas	55.8	0	0%
CEgW	*Eucalyptus gypsophila* Woodland on Calcrete	309.9	87.7	28.3%
CCpW	*Casuarina pauper* Woodland on Calcrete	682.3	5.6	0.8%
CMxS	*Melaleuca xerophila* Shrubland on Calcrete	664.4	175.1	26.4%
CAbS	*Acacia burkittii* Shrubland on Calcrete	1543.3	89.8	5.8%
CMiS	*Melaleuca interioris* Shrubland	6.3	0	0%
CErG	*Eragrostis* sp. Yeelirrie Calcrete Grassland on Calcrete	119.6	54.7	45.8%

Vegetation community code	Vegetation Community Name	Area of Community within Local Study Area (ha)	Total Area to be Cleared (ha)	Percentage to be Cleared (%)
CApS	*Atriplex* sp. Yeelirrie Station Shrubland	192.2	71	36.9%
CRsS	*Rhagodia* sp. Yeelirrie Station Shrubland	22.1	0	0%
CMpS	*Maireana pyramidata* Shrubland	147.5	45.2	30.6%
CLaS	*Lycium australe* Shrubland	140.6	94.8	67.4%
CMGbS	Mulga *Grevillea berryana* Shrubland	47.9	43.3	90.4%

EPA Position Statement No. 2 (EPA, 2000) indicates that "there would be an expectation that a proposal would demonstrate that the vegetation removal would not compromise any vegetation type by taking it below the "threshold level" of 30% of the pre-clearing extent of the vegetation type". i.e. more than 70% of the pre-clearing extent is proposed to be disturbed.

As presented in Table 9-11 the Project will directly impact one vegetation association CMGbS (Mulga *Grevillea berryana* Shrubland) beyond this threshold level within the Local Study Area. The Mulga *Grevillea berryana* Shrubland (which includes *Acacia ayersiana*) on Calcrete is a small vegetation association situated on the flanks the calcrete landforms of the Yeelirrie palaeochannel. The component species are widespread and abundant where they occur, however the regional representation of Mulga - *Grevillea berryana* Shrubland on Calcrete is not known past the Local Study Area. This is most likely due to low intensity mapping outside Local Study Area.

Two other vegetation associations that will have more than 50% (but less than 70%) cleared within the Local Study Area are *Lycium australe* shrubland (CLaS) and *Eragrostis* sp. Yeelirrie Calcrete on Playa (PLEsp).

- *Lycium australe* is a common species of salt lake margins in the eastern part of the south-west and the Western part of the Eremaean Botanical provinces where it often grows as a dominant to codominant shrub. At Lake Mason, it may be associated with *Cratystylis subspinescens*, *Eremophila arachnoides* subsp. *arachnoides* (P3), *Maireana pyramidata* or *Tecticornia* spp. shrubs. The regional representation of *Lycium australe* shrubland on Calcrete vegetation association similar in species composition to that at Yeelirrie is currently not known, most likely due to the low intensity mapping outside the study area.
- *Eragrostis* sp. Yeelirrie Calcrete is a common species occuring on calcrete platforms on lake margins and is known from near Yalgoo to east of Wiluna. It is particularly abundant at Lake Mason and was noted extensively in recent surveys by Western Botanical. However, the regional representation of *Eragrostis* sp. Yeelirrie Calcrete grasslands, either as the dominant vegetation association or in mosaics with other adjacent vegetation types, is currently not known outside the study area.

The Project will not have any impacts on vegetation associations which are listed as PECs or TECs by DPaW or TECs listed under the EPBC Act.

Impact of Groundwater drawdown on potentially phreatophytic vegetation

Groundwater drawdown impacts are discussed in detail in Section 9.5. Cameco has mapped the vegetation communities containing potentially phreatophytic vegetation that occur within the 1 m drawdown contour, over the life of the mine (Figure 9-6). Table 9-12 shows the percentage of the total mapped area of the potentially phreatophytic vegetation communities that occur within the 1 m drawdown contour. Cameco has also considered the impacts on phreatophytic vegetation from reinjection. However the entire area affected by reinjection is within the proposed pit and 1 m drawdown contour.

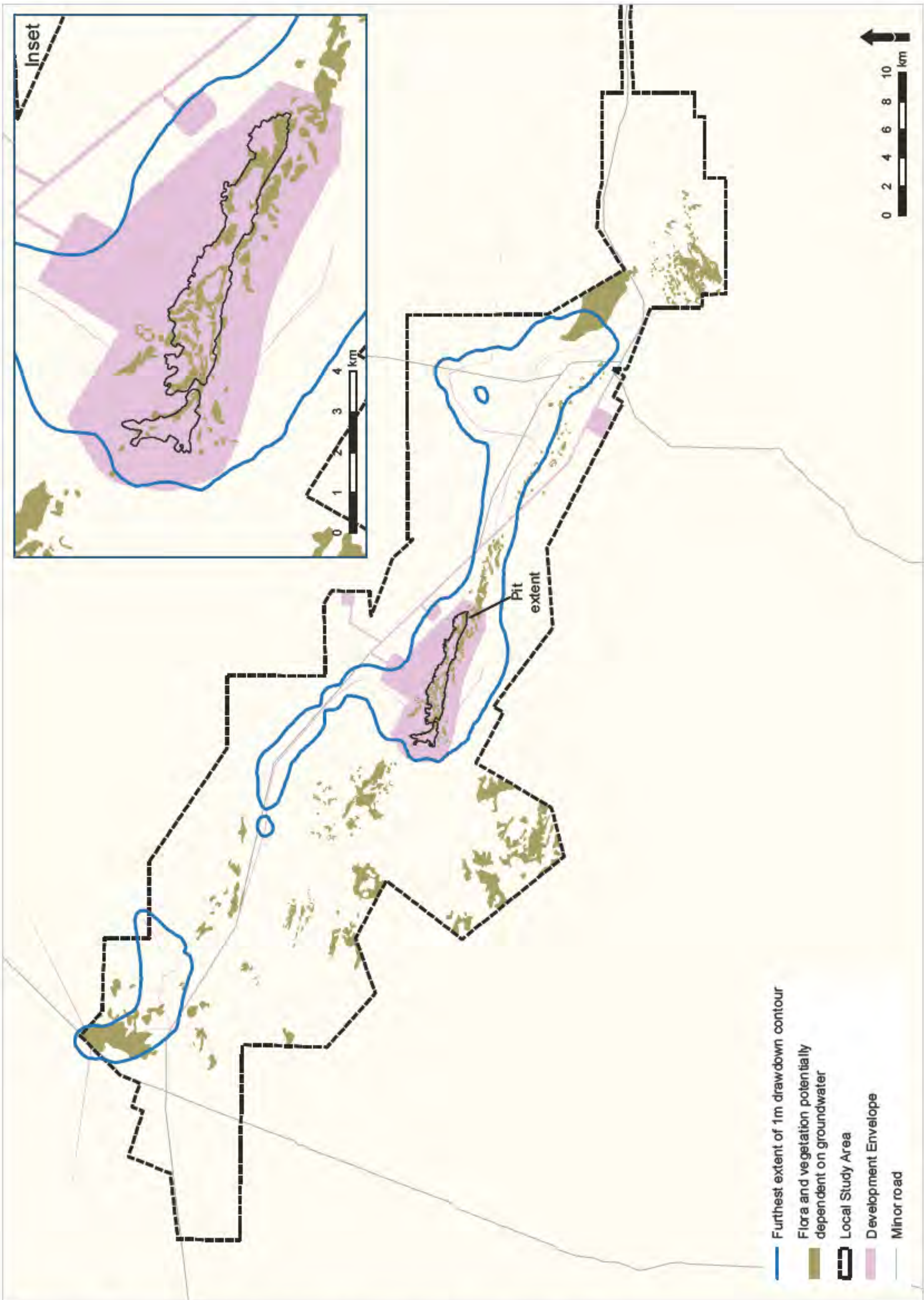


Figure 9-6: Phreatophytic vegetation associations within local Study Area

As previously mentioned the Mulga - *Grevillea berryana* Shrubland with *Acacia ayersiana* on Calcrete, is a small vegetation association that is situated on the flanks the calcrete landforms of the Yeelirrie palaeochannel. Both the component species are widespread and abundant where they occur, however the regional representation of the association is not known beyond the Local Study Area. This is most likely due to low intensity mapping outside Local Study Area.

A vegetation condition monitoring program will be implemented within the Area likely to be affected by groundwater abstraction. The program would include monitoring control sites and potential impact sites in the vegetation communities outlined in Section 9.1.4.2 within the predicted drawdown zone. The vegetation monitoring results would be correlated with changes in groundwater levels, and contingency measures developed, should a change be observed that can be attributed to these activities. Contingency measures are expected to include rotation of bores to minimise drawdown or irrigation of susceptible communities outside of the Development Envelope (but within the drawdown zone), if practical.

Table 9-12: Phreatophytic vegetation associations within 1 m groundwater drawdown

Vegetation Community Code	Phreatophytic Vegetation Community	Area within Local Study Area (ha)	Area to be Cleared (ha)	Area within modelled 1 m drawdown	Total % Potentially Impacted
PLAET	*Acacia* spp. and *Eremophila* spp. Thicket	384.3	36.4	123.2	41.53
PLAMI	*Acacia* spp. and *Melaleuca interioris* Shrubland	101.4	0	15.3	15.09
CEgW	*Eucalyptus gypsophila* Woodland on Calcrete	309.9	87.7	23.4	35.85
CCpW	*Casuarina pauper* Woodland on Calcrete	682.3	5.6	19	3.61
CMiS	*Melaleuca interioris* Shrubland	6.3	0	3.7	58.73
SASP	Sand plain Spinifex Hummock Grassland	2052.1	7.3	764.6	37.62
SAGS	Sand plain Spinifex Hummock Grassland with *Eucalyptus gongylocarpa*	2885.6	0	285.3	9.89
SMGbS	Mulga *Grevillea berryana* Shrubland	47.9	43.3	4.5	99.79
CMxS	*Melaleuca xerophila* Shrubland on Calcrete	664.4	175.1	149.4	48.84
	Total	7134.2	355.4	1388.4	24.44

Effects of changes to surface water flow

As part of monitoring of the integrity of surface water diversion and management structures (Section 9.4), Cameco will also monitor nearby vegetation health to determine if water ponding, water starvation or erosion and sedimentation is occurring that could adversely affect vegetation condition. Whilst flood water depth is expected to increase (from baseline) upstream of the mine site as a result of the surface water diversion bund, the effects are expected to be localised.

Introduction of weeds

In addition to direct impacts of clearing, the Project has the potential to introduce weeds to, or spread weeds within, the Project Area. Seeds may be carried into the Project on vehicles and machinery, or in soil moved within the Project Area.

All earth moving equipment and other vehicles or machinery will be cleaned of all soil and seeds before mobilisation into new clearing areas. Weed control will be undertaken for infestations with the potential to spread. Vegetation removed during clearing activities will be temporarily stockpiled to be used as mulch and a seed source in progressive revegetation. Soil that is suitable for rehabilitation will be stripped and stored in low stockpiles to retain seed viability and be protected from erosion and accidental disturbance.

Cameco will develop a Flora and Vegetation and Management Plan to minimise and manage potential impacts of the Project on the flora and vegetation communities of the Project Area. As part of this management plan Cameco will implement a ground disturbance procedure that will apply to all clearing activities. Areas proposed to be cleared will first be inspected by environmental personnel to determine if there are any significant flora present within the area or other sensitive environmental areas, and to ensure clearing is conducted in accordance with the necessary approvals. Clearing will be kept to the minimum area required for safe and efficient operation. Clearing will not be conducted during or immediately after significant rain to reduce the risk of erosion and damage to soil structure.

Impacts from dust and radiation

This section discusses the potential radiological effects of the operation on flora and vegetation. The assessment considers the primary pathway for impacts outside the operation, which is the release of airborne dusts and their deposition in the environment. The Project has been designed to prevent off-site release of water for events up to 1:1,000 ARI rainfall event therefore this pathway was not considered further.

The deposition of Project-originated dust could result in the deposition of radionuclides onto soils and their subsequent incorporation into the soils.

The assessment utilises the Environmental Risk from Ionising Contaminants (ERICA) software tool and the change in soil radionuclide concentrations to make a qualitative assessment of potential risk to a set of standard flora species. For this assessment, Cameco has derived some area and plant species-specific concentration ratios from radionuclide surveys conducted in 2010 and 2011 by BHP Billiton. As there is limited Australian concentration ratio data for flora species in ARPANSA (2014), the site specific concentration ratios have been used.

The ERICA Tool

The ERICA Assessment tool was developed under the European Commission to provide a method of assessing the impact of radiological contaminants on the natural environment (Brown et al. 2008; Larsson 2008). The tool contains two major data sources. The first, the database FREDERICA, contains information on the effects of radiation exposure on populations, and includes data on four main "endpoints": morbidity, mortality, reproduction and mutation (Copplestone *et al*. 2008). The second is a collection of databases that allows estimation of the radiation doses that will accrue to biota from radiological contaminants in their environment.

The International Commission on Radiological Protection has recommended that environmental radiological effects should be assessed on a series of "reference organisms", and these are incorporated into the ERICA tool (ICRP 2003).

The starting point for an ERICA assessment is the radionuclide concentrations of the medium in which or on which the reference organisms are living, in this case soil. This allows the external dose rate for the organisms to be derived, and in addition "concentration ratios" from the ERICA database are used to calculate the radionuclide concentrations in the organisms, and hence the internal dose rates.

The ERICA assessment process can be carried out in three "tiers".

Tier 1 is a simple highly conservative assessment, designed to easily identify situations which can be considered of negligible radiological concern.

Tier 2 is used where a Tier 1 assessment indicates that there may be organisms at risk, and allows the use of more realistic and less conservative parameters to allow the estimation of dose rates to the organisms. These dose rates are then assessed against a screening dose rate to determine if there is a likelihood that populations could suffer harm.

Tier 3 is not a screening tier but is designed to provide guidance in further investigation of situations where Tier 2 indicates that there may be a significant concern of radiological harm.

The default screening dose rate adopted by ERICA is 10 µGy/h. This dose rate (described as the "predicted no-effect dose rate", PNEDR) was derived from the dose estimated to give a 10% effect (i.e. to one of the end points noted above) to 5% of the species present by applying a safety factor of five. This screening rate is expected to protect the most radiosensitive organisms likely to be present in an environment (Garnier-Laplace *et al*. 2008; Copplestone *et al*. 2008).

The ERICA tool allows other screening dose rates to be adopted. For example, several organisations have suggested that no measureable effects would be observed for dose rates of 40 µGy/h (terrestrial animals) and 400 µGy/h (terrestrial plants) (IAEA 1992; UNSCEAR 1996; United States Department of Energy 2002). The ERICA tool presents the results as the dose rates to the organisms, and also in terms of the "Risk Quotient" (i.e. the ratio of the dose rate to the screening rate). Dose rates and risk quotients are presented both for the "expected value" and a "conservative value". The default conservative value is three times higher than the expected value and represents the value at which there is only a 5% chance that the calculated dose rate exceeds the screening level. This represents a further level of conservatism.

The results of an ERICA assessment can be described in terms of three dose rate bands (Brown *et al*. 2008):

RQExpt > 1 (i.e. expected dose rate > 10 µGy/h)
Screening dose is exceeded. Further assessment needed.

RQCons > 1 but RQExp < 1 (i.e. expected dose rate 3.3 – 10 µGy/h)
Substantial probability that screening dose rate is exceeded. Assessment should be reviewed.

RQCons <1 (i.e. expected dose rate <3.3 µGy/h)
Low probability that screening dose rate will be exceeded. Environmental risk is considered negligible.

A potential disadvantage of using the ERICA tool for Australian situations is that many of the parameters are derived for temperate northern hemisphere flora and fauna which do not directly equate with Australian flora and fauna. The standard ERICA factors are generally used because there is a lack of specific Australian data. However, in this instance there is some region specific radionuclide concentration data that was collected by BHP Billiton and that has been used to develop local flora concentration ratios.

Soil Radionuclide Concentrations

The air quality modelling has produced dust deposition estimates (Section 9.8.5). The modelling produces estimates of the potential impact that the operation will have irrespective of the naturally occurring background levels. This assessment has been conducted at the modelled project impact contour of 0.4g/m^2/month, which occurs at approximately the operations boundary. For a 15 year project, the total predicted dust deposition is calculated to be 72 grams per m^2. For the whole operation, the average radionuclide content of the emitted dust is 9.4Bq/g per radionuclide.

Once deposited, the Project dust would mix with the soil through a combination of physical, chemical and biological processes. For this assessment, it has been assumed that the mixing depth is 10 mm (Kaste *et al*. 2007). The soil density was assumed to be 1.5 t/m³.

Therefore the increase in radionuclide concentration in the soil at the Project boundary after 15 years of operations is calculated as follows;

- total radionuclide deposition per m² = 72 g x 9.4 Bq/g = 677 Bq
- total mass of soil per m² = 1 m x 1 m x 0.01 m x 1.5 t/m3 = 15 kg
- increase in soil radionuclide concentration = 677 Bq/15 kg = 45 Bq/kg

Concentration Ratios

Concentration ratios for flora sampled during 2010 is presented in Table 9-13. These figures were obtained from the baseline radionuclide surveys by taking the average radionuclide concentrations in flora and dividing by the average soil concentrations.

Table 9-13: Summary of concentration ratios for sampled vegetation

Species	Concentration Ratios				
	U^{238}	Th^{230}	Ra^{226}	Pb^{210}	Po^{210}
Acacia aneura	0.10	0.30	0.01	0.31	0.56
Acacia ayersiana	0.11	0.03	0.01	0.36	0.56
Ptilotus obovatus	0.17	0.07	0.06	0.20	0.20

The derived concentration ratios for each local flora species have been averaged to provide a single figure and Table 9-14 provides a comparison of the default ERICA concentration

Table 9-14: Comparison of concentration ratios

Element	Concentration Ratios			
	ERICA Default (Tree)	ERICA Default (Shrub)	Cameco (Tree/ Shrub)	Shrubs (ARPANSA 2014)
Uranium	0.007	0.061	0.130	-
Thorium	0.001	0.061	0.130	-
Radium	0.012	0.330	0.030	0.15
Polonium	0.073	0.330	0.440	-
Lead	0.070	0.320	0.290	-

ERICA Assessment

A Tier 2 ERICA assessment was conducted using a soil radionuclide concentration of 45 Bq/kg (each uranium series radionuclide) and the derived concentration ratios (see Table 9-14) and the resulting derived dose rates are shown in Table 9-15.

Table 9-15: Tier 2 ERICA Assessment

Organism	CR Origin	Risk Quotient (expected value)	Risk Quotient (conservative value)
Lichen & bryophytes	Default	1.06	3.18
Grasses & herbs	Default	0.20	0.60
Shrub	Experimental	0.13	0.38
Tree	Experimental	0.13	0.38

Note that Table 9-14 shows that the ERICA default value for radium for shrubs is approximately 10 times higher than the local derived result. An additional ERICA assessment was conducted using the higher radium concentration ratio value and this gave results three times higher than those shown in Table 9-15, however, both the expected value and conservative values were less than the screening value.

The assessment identified lichen and bryophytes as species that would trigger the screening level of 10 µGy/h. The baseline flora surveys conducted (Western Botanical 2011) made general observations for lichen, which showed that they were relatively abundant through the region.

The expected dose rate derived for lichen and bryophytes is just higher than the screening level of 10 µGy/h. The reason for this is likely to be that lichens (in particular) do not have a well-developed root system, and derive most of their nutrients from dust falling on them. Consequently, they receive a higher dose from the deposition of dusts than for other organisms.

Lichen and bryophytes are known to be particularly radio-resistant and a threshold no-effect dose rate has been estimated at approximately 125,000 µGy/h, with some diversity reduction observed at 1.1 Gy/h (UNSCEAR 1996). These dose rates are over 10,000 times the default screening dose rate used in ERICA, and indicate that no effect would be expected from any potential dust emissions from the Project.

Dust management and suppression measures will be undertaken as outlined in Section 9.8.5. Water used for dust suppression may be saline (up to 100,000 mg/L Total Dissolved Solids [TDS]) and therefore care will be taken not to spray this water on vegetation, and control run off into vegetated areas.

Impact from altered fire patterns

Alteration of natural fire regimes as a result of improved access and increased human activity can lead to a change in the floristics of an area.

Cameco will manage this risk through implementation of a fire ban across the Project Area and education of the workforce. Hot work permits will be required prior to commencing any work activity that may create an ignition source. Fire extinguishers will be available in all hot work areas and personnel will be trained in their use.

Combined worst-case impacts on vegetation communities

Cameco has looked at the potential combined worst-case impacts on vegetation communities as a result of clearing, dust deposition, groundwater drawdown and inundation as a result of altered surface drainage patterns. For this assessment, the following criteria were used to map and calculate these impacts:

- the clearing footprint;
- dust deposition (>2 g/m^2/month);
- groundwater drawdown (>1 m); and
- inundation (from a 1:1,000 year ARI) rainfall event of >0.5 m).

The areas potentially impacted are shown on Figure 9-7. However, in reality these combined worst-case conditions are not expected to occur.

The figure shows that dust deposition will be mostly restricted to the pit and plant area due to the dust controls to be implemented for the Project (Section 9.8). Groundwater drawdown encompasses the pit area and extends to the north, northwest, and south east of the pit as a result of pit dewatering and borefield operations (Section 9.5). Under a 1:1,000 year ARI event, flooding of more than 0.5 m is expected to extend to the north and south of the pit, and upstream (northwest) of the pit, as a result of the surface water diversion bunding (Section 9.4).

Areas of vegetation communities potentially affected in the worst-case scenario are presented in Table 9-16. It should be noted however, that a number of vegetation communities within the drawdown contour are not expected to be groundwater dependent and therefore are unlikely to be affected by drawdown of greater than 1 m. The results indicate that there are three vegetation communities with more than 75% of the community (mapped within the study area) occurring within the footprint of the combined worst-case impacts:

- Mulga Shrubland on Granite Rise (GRMS) – approximately 97.9% of this community that is mapped within the study area could be affected, as a result of inundation from a 1:1,000 year ARI rainfall event. However, the likelihood of this occurring during the life of the Project is extremely low and the predicted impact on this community is expected to be restricted to clearing (0.16%).
- Hardpan Plain Mulga Shrubland (HPMS) – approximately 79.1% of this community that is mapped within the study area could be affected as a result of inundation from a 1:1,000 year ARI rainfall event. This does not include the area within the groundwater drawdown contour of 0.5 m as this vegetation community is not expected to be groundwater-dependent. However, the likelihood of this occurring during the life of the Project is extremely low and the predicted impact on this community is expected to be restricted to clearing (1.67%).
- Mulga *Grevillea berryana* Shrubland (CMGbS) – approximately 99.8% of this community that is mapped within the study area could be affected as a result of clearing and groundwater drawdown impacts. However, as discussed above, the component species are widespread across the region, and abundant where they occur.

Table 9-16: Combined worst-case impacts on vegetation associations within the Local Study Area

			Direct Impacts (ha)	Additional area potentially affected by indirect impacts (ha)			
Vegetation community code	Vegetation Community Name	Area of Community within Local Study Area (ha)	Total Area to be Cleared (ha)	Dust Deposition (>2 g/m²/ month)	Groundwater drawdown (>1 m drawdown)	Surface Water (>0.5 m flooding after 1,1000 year ARI)	Worst Case percentage impacted (%)
SAES	Stony *Acacia galeata* and *Eremophila* spp. Shrubland	311.1	0	0	0	0	0
BCLS	Breakaway Chenopod Low Shrubland	54.4	0	0	0	0	0
GFGr	Granite Foot Slope Grassland	43.4	0	0	0	0	0
GPoS	*Ptilotus obovatus* Shrubland	133.8	2.3	0	0	47.8	37.4
Qtz	Quartz Ridge	15.8	0	0	0	0	0
GR	Granite Rise	47.7	0	0	0	0	0
GRMS	Mulga Shrubland on Granite Rise	1159.4	1.9	0	0	1132.9	97.9
SASP	Sand plain Spinifex Hummock Grassland	2052.1	7.3	0	764.6	0	37.6
SAWS	Sand plain Spinifex Hummock Grassland with Wattles	16698.8	94	0	4910*	152.4	1.48
SAMA	Sand plain Spinifex Hummock Grassland with Mallee	30112.2	429.9	0	3869.3*	3123.7	11.8
SAHS	Sand plain Spinifex Hummock Grassland with Heath	2258.5	11.2	0	1088.3*	165.6	7.8

			Direct Impacts (ha)	Additional area potentially affected by indirect impacts (ha)			
Vegetation community code	Vegetation Community Name	Area of Community within Local Study Area (ha)	Total Area to be Cleared (ha)	Dust Deposition (>2 g/m²/ month)	Groundwater drawdown (>1 m drawdown)	Surface Water (>0.5 m flooding after 1,1000 year ARI)	Worst Case percentage impacted (%)
SAGS	Sand plain Spinifex Hummock Grassland with *Eucalyptus gongylocarpa*	2885.6	0	0	285.3	0	9.9
SAMU	Sandplain Mulga Spinifex Hummock Grassland	14186.9	270.5	19.5	1803.7*	2426.6	19.2
WABS	Wanderrie Bank Grassy Shrubland	1684.5	5.2	0	215.5*	347.7	21
SDSH	Sand Dune Shrubland	164	0	0	0	0	0
HPMS	Hardpan Plain Mulga Shrubland	11198.5	187.4	0	1150.9*	8672.7	79.1
DRMS	Drainage Tract Mulga Shrubland	283.3	1.9	0	164.1*	0	0.7
DRES	Drainage Line *Eucalyptus camaldulensis* Woodland	5	0	0	0	0	0
GRMU	Mulga Groves on Hardpan Plain	1410	0	0	114.4*	2.5	0.2
PLAPoS	*Acacia* spp. and *Ptilotus obovatus* Shrubland	2798.6	343.8	0	467.7*	266.2	21.8
PLAET	*Acacia* spp. and *Eremophila* spp. Thicket	384.3	36.4	0	123.2	33.1	50.14
PLAMi	*Acacia* spp. and *Melaleuca interioris* Shrubland	101.4	0	0	15.3	0	15.1
PLMf	*Muehlenbeckia florulenta* Shrubs	17.7	0	0	4*	4.1	23.2
PLCsMp	*Cratystylis subspinescens* and *Maireana pyramidata* Shrubland	639.3	7.9	0	0	0	1.2
PLEmc	*Eremophila maculata* ssp. *brevifolia* Shrubland	8.5	0	0	0	0	0
PLEml	*Eremophila malacoides* Shrubland	197.8	0	0	6.0*	0	0
PLEsp	*Eragrostis* sp. Grassland on Playa	15.2	8.1	0	0.5*	0.5	53.3
PLCh	Chenopods on Scalded Areas	55.8	0	0	0	35	62.7

			Direct Impacts (ha)	Additional area potentially affected by indirect impacts (ha)			
Vegetation community code	Vegetation Community Name	Area of Community within Local Study Area (ha)	Total Area to be Cleared (ha)	Dust Deposition (>2 g/m²/ month)	Groundwater drawdown (>1 m drawdown)	Surface Water (>0.5 m flooding after 1,1000 year ARI)	Worst Case percentage impacted (%)
CEgW	*Eucalyptus gypsophila* Woodland on Calcrete	309.9	87.7	0	23.4 (entirely within >0.5 m flooding after 1,1000 year ARI)	56	46.4
CCpW	*Casuarina pauper* Woodland on Calcrete	682.3	5.6	0	19 (entirely within >0.5 m flooding after 1,1000 year ARI)	285.8	42.7
CMxS	*Melaleuca xerophila* Shrubland on Calcrete	664.4	175.1	0	105.4*	0	26.4
CAbS	*Acacia burkittii* Shrubland on Calcrete	1543.3	89.8	0	12.7*	782	5.82
CMiS	*Melaleuca interioris* Shrubland	6.3	0	0	3.7	2.6	26.35
CErG	*Eragrostis* sp. Yeelirrie Calcrete Grassland on Calcrete	119.6	54.7	0	0	0	5.82
CApS	*Atriplex* sp. Yeelirrie Station Shrubland	192.2	71	0	0	0	36.9
CRsS	*Rhagodia* sp. Yeelirrie Station Shrubland	22.1	0	0	0	2	9
CMpS	*Maireana pyramidata* Shrubland	147.5	45.2	0	21.3	0	45.1
CLaS	*Lycium australe* Shrubland	140.6	94.8	0	0	0	67.4
CMGbS	Mulga *Grevillea berryana* Shrubland	47.9	43.3	0	4.5	0	99.8

*Not expected to be groundwater dependent

9.1.5.2 Impacts on Conservation Significant Flora

Impacts on Priority flora

Direct impacts to known flora with conservation significance are discussed in detail in the Conservation Species Management Plan prepared by Cameco. Of the 12 known Priority species presented in Table 9-4 and present within the Local Study Area, only three species, *Eremophila arachnoides* subsp. *arachnoides* P3, *Bossiaea eremaea* P3 and *Euryomyrtus inflata* P3 will be directly impacted by the Project. The impact to these species is considered to be low due to the small percentage of impact (Table 9-17) within the Local Study Area and due to them being well represented in the broader north-eastern Goldfields. The location of these species within the Study Area is also shown in Figure 9-4.

Table 9-17: Priority flora to be impacted by the proposal

Species Name	Status	Number of Plants within Local Study Area	Plants Proposed to be Cleared	Plants Proposed to be cleared (%)
Bossiaea eremaea	P3	36442	1562	4.29
Eremophila arachnoides subsp. *arachnoides*	P3	43255	5120	11.84
Euryomyrtus inflata	P3	134520	410	0.30

It should also be noted that the priority one species *Rhagodia* sp. Yeelirrie Station (K.A.Shepherd *et al*. KS1396) occurs both within and outside the Development Envelope. Cameco proposes to avoid this species and will establish a conservation area for the population (~100 plants) inside the development envelope as shown in Figure 9-8. However, due to proposed alterations in the surface water flow there is the potential for an indirect impact on the 100 plants (4.8%). As this population of *Rhagodia* sp. Yeelirrie Station (K.A. Shepherd *et al*. KS1396) occurs on the fringes of a clay pan that already experiences long periods of inundation it is unlikely that the plants will be significantly impacted.

Management of conservation significant flora will be in accordance with the Conservation Species Management Plan (Appendix E3). Should Priority flora species be recorded during pre-disturbance checks these would not be disturbed without consultation with DPaW to ensure the species conservation status is not adversely affected.

Combined worst-case impacts on significant flora

Cameco has looked at the potential maximum worst-case impacts on significant flora as a result of clearing, dust deposition, groundwater drawdown and inundation as a result of altered surface drainage patterns. For this assessment, the following criteria were used to map and calculate these impacts:

- the clearing footprint;
- dust deposition (>2 g/m^2/month);
- groundwater drawdown (>1 m); and
- inundation (1:1,000 year ARI event of >0.5 m).

The areas potentially impacted are shown on Figure 9-7. However, as noted above, these conditions are not expected to occur simultaneously.

The impacts of dust deposition are expected to occur within the pit and plant area. *Eremophila arachnoides* subsp. *arachnoides* is present in this area. However, this area will largely be disturbed as a result of clearing. Inundation as a result of a 1:1,000 year ARI rainfall event could affect populations of *Rhagodia* sp. Yeelirrie Station, *Bossiaea eremaea* and *Eremophila arachnoides* subsp. *arachnoides*. However, the likelihood of this occurring during the life of the Project is considered extremely low. *Euryomyrtus inflata*, *Bossiaea eremaea*, and *Eremophila arachnoides* subsp. *arachnoides* occur within the 1 m drawdown contour. However, these species are not considered groundwater-dependent.

Numbers of plants of each priority species potentially affected in the worst-case scenario are presented in Table 9-18. The results indicate that less than 30% each of the priority flora populations recorded within the Local Study Area will potentially be affected under worst-case conditions.

The impacts on the threatened species *Atriplex* sp. Yeelirrie Station are discussed in more detail below.

Table 9-18: Combined worst-case impacts on Priority flora within the Local Study Area

			Direct Impacts (#plants)	Additional plants potentially affected by indirect impacts (#plants)			
Species Name	Status	Number of Plants within Local Study Area	Plants Proposed to be Cleared	Dust Deposition (>2 g/m²/ month)	Groundwater drawdown (>1 m draw-down)	Surface Water (>0.5 m flooding after 1,1000 year ARI)	Worst Case percentage impacted (%)
Bossiaea eremaea	P3	36442	1562	0	14504*	4139	15.6
Eremophila arachnoides subsp. *arachnoides*	P3	43255	5120	0	285*	6350	26.5
Euryomyrtus inflata	P3	134520	410	0	42775*	0	0.3
Neurachne lanigera	P1	300	0	0	300*	0	0
Rhagodia sp. Yeelirrie Station	P1	2200	0	100	100* (same plants that are potentially affected by dust)	100 (same plants that are potentially affected by dust)	4.5

* Not considered groundwater dependent

9.1.5.3 Impacts on Theatened Flora (*Atriplex* sp. Yeelirrie Station)

As previously discussed, the Eastern and Western populations of *Atriplex* sp. Yeelirrie Station are genetically distinct, and that the two populations (genotypes) should be treated separately with regard to conservation measures. The Western Population of *Atriplex* sp. Yeelirrie Station lies wholly within the economic orebody and encompasses two sub-populations that are located in close proximity to each other. Implementation of the Project will involve total removal of the Western Population, taking 84,542 plants over an area of 76 ha, representing 30.71% of the overall population and 36.69% of the overall area of occupancy of this species. The Eastern Population of *Atriplex* sp. Yeelirrie Station, 190,755 plants over an area 130 ha, will be conserved and will not be impacted. As the Western Population genotype of *Atriplex* sp. Yeelirrie Station lies wholly within the economic orebody, minimisation or avoidance of impacts is not possible.

Protection of the Eastern genotype

The eastern genotype of *Atriplex* sp. Yeelirrie Station will not be affected by development activity related to the Project and Cameco proposes permanent protection from external pressures of the entire Eastern population as presented in Figure 9-9. This will be achieved through fencing of the population to exclude livestock from neighbouring pastoral leases. Tenure options, including the establishment of a Conservation Area, will be investigated to determine the best option to ensure long term protection.

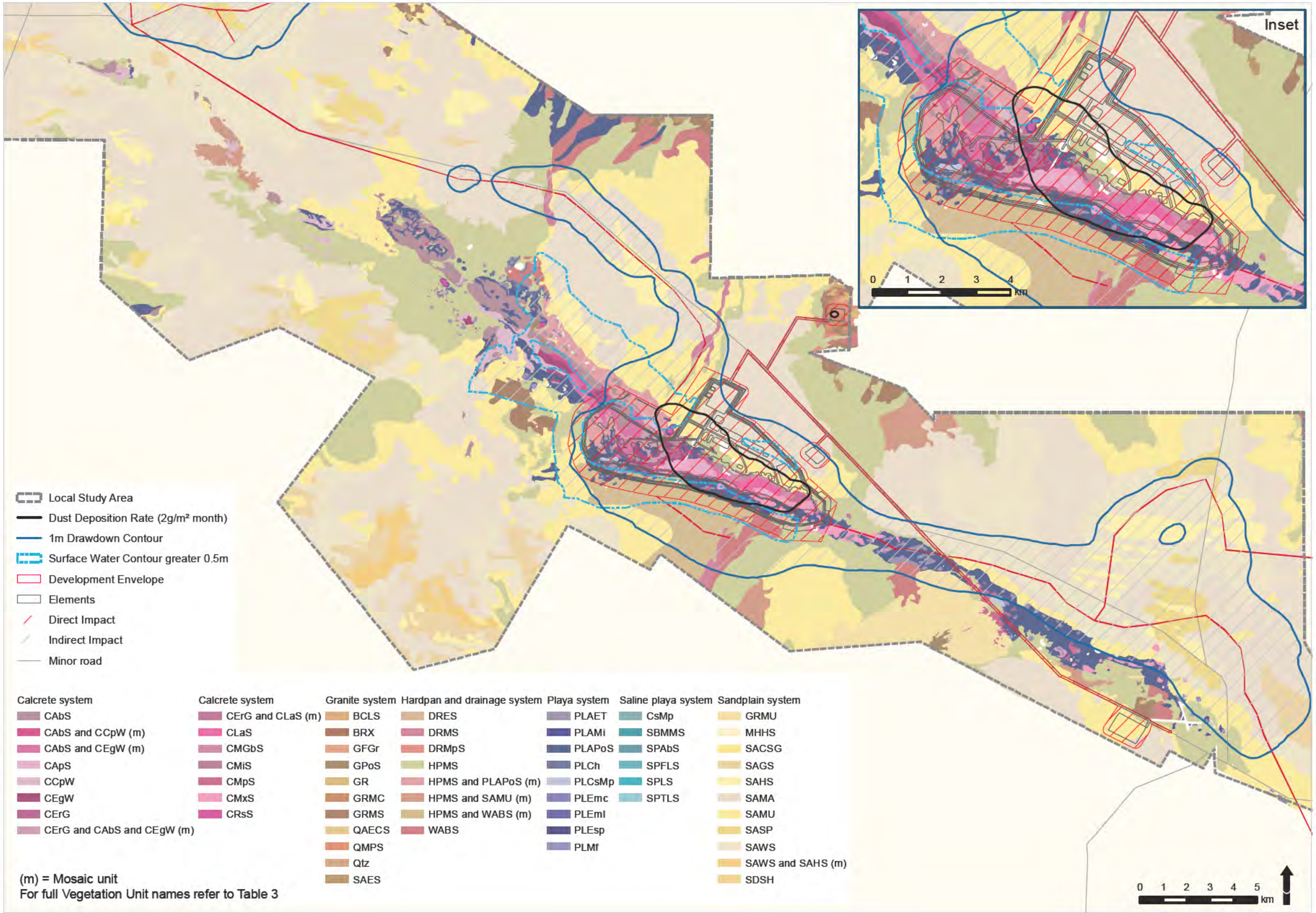


Figure 9-7: Combined worst-case impacts on vegetation communities within the local study area

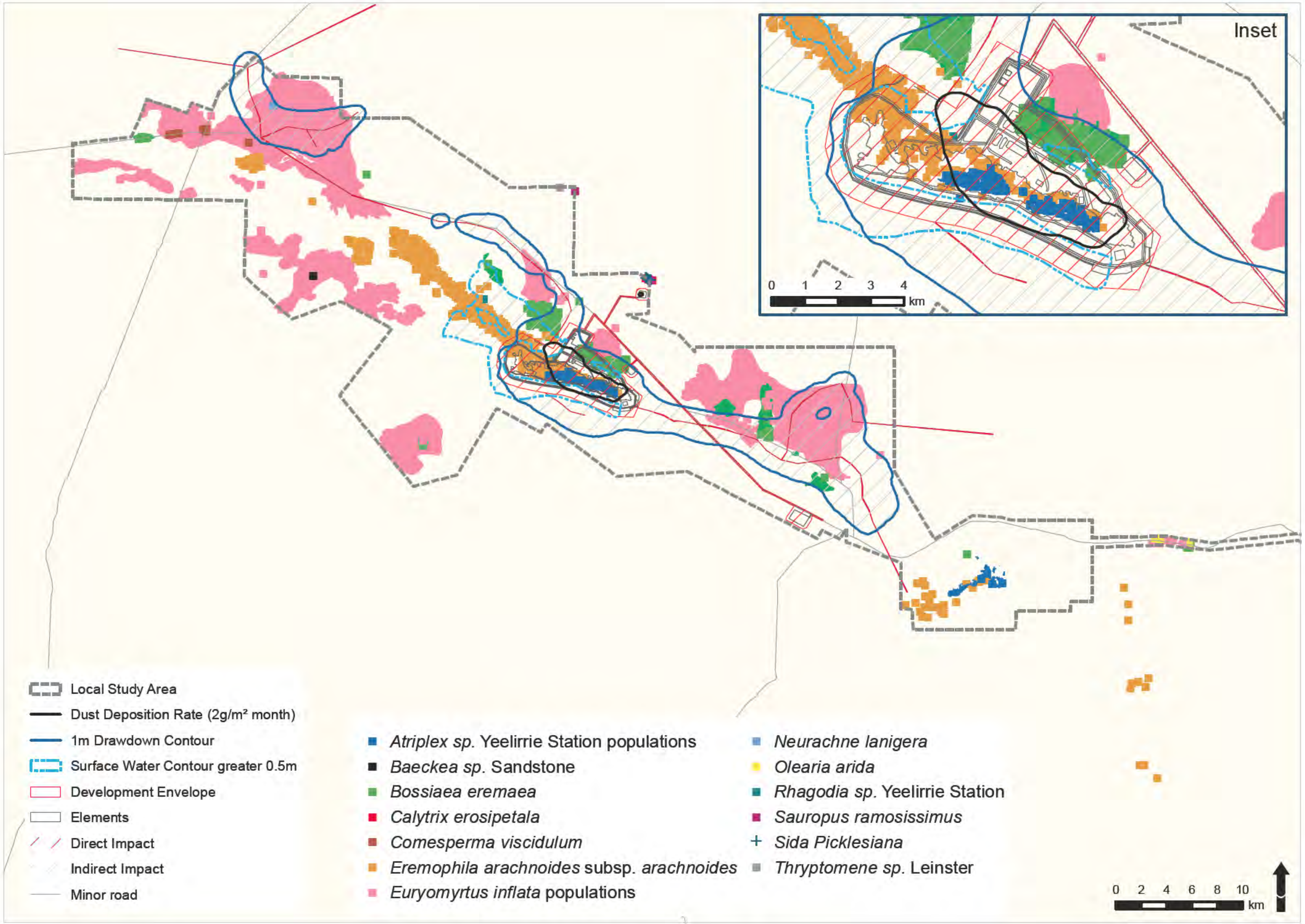


Figure 9-8: Combined worst-case direct and indirect impacts on significant flora in the study area

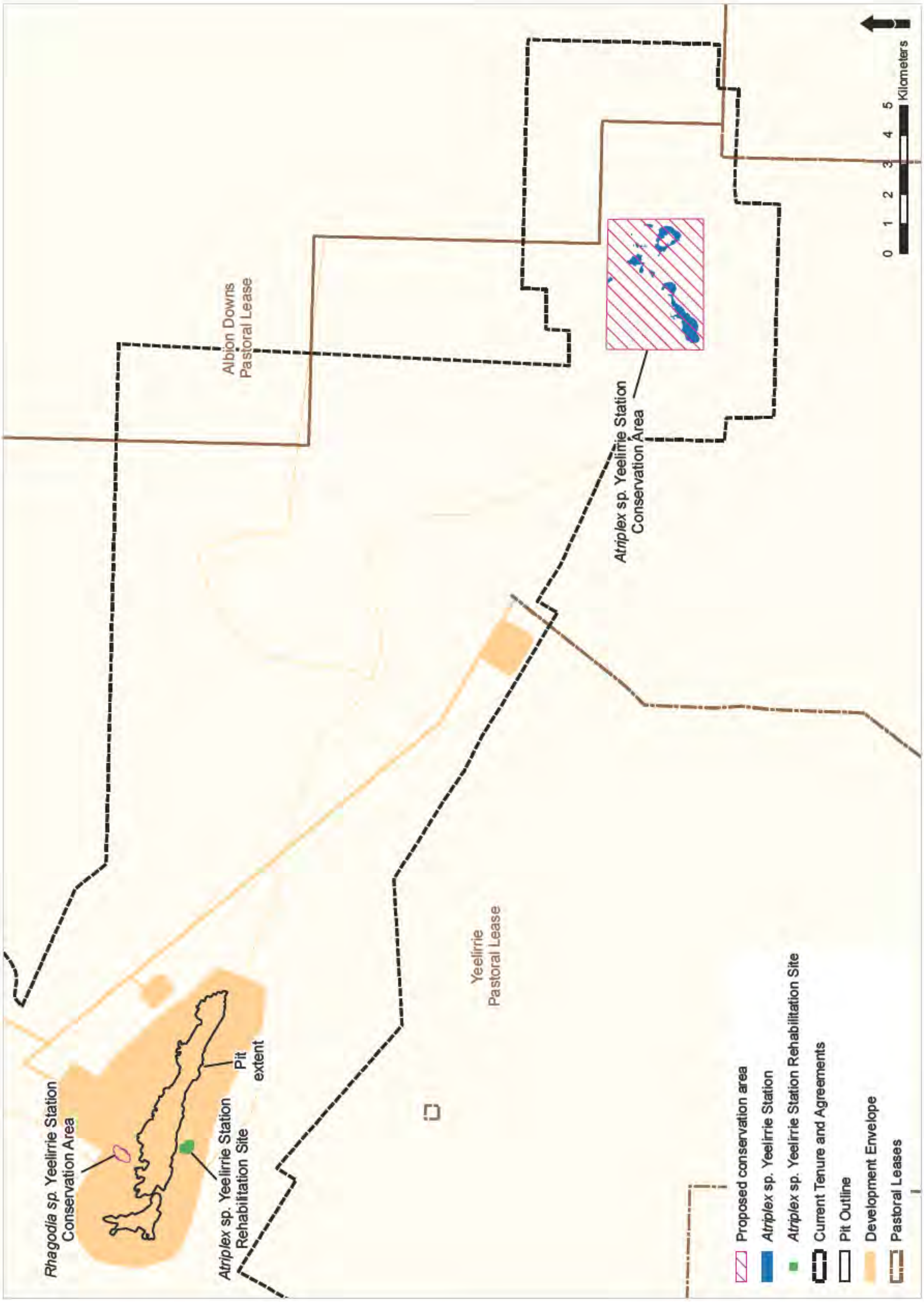


Figure 9-9: Proposed conservation areas

Measures will also be taken to protect the Rehabilitation population to ensure it is not cleared during mine development. Long term protection of this site will continue to provide a useful reference point for the comparison of population dynamics of the species.

Preservation by re-establishment of the Western genotype

In order to preserve the Western genotype, Cameco proposes to establish new populations of *Atriplex* sp. Yeelirrie Station (Western genotype) and has commenced investigations and research to provide some reasonable evidence that this can be achieved.

The multiple lines of investigation include the following:

- Investigations into seed collection, storage and long term seed viability, to ensure that seed harvested from natural populations can be stored for future use.
- Population demographic studies, to understand the population structure of the natural populations so that it can be used to assess the structure of future established populations.
- Hydrogeological studies of the natural habitat of the species so that potential new sites can be assessed.

The results of the investigations are discussed further below.

Seed collection, storage and viability

Atriplex sp. Yeelirrie Station produces seed annually, generally following significant rainfall events. A single seed is held in each bract. Bracts are indehiscent and stay on the plant for a period greater than 12 months. The seed is tightly held in the bract but can be extracted mechanically. Seed was collected from *Atriplex* sp. Yeelirrie Station during October and November 2010. At the time of collection both fresh bracts (produced in 2010) and old bracts (produced prior to 2010) were present on the plants in the populations that were targeted on the resource areas. The purpose of the seed collection program was to collect, process and store seed to undertake investigations into its viability and germination and for future use in rehabilitation or translocation trials. Approximately 3.69 million seeds were collected and continue to be stored for future use (Landcare Services 2011).

Germination and Viability testing was conducted on representative samples of fresh and old seed in 2011. The results are shown in (Table 9-19).

Table 9-19: Seed germination and viability results, 2011

Material tested	Germination Rate	Viability
Fresh excised seed	78%	96%
Old excised seed	73%	79%
Fresh seed in-bract	0%	85%
Old seed in-bract	22%	66%

Additional germination testing was conducted in late 2014 on the seed collected in August that year under DRF Permit 35-1415. The results showed germination rates of old and new seed did not vary significantly with rates between 72% and 92% observed, however, seed retained within the bracts did not begin to germinate at high rates (up to 50%) until three weeks of testing while excised seeds germinated rapidly in the second week. The results are reported in Western Botanical (2015d) (Report WB849; Appendix E6).

In summary, fresh seed has a higher viability rate than older seed and fresh seed excised from the bracts germinates at a higher rate than old excised seed. Germination rates are lower when the seed is retained in the bract, presumably due to a physical or chemical germination inhibition, which does begin to break-down after about three weeks. As fruits age, the rate of germination inhibition is reduced.

Plant demographics

Western Botanical (2011) reported an overall mature plant population estimate of ~275,297 across both populations where an average of 1,112 mature plants per ha were reported in the Western population (84,510 plants over 76 ha) and 1,467 mature plants per ha were reported in the Eastern population (190,646 plants over 130 ha).

The assessment of *Atriplex* sp. Yeelirrie Station undertaken in March 2015 established a baseline data set for future assessment of population dynamics and population viability analysis.

During the baseline field surveys, a third population of the species was assessed. This population of 109 individuals is growing in an area that was disturbed by exploration activities conducted in the 1980's and was subsequently rehabilitated in 1994. A further seven live plants have been noted in rehabilitation north of the deposits. It is believed that *Atriplex* sp. Yeelirrie Station seed was introduced to the site with soil.

Field assessment sites were established and the three populations have been assessed and statistically compared with the purpose of i) establishing a baseline data set of "mature" populations upon which to compare any new population that might be established in the future, and ii) to determine the performance of the rehabilitation population compared to the natural populations. The results are reported in Western Botanical (2015b) (Report WB844; Appendix E7).

- There was no significant difference in observed adult plants between the western and eastern populations, but a significant difference between the two natural populations and the rehabilitation population.
- Observed juvenile numbers within strip plots did not significantly differ from expected numbers between Western and Eastern populations, but no juvenile plants were recorded in the monitoring plots of the rehabilitation population. A high rate of seedling mortality was observed on the natural populations.
- No significant difference was found between populations in the observed proportion of male and female plants.
- Female canopy condition at the rehabilitation population was significantly lower than the two natural populations.
- There was no significant differences in adult plant variables including volume index, leading shoot length, male canopy condition, male flower abundance, and male fruit abundance amongst populations.

These results confirm physical observations that the rehabilitation population, on different and probably sub-optimal soils compared to the natural populations, does not function as successfully as the natural populations, but does perhaps demonstrate that the species is adaptable to sub-optimal soils and will have generational survival.

Identification of suitable translocation sites

The identification of potential new sites for the Western Population of *Atriplex* sp. Yeelirrie Station was undertaken by Western Botanical (2015c), with their suitability investigated by SWC (2015b). Potential sites outside of the two known populations of *Atriplex* sp. Yeelirrie Station were identified using regional airborne radiometric data (i.e. K, U, Th) to identify locations hosting similar clay soils that may be capable of supporting the *Atriplex* sp. Yeelirrie Station. Identified sites were then assessed for access rights and protection from potential threats. Western Botanical (2015c) then completed a field survey, and preliminary soil testing, of all short-listed locations to establish whether the pedogenic and hydrologic conditions were similar to those within the Western population of the Yeelirrie palaeochannel.

Several sites within the Lake Mason palaeodrainage channel, which is located on neighbouring Lake Mason Station and managed for conservation purposes by DPaW, were identified as potentially suitable based on the criteria listed in the Western Botanical (2015c) report. SWC (2015b) investigated each of these using the same methodology as that employed to characterise the ecophysiological functioning of the *Atriplex* sp. Yeelirrie Station Western and Eastern populations at Yeelirrie. (Tables 9-21 to 9-23)

Based on the need for slight rises above a clay pan surface, and salinity levels in the surface clays around 500 mS/m, three sites (Sites 4 – 6; Table 9-20) were identified as potentially suitable. SWC (2015b) identified that the physical, geochemical and hydraulic properties of these sites were similar to those occurring within the Western and Eastern Populations of the Yeelirrie paleodrainage channel.

The areas of sites thought to be suitable translocation sites within Sites 4 to 6 is shown in Table 9-20 and compared with the Western Population area at Yeelirrie. It can be seen that the combined area of Sites 4 – 6 is 24.3 ha, which is around 32% of the total area occupied by the Western Population at Yeelirrie.

Sites 1, 2, 3 were also assessed during the investigation but are currently thought to be sub-optimal sites. At these sites the same micro-topographic relief doesn't exist so the *Atriplex* sp. Yeelirrie Station may experience greater levels of inundation, restricting their establishment.

However, the level and length of time these areas are inundated would need to be quantified as it may be similar as for the Yeelirrie sites. Alternatively, direct seeding methods (used in seeding *Atriplex* species on saline agricultural land) that create minor mounding for the placement of seed may be employed to assist in the development of the micro habitat. An additional 59.39 ha, in and around the sites, has been assessed as likely possessing optimal – suboptimal conditions, and these sites will be further explored to assess their suitability.

Table 9-20: Areas of suitable Lake Mason translocation sites compared to the Yeelirrie western population

Site	Area (ha)	% of Yeelirrie Western Population
Optimal sites		
Site 4	11.64	15.3
Site 5	8.97	11.8
Site 6	3.72	4.9
Sub-optimal sites		
Site 1	13.59	17.9
Site 2	6.29	8.3
Site 3	3.37	4.4
Other potential sites	59.39	78.1
Total	106.97	140.8

Table 9-21: Average multi-element composition of the dominant soil types within the clay pans

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Yeelirrie Sites						
Al	40,240	69,800	16,723	27,600	41,200	69,800
As	7	11	5	8	12	16
B	125	250	30	41	147	260
Ba	70	160	23	30	43	57

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Ca	34,710	88,000	50,867	130,000	59,200	160,000
Cd	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Co	7.2	8.7	7.1	12.0	6.7	8.6
Cr	53	71	32	46	46	70
Cu	14	22	6.6	9.7	13	21
Fe	21,790	34,000	10,533	16,000	20,460	34,000
Mg	61,200	84,000	24,400	48,000	51,200	67,000
Mn	255	410	98	160	199	350
Mo	1.0	2.4	0.3	0.5	1.1	1.8
Na	5,670	28,000	513	1,200	5,448	11,000
Ni	15	23	7	11	14	23
Pb	4.5	8.1	2.9	3.5	4.7	7.9
V	89	110	55	71	100	150
Zn	38	61	14	24	33	56
Lake Mason Sites						
Al	29,900	49,200	23,100	36,300	42,400	-
As	3	4	8	14	5	-
B	244	370	133	330	120	-
Ba	39	61	30	48	68	-
Ca	54,000	92,000	88,250	130,000	72,000	-
Cd	<0.05	<0.05	<0.05	<0.05	<0.05	-
Co	5.9	11.0	6.0	8.5	9.4	-
Cr	57	100	41	56	87	-
Cu	14	27	12	20	23	-
Fe	20,000	36,000	14,775	22,000	29,000	-
Mg	77,333	81,000	43,750	89,000	71,000	-
Mn	243	420	123	180	340	-
Mo	0.6	1.0	0.3	0.3	0.9	-
Na	10,633	20,000	3,633	6,700	17,000	-
Ni	17	33	10	16	26	-
Pb	2.6	4.1	3.7	7.1	3.0	-
V	62	83	96	220	80	-
Zn	31	55	22	36	45	-

Table 9-22: Average bioavailable trace element composition of the dominant soil types within the clay pans

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Yeelirrie Sites						
Al	348	>550	360	480	266	>550
As	0.4	0.7	0.8	1.7	1.1	2.1
B	46	100	4.4	6.6	56	100

Element	Clay		Loam		Calcareous Loam	
	Avg	Max	Avg	Max	Avg	Max
Ca	>5,500	>5,500	4,400	>5,500	5,500	>5,500
Cd	0.01	0.02	0.01	0.01	0.01	0.01
Co	0.31	0.91	0.51	0.99	0.31	0.77
Cu	0.2	0.5	0.2	0.4	0.2	0.3
Fe	64	120	52	62	61	110
K	511	>550	283	>550	550	>550
Mg	500	500	643	930	500	500
Mn	29	74	23	33	18	38
Mo	0.04	0.15	0.01	0.02	0.13	0.30
Na	552	>1,000	347	960	810	>5,500
Ni	0.4	0.6	0.3	0.4	0.3	0.3
P	18	48	4	6	13	30
Pb	1.2	1.8	0.9	1.3	1.4	2.1
S	90	160	157	>250	0	>250
Se	0.3	0.6	0.1	0.2	0.2	0.3
Zn	0.2	0.3	0.2	0.3	0.1	0.2
Lake Mason Sites						
Al	437	>550	211	480	480	-
As	0.3	0.7	0.7	1.3	0.3	-
B	71	100	28	100	44	-
Ca	>5,500	>5,500	>5,500	>5,500	>5500	-
Cd	0.01	0.01	0.02	0.06	<0.01	-
Co	0.13	0.24	0.10	0.16	0.13	-
Cu	0.2	0.3	0.1	0.1	0.2	-
Fe	149	180	75	200	49	-
K	533	>550	385	>550	>550	-
Mg	500	500	463	500	500	-
Mn	12	17	4.7	8.9	8.5	-
Mo	0.07	0.12	0.02	0.06	0.02	-
Na	>1,000	>1,000	810	>1,000	>1,000	-
Ni	0.4	0.4	0.2	0.4	0.3	-
P	24	29	11	13	12	-
Pb	1.2	1.3	1.2	1.8	1.4	-
S	130	140	113	125	125	-
Se	0.2	0.4	0.1	0.2	0.2	-
Zn	0.1	0.1	0.1	0.2	<0.1	-

Table 9-23: Average nutrient composition of the dominant soil types within the clay pans

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Yeelirrie Sites									
Total N	0.018	0.044	0.077	0.012	0.021	0.039	0.016	0.021	0.027
Total P	89	174	300	43	68	89	54	143	250
Colwell P	2	10	21	4	5	6	2	5	6
Total K	2,300	4,790	9,300	500	1,650	3,500	2,500	6,380	11,000
Colwell K	410	1,510	3,300	150	527	1,200	1,000	1,640	2,600
Total S	110	3,138	25,000	92	33,511	100,000	520	24,524	85,000
KCl ext. S	4	717	4,000	32	2,167	6,300	320	3,224	7,200
Lake Mason Sites									
Total N	0.009	0.013	0.017	0.021	0.040	0.070	-	0.017	-
Total P	120	187	310	80	138	240	-	230	-
Colwell P	17	22	25	5	8	15	-	7	-
Total K	1,200	2,633	4,300	1,400	2,150	4,000	-	4,700	-
Colwell K	580	1,093	1,500	240	473	740	-	1,400	-
Total S	970	34,990	54,000	1,400	38,500	77,000	-	26,000	-
KCl ext. S	140	4,113	7,100	14	3,401	6,800	-	3,000	-

Summary

The work outlined above, while preliminary, provides reasonable evidence to support a proposition that a population of *Atriplex* sp. Yeelirrie Station could be established to replace the Western population that would be lost as a result of proceeding with the Project. The work indicates the following:

- Individual plants hold seed over several seasons. Seed can be readily harvested and stored and will maintain viability for reasonable periods of time.
- Seed is readily able to be germinated and should respond well to direct seeding methods. Atriplex species have been cultivated for agricultural applications on a range of soil types and there is a strong body of expertise supporting techniques for successful revegetation from seed and seedlings.
- As evidenced by the rehabilitation population, the species is able to grow on a range of soil types, including soils that exhibit different salinity and profile characteristics to the soils of the natural populations.
- Potential translocation sites with similar soil and landscape characteristics have been identified and briefly assessed. These locations occur on land with tenure that would allow long term protection.

Prior to commencing work on the ground to establish the new population, Cameco would initiate a program to address the following:

- Ongoing implementation of activities contributing to a research plan to further understand the species and to support potential translocation, including seed collection and propagation research and trials.

- Development of an Interim Recovery Plan (IRP), leading to the development and approval of a full Recovery Plan in consultation with the Department of Parks and Wildlife (DPaW).
- Development of a Trial Translocation Plan (TTP) in consultation with DPaW.

Research Programme

Table 9-24 summarises the research completed to date and outlines a plan for work to be undertaken over the next three years.

Table 9-24: *Atriplex* sp. Yeelirrie Station Research Programme - Completed and Proposed.

Task	Status/Description
2014	
Undertake a preliminary assessment of the Rehabilitation Population of *Atriplex* sp. Yeelirrie Station and compare population dynamics with the Western Population.	Population census of Rehabilitation Population undertaken, demographic studies commenced, vegetation and soil profiles described (Western Botanical 2014).
Undertake seed germination testing of *Atriplex* sp. Yeelirrie Station western genotype seed collected in 2010.	Seed germination testing undertaken, demonstrated viable and germinable seed present within populations in both 2010 and 2014. Demonstrated short term dormancy which is overcome by removal of the enclosing bracts and/or leaching (Landcare Services 2011, Western Botanical 2015d, unpublished data).
2015	
Undertake a preliminary assessment of the Rehabilitation Population of *Atriplex* sp. Yeelirrie Station and compare population dynamics with the Western Population.	Demographic studies expanded in March 2015 (Western Botanical 2015c) and further soil profile assessments undertaken in April 2015.
Resolve the taxonomic status of *Atriplex* sp. Yeelirrie Station.	Part funding was provided to DPaW's Western Australian Herbarium to assist them to undertake a review to define the taxonomy of *Atriplex* sp. Yeelirrie Station, Eastern and Western Genotype. A paper dealing with the taxonomy of the species has been prepared by K.A. Shepherd and K.R.Thiele but remains unpublished at this stage. In summary, the research paper describes "A rare, new, tetraploid *Atriplex* located ... c. 30 km apart in arid Western Australia, is supported as distinct from other known species by morphological and molecular evidence. While the level of genetic differentiation is similar to that previously reported between subspecies in other *Atriplex*, the new taxon is described as a single species".
Establish a statistical framework that can be applied to measure the success of any future translocation program.	Meetings have been held with DPaW and agreement on sampling methodology for the demographic assessment and statistical framework for analysis has been developed. Data from the Western and Eastern Populations of *Atriplex* sp. Yeelirrie Station has been collected and will be presented for review to confirm the analysis techniques are suitable to use in the future to assess new translocated populations.
Identify possible translocation sites and undertake site analysis and hydrogeological assessment	A field trip to identify potential translocation sites at Lake Mason has been completed and a number of sites identified. Test pits have been dug to assess soil test in comparison to soil types on the Western populations. Western Botanical 2015b, 2015c)
2016	

Task	Status/Description
Undertake an environmental assessment for the introduction of *Atriplex* sp. Yeelirrie Station into new locations.	Undertake a field assessment and prepare an impact assessment report as required for the IRP and TTP.
Continue to develop Conservation Species Management Plan in consultation with DPaW.	Develop plan internally with advice from DPaW
Develop IRP in consultation with DPaW	Develop plan internally with advice from DPaW
Develop TTP in consultation with DPaW	Develop plan internally with advice from DPaW
Collect and process seed from the Western Population of *Atriplex* sp. Yeelirrie Station to increase seed bank. Lodge seed with the DPaW Seed Bank.	Obtain licence and undertake seed collection. Prepare (clean and fumigate) seed for storage
Undertake seed treatment, germination trials and pot trials. Testing on newly collected seed and stored seed of various ages.	Trials to be planned with input from Chatfield Nursery, WA's largest agricultural nursery with experience in seed treatments and germination trials.
2017	
Collect and process seed from the Western Population to increase seed bank.	As above
Undertake planting in selected and approved translocation trial sites.	Design plan with input from Chatfield Nursery
Field visit to trial translocation sites to monitor success and produce internal memo.	
2018	
Assess and report on the success of the 2017 plantings.	Undertake population dynamic assessment of the trial translocation sites.
Undertake planting in translocation sites.	As above
Field visit to trial translocation sites.	Inspection and review of progress of translocation sites with DPaW and OEPA.

9.1.5.4 Summary of Management Measures

General - Avoid and Minimise

- Clearing will be kept to the minimum area required for safe and efficient operation.
- Cameo will conduct Level 2 surveys of borefields and corridors and any other areas not covered by the existing Level 2 flora survey and provide a report of the survey as part of an application for a Clearing Permit prior to the commencement of ground disturbing activity.
- Cameco will implement ground disturbance procedures that will apply to all clearing activities. Clearing will not be conducted during or immediately after rain to reduce the risk of erosion and damage to soil structure.
- All earth moving equipment and other vehicles or machinery will be cleaned of all soil and seeds before mobilisation into new clearing areas. Weed control will be undertaken for infestations with the potential to spread.
- A vegetation condition monitoring program will be implemented to monitor potentially groundwater dependent vegetation communities within the drawdown zone and compare with control sites. Contingency measures will be developed, should there be a risk of impacts on groundwater dependent communities.
- As part of monitoring of the integrity of surface water diversion and management structures, Cameco will also monitor nearby vegetation health.
- Dust management and suppression measures will be undertaken (refer to Section 9.8.6).

- Hot work permits will be required for any work that may generate an ignition source. Fire extinguishers will be available in all work areas and personnel will be trained in their use.

Rehabilitate

- Vegetation removed during clearing activities will be temporarily stockpiled to be used as mulch and a seed source in revegetation. Overburden material that is suitable for rehabilitation will be stripped and stored in low stockpiles to retain seed viability and be protected from erosion and accidental disturbance.
- Disturbed areas that are no longer required will be progressively rehabilitated over the life of the mine. The pit will be progressively backfilled and rehabilitated from year 11.

Conservation Significant Species - Avoid and Minimise

- Cameco will continue to develop and implement the Conservation Species Management Plan. Measures will include protection of the Eastern Population of *Atriplex* sp. Yeelirrie Station by fencing and the establishment of firebreaks, and implementation of a research plan for the reestablishment of the Western Population of the species, through translocation. Work undertaken to date provides reasonable evidence to indicate that this could be achieved.
- Cameco will avoid direct disturbance of *Rhagodia* sp. Yeelirrie Station where practicable. Cameco is proposing to establish a conservation area for the known population present inside the Development Envelope.
- Protection of the Eastern Population of *Atriplex* sp. Yeelirrie Station through fencing and land tenure changes (if practicable).
- Implementation of the research plan for the reestablishment of the Western Population of *Atriplex* sp. Yeelirrie Station.
- Protection of *Rhagodia* sp. Yeelirrie Station Population within the Development Envelope.
- Progressive rehabilitation of the Project area in accordance with the Mine Closure and Rehabilitation Plan.

9.1.6 Commitments

Cameco commits to:

- Developing and implementing a Flora and Vegetation Management Plan.
- Developing and implementing the Conservation Species Management Plan.

9.1.7 Outcomes

Residual impacts on significant flora are predicted to occur as a result of implementation of the Project and therefore offsets are proposed. These are discussed in Section 12.4.

Taking into account the Project design, the proposed management measures, and the proposed implementation of a revegetation and offset strategy to replace the Western population genotype of *Atriplex sp*. Yeelirrie Station, Cameco believes that the Proposal will meet the EPA's objectives of maintaining the representation, diversity, viability and ecological function at the species, population and community level.

9.2 Subterranean Fauna

9.2.1 EPA Objective

The EPA's objective with regards to subterranean fauna is:

- To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.

9.2.2 Relevant Legislation and Policy

An overview of the legislation and policies applicable to native fauna, including subterranean fauna are discussed in Section 9.3.2.

Guidance specific to subterranean fauna (stygofauna and troglofauna) are provided by the EPA's Environmental Assessment Guideline No. 12 (EAG12) (EPA 2013) and Guidance Statement 54a (GS54a) (EPA 2007). EAG12 supersedes the earlier Guidance Statement 54 (GS54) (EPA 2003) and provides a policy framework outlining how subterranean fauna should be considered in environmental impact assessment. It is designed to promote a more consistent approach to assessment and subsequent approval outcomes. GS54a (a later technical appendix to GS54) provides guidance on sampling methods and survey considerations for assessing subterranean fauna.

Ecological Communities

The Western Australia Minister for the Environment may list an ecological community as being threatened if the community is presumed to be, or at risk of becoming, totally destroyed. The DPaW maintains the list of threatened ecological communities (TECs), which currently contains 376 TECs, of which 25 are also listed under the EPBC Act. There are no TECs within the vicinity of the Project.

Ecological communities with insufficient information available to be considered as TECs, or which are rare but not currently threatened, are placed on a list managed by DPaW and referred to as priority ecological communities (PECs). The Project Area contains PEC No. 49 '*Yeelirrie calcrete groundwater assemblage type on Carey palaeodrainage on Yeelirrie Station*', which is considered to have 'unique assemblages of invertebrates [that] have been identified in the groundwater calcretes' (Figure 9-10). Four categories of PEC are recognised with Priority 1 referring to those considered to be most restricted in occurrence. The Yeelirrie PEC is Priority 1.

Two other Priority 1 PECs ('*Hinkler Well calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station*' and '*Kaluwiri calcrete groundwater assemblage type on Raeside palaeodrainage on Kaluwiri Station*') occur in the periphery of the Yeelirrie PEC but do not occur in the study area. A fourth Priority 1 PEC '*Albion Downs calcrete groundwater assemblage type on Carey palaeodrainage on Albion Downs Station*' is located within the Yeelirrie study area but outside of the Development Envelope and predicted area of impact.

9.2.3 Existing Environment

9.2.3.1 Regional context

Recent research has demonstrated that the Yilgarn region of Western Australia, along with the Pilbara, is rich in subterranean fauna (Guzik *et al*. 2011; Humphreys 2001). It has been suggested that subterranean fauna in arid WA have colonised subterranean habitats as the Australian continent moved north and the climate became progressively drier since the late Miocene, some 10 million years ago (Byrne *et al*. 2008; Byrne *et al.* 2011). The richness of stygofauna in the Yilgarn is considered to have arisen from many independent colonisations of former surface species over time into emerging subterranean habitats, followed by subsequent extensive in-situ speciation (Harrison *et al*. 2014; Karanovic *et al*. 2014).

Figure 9-10: Priority ecological communities with the Study Area

9.2.3.2 Stygofauna in the Yilgarn

The calcrete bodies in the palaeovalleys of the Yilgarn are particularly rich in stygofauna beetles, amphipods and some other groups of crustaceans, with species in many taxonomic groups thought to be restricted to single calcretes (Bradford *et al.* 2010; Guzik *et al.* 2008; Leys and Watts 2008) or even small areas within a single calcrete (Karanovic and Cooper 2011). This pattern of species distribution has resulted in the theory that each body of calcrete represents a subterranean 'island'. It has been hypothesised that unfavourable salinities, fine alluvial and clay deposits or other unsuitable habitat between bodies of calcrete represent barriers to species dispersal (Cooper *et al.* 2002). Although stygofauna occur in a range of habitats in the Yilgarn other than palaeovalleys, sampling to date suggests that species richness in other habitats is lower than in calcrete and the associated alluvium and colluvium of palaeovalleys (e.g. Bennelongia 2007, GHD 2010a).

An analysis by Subterranean Ecology (2011) (Appendix F2) of stygofauna records from 68 calcretes in seven palaeodrainage systems in the Yilgarn (Murchison, Moore, Raeside, Carey, Nabberu, Carnegie and Burnside) showed that sampling effort has been highly variable. While patterns of richness must be regarded as uncertain until more sampling has occurred, the calcretes yielding most species to date lie in the Carey and Raeside palaeodrainage systems. Other than Yeelirrie, Subterranean Ecology (2011) considered the most species-rich calcretes to be Hinkler Well (33 species), Urdamurdah (28), Lake Violet (24) and Paroo (21) in the Carey drainage system and Depot Springs (21) in the Raeside drainage system. More recent data from Outback Ecology (2011 and 2012 addendum) appears to suggest that Urdamurdah supports at least 48 species.

Subterranean Ecology (2011) also examined the distribution patterns of individual stygofauna species among calcretes and concluded that about 18% of species were widespread and occurred in well separated calcretes, 12% had ranges extending into neighbouring calcretes and 61% of species were restricted to a single calcrete (the ranges of the remaining species could not be determined).

In second analysis on a more restricted set of calcretes (Hinkler Well, Urdamullah, Lake Violet and Paroo in the headwaters of the Carey system and Depot Springs in the Raeside system), up to 46% of species appeared to have ranges extending into a nearby calcrete. However, this study preceded the detailed genetic and taxonomic work undertaken on some copepod and amphipod genera at Yeelirrie and at Sturt Meadows that showed fine-scale species radiations (Bradford *et al*. 2010; Karanovic and Cooper 2011, 2012, Karanovic *et al*. 2011). If a similar pattern occurs elsewhere in the Carey system, the proportion of species confined to individual calcretes would be higher than estimated by Subterranean Ecology (2011).

9.2.3.3 Troglofauna in the Yilgarn

Troglofauna occur widely, at moderate species richness but low abundance, in mineralised rocks of the Yilgarn (Bennelongia 2009; GHD 2010b). They are less diverse in this habitat in the Yilgarn than in similar habitats in the Pilbara.

Troglofauna may be abundant in the unsaturated zone of calcretes in the Yilgarn (Guzik *et al*. 2011; Humphreys 2008). They may also occur in lower abundance in adjacent coarse alluvium.The groups collected in calcrete include palpigrads (Barranco and Harvey 2008; Giribet *et al*. 2014), pseudoscorpions (Edward and Harvey 2008; Harrison *et al*. 2014), spiders (Baehr *et al*. 2012; Platnick 2008) and isopods (Taiti 2014). The analysis of Yilgarn calcretes by Subterranean Ecology (2011) showed that troglofauna have been recorded from calcretes in the Murchison, Moore, Nabberu and Carey palaeodrainage systems. Other than Yeelirrie, the most species-rich calcretes are Sturt Meadows (17 species) in the Raeside system and Uramurdah (15 species), Lake Violet (8 species), Bubble Well (8 species) and Nambi (7 species) in the Carey system.

Troglofauna species mostly have more restricted ranges than stygofauna (Lamoureux 2004; Halse and Pearson 2014) and, given the calcrete ‘island’ theory of occurrence, they are expected to be mostly restricted to single calcretes in the Yilgarn.

9.2.3.4 Yeelirrie habitat characterisation

The Yeelirrie palaeochannel is located in the northeastern part of the Archaean Yilgarn craton and comprises five major land forms:

i) breakaways;
ii) wash plains;
iii) sand plains;
iv) playas; and
v) calcretes.

These landforms were further refined within the Project Area by DC Blandford and Associates, 2011 (Section 9.10.4 and Appendix M1).

The average annual rainfall for Yeelirrie is 238 mm, although the frequency and amount of rainfall during any given year is highly variable (URS 2011b). Groundwater recharge in arid areas is mostly dependent upon infrequent, high-intensity rainfall events such as ex-tropical cyclones in summer and frontal storms in winter (URS 2011b).

The term “calcrete” is used here to describe collectively the surficial pedogenic (soil formed calcrete) and the deeper non-pedogenic dolocrete formed at the sub-surface water table interface. Both carbonate types are formed by the in-situ replacement or displacement of the alluvial and colluvial deposits by magnesium and calcium carbonate precipitated from carbonate-saturated groundwater (Mann and Horwitz 1979). Within portions of the calcrete system the surficial calcrete and the non-pedogeneic dolocrete merge into one vertically continuous body which is saturated below the water table and unsaturated above. In other areas the two carbonate types can be developed independently so that a near surface calcrete expression does not necessarily imply underlying saturated dolocrete. There is further complication in that areas of calcrete are rarely uniform;

instead they comprise a variable mixture of calcrete, alluvium/colluvium and clays with carbonate-dominated water chemistry.

The calcrete at Yeelirrie outcrops as a low broad mound along the axis of the palaeochannel. This outcropping is the result of active erosion (wind and ephemeral surficial water flow) of overlying and marginal unconsolidated sediment leaving the carbonate exposed at the surface. Carbonate formation is believed to have begun about 30 million years ago, and has remained in a constant state of re-mobilisation and formation (Mann 1979; Morgan 1993). The continuous dissolution and re-precipitation of carbonate in the system has resulted in high internal structural variability and overall subsurface geometry.

The occurrence of calcrete at Yeelirrie, with associated groundwater conditions in the surrounding alluvium and colluvium, is believed to be the factor that makes Yeelirrie highly suitable habitat for stygofauna and troglofauna. It should also be emphasised that stygofauna and troglofauna are not confined only to calcrete habitat. They also occur in the alluvium and colluvium that is referred to under the broad term "calcrete". Alluvium is the major stygofauna habitat world-wide (Gibert and Deharveng 2002) and alluvium and colluvium around the margin of the calcrete provide important stygofauna habitat (Appendix F1). Alluvium and colluvium may also be used by troglofauna.

The watertable provides the boundary between stygofauna and troglofauna habitats and lies at a depth of about 5 m through most of the Yeelirrie calcrete, although it reaches about 10 m depth to the northwest. Much of the saturated calcrete is 3 to 5 m thick but it is up to 13 m thick in the northwest. It is likely the thickness of saturated calcrete declines towards the margins of the area of calcrete body. The unsaturated calcrete comprising troglofauna habitat is probably 2 to 3 m thick across most of Yeelirrie and thicker in the northwest, where it may be up to 10 m. During periods of flooding, when the watertable rises, the volume of troglofauna habitat is likely to contract and there may be a temporary expansion of the volume of stygofauna habitat.

Several factors combine to create a highly variable, three-dimensional mosaic of subterranean microhabitats at Yeelirrie. Important factors include physical structure (which as described above comprises a complex structure with variable sized voids), chemistry (especially salinity which varies both horizontally and vertically), hydrological processes (annual and seasonal changes in groundwater levels, flows, recharge and discharge) and interaction with the ground surface (e.g. infiltration, availability of vegetation roots and other organic matter, level of nutrients and oxygen).

Groundwater salinity shows an overall gradient within the study area, with average salinities varying from about 1-2 gL^{-1} in the northwest to 10-25 gL^{-1} in the southeast. More challengingly from the viewpoint of habitat characterisation, within these gradients salinities can vary more than an order of magnitude over tens of metres (eg about about 2 gL^{-1} to 33 gL^{-1} within the proposed mine pit). Salinity may also vary vertically by a factor of about three.

9.2.4 Studies and Investigations

9.2.4.1 Environmental assessment surveys

Three main phases of subterranean fauna survey at Yeelirrie can be distinguished:

i) prior to 2009;
ii) 2009-2010 as part of the EIA for BHP Billiton's Yeelirrie Project; and
iii) 2015 as part of the Cameco Yeelirrie Uranium Project.

Prior to 2009 (Phase 1), very little was known about subterranean fauna communities at Yeelirrie because of limited survey effort. The Western Australian Museum did a limited amount of collecting that yielded three species from three bores: Amphipoda indet., the isopod Oniscidea indet., and the copepod *Mesocyclops brooksi*. Sampling of two bores in the neighbouring Albion Downs calcrete also revealed three species: the amphipod Chiltoniidae indet., the copepod Harpacticoida indet., and the syncarid Parabathynellidae indet.

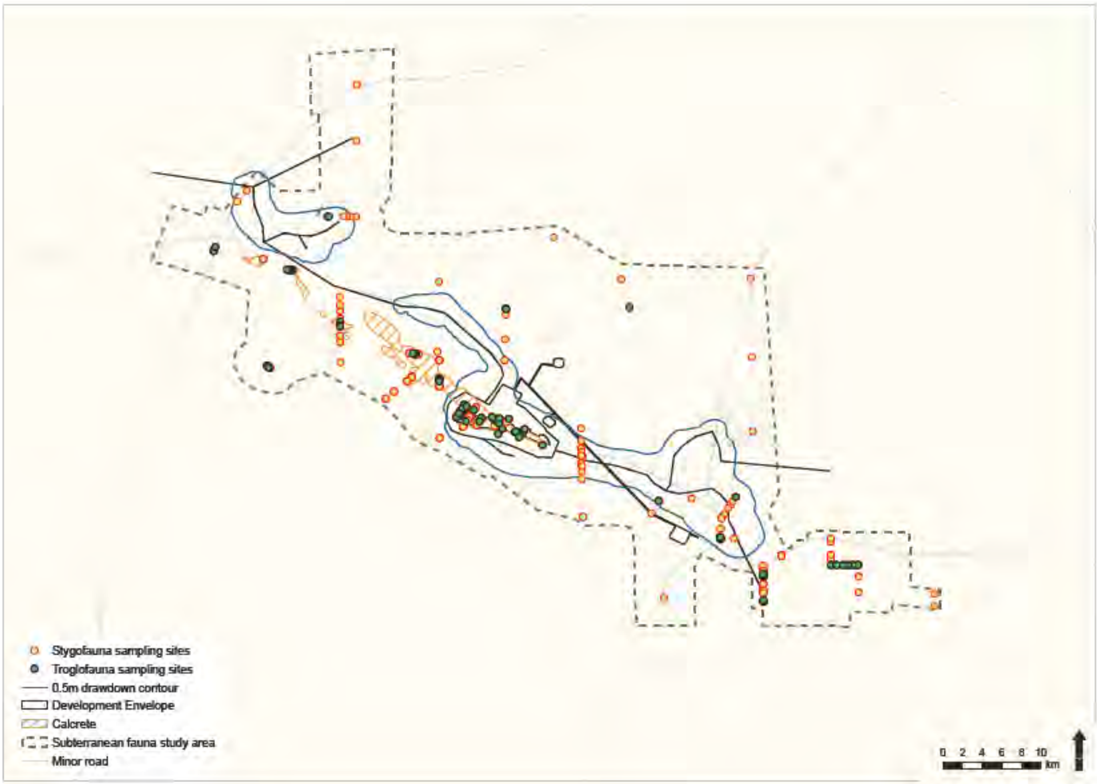


Figure 9-11: Stygofauna and troglofauna sampling locations

Sampling effort increased substantially in Phase 2 when six surveys were conducted by Subterranean Ecology (2011) from March 2009 to September 2010 as part of the EIA for BHP Billiton's Yeelirrie Project (Appendix F2). Altogether, 347 stygofauna samples were collected from 162 bores and 448 troglofauna samples were collected from 100 drill holes, although in many cases the troglofauna samples consisted of complementary 'scrape' and 'trap' samples from the same holes during the same sampling event and may better be regarded as constituting single paired samples (see Table 9-25). Figure 9-11 shows the location of all sampling sites.

In Phase 3 in 2015, Cameco commissioned collection of 66 additional stygofauna samples to improve knowledge of stygofauna distributions (Bennelongia 2015) (Appendix F1).

Genetic analysis was used extensively in the identification processes of Phases 2 and 3 by Subterranean Ecology (2011) and Bennelongia (2015) (Appendices F1 and F2). Sometimes it was the sole means of identifying species (e.g. enchytraeid worms), for some groups it was used to confirm morphological assignments of species (e.g. copepods). In the case of copepods, much of the identification decision process has been documented in the scientific literature as the species were formally described (Karanovic and Cooper 2011, 2012; Karanovic *et al*. 2011). While genetic analysis was an invaluable tool, it did not always provide definitive information about species boundaries and, consequently, it is possible that further collecting and analysis may lead to small changes in the number of species recognised as occurring at Yeelirrie and the distributions of those species (Bennelongia 2015).

In total, 110 species of subterranean fauna were collected in Phase 2 sampling (Appendix F2). This comprised 55 species of stygofauna and 45 species of troglofauna. The 55 stygofauna species consisted of 46 species of aquatic stygofauna and a further nine species of 'amphibious' subterranean fauna that are thought to occur at the interface between groundwater and unsaturated subterranean habitat.

Table 9-25: Stygofauna sampling effort in the study area (2009-2010)

	Area to be affected by the proposed development	Area unaffected by the proposed development	Total
Designated stygofauna samples 2009-2010			
Drill holes	66	96	162
Samples	138	209	347
Designated troglofauna samples			
Drill holes	21	79	100
Paired samples[1]	36	105	141
Single samples	29	137	166

[1] Pairs of samples, each consisting of a scrape and trap sample from the same bore on same trap-set date.

Sampling during Phase 3 collected 15 additional stygofauna species that had not previously been collected at Yeelirrie, bringing the total number of stygofauna species known from the area to 70 species and the total number of subterranean fauna species to 115 species (see Table 9-26) (Bennelongia 2015).

The overall sampling effort at Yeelirrie is much higher than has occurred in the subterranean fauna assessment of any other area of the Yilgarn. While the sampling has been very comprehensive, the occurrence of subterranean fauna below ground makes them inherently difficult to study. There are three major problems with subterranean fauna sampling:

- Sampling can only occur via bores and if there are no existing bores in an area likely to be suitable for a particular species, new bores must be drilled with the attendant cost and environmental damage.
- Identifying occurrences of suitable habitat or microhabitats outside the impact area is usually very difficult because of the high subterranean heterogeneity and the lack of correlation between surface features and underlying habitat. Many species are probably restricted to small patches of a particular microhabitat, defined by salinity.
- Many subterranean species occur at low abundance and are infrequently collected, even when present. Eberhard *et al*. (2009) showed that 12 samples collected at least a month apart are required to collect all the stygofauna species from a high-yielding bore. A further complication is that many bores are either constructed in a way that makes them unsuitable for subterranean fauna or do not intersect appropriate subterranean spaces. These bores never yield, even when adjacent bores consistently do so.

The problems outlined above mean it is often difficult to demonstrate wider occurrence of a species known only from the Project impact area. The difficulties of identifying the number and exact locations of areas containing the species' preferred microhabitat does not only present challenges to sampling. It also means that inferring the distribution of a species based on habitat surrogates can be problematic.

9.2.4.2 Subterranean fauna communities

The 70 stygofauna species at Yeelirrie represent greater stygofauna richness than is known from any other part of the Yilgarn but this is at least partly attributable to the high sampling effort. The community at Yeelirrie is dominated by crustacean groups, namely copepods (49% of species), worms (23%) and syncarids (12%).

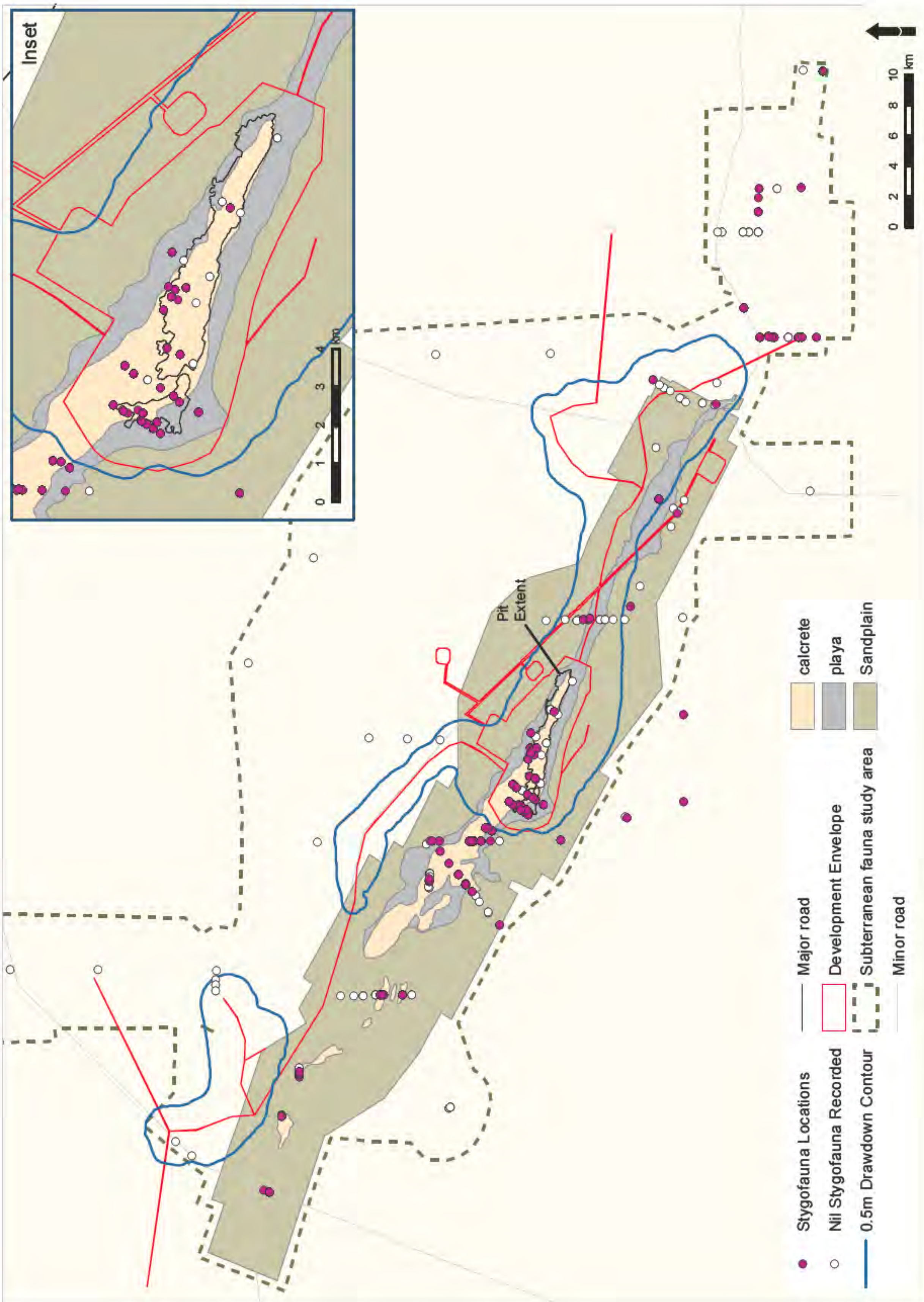


Figure 9-12: Stygofauna locations and major landforms

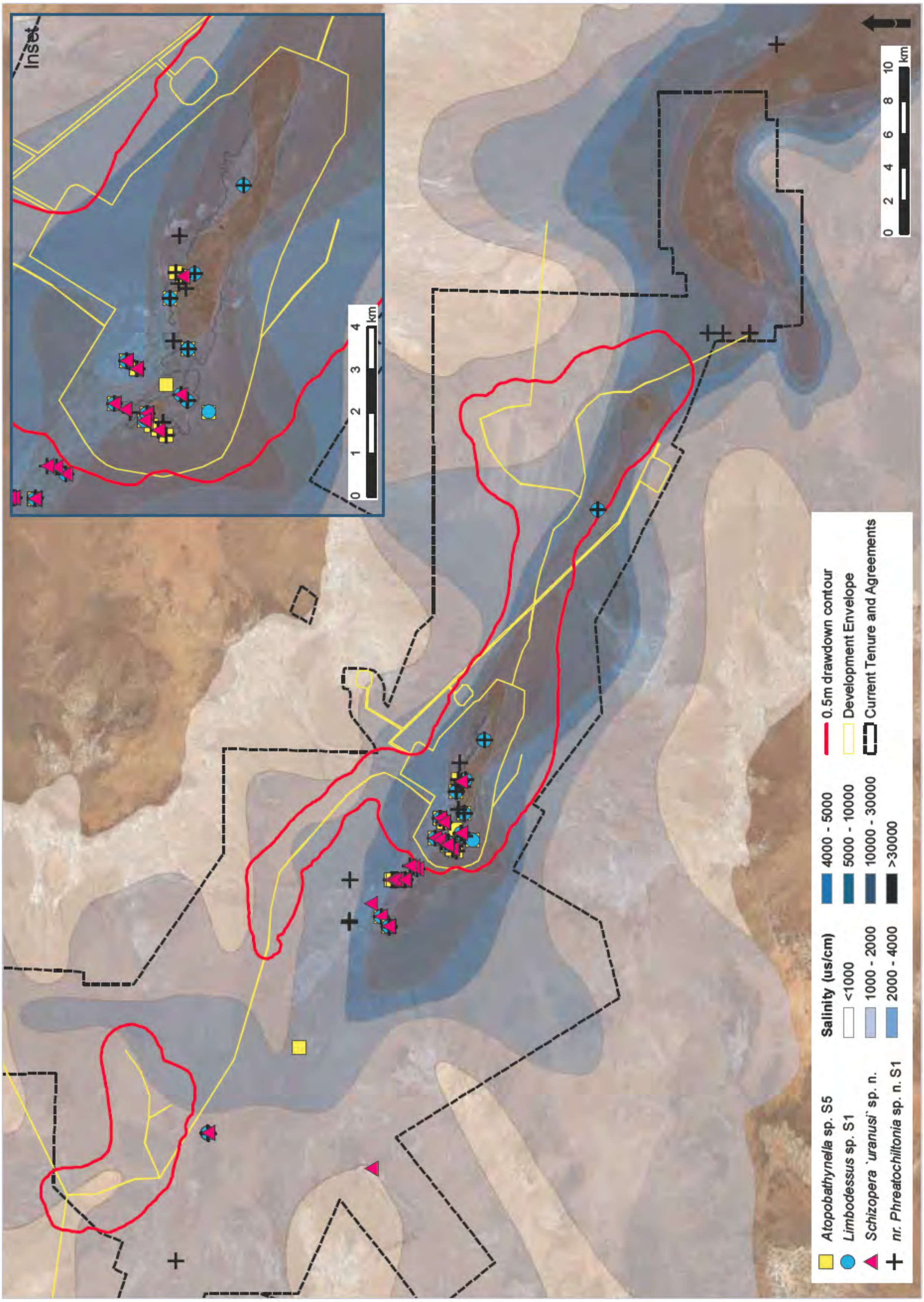


Figure 9-13: Modelled salinity levels and distribution of four widespread stygofauna species

The broad distribution patterns of the stygofauna species at Yeelirrie may be summarised as follows:

- Three species are also known from other calcretes in the Yilgarn region (*Halicyclops kieferi*, *Mesocyclops brooksi*, *Australocamptus hamondi*, and possibly one species of *Halicyclops* cf. *eberhardi*).
- Possibly one of the species of *Halicyclops* cf. *eberhardi* (most likely sp. A) is also known from other calcretes.
- 14 species (20%) have only been found inside the inferred calcrete area.
- 7 species (10%) have only been found inside the inferred playa area.
- 18 species (26%) are common to calcrete and playa areas.
- 27 species (39%) have only been found in the sandplain areas (alluvium and colluvium around the calcrete).

While collecting records suggest many species at Yeelirrie have small ranges and are restricted to narrow bands of salinity, nearly all of the larger species occurring in the calcrete are widespread. This suggests there is no physical barrier to movement, or occurrence, throughout the calcrete. Figure 9-13 illustrates this point by showing the distribution of the four most widespread stygofauna species at Yeelirrie and the modelled salinity levels in which they are found (actual salinities, which are likely to be more variable, were often not recorded). Two large species, the amphipod nr. *Phreatochiltonia* sp. n. S1 and the beetle *Limbodessus* sp. S1 have ranges of >60 km and >40 km, respectively. The small copepod *Schizopera uranusi* and syncarid *Atopobathynella* sp. S5 have ranges of 24 km and 17 km. Based on modelled groundwater salinity, all four species are euryhaline and are found in both fresh and saline groundwater. While Figure 9-13 does not imply that all species at Yeelirrie are widespread, it suggests that the ranges of many species will be greater than currently documented and that ranges within Yeelirrie will be limited by factors other than physical habitat.

Table 9-26: Stygofauna species recorded at Yeelirrie.

Species known only from the predicted area of groundwater drawdown are shaded in blue. Northwest indicates the species occurs west of the mine pit-outside groundwater drawdown, southeast means the species east of the mine pit and outside groundwater drawdown, granite indicates the species occurs in the outer part of the study area, Yeelirrie playa indicates the species occurs west of the mining tenement in the vicinity of Yeelirrie and Albion Downs playas (see Bennelongia 2015 for more detail (Appendix F1)). No species was restricted to the northwest groundwater drawdown.

Taxonomic group	Species	Known distribution	Remarks
Rotifera			
	Bdelloidea sp. 2:2	Central calcrete	New in 2015
Nematoda			
	Gen indet., Sp. indet.	Widespread	New in 2015
Platyhelminthes			
	Turbellaria sp.	Northwest	New in 2015, unknown range
Oligochaeta			
Aelosomatidae	*Aeolosoma* sp. S1	Yeelirrie playa	
Enchytraeidae	Enchytraeidae sp. Y1	Yeelirrie playa	
	Enchytraeidae sp. Y2	Northwest	
	Enchytraeidae sp. Y3	Northwest	
	Enchytraeidae sp. Y4	Central drawdown	Known only from impact area

Taxonomic group	Species	Known distribution	Remarks
	Enchytraeidae sp. Y5	Central drawdown	Known only from impact area
	Enchytraeidae sp. Y6	Central drawdown	Known only from impact area
	Enchytraeidae sp. Y7	Northwest	
	Enchytraeidae sp. B03	Northwest	New in 2015
	Enchytraeidae sp. B04	Southeast	New in 2015
	Enchytraeidae sp. B05	Central drawdown	New in 2015
Naididae	Naididae sp. S4	Widespread	
	Naididae sp. S5	Widespread	
Phreodrillidae	Phreodrilidae sp. S8	Widespread	
	Phreodrillidae sp. B06	Northwest	New in 2015
	Phreodrillidae sp. B07	Southeast	New in 2015
Crustacea			
Amphipoda	nr. *Phreatochiltonia* sp. n. S1	Widespread	
Syncarida	*Atopobathynella* sp. 'line K'	Central drawdown	Known only from impact area
	Atopobathynella sp. S4	Northwest	
	Atopobathynella sp. S5	Widespread	
	Atopobathynella sp. Y1	Northwest	
	Atopobathynella sp. Y2	Northwest	
	Atopobathynella sp. Y3	Northwest	
	Bathynellidae sp. S2	Widespread	
	Bathynellidae sp. S4	Yeelirrie playa	
Cyclopoida	*Dussartcyclops* 'dostoyevskyi' sp. n.	Widespread	
	Halicyclops cf. *eberhardi* sp. A	Widespread	Possibly widespread in Yilgarn
	Halicyclops cf. *eberhardi* sp. B	Central drawdown	Known only from impact area
	Halicyclops cf. *eberhardi* sp. C	Yeelirrie playa	
	Halicyclops cf. *eberhardi* sp. D (B01)	Southeast	New in 2015
	Halicyclops kieferi	Assumed widespread	New in 2015, widespread in Yilgarn
	Mesocyclops brooksi	Assumed widespread	Occurs across southern Australia
Harpacticoida	'Dussartstenocaris' 'idioxenos'	Northwest	
	Australocamptus hamondi	Assumed widespread	Widespread in Yilgarn
	Kinnecaris esbe	Yeelirrie playa	
	Kinnecaris linesae	Northwest	

Taxonomic group	Species	Known distribution	Remarks
	Kinnecaris lined	Central drawdown	Known only from impact area
	Kinnecaris linel	Yeelirrie playa	
	Kinnecaris 'linep' sp. n.	Northwest	
	Kinnecaris uranusi	Widespread	
	Nitokra esbe	Yeelirrie playa	
	Nitokra yeelirrie	Widespread	
	Nitokra sp. B03	Southeast	New in 2015
	Novanitocrella 'araia' sp. n.	Central drawdown	Known only from impact area
	Pseudectinosoma 'pentedicos' sp. A	Widespread	
	Pseudectinosoma 'pentedicos' sp. B	Widespread	
	Pseudectinosoma 'pentedicos' sp. C	Widespread	
	Schizopera akation	Widespread	
	Schizopera akolos	Central drawdown	Known only from impact area
	Schizopera analspinulosa	Widespread	
	Schizopera analspinulosa linel	Yeelirrie playa	
	Schizopera emphysema	Central drawdown	Known only from impact area
	Schizopera kronosi	Widespread	
	Schizopera leptafurca	Widespread	
	Schizopera 'linen' sp. n.	Yeelirrie playa	
	Schizopera uranusi	Widespread	
	Schizopera sp. 7439	Central drawdown	Known only from impact area
	Schizopera sp. B16	Southeast	New in 2015
	Schizopera sp. B17	Southeast	New in 2015
Isopoda	Philoscidae sp. n. S1	Yeelirrie playa	
	Philoscidae sp. n. Y2	Central drawdown	Known only from impact area
Ostracoda	*Candonopsis* sp. n. Y1	Widespread	
	Cyprididae sp. indet.	Central	New in 2015
	Strandesia sp. indet.	Central	New in 2015
Insecta			
Coleoptera	*Limbodessus* sp. n. '*yeelirriensis*'	Widespread	
	Limbodessus sp. S1	Widespread	
	Paroster sp. n. '*angustus*'	Widespread	

The 45 troglofauna species documented at Yeelirrie (Table 9-27) also represent greater richness than is known elsewhere in the region. The difference between Yeelirrie and other Yilgarn calcretes is largely attributable to the large sampling effort at Yeelirrie and the fact there has been little extensive sampling of troglofauna in other calcretes of the Yilgarn,. Most previous troglofauna sampling in Yilgarn calcretes did not use the scraping technique, which means yields were substantially reduced (Halse and Pearson 2014).

The distributions of the troglofauna species collected may be summarised as follows (see Figure 9-14):

- 11 species (24%) have only been found inside the inferred calcrete area.
- 3 species (6%) have only been found within the inferred playa area.
- 8 species (17%) are common to both the calcrete and playa areas.
- 19 species (42%) have only been found in the sandplain areas (alluvium and colluvium around the calcrete).
- 3 species (6%) species are common to calcrete and sandplain areas.
- 1 species (2%) is common to playa and sandplain areas.

Figure 9-15 shows the distribution of the more widely abundant troglofauna species across the study area.

Two of the troglofauna species collected at Yeelirrie are likely to be widespread in the Yilgarn. These are the hemipteran Meenoplidae sp. Y1 and millipede Polyxenida sp. S1 (Yeelirrie) (Bennelongia 2015).

Table 9-27: Troglofauna species recorded at Yeelirrie.

Species known only from the proposed mine pit are shaded in blue. See Appendix F1 for explanation of distribution areas.

Taxonomic group	Species	Known distribution
Crustacea		
Isopoda	*Troglarmadillo* sp. n. S12	Yeelirriee playa
	Troglarmadillo sp. n. S13	Widespread
	Troglarmadillo sp. n. S7A	Northwest
	Troglarmadillo sp. n. S7C	Northwest
	Troglarmadillo sp. n. S9	Northwest
	Trichorhina sp. n. F	Mine pit
	Trichorhina sp. n. G	Northwest
	Trichorhina sp. n. H	Northwest
	Trichorhina sp. n. I	Southeast
	Stenoniscidae sp. n. Y1	Yeelirrie playa
Arachnida		
Araneae	*Opopaea* sp. n. Y2	Yeelirrie playa
	Prethopalpus callani	Widespread
	Prethopalpus sp. n. B	Yeelirrie playa
	Desognanops sp.n. Y1	Widespread
Palpigradi	*Eukoenenia* sp. n. S2	Widespread

Taxonomic group	Species	Known distribution
Pseudoscorpiones	*Tyrannochthonius* sp. n. Y1	Mine pit
	Tyrannochthonius sp. n. Y2A	Widespread
	Tyrannochthonius sp. n. Y2C	Yeelirrie playa
	Tyrannochthonius sp. n. Y3	Yeelirrie playa
	Tyrannochthonius sp. n. Y4	Widespread
	Tyrannochthonius sp. n. Y5	Yeelirrie playa
	Austrohorus sp. n. Y1	Mine pit
	Austrohorus sp. n. Y2	Yeelirrie playa
Myriapoda		
Chilopoda	Geophilidae sp. Y1	Widespread
	Cryptops sp.Y1	Widespread
Diplopoda	Polyxenida sp. S1 (Yeelirrie)	Widespread
Pauropoda	Pauropoda sp. S6A	Northwest
	Pauropoda sp. S6B	Mine pit
	Pauropoda sp. Y1	Northwest
	Pauropoda sp. Y2	Northwest
	Pauropoda sp. Y3	Yeelirrie playa
Symphyla	Symphyla sp. Y1	Northwest
	Symphyla sp. Y2	Northwest
	Symphyla sp. Y3	Northwest
	Symphyla sp. Y4	Northwest
	Symphyla sp. Y5	Yeelirrie playa
	Symphyla sp. Y6	Yeelirrie playa
	Symphyla sp. Y7	Mine pit
Hexapoda		
Diplura	Japygidae sp. Y3	Widespread
	Parajapygidae sp. Y1	Widespread
	Projapygidae sp Y2	Widespread
Hemiptera	Enicocephalidae sp. Y1	Yeelirrie playa
	Meenoplidae sp. Y1	Widespread
Thysanura	Atopatelurini sp. n. Y2	Southeast
	Hemitrinemura sp. n. Y1	Widespread

9.2.4.3 Taxonomy

Sixteen of the stygofaunal copepod species and one of troglofaunal spider species from Yeelirrie have been formally described since 2011. They are the copepod *Dussartstenocaris idioxenos*, *Kinnecaris esbe*, *K. linesae*, *K. lined*, *K. uranusi*, *Nitokra esbe*, *N. yeelirrie*, *Schizopera akation*, *S. akolos*, *S. analspinulosa*, *S. analspinulosa linel*, *S. emphysema*, *S. kronosi*, *S. leptafurca*, and *S. uranusi*, and the

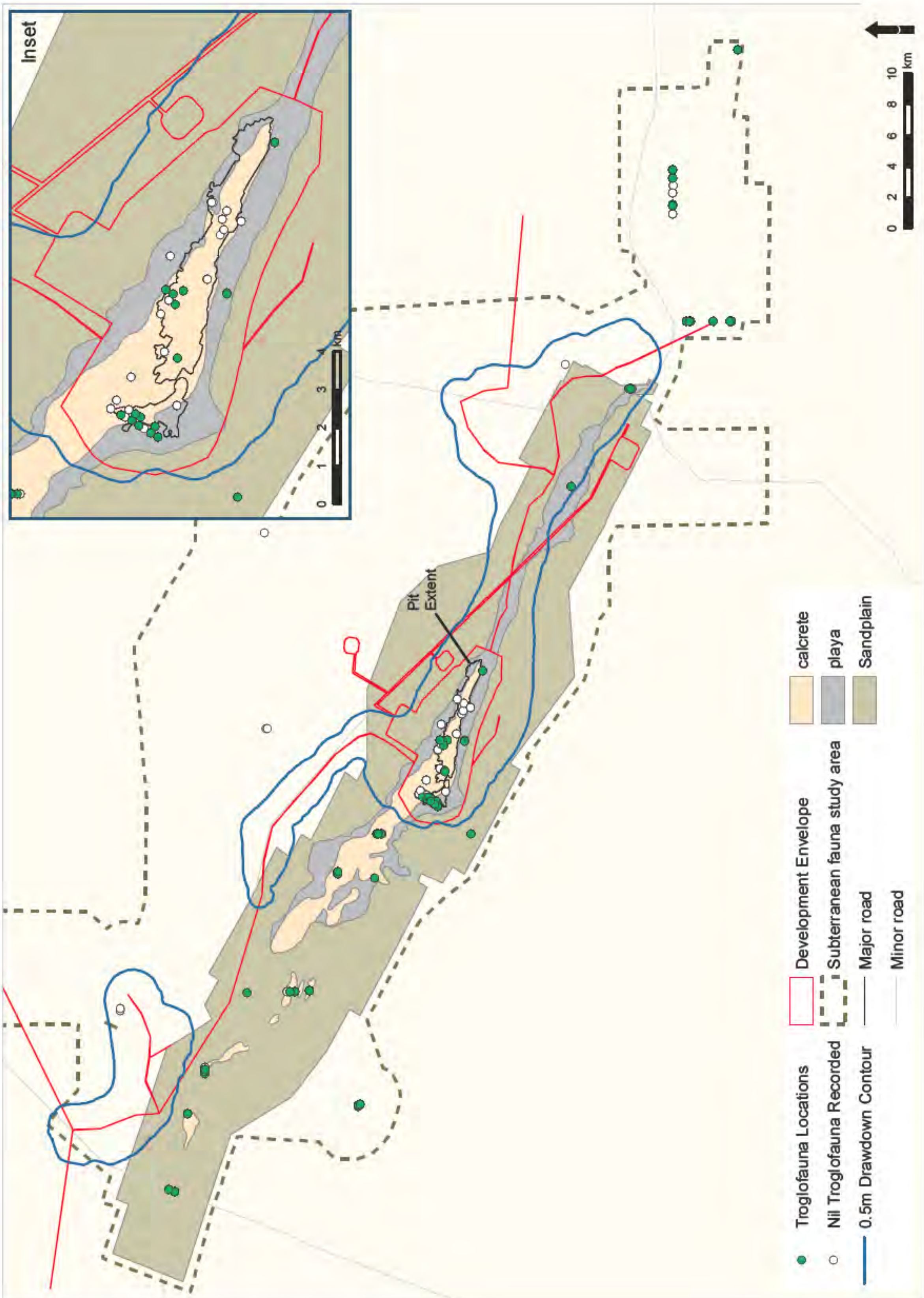


Figure 9-14: Troglofauna locations and major landforms

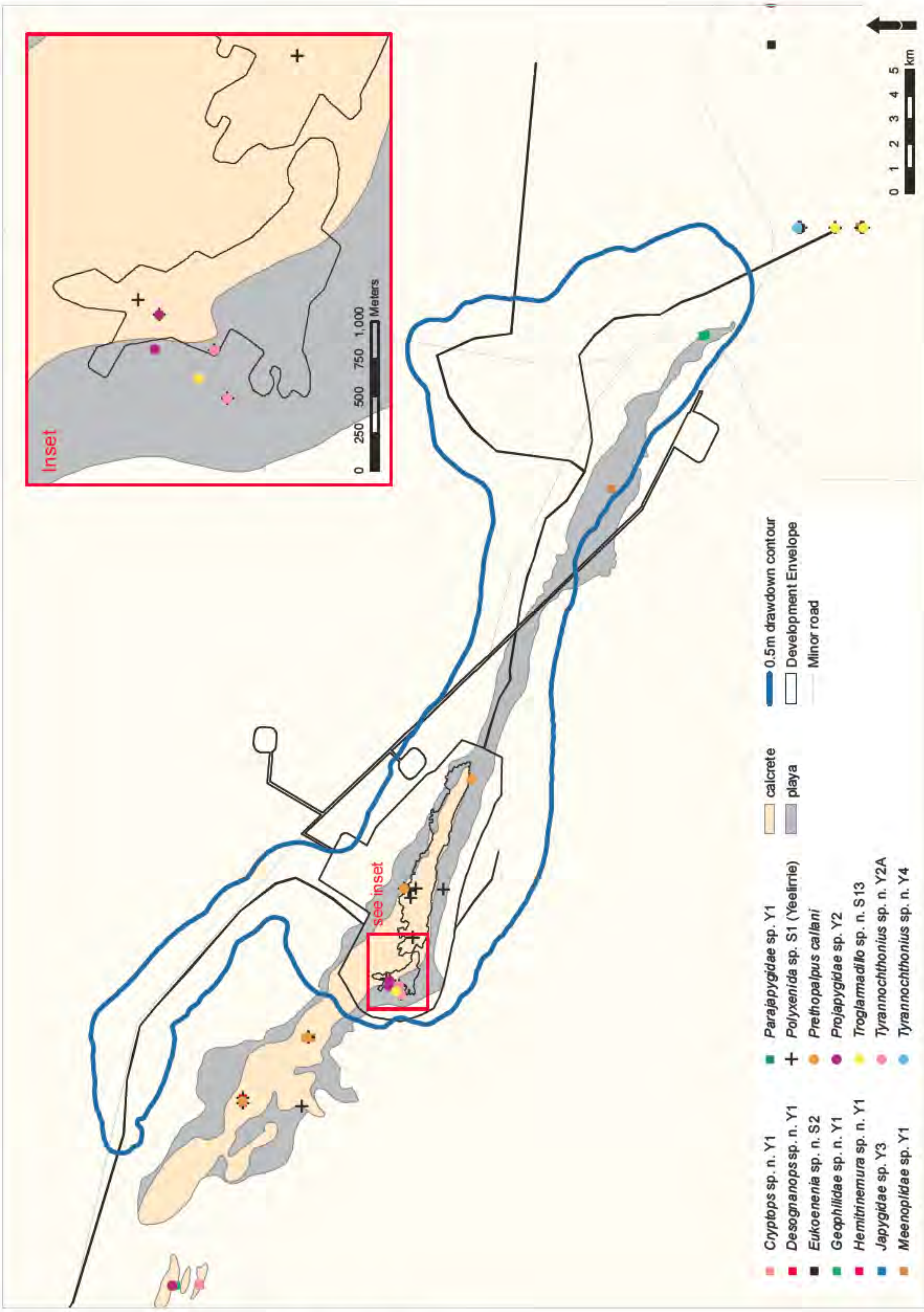


Figure 9-15: Widely abundant troglofauna species

goblin spider *Prethopalpus callani* (Baehr *et al*. 2012; Karanovic and Cooper 2011 a, b; Karanovic and Cooper 2012; Karanovic et al. 2014).

9.2.5 Potential Impacts on Subterranean Fauna

Habitat loss represents the most significant potential threat to subterranean fauna and is considered here as the principal threatening process. Loss of relatively small areas of subterranean habitat may have the potential to threaten the persistence of some subterranean fauna species because of the very small ranges of some species (less than 100 ha for some troglofauna species; see Halse and Pearson 2014).

Loss of stygofauna habitat at Yeelirrie will occur mainly through groundwater drawdown although the area excavated for the mine pit (which is contained within the area of groundwater drawdown) will also represent lost habitat. Although annual changes of 2 m occur at Lake Way to the north (Mann and Horwitz 1979), natural annual fluctuations of groundwater levels at Yeelirrie are probably <1 m. Given that the thickness of saturated calcrete, which is considered to be the main stygofauna habitat at Yeelirrie, is only 2 to 3 m across much of Yeelirrie, substantial drawdowns are likely to fully dewater the calcrete and cause major habitat loss for stygofauna. Smaller drawdowns may result in significant changes to groundwater salinities within calcretes because of the natural vertical salinity gradient.

It is common practice when examining relatively deep and uniform aquifers to assume that only drawdowns of >2 m over and above natural fluctuations will have significant conservation impacts on stygofauna. On account of the relative thinness of the saturated calcrete in most of the drawdown area at Yeelirrie, a more precautionary threshold of >0.5 m was identified as the point when groundwater drawdown may result in enough loss of stygofauna habitat to have significant conservation effects.

Loss of troglofauna habitat at Yeelirrie will occur through excavation for the mine pit. In addition there may be a small area around the mine pit (extending only a few metres) in which drying of habitat and the effects of mine pit activities will reduce habitat quality sufficiently to have conservation effects. Outside the proposed mine pit and this narrow buffer, there should be no significant loss of habitat.

9.2.6 Subterranean Fauna Assessment

9.2.6.1 Impacts on the Yeelirrie PEC

The Yeelirrie Priority 1 PEC represents a conservation significant community. It is currently defined spatially as a buffered area (Figure 9-10), without any delineation of the core area containing the ecological community of interest from the surrounding buffer, although the Yeelirrie calcrete is the focus of the listing. At the time the PEC was first listed, only three stygofauna species were known to occur at the calcrete and the compositional characteristics of the community were not defined. Following Phase 2 and 3 sampling, it has been shown that the study area supports 115 subterranean fauna species, of which 70 are stygofauna.

Figure 9-16 illustrates the modelled maximum drawdown impacts throughout the entire length of the palaeochannel around Yeelirrie. The figure utilises known bore information to show lithological units, depth of groundwater and aquifer thickness. As illustrated in the figure, there are large areas that experience a drawdown of > 0.5 m, however a significant percentage of the aquifer remains as stygofauna habitat.

Given that the amount of drawdown varies along the palaeochannel, as well as between landscape units, it is difficult to assess potential impacts on the PEC without clear definition of its extent and species composition. Furthermore, there is no widely accepted framework for determining what represents an unacceptable loss of area from an ecological community, especially when it occurs within a single area. Most proposed schemes are based on communities that have multiple occurrences across the landscape (e.g. Rodriguez et al. 2011).

Drawdown of >0.5 m at Yeelirrie will impact on approximately 37% and 60% of the areas of inferred calcrete and playa, respectively (Figure 9-12). The proportion of sandplain impacted will be small because it is an extensive landscape unit. Twenty per cent of stygofauna species are currently known only from the inferred calcrete, a further 36% of species are known only from the inferred calcrete and playa, and 44% of species occur in the sandplain or are probably widely distributed in the Yilgarn.

When assessing the impact of the Project on conservation values of the PEC, it should be recognised that there will not be total loss of stygofauna habitat in all areas where groundwater drawdown is >0.5 m (Figure 9-11). In fact at bore YYHC0075 (Figure 9-16), which is approximately 3 km south east of the pit, drawdown is predicted to be 4.4 m and below this 16.7 m (79%) of the aquifer will remain intact. In much of the area of inferred calcrete, some calcrete and the underlying alluvium will remain saturated. It is expected that the overall ecological character of the PEC will show little change in terms of species richness and composition as a result of Project development because most species have part of their populations outside the area of groundwater drawdown.

9.2.6.2 Listed Species

None of the 115 subterranean fauna species from Yeelirrie is currently listed for special protection under the State WC Act or Commonwealth EPBC Act.

9.2.6.3 Stygofauna

Seventy stygofauna species have been recorded from the Project Area, with populations of 86% of these species found outside the mapped extent of groundwater drawdown.

Ten species are currently known only from the mine pit and associated areas of predicted groundwater drawdown (Figure 9-17). Nine of the species are known from single bores and the other species is known from two bores. No restricted species have been recorded only from the northwest area of groundwater drawdown (Figure 9-12), which is associated with additional groundwater abstraction for processing water.

Discussion of the distributions of the ten stygofauna species known only from the predicted area of groundwater drawdown is provided below (also see Appendix F1).

Enchytraeidae sp. Y4

In total, 1133 enchytraeid worms were collected throughout the Yeelirrie calcrete and the Yeelirrie Playa and only a handful of specimens were DNA sequenced to show that nine species are present. Subterranean oligochaetes, including enchytraeids, are thought to be moderately widespread (Pinder 2008), so that the pattern of localised occurrence at Yeelirrie that may be inferred from DNA results would be unusual. It is more likely that Enchytraeidae sp. Y4, which was detected genetically from a single animal occurs more widely at Yeelirrie (the other 37 enchytraeids in the sample were assumed to be Enchytraeidae sp. Y4).

Subterranean Ecology (2011) examined many specimens from many samples genetically and, to contain costs, mostly analysed only one animal of each morphotype. In the case of enchytraeid worms, few species were expected and there was no attempt to identify morphotypes. Therefore, it was assumed all specimens in a sample belonged to the same species as defined by DNA sequencing.

Enchytraeidae sp. Y6

This amphibious species was collected at a single bore hole within the proposed mine pit. Identification was based on a single animal and the other three enchytaeid worms in the same bore sample were assumed to be Enchytraeidae sp. Y6. Based on the belief that enchytraeid species are usually moderately widespread, it is considered to be likely that Enchytraeidae sp. Y6 occurs more widely at Yeelirrie.

Atopobathynella sp. 'line K'

This syncarid species was collected from a single bore hole in the southeastern part of the groundwater drawdown. Syncarids are conventionally considered to have small ranges. However, *Atopobathynella* sp. 'line K' is one of six species of *Atopobathynella* collected in the study area and two of the three species collected from multiple bores were widespread (Table 9-26). The most numerous species (*Atopobathynella* sp. S5) has a known linear range of 20 km (Figure 9-13). This suggests further sampling may show *Atopobathynella* sp. 'line K' occurs outside the area of groundwater drawdown.

Halicyclops cf. *eberhardi* sp. B

The copepod *Halicyclops* cf. *eberhardi* sp. B was collected as 372 specimens in four samples from a single bore on the periphery of the proposed mine pit and within the area of groundwater drawdown. The closely related *H.* cf. *eberhardi* sp. A is more widely distributed in the Yeelirrie calcrete and, perhaps, regionally. Another closely related species, *H.* cf. *eberhardi* sp. C, was collected at Yeelirrie playa. Little can currently be said about the likely range of *H.* cf. *eberhardi* sp. B other than it must be larger than currently documented. Copepods are often are abundant in particular microhabitats (Galassi *et al*. 2009) and the large number of specimens collected from a single bore suggests this applies to *H.* cf. *eberhardi* sp. A.

Collection of a species in large numbers from only one hole also suggests that sampling stochasticity is not a likely reasons that *H.* cf. *eberhardi* sp. A was collected from only one bore. A more likely explanation is that the species occurs in microhabitat with a patchy, and probably infrequent, occurrence. Such a microhabitat might be quite widespread, at least subregionally, and delineated by a particular factor such as salinity, or a combination of salinity and other factors (see Section 9.2.2.4). However, identifying the locations of particular habitats in a heterogeneous area such as Yeelirrie is difficult.

Kinnecaris lined

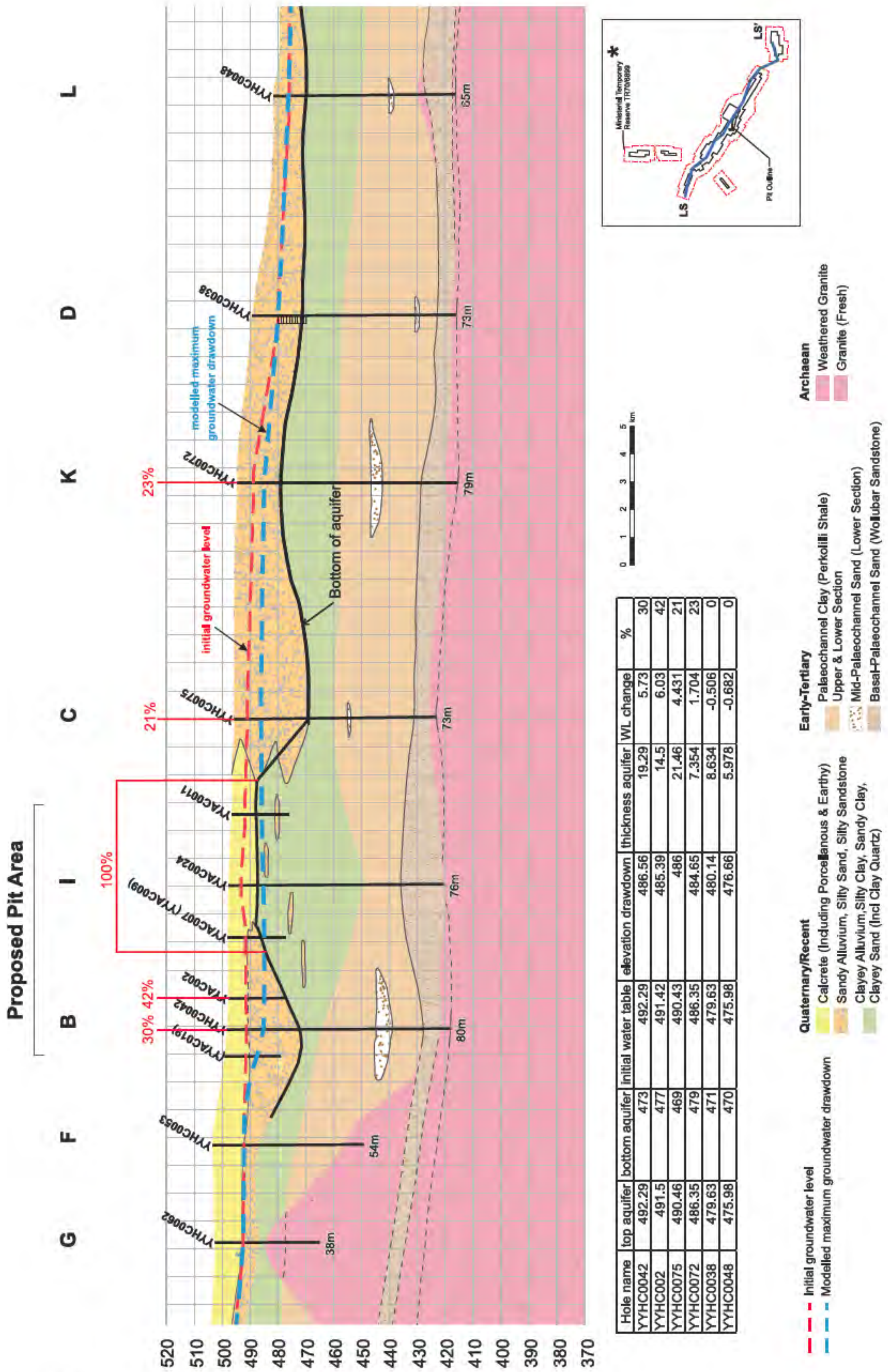
One hundred specimens of the copepod *Kinnecaris lined* were collected from a single bore in the southeastern part of the central groundwater drawdown. The identification was based on DNA sequence data and morphology (Karanovic and Cooper 2011). Given that six species of *Kinnecaris* occur in the study area, with all species other than *K. uranusi* having restricted known ranges, it is likely most of species of *Kinnecaris* at Yeelirrie occupy specific microhabitats within the study area. Little can be said currently about the likely distribution of *K. lined* but further sampling may show it occurs outside the area of groundwater drawdown.

Novanitocrella 'araia' sp. n.

The copepod *Novanitocrella* 'araia' sp. n. is known only from a single animal in a sample from within the proposed mine pit. The species is defined morphologically and a further 123 animals belonging to a subspecies *Novanitocrella* 'araia linec' ssp. n. are known from the east of the mine pit within the area of groundwater drawdown. The species and subspecies are treated here as a single taxonomic unit with a known range of 11 km. The only other species of the genus, *N. aboriginesi*, has a known linear range of about 20 km (Karanovic 2004) and it is likely that further sampling will show *Novanitocrella* 'araia' sp. n. occurs outside the area of groundwater drawdown.

Schizopera akolos

In total, nine species and one subspecies of the copepod *Schizopera* have been collected from Yeelirrie, with all four species recorded from multiple bores being widespread (Table 9-26). *Schizopera akolos* was collected as four animals in two samples from a single bore at the western end of the proposed mine pit. It is likely that *Schizopera akolos* occupies a relatively rare microhabitat



Hole name	top aquifer	bottom aquifer	initial water table	elevation drawdown	thickness aquifer	WL change	%
YYHC0042	492.29	473	492.29	486.56	19.29	5.73	30
YYHC002	491.5	477	491.42	485.39	14.5	6.03	42
YYHC0075	490.46	469	490.43	486	21.46	4.431	21
YYHC0072	486.35	479	486.35	484.65	7.354	1.704	23
YYHC0038	479.63	471	479.63	480.14	8.634	-0.506	0
YYHC0048	475.98	470	475.98	476.66	5.978	-0.682	0

Figure 9-16: Longitudinal cross-section

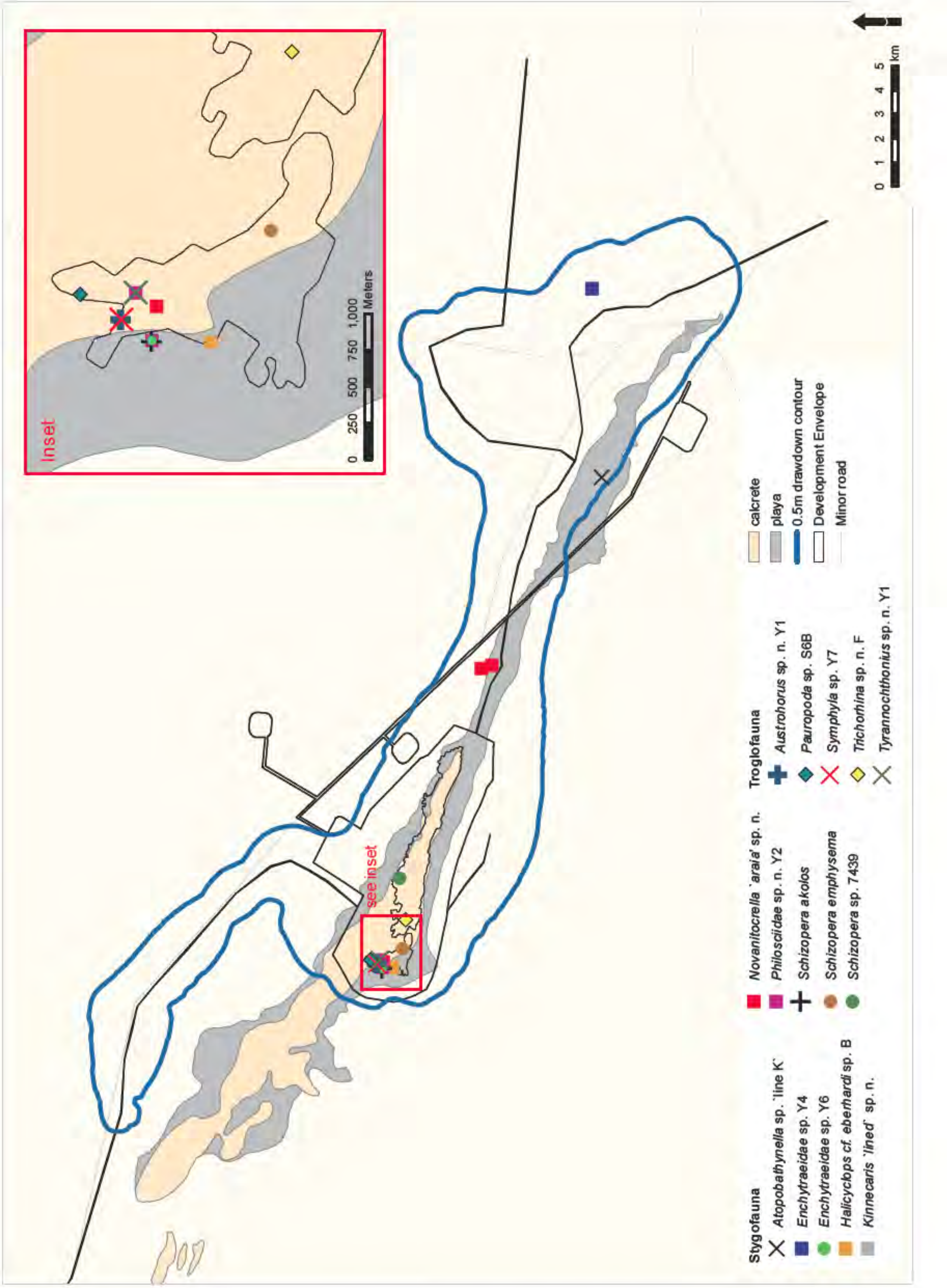


Figure 9-17: Subterranean fauna species known only from within predicted area of drawdown

(see Bradford 2010). Genetic data suggest the high richness of *Schizopera* species at Yeelirrie is the result of multiple invasions of surface species, as well as local speciation (Karanovic and Cooper 2012). DNA data suggest one of the invading species was *Schizopera akolos* and a wide range at Yeelirrie might be expected for such a species. Thus, while the likely range of *Schizopera akolos* is uncertain, it certainly larger than currently documented and further sampling may show *Schizopera akolos* occurs outside the area of groundwater drawdown.

Schizopera emphysema

Eight animals of *Schizopera emphysema* were collected in four samples from one bore within the proposed mine pit. As with *S. akolos*, this species probably occupies a discrete microhabitat within the study area because it was not collected from any of the three bores a few metres away (Karanovic and Cooper 2012). Like *Schizopera akolos*, *S. emphysema* belongs to a clade of surface-invading species that might be expected to be widespread and it is considered likely the species has a patchy occurrence at Yeelirrie corresponding with occurrences of its preferred microhabitat. Further sampling may show *Schizopera emphsema* occurs outside the area of groundwater drawdown at Yeelirrie.

Schizopera sp. 7439

Schizopera sp. 7439, which was identified by genetic analysis of a single animal, was collected in one sample of five animals from one bore within the proposed mine pit. It was not recognised morphologically prior to DNA analysis and therefore may have occurred in other samples without being recognised and recorded. As this species is known from a single sample, with identification based on a single individual, the probability that collection of additional specimens will increase its range is high but little can be concluded currently about its likely distribution.

Philosciidae sp. n. Y2

This amphibious isopod species was collected as five specimens in four samples from two bore holes within the proposed mine pit. Terrestrial isopods often have restricted ranges (Judd *et al*. 2003) and other subterranean philosciids have sometimes been shown to be restricted to single calcretes or to have mine-scale distributions (Cooper *et al*. 2008; Taiti and Humphreys 2001). Little can be said about the likely range of *Philosciidae* sp. Y2 but further sampling may show *Philosciidae* sp. Y2 occurs outside the area of groundwater drawdown.

9.2.6.4 Troglofauna

Forty-five troglofauna species have been recorded from the Project Area, with the populations of 89% of these species found outside the proposed mine pit.

Discussion of the distributions of the five troglofauna species known only from the area of the proposed mine pit is provided below (Figure 9-17; see also Appendix F1).

Trichorhina sp. n. F

Three of the four species of the isopod *Trichorhina* collected in the study area are known from single bores, with *Trichorhina* sp. n. F being represented by a single animal within the proposed mine pit. The fourth species, *Trichorhina* sp. n. G, occurs in multiple bores with a linear range of about 14 km but is restricted to the northwestern part of the Yeelirrie calcrete. It is likely *Trichorhina* sp. n. F will have a small range but further sampling may show it occurs outside the mine pit.

Tyrannochthonius sp. n. Y1

Three of the six species of the pseudoscorpion *Tyrannochthonius* at Yeelirrie were collected from two or three bores. As a result, both *Tyrannochthonius* sp. n. Y2A and *Tyrannochthonius* sp. n. Y4 showed relatively wide distributions (13 and 26 km, respectively). Most subterranean pseudoscorpions have similar ranges (Harvey and Edward 2007; Harvey and Leng 2008) and it appears that the restricted range of *Tyrannochthonius* sp. n. Y1 is the result of a single animal being collected. Further sampling is likely to show that *Tyrannochthonius* sp. n. Y1 is more widespread.

Austrohorus sp. n. Y1

Both species of the pseudoscorpion *Austrohorus* collected in the study area came from single bore holes. *Austrohorus* sp. n Y1 was represented by a single animal collected approximately 220 m from the edge of the proposed mine pit. Little can be said about its likely range other than that most pseudoscorpions have linear ranges that are at least an order of magnitude greater than this (Harvey and Edward 2007; Harvey and Leng 2008). Further sampling may show that *Austrohorus* sp. n Y1 is more widespread.

Pauropoda sp. S6B

All five pauropod species collected at Yeelirrie have apparently restricted distributions, although in some cases it was because single animals were collected. Pauropoda sp. S6B was collected in one sample containing three animals, only one of which was analysed genetically. Recent taxonomic work on surface pauropods in Australia suggests that Western Australia has many endemic species but range information is limited because there has been little collecting (Scheller 2010; Scheller 2013). Collections of troglofaunal pauropods in the Pilbara suggest they have similar ranges to pseudoscorpions and are less tightly restricted than many troglofauna species (Halse and Pearson 2014). It is considered to be likely that the range of Pauropoda sp. S6B extends beyond the proposed mine pit, especially considering the proximity of the one record to the edge of the mine pit.

Symphyla sp. Y7

All seven symphylan species collected from Yeelirrie have apparently restricted distributions, although as with pauropods this is often the result of single animals being collected. Symphyla sp. Y7 was represented by a single specimen and little can be said about its likely range because of the poor taxonomic framework for this group in Australia and the resultant lack of species level identifications and range information. Thus, it must be considered possible that Symphyla sp. Y7 is restricted to the proposed mine pit, although the proximity of the one record to the edge of the mine pit indicates that, on balance, the species' range is more likely to extend outside.

9.2.6.5 Impacts on Species

A comprehensive subterranean fauna sampling program at Yeelirrie has documented most of the species in the area and provided information on their distributions in relation to Project impacts. It is clear that the conservation status of most species known from the PEC will not be affected by mining and groundwater drawdown, although 10 species of stygofauna and five species of troglofauna are currently known only from areas proposed to be impacted by mining or de-watering.

Some additional sampling was undertaken, both in 2009-2010 and 2015 to attempt to show wider occurrence of these 15 species. However, the fine-scale heterogeneity of salinity and other habitat characteristics of the subterranean environment at Yeelirrie make it difficult to design an appropriate sampling program. This was highlighted by the considerable mis-match between the modelled salinity of bores used for targeted sampling in 2015 and the actual values recorded in those bores during when sampling. Seven of the eight restricted species for which salinity information was available had been recorded in the impact area at salinities of 10-25 gL^{-1}. However, 67% of the bores sampled outside the impact area to show wider occurrence of apparently restricted species were in groundwater of <5gL^{-1}, despite modelling suggesting salinities would be mostly 15-20 gL^{-1} (Appendix F1).

For nine of the 15 species currently known only from the proposed mine pit or groundwater drawdown area, it is considered there is sufficient surrogate evidence from related species to indicate the species are likely to occur outside these impact areas. These species are:

- Enchytraeidae sp. Y4, Enchytraeidae sp. Y6. It is likely these species were apparently restricted because there were DNA identifications of only a very small proportion of the animals collected. Enchytraeidae sp. Y5, which also appeared to be restricted on the basis on sampling results from 2009-2010, was shown in 2015 to be more widespread (see below).

- *Atopobathynella* sp. 'line K'. Species of *Atopobathynella* that were collected from multiple bores are mostly widespread at Yeelirrie.
- *Schizopera akolos*, *Schizopera emphysema*. All species of *Schizopera* collected from multiple bores are widespread at Yeelirrie. Phylogenetic evidence suggests these two species are have colonised from the surface and, therefore, are likely to have a moderately wide range at Yeelirrie.
- *Tyrannochthonius* sp. n. Y1, *Austrohorus* sp. n. Y1. Troglofaunal pseudoscorpions are usually moderately widespread.
- Pauropoda sp. S6B, Symphyla sp. Y7. These species occur so close to edge of proposed mine pit that their ranges will extend outside. In addition, pauropods are mostly moderately widespread.

There is not strong surrogate evidence of wider range for six of the 15 species. However, five species require only small range extensions to occur outside the impact areas. These range extensions are well within the probable magnitude of the species ranges:

- *Halicyclops* cf. *eberhardi* sp. B. This genus has shown considerable speciation at Yeelirrie. Although the species probably has a small range, it was found close to the boundary of groundwater drawdown and probably occurs outside.
- *Kinnecaris lined*. This genus has shown considerable speciation at Yeelirrie. Although the species probably has a small range, it was found close to the boundary of groundwater drawdown and probably occurs outside.
- *Novanitocrell*a 'araia' sp. n. The taxonomy of this species is complex and it may in fact consist of two species but Novanitocrella 'araia' sp. n. has a smaller range than the only described species of the genus and occurs near the western boundary of groundwater drawdown. With a small range extension the species would occur outside the proposed impacted area.
- *Philosciidae* sp. n. Y2. With a small westward range extension, the species would occur outside the area of proposed groundwater drawdown.
- *Trichorhina* sp. n. F. This is the species of troglofauna most likely to be restricted to the mine pit on the basis of existing information but, with a range extension of <1 km, it would extend beyond the mine pit.

One of the 15 species should be treated as having uncertain taxonomic, as well as conservation, status because of the way it was identified:

- *Schizopera* sp. 7439. This specimen was identified genetically during the 2009-2010 sampling (Subterranean Ecology 2011) and then subjected to further analysis by Karanovic and Cooper (2010). In the latter publication, it is unclear whether they consider *Schizopera* sp. 7439 to be a cryptic species that looks like *Schizopera uranusi* or the result of contamination during analysis. It is considered that further verification of the validity of the specimen as a valid taxonomic unit is required before it is treated as being restricted to the impact area.

While evidence is presented above to suggest wider occurrence of 14 species and taxonomic uncertainty about an additional 15th species, it is emphasised again that predicting the true ranges of these 15 species through both field sampling and surrogate analysis is difficult without good understanding of the factors driving habitat selection by the individual species. Accurate determinations, and even predictions, of ranges usually require that animals have been collected from 25-30 sites with a sampling regime that is spatially unconstrained (Wisz *et al*. 2008). It is unlikely that anywhere near this number of records can be collected for subterranean fauna species occurring in rare microhabitats because of the inability to target specific habitats when sampling as discussed in Section 9.2.4.1.

In some cases, however, small numbers of samples will show that species ranges extend beyond the impact area. The collection of two additional specimens of Enchytaeidae sp. Y5 during a targeted sampling program in 2015 showed that this species has a linear range of at least 23 km and occurs outside the proposed mine pit. Previously, this genetically identified enchytraeid was known only from two bores in the mine pit (Appendix F1).

In summary, the sampling for subterranean fauna at Yeelirrie has been the most comprehensive of any subterranean fauna survey in the Yilgarn and the results confirm some of the research related theories about stygofauna habitat, including that calcrete areas are productive habitats hosting significant species richness. Geological work and the subterranean fauna sampling results also show, however, that calcrete habitat is not easily defined and subterranean fauna species are not limited to areas described as calcrete.

9.2.7 Management

Management options to protect subterranean fauna are difficult especially considering the uncertainty and limitations of the study and impact assessment. Cameco has investigated numerous management strategies to reduce its impact on subterranean sauna, including:

- **Sterilisation of the economic orebody**: this strategy will have a significant impact on the economics of the project. The strategy could potentially be effective to reduce the impact to troglofauna species currently only known from the pit as four of the troglofauna species (*Tyrannochthonius* sp. n. Y1, *Austrohorus* sp. n. Y1, Pauropoda sp. S6B and Symphyla sp. Y7) are only known from the northwestern corner of the pit. However as discussed in Section 9.2.5.4, given the close proximity of all four species to the edge of the pit, the range of these species is likely to extend outside the pit and impact zone. This management strategy will not have a net benefit to restricted stygofauna species because of the requirement for dewatering. This strategy is not being proposed because it offers no net benefit to any likely restricted species and the overall impact to the economics of the project is significant.
- **Dewatering strategy and location of production supply well fields**: The groundwater model is currently conceptual in nature, however given the long history of the Albion Downs Wellfield and the historical work by WMC, Cameco has a high level of confidence that water can be sourced from the palaeochannel. Less confidence and more uncertainty of impacts is present for the Western Brackish Wellfield, Northern Brackish Wellfield and Eastern Brackish Wellfield (as described in Appendix I1), however these areas do not contain preferred subterranean fauna habitat. During the water modelling process Cameco has implemented the following in order to reduce impact to stygofauna:
  - No abstraction wells have been located within the palaeochannel to the northwest of the proposed mine pit. While this area is potentially an excellent source of groundwater, it also supports many stygofauna species and is the location of likely range extension for the species currently only known from impact area. Cameco has deliberately not located any abstraction wells in this area in order to reduce impact to stygofauna species and maintain a significant amount of calcrete habitat within the palaeochannel.
  - No abstraction wells have been placed within the mine pit. This has reduced the drawdown impact to the northwest, and area that supports many stygofauna species and is the location of likely range extension for the species currently only known from impact area.
  - Despite not having a benefit to species currently only known from the area of impact Cameco has also removed a number of planned abstraction wells from the palaeochannel in the Western Brackish Wellfield. This has resulted in a reduced impact to the palaeochannel and suitable habitat in the area (a number of species have been collected from this area).

More work can still be undertaken in this area to further reduce the impact to habitat and the species currently only known from the area of impact. However Cameco is currently unable to progress this further given the current knowledge (Western Brackish Wellfield, Northern Brackish Wellfield and Eastern Brackish Wellfield) and the need to have high level of confidence in water supply at this stage of the Project. Cameco is committed to undertaking further testing of the wellfields during a Definitive Feasibility Study (DFS). This information will allow Cameco to further refine the groundwater model and look for opportunities to relocate abstraction wells from the palaeochannel.

- **Consideration of a groundwater barrier wall**: As discussed and presented in Appendix I1 (Section 5.7) Cameco also considered installation of a bentonite slurry wall in order to reduce the drawdown impact up gradient of the wall. Modelling indicates that a barrier wall would have a limiting drawdown effect on water table and would currently not provide a net benefit to species only known from the area of impact. Given this and the fact that installation of a slurry wall would come at a significant cost and result in additional vegetation clearing, this management option is currently not considered feasible.

Of the management strategies considered, the only feasible and effective option to reduce impact is through the implementation of a dewatering strategy and strategically located production supply wells. This strategy will be further refined and investigated prior to the commencement of the Project during a DFS study when further testing of the groundwater supply areas will occur. Potential options include:

- locating well fields in the alluvium/weathered bedrock aquifers in the areas north of the valley floor and north of the proposed pit; and
- investigating additional water sources outside the palaeochannel and not in preferred stygofauna habitat, with the potentially of relocating entire well fields.

Prior to Project commencement Cameco will develop a Subterranean Fauna Management Plan, which will be closely integrated with the Groundwater Management Plan (Section 9.5.6). The plan will detail the results of the DFS investigation and include the following at a minimum:

- Develop subterranean fauna monitoring program.
- Set trigger criteria and contingency actions.
- Outline reporting requirements.

In summary, Cameco has utilised the hierarchy of control to manage the impact of the Project on stygofauna. This includes the following:

- **Avoid.** No abstraction wells have been located within the palaeochannel to the northwest of the pit. While this area is potentially an excellent source of groundwater, it also supports many stygofauna species.
- **Minimise.** Abstraction wells will be relocated throughout the supply area to reduce the groundwater impact where possible. Cameco believes that there are number of opportunities to continue to minimise this impact and these opportunities will be explored during a DFS.

9.2.8 Commitments

Cameco will develop and implement a Subterranean Fauna Management Plan, which will be closely integrated with the Groundwater Management Plan. Cameco is also committed to having further discussions with the OEPA and DPaW to determine a suitable offset.

9.2.9 Outcomes

Residual impacts on subterranean fauna are predicted to occur as a result of implementation of the Project and therefore offsets are proposed (Section 12.4). Cameco will have further conversations with OEPA and DPaW to determine suitable offsets.

Taking into account Project design, the proposed management measures, and the proposed offsets strategy of ongoing investigations to expand the range of species currently considered restricted, Cameco believes that the proposal will meet the EPA objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.

9.3 Terrestrial Fauna

9.3.1 EPA Objective

The EPA's objective for terrestrial fauna is:

- To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.

9.3.2 Relevant Legislation and Policy

This section only addresses State requirements for the protection of fauna. Requirements under the Federal EPBC Act are discussed in Section 10.1.

All native fauna in Western Australia are protected under the *Wildlife Conservation Act 1950* (WC Act). Native fauna species that are rare, threatened with extinction, or have high conservation value are specially protected under the WC Act. The Wildlife Conservation (Specially Protected Fauna) Notice classifies rare and endangered fauna using four conservation schedules:

Schedule 1 – Fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection.

Schedule 2 – Fauna which are presumed to be extinct and are declared to be fauna in need of special protection.

Schedule 3 – Birds which are subject to international agreements and conventions relating to the protection of migratory birds (Section 10.1) and birds in danger of extinction, which are declared to be fauna in need of special protection, and

Schedule 4 – Fauna that are in need of special protection, for reasons other than those reasons mentioned in Schedules 1, 2 or 3.

Threatened Fauna listed under Schedule 1 are classified as follows according to their level of threat using the IUCN Red List criteria:

Critically Endangered (CR): Considered to be facing an extremely high risk of extinction in the wild.

Endangered (EN): Considered to be facing a very high risk of extinction in the wild.

Vulnerable (VU): Considered to be facing a high risk of extinction in the wild.

Extinct (EX): There is no reasonable doubt that the last individual has died.

In addition to Schedules 1-4, DPaW produces a supplementary list of Priority Fauna. Priority Fauna are species that have been identified as requiring further survey and evaluation of their conservation status before deciding whether to list them as Schedule Fauna. Five Priority codes are defined by the DPaW:

Priority One (P1): Poorly-known species (on threatened lands). Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well-known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

Priority Two (P2): Poorly-known species (on conservation lands). Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well-known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

Priority Three (P3): Poorly-known species (some on conservation lands). Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well-known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

Priority Four (P4): Rare, Near Threatened and other species in need of monitoring.

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.

(b) Near Threatened. Species that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

Priority Five (P5): Conservation Dependent species. Species that are not threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

The EPA Position Statement No. 3 outlines the use of terrestrial biological surveys as an element of biodiversity protection in Western Australia (EPA 2002b). Proponents are expected to undertake field surveys that meet the standards, requirements and protocols as determined and published by the EPA. The majority of the studies relied on here were commissioned by the previous owners of the Project, BHP Billiton. Cameco and its consultants have reviewed the fauna surveys undertaken for the Project to confirm the surveys met the requirements for Level 2 biological surveys for assessment of the impacts of the Project.

Further detail on the requirements for fauna surveys is provided in EPA Guidance Statement No. 56 (EPA 2004) and Technical Guide on Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA & DEC 2010).

Guidance Statement No. 20 (EPA 2009) addresses the general standards and risk-based approach for the sampling and assessment of short-range endemic (SRE) invertebrate fauna species in Western Australia. The guidance outlines the EPA's expectations in respect of the quality and quantity of information derived from these surveys, and the consequent analysis, interpretation and reporting.

9.3.2.1 Conservation significance species

Three broad levels of conservation significance can be recognised and are used for the purposes of this assessment:

Conservation Significance (CS) 1: Species listed under the EPBC Act or WC Act;

Conservation Significance (CS) 2: Species listed as Priority by the DPaW but not listed under the EPBC Act or WC Act; and

Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

Conservation significance level 3 (CS3) has no legislative or published recognition and is based on interpretation of distribution information, but is used here as it may have links to preserving biodiversity at the genetic level (EPA 2002). If a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. Short Range Endemic (SRE) invertebrate species (*sensu* Harvey 2002) are also considered to be CS3.

9.3.3 Studies and Investigations

9.3.3.1 General Approach to Fauna Impact Assessment

The purpose of impact assessment is to provide managing agencies with the information they need to decide upon the significance of impacts upon fauna from a proposed development. In this section, the impact assessment process is based on fauna values and impacting processes as summarised below, and the development of proposed action to mitigate impacts:

- Fauna values:
  - assemblage characteristics: uniqueness, completeness and richness;
  - species of conservation significance;
  - recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
  - patterns of biodiversity across the landscape; and
  - ecological processes upon which the fauna depend.
- Impacting processes:
  - habitat loss (leading to population decline and fragmentation);
  - habitat degradation (due to weed invasion);
  - ongoing mortality (leading to population decline);
  - species interactions (feral or overabundant native species);
  - changes in hydroecology;
  - altered fire regimes;
  - disturbance; and
  - bioaccumulation.

In 2015, Cameco commissioned Bamford Consulting Ecologists (BCE) to conduct an update of the impact assessment by reviewing previous reports on the fauna of the area, and revising and updating the species lists presented in earlier reports in terms of taxonomy and changes in conservation legislation. These reports are included in the appendices (BCE 2015a, BCE 2015b; Appendix G1 and G2).

Summary of previous work

A significant level of fauna survey activity has been completed by BHP Billiton and others prior to the acquisition of the Project by Cameco.

The Yeelirrie State Agreement area and surrounds have been extensively surveyed as summarised in Table 9-28 and Table 9-29. Observations on fauna were recorded at Yeelirrie Station during the previous mining trials (anon. 1978), and the Malleefowl Preservation Group (MPG) undertook systematic surveys for Malleefowl at Yeelirrie Station between 2000 and 2006 (Benshemesh *et al.* 2008).

Regional information on fauna was available from Cowan (2001), who reported on vertebrate fauna, and particularly those of conservation significance, in the Murchison subregion. Thompson and Thompson (2006) prepared an inventory of 131 reptile species from a ten year survey covering the area from Wiluna, south to Norseman, west to Merredin, and east to Laverton. Dell *et al.* (1998) summarise the results of surveys of fauna of the Eastern Goldfields undertaken from 1979 to 1981 by the Biological Surveys Committee of Western Australia. In addition to these databases and regional studies, there is information on fauna of Wanjarri Nature Reserve, 50 km east of Yeelirrie (DPaW 2015).

Information from the above sources was supplemented with species expected in the area based on general patterns of distribution. As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented are based on the Western Australian Museum's (WAM) Checklist of the Fauna of Western Australia 2015. The authorities used for each vertebrate group were: amphibians (Doughty and Ellis 2014a), reptiles (Doughty and Ellis 2014b), birds (Johnstone 2013) and mammals (How *et al*. 2013).

Surveys were undertaken by BCE in March 2009, July 2009 and November 2009 (Appendix G3), and included all the major habitats present in the study area (Table 9-29). These surveys involved detailed assessment of 15 sites and were considered equivalent to a Level 2 survey as described in EPA Guidance Statement No. 56 (EPA 2004). In May 2010, BCE conducted targeted and systematic transect searches for conservation significant fauna (e.g. Black-flanked Rock-Wallaby, Mulgara and Malleefowl) (BCE 2011a) (Appendix G3). Other fauna surveys conducted in the region include Rosslyn Hill (70 km north of the study area, (BCE 2014) and near Wiluna (KLA 2012; Outback Ecology 2011). Where relevant, the results of these surveys have been included in the fauna assessment.

Recent work

In 2015, BCE conducted a review of the existing information on the fauna of the Project Area to confirm the extent and validity of the historical work and to revise and update the species lists. The review included a desktop literature review and an extensive site inspection undertaken in March 2015.

The purpose of the field surveys was to supplement existing information compiled from the desktop review, in particular, to determine the fauna assemblages utilising the habitats of the study area and to target species of conservation significance. A summary of the results of these surveys is provided in BCE (2015a) (Appendix G1)

It is important to note that the species lists generated from the desktop review include records drawn from a large region and possibly from environments not represented in the study area. In general, however, species identified by the desktop review process are considered to be potentially present in the study area whether or not they were recorded during field surveys.

Sources of information used for the fauna assessment are listed in Table 9-28. Database searches for State-listed fauna included the WA DPaW Naturemap (incorporating the Western Australian Museum's FaunaBase and the DPaW Threatened and Priority Fauna Database), Birds Australia's Atlas Database and the Atlas of Living Australia Database.

Table 9-28: Sources of information used for the desktop assessment.

Information source	Types of records held on database	Area searched (year)
Database searches		
NatureMap (DPaW 2015)	Records in the WAM and DPaW databases. Includes historical data and records on Threatened and Priority species in WA.	Site plus 40 km buffer (Searched January 2015).
BirdLife Australia Atlas Database (Birdlife Australia 2015)	Records of bird observations in Australia, 1998-2014.	One degree square containing site (Searched January 2015).
Atlas of Living Australia (ALA 2015)	Records held in Australian Museums and government departments.	Yeelirrie study area and surrounds (Searched January 2015).
Malacology and Terrestrial Invertebrate Database (WAM 2009)	Records of the WAM.	Between 26°30' S to 27°30' S, and 119°00' E to 121°00' E. (Searched 2009)
Previous reports		
Vertebrate Fauna Assessment Yeelirrie Project - Baseline Report (BCE 2011a) (Appendix G3)	Detailed Fauna Assessment of the Yeelirrie Study Area, conducted by BCE in 2009 and 2010.	Yeelirrie study area (2009–2010).
Proposed Yeelirrie development Short-range endemic invertebrate baseline Survey (Ecologia 2011a) (Appendix G4)	Detailed Invertebrate Fauna Assessment of the Yeelirrie Project, conducted by Ecologia in 2009 and 2010.	Yeelirrie study area (2009–2010)
Fauna Assessment of the Rosslyn Hill Mine (BCE 2014)	Detailed Fauna Survey conducted by BCE in late 2014.	Rosslyn Hill mining, 70 km north of Yeelirrie study area (2014).
Fauna Assessment at Wiluna West (KLA 2012)	Detailed Fauna Survey conducted by KLA in late 2011.	Wiluna West project, approximately 40 km north of Yeelirrie study area (2011).
Fauna Assessment at Wiluna Uranium Project (Outback Ecology 2011)	Detailed Fauna Survey for Toro Energy Limited Wiluna Uranium Project	Wiluna, approximately 60 km north-west of Yeelirrie study area (2011).
Fauna Assessment of Lorna Glen (DPaW 2015; Cowan 2008)	Species recorded on Lorna Glen station which contains several habitats similar to those found at Yeelirrie (J. Turpin, pers. obs.)	Lorna Glen approximately 180 km north-west of Yeelirrie study area (2008–2014).

Table 9-29: Vertebrate and invertebrate fauna survey techniques, dates and sampling effort

Survey technique	Total sampling effort	22-30 March 2009	17-22 July 2009	2-11 Nov 2009	6-11 May 2010	13-18 March 2015
Pitfall traps	1,115 trap-nights	X		X		
Elliott traps (including targeted trapping for Mulgara)	835 trap-nights	X		X		
Funnel traps	695 trap-nights	X		X		
Cage traps	100 trap-nights	X				
Bird census	Mornings over ten days at 149 locations with 1,115 census events	X		X		
Harp traps and Anabat echolocation detection	5 nights	X		X		
Motion sensitive cameras	33 nights	X	X	X		
Spotlighting	2 hours/night over 4 nights	X		X		
Targeted searches for Black-flanked Rock-Wallaby	35 hours over 5 days. 2 hours in March 2015	X	X	X	X	X
Targeted searches for Mulgara	80 hours over 9 days. Opportunistic in March 2015	X	X	X	X	X
Targeted searches for Malleefowl	80 hours over 9 days. Opportunistic in March 2015	X	X	X	X	X
Searches for evidence of other conservation significant species	Opportunistically over 19 days in 2009/2010, and over 4 days in 2015.	X	X	X	X	X
Opportunistic observations and searches	During all survey periods	X	X	X	X	X
Targeted searches for the Slender-billed Thornbill and Striated Grasswren	10 hours over 2 days in March 2015. Similar effort in 2009					X
Targeted searches for the Shield-backed Trapdoor Spider and other invertebrates of conservation significance	19 hours over 4 days in March 2015 (BCE). Previous intense surveys by Ecologia in 2009 and 2010 (see 9.3.3.2 below)					X

9.3.3.2 Invertebrate fauna

Invertebrate species considered to be short range endemics (SREs) are of conservation significance, however many have no legislative or published recognition and their significance is based on interpretation of SRE distribution information (Conservation significance Level 3). Harvey (2002) defines invertebrates as SRE species if they have a distribution of <10,000 km^2, and notes that the majority of species that have been classified as SREs have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of SRE species: terrestrial Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans) and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the SRE species hinders their conservation (Harvey 2002).

The species distribution for invertebrates was assessed on a regional basis (Murchison bioregion) since specific knowledge of invertebrate diversity is limited within the Project footprint and surrounding local areas. Therefore, the list of species obtained from database searches represents invertebrate species (targeting SREs) with the potential to be present in the study area. This is particularly important for significant invertebrate species that are often sparse and hard to find. In addition, a search of the Malacology and Terrestrial Invertebrate Database (Western Australian Museum) was conducted for the area (26°30' S to 27°30' S, and 119°00' E to 121°00' E).

Invertebrate fauna sampling

Previous work

During 2009 and 2010, invertebrate fauna assessments were conducted at the Yeelirrie study area (Ecologia 2011a; 2011b) (Appendix G4). The surveys were conducted in accordance with Guidance Statement No. 20: Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA 2009). Invertebrate survey methodology and effort is provided in Ecologia (2011a; 2011b) (Appendix G4). Other surveys conducted in the region include at Rosslyn Hill (70 km north of the study area, BCE 2014) and near Wiluna (KLA 2012; Outback Ecology 2011). Where relevant, the results of these surveys were drawn upon to develop this fauna assessment.

Recent work

In 2015, Cameco commissioned BCE to carry out a review of the existing information on the invertebrate fauna of the area and to revise and update the species lists presented in the earlier reports in terms of taxonomy and changes in conservation legislation. An extensive site inspection (four days) was undertaken in March 2015 with particular emphasis on searching for signs of conservation significant invertebrate species within the study area (BCE 2015b; Appendix G2).

During this site inspection, locations where *Idiosoma* sp. had been found by Ecologia were targeted in order to characterise the environment with which this species is associated, and to collect specimens to confirm the identification and determine the relationship of the species to the Shield-backed Trapdoor Spider *Idiosoma nigrum*. The Shield-backed Trapdoor Spider is listed under both State and Federal legislation, but Ecologia concluded the taxon they found at Yeelirrie was a related, undescribed but therefore unlisted species, although likely to be an SRE.

9.3.4 Existing Environment

Regional Context

The area of the proposed Yeelirrie development lies within the Eastern Murchison subregion of the Murchison Bioregion. The Murchison Bioregion falls within the Bioregion Group 2 classification, which is described as areas of 'native vegetation that are largely contiguous but are used for commercial grazing' (EPA 2004).

The key features of the region with relevance to terrestrial fauna are as follows:

- A north-west to south-east palaeo-valley with granite breakaways and a valley floor characterised by outcropping calcrete rises and a series of flats and clay flats. The margins of the calcrete system are surrounded by numerous irregular small to large playas that run approximately parallel to the calcrete expression.
- The vegetation of the region reflects its semi-arid climate, including Spinifex grasslands, Acacia and Mulga woodlands and some areas of the calcrete rises supporting open eucalypt woodland.
- There is widespread evidence of habitat modification and fragmentation through livestock grazing, introduced animal and plant species and altered fire regimes.
- Only 1.4% of the subregion is vested within conservation reserves (Cowan 2001). These are the Lake Mason and Kaluwirri Pastoral Leases, which lie approximately 30 km west of the Yeelirrie study area, and the Wanjarri Nature Reserve located 50 km east of the Yeelirrie study area.

9.3.4.1 Fauna habitats

BCE (2011a) describes eight major Vegetation and Substrate Associations (VSAs) (distinct environments that provide habitat for fauna) occurring across the Study Area (Figure 9-18):

- Granite Outcrops and Breakaways. Supporting mixed shrubland on gravelly/sand. Some areas of chenopod shrubland on heavier soil also present;
- Hardpan Mulga. Mulga woodland with poorly-developed understorey on hard loam soils;
- Calcrete. Low calcrete rises with Eucalypt open woodland (variable) over a sparse shrubland;
- Calcrete Outwash. Clayey-loam and clay flats, subject to occasional inundation with some open claypans. Vegetation includes Acacia open shrubland, sometimes with thickets of *Melaleuca xerophila*, and chenopod shrub-heaths;
- Chenopod Shrubland over Sandplain. These shrublands occur in sandy soils on the margins of playas in the southeast of the study area;
- Spinifex Sandplain. Sandplains dominated by Triodia hummock grasslands and scattered shrubs with areas of open Acacia/Eucalypt woodland;
- Mulga over Spinifex Sandplain. Mulga woodland over Spinifex on sandy-loam soils; and
- Acacia woodland over sparse Spinifex. Areas of dense Acacia woodland with or without a Spinifex understorey of variable density.

Further information on the flora and vegetation within the Study Area is provided in Section 9.1.

9.3.4.2 The Vertebrate Fauna Assemblage

The fauna assemblage of the Yeelirrie study area was generated and updated using previous reports in the area (BCE 2011a; 2014), relevant fauna databases, current literature and a site inspection in March 2015. The vertebrate fauna assemblage is expected to be composed of 294 species, including: 11 frog, 88 reptile, 156 bird, 30 native mammal and nine introduced mammal species (Appendix G1). Thirty-five of the species expected to occur in the region are of conservation significance. Field investigations have confirmed the presence of 173 fauna species, comprising of four frog, 49 reptile, 94 bird, 21 native mammal and five introduced species (BCE 2015a).

Overall, the assemblage of vertebrate fauna expected to occur reflects the transition zone from the Murchison to the arid interior. This assemblage contains both species typical of the Murchison area (e.g. Woolley's Pseudantechinus, Stripe-tailed Monitor) and species typical of the central deserts (e.g. Striated Grasswren), and some more typical of the south-west (such as the Grey Currawong, Regent Parrot and Malleefowl). As a result, a diverse fauna assemblage is expected to occur within the study area where ranges of species with predominantly southern, eastern or northern distributions overlap. Consequently, some fauna species expected in the region occur near the extreme edge of their range.

9.3.4.3 Vertebrate Fauna of Conservation Significance

Of the 35 conservation significant species which could potentially occur within the Yeelirrie study area, (Table 9-30), twenty-two species are of high significance (Conservation Significance [CS] Level 1), being listed under legislation; five are of moderate conservation significance (CS2), being listed as priority species by DPaW; and eight species of local significance (CS3), because they have restricted distribution or are listed as declining in the region. The list includes two reptile species, 27 bird species and six mammal species. Ten of the 35 species were confirmed by BCE as being present in the region during the surveys conducted in 2011 and 2015.

The categories used for the expected status of fauna in the study area include:

- **Resident**: species with a population permanently present in the survey area;
- **Regular migrant or visitor**: species that occur within the survey area regularly in at least moderate numbers, such as part of annual cycle;
- **Irregular visitor**: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the survey area in at least moderate numbers and for some time;
- **Vagrant**: species that occur within the survey area unpredictably, in small numbers and/or for very brief periods. Therefore, the survey area is unlikely to be of importance for the species; and
- **Locally extinct**: species that has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

The Northern Marsupial Mole (*Notoryctes caurinus*) is listed under Schedule 1 of the WC Act and as Endangered under the EPBC Act, but no suitable habitat for this species (i.e., sand dunes) is present in the study area or close to the study area. Searches of other databases found the species more than 400 km away (DPaW 2015). Therefore, this species has been omitted as potentially being present in the Project Area. The Oriental Plover (*Charadrius veredus*) listed under Schedule 3 of the WC Act is a migratory wetland species but is unlikely to occur in the study area, except possibly as a vagrant.

The suite of significant species includes many that are expected to occur only as vagrants or irregular visitors, and thus for which the site is of low importance, except where it may have value for connectivity. Some species, such as the Night Parrot, are unlikely to be extant in the Project Area but have been included in species lists based on previous records, distribution and suitable habitat. Conservation significant fauna species listed under State legislation are discussed in detail below. Further discussion of species listed under the EPBC Act is provided in Section 10.1.3. Locations of records of conservation significant fauna are provided in Figure 9-18. Potential impacts on fauna and proposed management actions are discussed in Section 9.3.5.

Table 9-30: Conservation status of significant vertebrate fauna species expected to occur in the Study Area (based on desktop reviews and surveys) and their expected status.

(Species recorded by BCE at Yeelirrie are indicated with 'X')

Common Name	Latin Name	Conservation Status (refer to Section 9.3.2)			Expected status in study area	Local records	BCE (2011a)	BCE (2015a)
		WC Act	P	CS3				
Conservation Significance 1 (CS1 – State listing only)								
*Malleefowl	*Leipoa ocellata*	S1			Resident	Yeelirrie	X	
*Black-flanked Rock-Wallaby	*Petrogale lateralis*	S1			Resident	Albion Downs	X	X
*Rainbow Bee-eater	*Merops ornatus*	S3			Regular migrant	Yeelirrie	X	X
*Fork-tailed Swift	*Apus pacificus*	S3			Irregular visitor	Yeelirrie		X
Peregrine Falcon	*Falco peregrinus*	S4			Resident	Yeelirrie	X	
Major Mitchell's Cockatoo	*Cacatua leadbeateri*	S4			Irregular visitor	Yeelirrie		
Grey Falcon	*Falco hypoleucos*	S1			Irregular visitor	Wanjarri		
*Princess Parrot	*Polytelis alexandrae*		P4		Irregular visitor	Wanjarri		
*Night Parrot	*Pezoporus occidentalis*	S1			Vagrant	None recent		
*Great Desert Skink	*Liopholis kintorei*	S1			Unknown	Wanjarri		
*Greater Bilby	*Macrotis lagotis*	S1			Vagrant	Wiluna		
*Eastern Great Egret	*Ardea modesta*	S3			Irregular visitor	Yeelirrie		
*Common Sandpiper	*Acitis hypoleucos*	S3			Irregular visitor	Meekatharra		
*Common Greenshank	*Tringa nebularia*	S3			Irregular visitor	Cue		
*Marsh Sandpiper	*Tringa stagnatalis*	S3			Irregular visitor	Cue		
*Wood Sandpiper	*Tringa glareola*	S3			Irregular visitor	Cue		
*Red-necked Stint	*Calidris ruficollis*	S3			Irregular visitor	Cue		
*Sharp-tailed Sandpiper	*Calidris acuminata*	S3			Irregular visitor	Yeelirrie		
*Curlew Sandpiper	*Calidris ferruginea*	S3			Irregular visitor	Lake Austin		

Common Name	Latin Name	Conservation Status (refer to Section 9.3.2)			Expected status in study area	Local records	BCE (2011a)	BCE (2015a)
		WC Act	P	CS3				
*Black-tailed Godwit	*Limosa limosa*	S3			Irregular visitor	Yeelirrie		
*Oriental Plover	*Charadrius veredus*	S3			Vagrant	None but returned from EPBC search		
Conservation Significance 2 (CS2)								
Australian Bustard	*Ardeotis australis*		P4		Resident	Yeelirrie	X	X
Striated Grasswren	*Amytornis s. striatus*		P4		Resident	Yeelirrie		
Brush-tailed Mulgara	*Dasycercus blythi*		P4		Resident	Yeelirrie	X	X
Long-tailed Dunnart	*Sminthopsis longicaudata*		P4		Resident	Rosslyn Hill		
Inland Long-eared Bat	*Nyctophilus major tor*		P4		Resident	Yeelirrie	X	
Conservation Significance 3 (CS3)								
Bush Stone-curlew	*Burhinus grallarius*			X	Resident	Yeelirrie	X	X
Square-tailed Kite	*Lophoictinia isura*			X	Resident	Yeelirrie	X	
Scarlet-chested Parrot	*Neophema splendida*			X	Irregular Visitor	Wanjarri		
Regent Parrot	*Polytelis anthopeplus*			X	Vagrant	Wanjarri		
Grey Honeyeater	*Conopophila whitei*			X	Resident	Wanjarri		
Rufous-crowned Emu-wren	*Stipiturus ruficeps*			X	Resident	Wanjarri		
Kultarr	*Antechinomys laniger*			X	Resident	Mount Keith		
Legless-lizard	*Aprasia picturata*			X	Resident	Wiluna		

* Also listed under the EPBC Act (Section 10.1.3)

WC Act listed species: S1 - S4 = Schedule 1 - 4,

DPaW Priority Species: P1 - P5 = Priority 1 - 5.

In addition, the Slender billed Thornbill (*Acanthiza iredalei*) which is not listed under the WC Act, but is listed as Vulnerable under the EPBC Act, has been recorded as an irregular visitor near Lake Way (Section 10.1).

State Listed Conservation Significant Species (CS 1)

Malleefowl (Schedule 1)

One Malleefowl mound was recorded within the study area by BCE during the field surveys (BCE 2011a). A recently used mound (based on the presence of eggshell fragments) was recorded amongst closed Acacia shrubland on the northern sandplain, approximately 2 km north of the resource area.

Additionally, the Malleefowl Preservation Group has conducted regular (annual) monitoring of Malleefowl mounds at Yeelirrie since 2000, with recent surveys conducted in 2013 and 2014 (Benshemesh *et al*. 2008; MPG 2014). Two active mounds from 40 known monitored mounds were recorded in 2013 and none in 2014, (Figure 9-18) indicating an extant population persists in the area.

Most known Malleefowl mounds are situated away from the orebody, within stands of dense Mulga woodland. A cluster of monitored mounds is located close to the study area, including approximately 10 km north of the orebody and 20 km south of the orebody but these are currently inactive (Figure 9-18).

Suitable habitat for this species does occur within the study area and development envelope, and a resident population is clearly present in the study area, with birds likely to at least move through the development envelope. Large areas of suitable habitat for this species occur outside the Project footprint.

At the periphery of a species' range, environmental conditions are typically stressful and populations are comparatively small and isolated (Scoble 2011). Yeelirrie lies near the northern limit of the Malleefowl's range (although a small population is known to the north at Lorna Glen, J. Turpin, *pers. obs.*). As such, the population at Yeelirrie is likely to be somewhat isolated and vulnerable to environmental change (BCE 2015a). The Yeelirrie population is likely to be small and therefore sensitive to the loss of a few individuals.

Black-flanked Rock-Wallaby (Schedule 1)

The Black-flanked Rock-Wallaby was known to occur in the region with several anecdotal reports of the species along the Barr Smith Range, and rock-wallaby scats were recorded from a cave within the Barr Smith Range, approximately 40 km east of the study area (BCE 2011a) (Figure 9-18). Several scats were collected during the 2015 assessment and forwarded to Australian Wildlife Forensic Services. Genetic analysis (White 2015) confirmed the species identification as the Black-flanked Rock-Wallaby (*Petrogale lateralis*), and most likely the sub-species *P. l. lateralis*.

The Black-flanked Rock-Wallaby relies on behavioural (occupying caves and exhibiting nocturnal foraging activity) rather than physiological responses for survival during adverse conditions (Bradshaw *et al*. 2001; King and Bradshaw 2008). As a result, sites containing permanent water (such as along the Barr Smith Range) are important for the species in the arid zone, allowing animals to occupy sub-optimal habitat with inferior thermal refuge (Pearson 2012). While much of the rocky habitat along the Barr Smith Range appears marginal, the presence of scattered waterholes in association with caves and rock crevices may allow the species to persist. While not expected to occur within habitats associated with the orebody, the species may persist in the extensive rocky habitats to the north and south (BCE 2015a). The assumed status of Black-flanked Rock-Wallaby remains "resident", although all scats located in 2015 were old and an extant population has not been located. There will be some disturbance to rocky habitats associated with the Barr Smith Range (e.g. quarry for access roads).

Night Parrot (Schedule 1)

The Night Parrot is included as potentially occurring due to the presence of suitable habitat and historical records. However an extant population is unlikely.

Great Desert Skink (Schedule 1)

The status of the Great Desert Skink is listed as Unknown. While no evidence of the species was recorded by BCE (2011a; 2015a), there is potential for the species to occur at Yeelirrie, due to the extensive availability of suitable habitat (spinifex sandplains) and records nearby (at Wanjarri Nature Reserve, DPaW 2015). The species has a clumped distribution which is influenced by fire regimes (McAlpin 1997).

Greater Bilby (Schedule 1)

There are anecdotal records of the Greater Bilby further north (e.g. Rosslyn Hill near Wiluna, BCE 2014), and the species is thriving at the DPaW managed Lorna Glen (J. Turpin, *pers. obs.*), approximately 180 km north-west of the study area. The Greater Bilby has a large home range and individuals can disperse widely (Southgate *et al.* 2007). As such, while no signs of Bilbies were recorded by BCE during field surveys, suitable habitat (spinifex sandplains) is extensive at Yeelirrie and it is feasible that individuals may move through the area currently, or in the near future.

Grey Falcon (Schedule 1)

The Grey Falcon is infrequently recorded over much of arid and semi-arid Australia and occurs at low densities (BirdLife International 2015). Regional records come from Wanjarri and Lorna Glen (DPaW 2015). The distribution of the Grey Falcon is centred on inland drainage systems and nests are usually in the tallest trees along watercourses. At Yeelirrie it is likely to occur as an occasional visitor only, as the site lacks the sort of tree-lined watercourses favoured by the species.

Peregrine Falcon (Schedule 4)

The Peregrine Falcon was recorded along a cliff ledge in the Barr Smith Range in 2009 (BCE 2011a) (Figure 9-18). The study area is likely to lie within the foraging territory of a pair, and these birds may nest on a cliff edge in the Barr Smith Range.

Major Mitchell's Cockatoo (Schedule 4)

The Major Mitchell's Cockatoo was formerly more widespread and is patchily distributed across its range (BirdLife Australia 2015). It has been formerly recorded at Yeelirrie, however BCE found no evidence of its occurrence and as such it is likely to be an irregular visitor.

Princess Parrot (Priority 4 – DPaW)

The Princess Parrot is considered a CS1 species due to its listing as Vulnerable under the EPBC Act (Section 10.1). At the State level it is listed as Priority 4 by DPaW. The Princess Parrot is an irregular visitor to the Yeelirrie area (sometimes at intervals of more than 20 years) and to most sites in its range (Garnett and Crowley 2000), and movements are largely unknown (Higgins 1999). The species has been recorded at Wanjarri Nature Reserve (DPaW 2015), however few other records exist for the region.

State Listed Migratory species (CS1)

Twelve migratory bird species (including two landbirds and ten waterbirds) listed under Schedule 3 of the WC Act, were identified as potentially occurring in the study area. These species are also listed as Migratory under the EPBC Act (Section 10.1).

Migratory landbirds

The Rainbow Bee-eater was recorded throughout the study area in 2009, 2010 and 2015 (BCE 2011a; 2015a). While of high conservation significance because of its listing as a migratory species under Schedule 3 of the WC Act and the EPBC Act, it is widespread across Australia and frequently uses disturbed environments.

The Fork-tailed Swift is likely to be an irregular visitor to the study area and was recorded at Yeelirrie during the 2015 survey, with two sightings of several (and possibly the same) birds (BCE 2015a). It is a highly aerial species and largely independent of terrestrial environments.

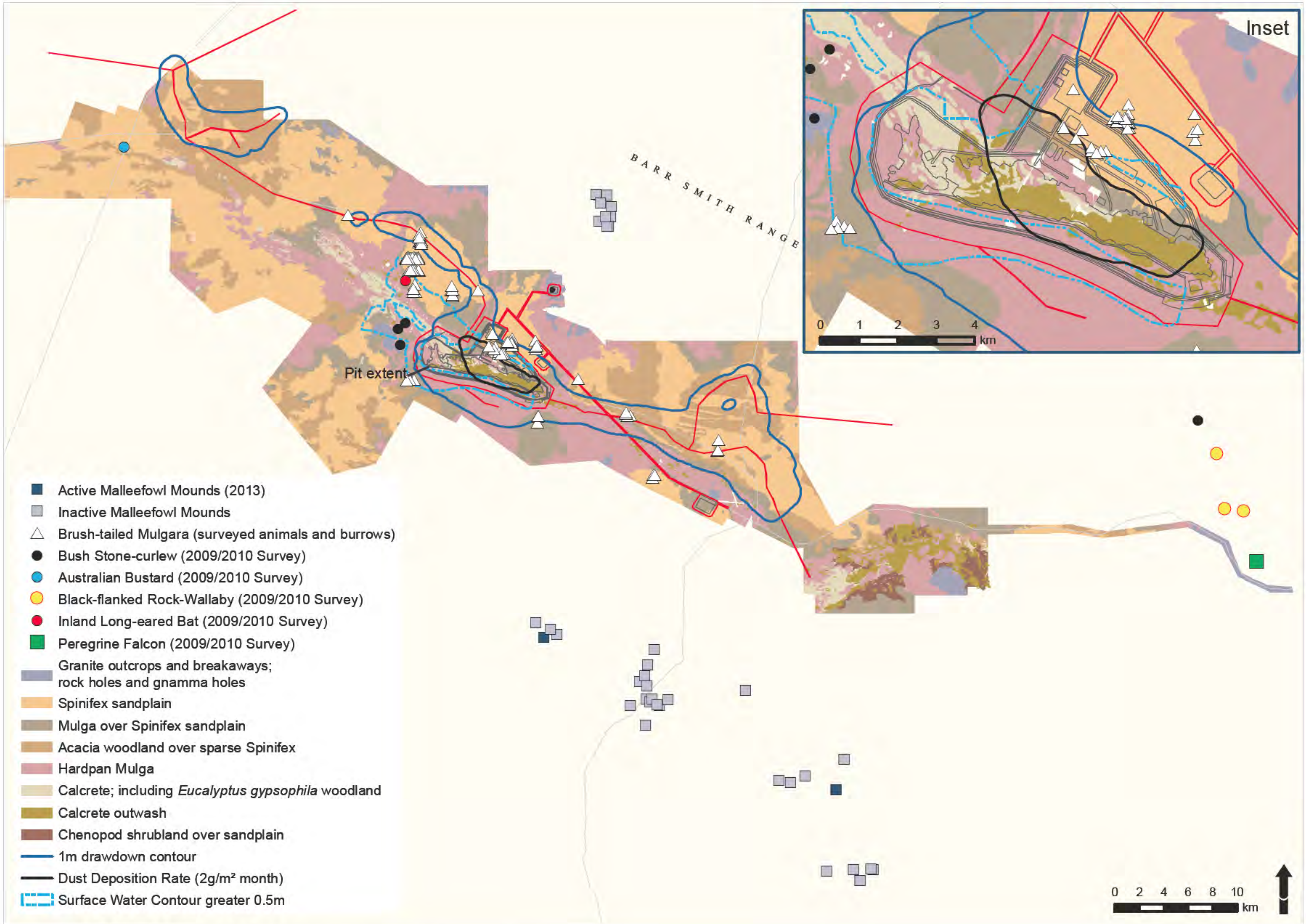


Figure 9-18: Locations of conservation significant fauna records across the Yeelirrie project

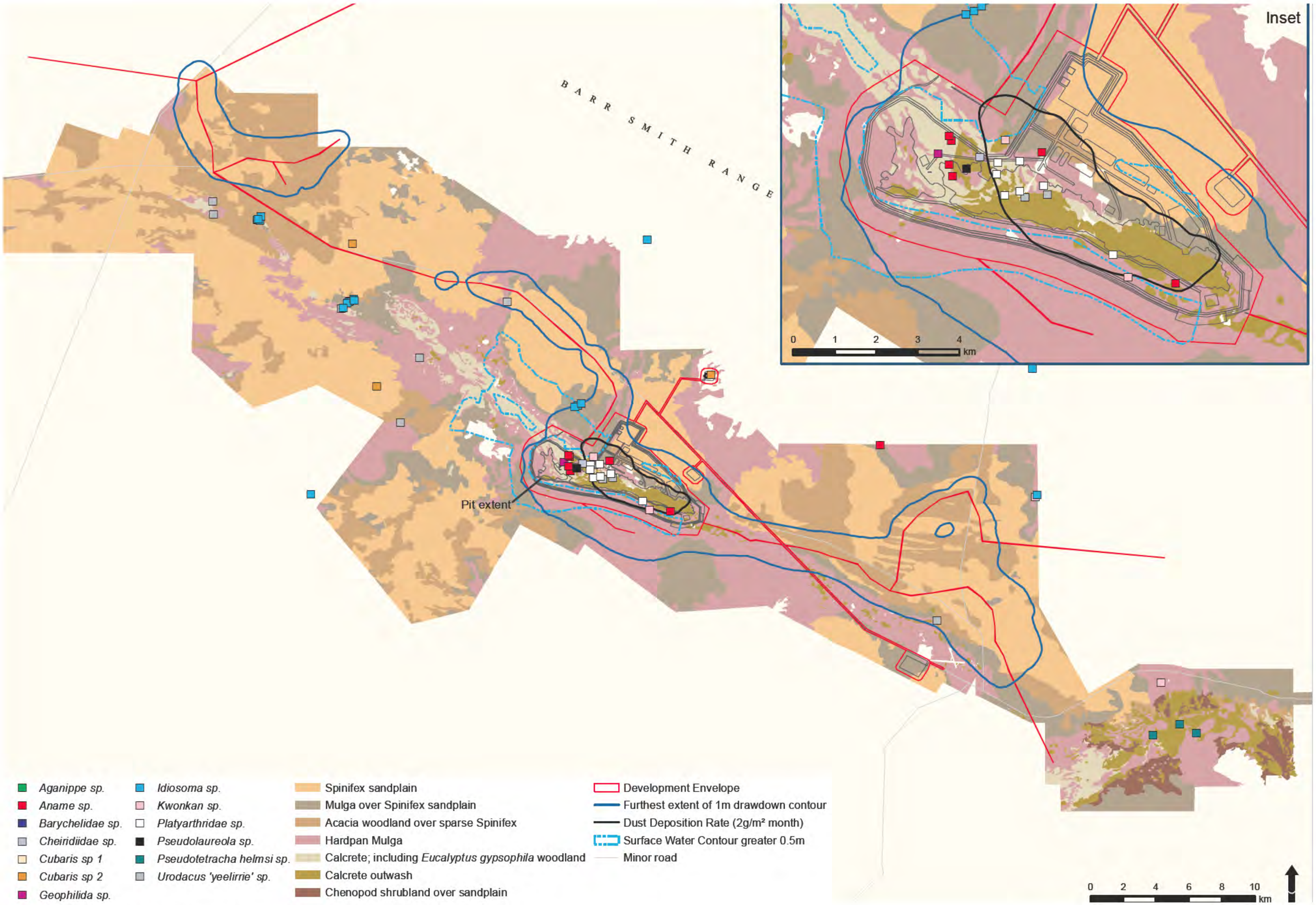


Figure 9-19: Short range endemic invertebrate fauna observations

Migratory waterbirds

Waterbirds listed as Migratory under Schedule 3 of the WC Act and under the EPBC Act, that may periodically utilise the study area during migration include the Eastern Great Egret, Oriental Plover, Common Sandpiper, Common Greenshank, Marsh Sandpiper, Wood Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper and Black-tailed Godwit. Of these, the Eastern Great Egret, Sharp-tailed Sandpiper and Black-tailed Godwit have been recorded in the area, although the godwit should be considered a rare vagrant as it is primarily a marine coastal species. The other species may utilise seasonal wetlands in the region irregularly; several seasonal wetlands were identified during a site inspection in March 2015 but no migratory waterbird species were observed (BCE 2015a).

All these migratory waterbirds (and other waterbird species expected to be present at least occasionally) may utilise seasonal or artificial waterbodies associated with the Project (e.g. the evaporation pond). The potential interaction of migratory waterbirds listed under the EPBC Act and the proposed Project is discussed in Section 10.1.4.

Species listed as Priority by the DPaW but not listed under legislation (CS2).

Australian Bustard (Priority 4)

The Australian Bustard was recorded throughout the Yeelirrie study area, particularly associated with spinifex sandplain. It was seen in 2009, 2010 and 2015 (BCE 2011a; BCE 2015a). It is a widespread species across much of the northern half of Australia.

Striated Grasswren (Priority 4)

While not recorded during the BCE surveys, there are three records of this species at Yeelirrie, including at a location approximately 5 km south of the orebody (BirdLife Australia 2015). This location was visited in March 2015 and while the environment appeared suitable, no birds were observed (BCE 2015a). This species has a highly patchy and fragmented distribution due to a reliance on mature spinifex grassland (Garnett *et al*. 2011) and can be difficult to detect. Given the Birdlife Australia record and the apparent suitability of the vegetation, it is likely to occur on the spinifex sandplains adjacent to the orebody.

Brush-tailed Mulgara (Priority 4)

The Brush-tailed Mulgara was recorded extensively across the Yeelirrie study area (BCE 2011a; 2015a) (Figure 9-18). It was most abundant within sandplain sites dominated by spinifex (and was absent from calcrete habitats). A total of 154 burrow systems was recorded in 842 ha of search area, equating to 0.18 burrows/ha; 86 burrows were active (0.1 burrows/ha, BCE 2011a). Suitable habitat for the Brush-tailed Mulgara comprises approximately 69.9 % (69,840 ha) of the study Area (BCE 2011a) and there are expected to be in excess of 6900 active burrow systems within this area (using the burrow densities observed at Yeelirrie). Brush-tailed Mulgara are generally considered to be solitary, with males and females found in the same burrow only during the mating season (van Dyck and Strahan 2008). Therefore, the study area may support several thousand Brush-tailed Mulgara.

Long-tailed Dunnart (Priority 4)

The Long-tailed Dunnart favours rocky habitats and is likely to occur within the breakaway systems to the north and south of the Yeelirrie orebody area. It was recorded on hills near Wiluna in November 2014 (BCE 2014).

Inland Long-eared Bat (Priority 4)

This species was recorded by BCE during the previous field surveys (BCE 2011a) and may rely on tree hollows within the *E. gypsophila* woodland subset of the Calcrete VSA.

Species not listed under legislation or in publications, but considered of at least local significance because of their pattern of distribution (CS3).

Eight species are considered to be of local conservation significance (CS3) due to restricted ranges,

- *Aprasia picturata* considered uncommon in the region;
- Square-tailed Kite, Kultarr, Grey Honeyeater*, Rufous-crowned Emu-wren*, Scarlet-chested Parrot*, which have been recorded near the limit of their range;
- Regent Parrot*; and
- Bush stone-curlew.

(*Recorded at the Wanjarri Nature Reserve, DPaW 2015).

The status of the Bush Stone-curlew was delisted in December 2014 from Priority 4 (DPaW) to unlisted, but is still considered locally significant as the species has suffered significant declines and is sparsely distributed in southern WA. The Bush Stone-curlew was recorded at several sites at Yeelirrie (BCE 2011a) and occurs both within habitats associated with the orebody and along drainage systems near rocky habitats associated with the Barr Smith Range. The species is moderately widespread and suitable habitat is extensive outside the study area.

9.3.4.4 Conservation significant invertebrate species

Ecologia (2011a, 2011b) conducted detailed invertebrate fauna assessments of the Yeelirrie study area during 2009/2010 and collected 42 species. Invertebrate surveys conducted by Ecologia (2011a) were reviewed by BCE in March 2015 (BCE 2015b; Appendix G2). Updated database searches and further field investigations identified 18 conservation significant invertebrates in the Yeelirrie study area (Table 9-31). This includes one species listed as Vulnerable under the EPBC and WC Acts, three confirmed SRE taxa and 13 species with the potential to be SRE taxa (based on the current but limited knowledge). Database searches revealed the possibility of at least one further listed species to occur, *Kwonkan moriartii* (Priority 4, DPaW), although three *Kwonkan* species were collected by Ecologia (2011a) and none was identified as *K. moriartii*. This suggests that *K. moriartii* may not be present and therefore it is not included in Table 9-31. Locations of conservation significant invertebrate species are provided in Figure 9-19).

Shield-backed Trapdoor Spider (Schedule 1)

The Shield-backed Trapdoor Spider (*Idiosoma nigrum*) was recorded from 17 locations at Yeelirrie by BCE (2015b) (Figure 9-19). This was the *Idiosoma* sp. recorded by Ecologia (2011a), but specimens collected in March 2015 were identified as the listed Shield-backed Trapdoor Spider by Phoenix Environmental (2015).

This species appears to occur in low densities but is widespread across the Yeelirrie lease, favouring Acacia shrublands with a sandy substrate to depth of at least 30 cm, and lacking the clay layer or hardpan that is common across much of the area. It appears to be absent from the grey loamy-clay soils around some calcrete areas and in the main development footprint. Spiders also appear absent from shallow, rocky soils of the Barr-Smith Range. The nearest other known records of the species come from Weld Range (approximately 200 km to the west), where it is restricted to the slopes of ironstone ridges (BCE 2015b).

The Shield-backed Trapdoor Spider occurs at Yeelirrie in apparently much lower densities than those observed elsewhere. The species has been recorded in densities of 50 - 400 spiders per hectare in suitable habitat on banded ironstone ridges of the Midwest (BCE 2011c). However, at Yeelirrie densities appear to be much lower, with typically only one or two spiders recorded across a number of hectares. At Yeelirrie, the spider does not appear to form matriarchal clusters, which is perhaps an artefact of low recruitment rates (BCE 2015b).

Table 9-31: Conservation status of significant invertebrate species recorded in the region. Records within and outside the disturbance footprint are noted. (based on Ecologia 2011a; BCE 2015b)

Taxa	Species Name	Conservation Status	Disturbance Footprint Collection		Vegetation and Substrate Association type					
			In	Out	HM	C	CO	SS	PB	PY
Mygalomorph	Shield-backed Trapdoor Spider **Idiosoma nigrum*	CS1 Schedule 1	Yes	Yes				X		
Isopod	Platyarthridae/ Bathytropidae	Confirmed SRE	Yes	No	X	X	X			
Isopod	*Pseudolaureola* sp.	Confirmed SRE	Yes	No			X			
Carabidae	Tiger beetle *Pseudotetracha helmsi*	Confirmed SRE	No	Yes						X
Mygalomorph	*Aganippe* sp.	Potential SRE	No	Yes	X					
Mygalomorph	*Aname* 'MYG170'	Potential SRE	Yes	No	X	X	X			
Mygalomorph	*Aname* 'MYG212'	Potential SRE	Yes	Yes			X	X		
Mygalomorph	Barychelidae	Potential SRE	Yes	No			X			
Mygalomorph	*Kwonkan* 'MYG171'	Potential SRE	Yes	No	X					
Mygalomorph	*Kwonkan* 'MYG172'	Potential SRE	Yes	No		X			X	
Mygalomorph	*Kwonkan* 'MYG210'	Potential SRE	No	Yes	X					
Mygalomorph	*Kwonkan* 'MYG211'	Potential SRE	No	Yes	X					
Scorpion	*Urodacus* 'yeelirrie'	Potential SRE	Yes	Yes	X	X	X			
Pseudoscorpion	Cheiridiidae	Potential SRE	Yes	No			X			
Isopod	*Cubaris* sp. 1	Potential SRE	Yes	No		X				
Isopod	*Cubaris* sp. 2	Potential SRE	Yes	Yes	X		X			
Centipede	*Geophilida*	Potential SRE	Yes	No	X					

* Also listed under the EPBC Act.

Vegetation and Substrate Associations (VSA) types = HM (Hardpan Mulga), C (Calcrete), CO (Calcrete Outwash), SS (Spinifex Sandplain), PB (Play B), PY (Playa Yeelirrie). VSA types are described in Section 9.3.4.2.

Isopod. Platyarthridae/Bathytropidae

Sixteen specimens of an undescribed slater genus and species from either the family Platyarthridae or Bathytropidae were collected from within the Project footprint, and were found within the Calcrete, Calcrete Outwash and Hardpan Mulga habitats (Ecologia 2011a). These families are poorly known in Australia and Western Australia with only one described species from each (Ecologia 2011a). The undescribed genus from Yeelirrie is considered to be an ancient Gondwanan group, and all of the previous examples of this morphology have been considered a SRE. Likewise, this species is considered to be a SRE (Ecologia 2011a) (Figure 9-19).

Isopod. Pseudolaureola sp

The Isopod *Pseudolaureola* sp. was collected from Calcrete Outwash (within the proposed mine footprint) and is thought be an undescribed species. The genus is considered a relictual taxon of the Gondwanan rainforest and all known species in the genus are SREs, therefore it is highly likely that this species is also a SRE (Ecologia 2011a).

Tiger beetle - *Pseudotetracha helmsi*

The tiger beetle *Pseudotetracha helmsi* was collected at three sites from the Yeelirrie Playa (Figure 9-19). Tiger beetles are predatory and some are known to have restricted distributions around ephemeral salt lakes (Ecologia 2011a). This species was previously known only from a few salt lakes located in the Murchison Bioregion and is considered a SRE. A tiger beetle collected by BCE at Sir Samuel salt lake in March 2015 was *Megacephala* sp. and is not considered an SRE (Phoenix Environmental 2015).

Other potential SRE invertebrates

A further 13 invertebrate species have the potential to be SREs (Table 9-31). However, due to the limited survey work in the region and therefore limited information on distribution, habitat and taxonomy, this cannot be confirmed; their possible SRE status may simply be an artefact of the lack of regional collection. The 13 species nominated as potentially SREs were classified based on their biology or taxonomy (Ecologia 2011a). Some appeared to be habitat-limited, while several specimens collected by Ecologia could not be identified to species level due to the poor taxonomic knowledge of such groups, but are considered potential SREs because of biology or knowledge of closely related species (i.e. closely related species have restricted distributions). Additionally, some undescribed species were collected from the Yeelirrie area (e.g. the spider *Aname*, the scorpion *Urodacus* 'Yeelirrie', the pseudoscorpion (Family Cheiridiidae) and two species of isopod *Cubaris*), and as such their distribution and SRE status are unknown.

9.3.4.5 Patterns of Biodiversity

The fauna assemblage varied in its distribution across the VSA types. Reptile species richness and abundance were highest on spinifex sandplain and in part of the calcrete VSA where *Eucalyptus gypsophila* formed an open woodland. Bird species richness and abundance were highest in this *E. gypsophila* woodland and in the two VSAs containing Mulga. With the exception of the *E. gypsophila* woodland subset of the Calcrete VSA, most of these VSAs are extensive outside the fauna study area. The rocky breakaways and outcrops away from the orebody support restricted species (such as the Black-flanked Rock-Wallaby, Long-tailed Dunnart, Woolley's Pseudantechinus) and the seasonal wetlands (playas) are likely to support irregular visits of migratory waterbirds.

A habitat analysis by Ecologia (2011a) showed no statistically significant difference between SRE species diversity and habitat type inside and outside the Project footprint. SRE species distribution depends on micro habitats ('island' habitats) rather than broadscale habitat types. Furthermore, all of the habitat types extend beyond the proposed Project Development Envelope indicating a potential for all species to be found outside the Project.

9.3.4.6 Key Ecological Processes

One of the dominant ecological processes currently affecting the fauna assemblage in the study area is hydrology, with other processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Long-unburnt habitats are important for some species, including the Malleefowl, Striated Grasswren and Shield-backed Trapdoor Spider.

9.3.4.7 Introduced Fauna

The desktop study identified nine introduced fauna species as potentially occurring in the Yeelirrie study area. Six species were recorded during the field surveys (BCE 2011a; 2015a). The European red fox is considered absent by the caretakers at Yeelirrie and appears to be very uncommon. Wild dogs/dingoes appear to be common and those seen have been of a consistent appearance, suggesting the level of interbreeding between domestic dogs and dingoes is low. The feral cat and rabbit were confirmed as resident and the camel and cattle confirmed as irregular visitors. The house mouse, donkey, horse and goat are expected to be resident, although goat numbers can be strongly suppressed by dingoes.

Predation by feral species is a major factor in the decline of Australian mammals (Burbidge and McKenzie 1989). Introduced herbivores can significantly alter the vegetation composition and thus fire regimes, in turn affecting native fauna that rely on these habitats. Dingoes can suppress the numbers of foxes, goats and feral cats, but the dingo is also an efficient predator.

9.3.5 Potential Impacts and Management

The impact assessment process is described in detail in BCE (2011a). While some impacts are unavoidable during a development, of concern are long term, deleterious impacts upon biodiversity and reflected in documents such as the Significant Impact Guidelines (DoE, 2013). Significant impacts may occur if:

- there is direct impact upon a VSA and the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna;
- there is direct impact upon conservation significant fauna; and
- ecological processes are altered and this affects large numbers of species or large proportions of populations, including significant species.

The impact assessment process therefore involves reviewing the fauna values identified through the desktop assessment and field investigations with respect to the Project and impacting processes. The severity of impacts on the fauna assemblage and conservation significant fauna can then be quantified on the basis of predicted population change.

9.3.5.1 Impacts to VSAs

Eight major VSAs were identified across the Yeelirrie Study Area and surrounding landscape (Figure 9-18 and Figure 9-19). Hardpan Mulga, Spinifex Sandplain, Calcrete Outwash, Mulga over Spinifex Sandplain and Calcrete dominate most of the disturbance footprint with much smaller areas of rocky breakaway also included. The uranium orebody is situated within the calcrete habitats, which are regionally uncommon although not restricted to the study area. Potential impacts on the general vertebrate fauna assemblage are likely to be greater in the *E. gypsophila* woodland subset of the Calcrete habitat, which has a high proportional representation in the study area. Other VSAs in the study area, such as the mulga and spinifex sandplains are widespread.

Areas of each VSA within the study area are given in Table 9-32 (BCE 2011a). The original disturbance footprint proposed by BHP Billiton, which correlates to Cameco's development envelope (Figure 6-2), was centred on the calcrete and calcrete outwash VSAs and extended on the adjacent sandplain and hardpan mulga. Minor areas of granite outcrop / breakaway are proposed for disturbance (17 ha), and the sandplains supporting chenopod shrubland (in the south-east) occurred outside the proposed disturbance. Proposed disturbance to the VSAs within the study area are outlined below (Table 9-32).

Cameco has looked at the potential maximum worst-case impacts on VSAs as a result of clearing, dust deposition, groundwater drawdown and inundation as a result of altered surface drainage patterns. Table 9-32, Figure 9-18 and 9-19 present the potential indirect impacts of the Project. Table 9-30 quantifies the potential worst case impact on habitat when considering groundwater drawdown (>1 m drawdown), dust deposition (>2 g/m^2/month) and surface water impacts (>0.5 m flooding during a 1:1000 year ARI).

Table 9-32: Areas of VSAs within the Study Area and disturbance footprint

			Direct Impacts (ha)	Additional area potentially affected by indirect impacts (ha)			
VSA Type	Study Area (ha)	Inside Development Envelope (ha)	To be cleared	Dust Deposition (>2 g/m²/month)	Groundwater drawdown (>1 m drawdown)	Surface Water (>0.5 m flooding after 1:1000 year ARI)	Worst Case percentage impacted (%)
Granite Outcrops and Breakaways	1,866	53.2	17 (0.9%)	0	0	135.3	8.2
Spinifex Sandplain	38473	910.7	612 (1.6%)	0	NA	527.2	3.0
Hardpan Mulga	21,230	1798.6	738 (3.5%)	0	NA	985.5	8.1
Calcrete	2,819	540.6	216 (7.7%)	0	13.0	329.5	19.9
Calcrete Outwash	3,095	685.7	548 (17.7%)	0	149.8	42.5	23.9
Chenopod Shrubland over Sandplain	1,215	0	0 (0%)	0	0	0	0
Acacia Woodland over Sparse Spinifex	17178	130.6	64 (0.4%)	0	4910	0.1	29.0
Mulga over Spinifex Sandplain	14186	659.7	145 (1.0%)	19.5	NA	906.8	7.6

The following should be noted when considering the worst case scenario on habitat:

- highly unlikely to occur;
- indirect impacts to habitat do not necessarily correlate to fauna impacts;
- dust impacts outside the Development Envelope are negligible;
- impacts of groundwater drawdown will not affect all species within the habitat; and
- impacts to habitat as a result of a 1:1000 year ARI event are likely to be temporary.

The likelihood of indirect impacts affecting conservation significant species is discussed further below.

9.3.5.2 Impacting processes

The following sections examine possible impacts upon fauna values based upon the impacting or threatening processes outlined in Bamford (2015a).

The key threatening processes are:

- habitat loss (leading to population decline and fragmentation);
- habitat degradation (due to weed invasion);
- mortality (leading to population decline);
- species interactions (feral or overabundant native species);
- hydroecology (including introduction of project-related water sources);

- altered fire regimes;
- disturbance; and
- bioaccumulation.

Loss of habitat leading to population decline

Some loss of habitat is inevitable but can be minimised through controls during clearing. Rehabilitation of disturbed areas may also be implemented as soon as possible after clearing. The small area of impact in relation to the surrounding landscape means that loss of VSAs is unlikely to have long term adverse impacts upon vertebrate fauna populations in the region. The *E. gypsophila* woodland subset of the Calcrete VSA would be impacted and is an area of high species richness and abundance, but the vertebrate assemblage does not appear unique or to contain species not found elsewhere in the area. For example, much of the species richness and abundance is due to species attracted by the concentration of Eucalypt canopy, leaf-litter and possibly tree-hollows. These features are found in other VSAs but the consequence of Project development may be a localised decline in population size of otherwise common species. Some SRE invertebrate species appear to have a high reliance on the Calcrete VSA with a resultant impact classed as Moderate (Table 9-34).

Loss of habitat leading to population fragmentation

Some landscape features within the development envelope may have a connectivity function for fauna, aiding them to move through the landscape. Therefore, impacts upon these features could disrupt this movement, facilitating population fragmentation. For example, the remaining patches of *E. gypsophila* woodland would be fragmented and this may affect the ability of some fauna species to move across the landscape. Such connectivity can be important for vertebrate fauna in which population size is low and thus population isolation can increase the risk of local extinction, but fragmentation is not considered a risk to vertebrate species in the area. The Slender-billed Thornbill is reliant on chenopod shrublands, but has not been recorded at Yeelirrie.

Degradation of habitat due to weed invasion

Weed invasion of the development envelope is currently minimal.

Ongoing mortality

Increased mortality is inevitable during clearing and from ongoing activities, such as roadkill due to animals being struck by vehicles, or birds striking infrastructure entrapment of fauna in open excavations and fauna attracted into production areas (e.g. in search of food, such as dead insects underneath lights, or water). In general, areas to be cleared are small within the context of the regional landscape so mortality during clearing is likely to represent only small proportions of regional populations. For common species, levels of mortality are unlikely to be significant in a conservation sense, but there are welfare issues. However, the viability of species that occur at low population densities in areas adjacent to the development envelope may be compromised by ongoing mortality. For example, a population of Malleefowl is present in the development envelope, while Black-flanked Rock-Wallabies may also persist. In populations that could be as low as 10 or 20 animals, roadkill is a concern and even the loss of one or two individuals can be significant.

Species interactions

Changes in species interactions often occur with development. Introduced species, including the feral cat, fox and rabbit, may have adverse impacts upon native species and development can alter their abundance. In particular, some mammal species are very sensitive to introduced predators and the decline of many mammals in Australia has been linked to predation by the fox, and to a lesser extent the feral cat (Burbidge and McKenzie 1989). Interactions between dingoes and foxes mean that fox numbers can increase if dingo numbers decline. Introduced grazing species, such as the rabbit, goat, camel and domestic livestock, can also degrade habitats and deplete vegetation that may be a food source for other species.

Existing stock watering points have been decommissioned as part of the station's environmental management, however the development would inevitably provide some opportunities for access to fresh water (e.g. from garden reticulation or water from air-conditioners). Changes in the abundance of some native species at the expense of others, could occur due to the provision of fresh watering points. Harrington (2002) found the presence of artificial fresh water points in the semi-arid mallee rangelands influences the abundance and distribution of certain bird species. Common, water-dependent birds were found to out-compete some less common, water-independent species. Over-abundant native herbivores, such as kangaroos, can also adversely affect less abundant native species through competition and displacement.

The dingo was recorded along the Barr Smith Range. Dingoes contribute to ecosystem stability by suppressing introduced predators (feral cat and fox) and herbivores (rabbit and feral goat, Dickman *et al*., 2009). This species may be playing an important role in the survival of the Black-flanked Rock-Wallaby along the Barr Smith Range and any management of feral species may need to consider this role.

Hydroecology

Impacts to fauna species may occur if interruptions to hydroecological processes affect VSAs. The two Mulga VSAs (Hardpan Mulga and Mulga over spinifex on sandy loam) are likely to be reliant on surface and sub-surface flows that may be altered by clearing, earthworks and drainage management. Several vegetation types within the Study Area (e.g. *E. gypsophila* woodland on the Calcrete VSA) are expected to be reliant on groundwater (Section 9.1.4) and may be affected by groundwater drawdown as a result of pit dewatering and operation of the water supply wellfield.

An assessment of the potential impacts from the 50 ha evaporation pond on migratory waterbird species was conducted by BCE (2015a). The development of the evaporation pond would establish a new and large artificial water body in an arid area and may attract numbers of waterbirds.

The evaporation pond will be approximately 1,000 m by 500 m and up to 5 m deep. The pond will be constructed from local earth and rock material with steep slopes and will be fenced.

Predicted mineral concentrations within the evaporation pond are expected to change over the life of the mine. Initially, the pH is predicted to be 10.64 (alkaline) with discharge of up to 42,632 t/ hr (at 1.07 t/m^3), with a salinity similar to seawater (31.05 g/L). Salinity is likely to increase to approximately ten times that of seawater over the life of the mine.

The evaporation pond has some potential to attract wildlife. Migratory waterbirds, including sandpipers, often live in environments where the only available drinking water is seawater but will drink water of lower salinity if available. If salinity stratification occurs, the surface layer of water may be palatable to some wildlife and the possibility exists of a lens of low salinity water forming at the surface following heavy rain, or from the accumulation of low salinity groundwater. However, these effects are likely to be offset by mixing following rain, and by evapo-concentration at other times. If exceptional rainfall did create a layer of near-fresh water, this would occur at a time when numerous other and more attractive/accessible sources of fresh water would be available in the region, including the numerous claypans within the study area. In comparison to natural water bodies, evaporation ponds are expected to be characterised by steep banks, which lack shallow sandy shores, riparian vegetation (habitat) and shade, and therefore less attractive to fauna.

In the modelling of the water quality, it was assumed that water will come to the evaporation pond after a settling period in the tailings storage facility of and will contain dissolved constituents only. The model considers the changing salinity and metals concentrations as additional tailings liquor and water from other sources is added.

The total dissolved solids (TDS) of the tailings slurry was predicted to be 106 g/L (URS, 2015). A number of scenarios of cycling evaporation and filling of the pond were modelled with similar results in that they both reach 200 g/L after just over one year. The uranium concentrations also show similar results between the two scenarios. The model predicts that uranium reaches 130 mg/L approximately. For both scenarios the model predicts the precipitation of several carbonates, including magnesium carbonate ($MgCO_3$), dolomite ($((CaMg))CO_3)_2$) and strontianite ($SrCO_3$).

- Frequent cycling of an evaporation cell between its operating volume (90% maximum volume) and its minimum transfer volume (80% maximum volume) resulted in a TDS of 200 g/L in approximately 1 year;
- The model shows that three solid phases dominate the precipitated solids, dolomite ($CaMg(CO_3)_2$), magnesite ($MgCO_3$), and strontianite ($SrCO_3$). The precipitation of the solids does not seem to significantly affect the pH of the water in the evaporation cell;
- The pH of the evaporation cell was maintained at about 9.5 with total evaporation of 10% and 34%. Even when 80% of the cell was evaporated, the pH and chemistry did not change significantly;
- Higher volume evaporation and transfers did not change the time it took to reach a TDS of 200 g/L;
- Uranium steadily increases in concentration through the life of the cell reaching about 130 mg/L at 200 g/L salinity;
- The high concentration of carbonates keeps uranium in solution by forming stable uranyl carbonates; and
- There is evidence to suggest that radium-226 significantly adsorbs to oxidized forms of iron and will remain bound to solids in the TSF.

Based on the modelling, uranium concentrations in the evaporation pond water is expected to increase to aroun 130 mg/L which is approximately double the Uranium No Observable Impact Level (NOAEL) benchmark of 68.8.mg/L for drinking water for birds, although how concentration change over time will need to be monitored. However, give the salinity levels of the pond water, it is unlikely that birds would consume the pond water. Note that the presence of a water body in an arid landscape will attract passing waterbirds at least occasionally, even if the water is completely unpalatable. A consequence of this could be occasional and largely unavoidable bird deaths, as some such passing waterbirds are likely to be weak and would be unlikely to survive under normal circumstances. In the Australian arid zone, dead waterbirds are quite commonly encountered beside roadside puddles and even on dry lake beds (M. Bamford *pers. obs*.).

Several deterrents will be used to discourage waterbirds from the evaporation pond and will be outlined in a Fauna Management Plan to be developed for the Project. Bird deterrents are used at the Olympic Dam mine site, South Australia, where acidic liquid is stored. A rotating beacon with an intermittent beam directed at a shallow angle across the water surface (in combination with gas guns) effectively discouraged most waterbirds (Read 1999).

Further mitigation measures include:

- conducting an ecological risk assessment of the evaporation ponds;
- implementing a water quality monitoring program and adapting fauna management strategies (e.g. bird deterrents) based on the outcomes of the program;
- monitoring bird visitation of the evaporation ponds and reporting fauna deaths; and
- fencing off the evaporation ponds from terrestrial mammals to minimise exposure during the initial period when the salinity of the water is close to sea levels.

If mitigation measures are successfully implemented, impacts on migratory water birds are expected to be minor.

Potential loss of habitat due to impacts on phreatophytic vegetation

As detailed in Table 9-12 (see Section 9.1), there is approximately 7,134.2 ha of phreatophytic vegetation associations within the Local Study Area. Of this potentially 1,388.4 ha will be impacted, experiencing a drawdown >1 m, through dewatering and water supply activities. Potential impacts to fauna as a result of this impact include:

- Malleefowl are associated with both Acacia shrubland and Mulga woodland, which are potentially phreatophytic. Areas of suitable habitat for this species occur within the local study area but are extensive outside the area of predicted drawdown and also outside the Local Study Area. The species appears to favour the dense shrublands on the rocky plateaus away from the predicted area of impact.
- Spinifex hummock grassland supports Mulgara and some conservation significant birds, such as the Striated Grasswren, but these particular vegetation species are unlikely to be groundwater dependent. Large areas of suitable habitat for this species occur outside the predicted area of impact.
- Some other habitats identified as groundwater dependent have the potential to support significant bird species, none of which have currently been recorded from the Local Study Area and so are thought to only rarely visit the area. For example *Eucalyptus gypsophila* woodland has the potential to support Major Mitchell's Cockatoo and Princess Parrot but populations do not currently reside at Yeelirrie.
- Conservation significant invertebrate species associated with phreatophytic vegetation associations are the Shield-backed Trapdoor Spider (Acacia shrublands) and Isopod. Platyarthridae/Bathytropidae (Hardpan Mulga). The Shield-backed Trapdoor Spider was recorded across a number of habitat types but appears to favour Acacia shrublands on the sandplain and Hardpan Mulga habitats which are extensive outside the predicted area of impact. Impacts to the Isopod. Platyarthridae/Bathytropidae (Hardpan Mulga) is unknown but Hardpan Mulga is also extensive outside the predicted area of impact.

In addition to groundwater drawdown impacts there may be impacts on fauna as a result of groundwater re-injection. However, the extent of this impact will be restricted to the final mine footprint.

As a result of this assessment the impact to fauna habitat from the impact to groundwater dependent ecosystems is likely to be low to negligible.

Altered fire regimes

While the biota of the region is probably adapted to a particular fire regime, it is likely this regime has been altered since European settlement. Utilising a mosaic burning regime is likely to benefit both native flora and fauna, and aid in the control of unplanned wildfires. Mulga in particular is sensitive to fire, while biodiversity in spinifex grasslands can be altered by changes in the fire regime. Mining activities can lead to a change in the fire regime if not appropriately managed.

Disturbance

Impacts of dust, light, disturbance and noise upon fauna are considered likely. This may impact fauna if there is an increase in artificial lighting in the development envelope. For example, mortality of insects was noted around existing operations due to insects being attracted to lights; the consequence of such mortality is not understood but on a precautionary basis should be minimised.

Bioaccumulation

Bioaccumulation of heavy metals and radionuclides within the environment can occur in both the short and long term. Heavy metals and radionuclides may enter the environment through seepage of contaminants from evaporation ponds or dispersal of mineralised dust. An organism may accumulate heavy metals through direct ingestion, inhalation or ingestion of contaminated organisms. While heavy metals occur naturally in the environment, they become a concern for fauna when their environmental concentration increases to the extent that the capacity of a species to regulate the internal concentration of metals is lost.

An assessment of the potential radiation impacts on terrestrial fauna and any other non-human biota was conducted using the ERICA tool.

9.3.5.3 Impacts on Conservation Significant Fauna

Impacts upon conservation significant vertebrate species are summarised in Table 9-33 and are mostly considered to be Negligible to Minor. Impacts to conservation significant invertebrate species are summarised in Table 9-34 and are predicted to be Minor to Moderate.

The higher risk to some significant invertebrates is due to their reliance on the Calcrete VSA which has the highest proportional impact of VSAs (Table 9-32). The generally low levels of impact are due to the site's location within a largely intact landscape; a landscape expected to contain large areas of the same VSAs as those present within the development envelope. With appropriate management, the combination of the above factors is likely to result in only localised reductions in the population size of common and some significant species, roughly proportional to the percentage of habitat impact. This is greatest for invertebrates that may be reliant upon calcrete areas that are well-represented within the disturbance footprint. Despite this, even these VSAs are represented outside the disturbance footprint and no regional loss of species or fauna assemblage viability is expected. Habitat degradation as a result of altered hydrology, fire, predation from feral fauna and birds visiting hazardous evaporation ponds may be of some concern. Potential impacts to key fauna values are summarised in Table 9-35.

Table 9-33: Impacts on conservation significant vertebrate species

(Status in area refers to the predicted status of the species and includes reference to records from recent surveys)

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Conservation Significance 1 (CS1) Threatened Species			
Leipoa ocellata Malleefowl Vul (EPBC) S1 (WCA)	Resident/ Recorded	Dense Acacia shrublands	**Minor.** Local population probably small and therefore sensitive to the loss of a few individuals, but the population is outside the Development Envelope. Potential impacts include roadkill, loss of habitat, increase in feral predators and a change in fire regime. Mitigation measures include management of fire and feral animals, restrictions on speed for project-related vehicles. Large areas of suitable habitat for this species occur outside the Project footprint.
Petrogale lateralis Black-flanked Rock-Wallaby Vul (EPBC) S1 (WCA)	Resident/ Old records (BCE 2011a; 2015a)	Rocky outcrops with caves and rock piles associated with the Barr Smith Range.	**Minor.** Increase in feral predators could impact on what is an isolated and relict population if it exists in the region. There is some risk of increased roadkill due to increased traffic on the Yeelirrie–Meekatharra Road. Mitigation measures include management of fire and feral animals, restrictions on speed for project-related vehicles.

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Polytelis alexandrae Princess Parrot Vul (EPBC) P4 (DPaW)	Irregular visitor/ Not recorded.	*E. gypsophila* woodland	**Negligible.** Only an irregular visitor to the study area. Recorded at Wanjarri Nature Reserve (DPaW 2015). Potential impacts include loss of habitat, removal of hollow- bearing trees, changes in fire regime, dust, light, noise and vibration. Management measures as above for the Malleefowl.
Acanthiza iredalei Slender-billed Thornbill Vul (EPBC)	Irregular visitor/ Not recorded.	Chenopod shrubland.	**Negligible.** Resident population unlikely and vegetation marginal for species, but could occur occasionally as a result of individuals dispersing from nearby. Management measures as above for Malleefowl and Princess Parrot. Preferred habitat for this species occurs on the Yeelirrie Pastoral Lease outside the development envelope.
Pezoporus occidentalis Night Parrot Cri End (EPBC) S1 (WCA)	Vagrant/ Not recorded.	Triodia grassland and sandplain	**Negligible.** Some loss of habitat and possibility of increased mortality on roadsides. An extant population is unlikely to exist in the region. The species may be nomadic, but may potentially occur due to the presence of suitable habitat and historical records.
Liopolis kintorei Great Desert Skink Vul (EPBC) S1 (WCA)	Unknown/ Not recorded.	Spinifex sandplains	**Negligible.** Not known from the study area and presence seems unlikely. Recorded at Wanjarri Nature Reserve (DPaW 2015a). If present, potential impacts include increased mortality, loss of habitat, increase in feral predators, changes in fire regime. Management measures include management plans for fire and feral animals (including stray stock), and restrictions on speed for project-related vehicles.
Macrotis lagotis Greater Bilby Vul (EPBC) S1 (WCA)	Vagrant/ Not recorded.	Spinifex sand plains.	**Minor.** Extensive habitat available in the study area and thus feasible for individuals to move through the area currently or in the future. Potential impacts if species present would include increased mortality, loss of habitat, increase in feral predation and changes in fire regime. Management measures include management plans for fire and feral animals (including stray stock) and restrictions on speed for project-related vehicles.
Falco hypoleucos Grey Falcon S1 (WCA)	Irregular visitor/ Not recorded.	Acacia shrublands and tree-lined watercourses.	**Negligible.** Only an irregular visitor to the study area. Recorded at Wanjarri Nature Reserve (DPaW 2015). Potential impacts include loss of habitat, changes in fire regime, dust, light, noise and vibration. Management measures as above for Malleefowl and Princess Parrot. Maintain breeding sites if found.

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Falco peregrinus Peregrine Falcon S4 (WCA)	Irregular visitor/ Not recorded. Resident/ Recorded (BCE 2011a)	Cliffs and *E. gypsophila* woodland.	**Negligible.** Probably a resident but impact may be limited to the potential displacement of a breeding pair. Potential impacts include loss of habitat, disturbance of nesting sites. Maintain breeding sites if found.
Lophocroa leadbeateri Major Mitchell's Cockatoo S4 (WCA)	Irregular visitor/ Not recorded.	*E. gypsophila* woodland.	**Negligible.** Only an irregular visitor to the study area. Potential impacts include loss of habitat, removal of hollow- bearing trees, changes in fire regime, dust, light, noise and vibration. Management measures as above for Malleefowl and Princess Parrot. Maintain breeding sites if found.
Conservation Significance 1 (CS1) Migratory Species			
Merops ornatus Rainbow Bee-eater Mig (EPBC) S3 (WCA)	Regular migrant/ Recorded (BCE 2011a; 2015a)	Sandy- loam soils.	**Negligible.** Species is widespread and versatile in natural and altered habitats. Potential impacts include increased mortality and loss of habitat. Mitigation measures include management plans for fire and feral animals and protecting nest sites during earthworks and road maintenance.
Apus pacificus Fork-tailed Swift Mig (EPBC)S3 (WCA)	Irregular visitor/ Recorded (BCE 2015a)	Not applicable: aerial species	**Negligible.** Highly aerial species and largely independent of terrestrial environments, so no impacts expected.
Migratory waterbirds (see Table 9-30)	Vagrants to irregular visitors, usually in very small numbers	Seasonal waterbodies	**Minor**. Only present infrequently and usually in small numbers. Potential impacts include loss of habitat, changes to hydroecology, introduction of hazardous and non-hazardous water bodies. Management measures include decommissioning of existing stock watering points and management of evaporation ponds.
Conservation Significance 2 (CS2)			
Ardeotis australis Australian Bustard P4 (DPaW)	Resident/ Recorded (BCE 2011a; 2015a).	Spinifex sand plains.	**Negligible.** Species is widespread. Potential impacts include increased mortality, loss of habitat, increase in feral predators, change in fire regime, dust, light, noise and vibration. Mitigation measures include implementation of management plans for fire and feral animals (including stray stock), and restrictions on speed for project-related vehicles.

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Amytornis striatus Striated Grasswren P4 (DPaW)	Resident/ Not recorded.	Spinifex sandplains with an overstorey of shrubs, usually mallee eucalypts.	**Minor.** Probably present in the area. Recorded at Wanjarri Nature Reserve (DPaW 2015) and in Birdlife records for Yeelirrie. Potential impacts include loss of habitat, increase in feral predators, change in fire regime, dust, light, noise and vibration. Mitigation measures include implementation of management plans for fire and feral animals (including stray stock), and restrictions on speed for project-related vehicles.
Dasycercus blythi Brush-tailed Mulgara P4 (DPaW)	Resident/ Recorded (BCE, 2011a; 2015a)	Spinifex sand plains, mulga shrubland and open woodland.	**Minor.** Some populations are present in the study area, but extensive suitable habitat occurs outside the study area. Potential impacts include increased mortality, loss of habitat, increase in feral predators, change in fire regime, dust, light, noise and vibration. Mitigation measures include management plans for fire and feral animals (including stray stock).
Sminthopsis longicaudata Long-tailed Dunnart P4 (DPaW)	Resident/ Not recorded.	Rocky ridges, stony slopes with Spinifex.	**Minor.** Key habitat outside impact areas. Recorded 70 km north of study area (BCE 2014). Potential impacts include loss of habitat, increase in feral predators and change in fire regime. Management measures include management plans for fire and feral animals.
Nyctophilus major Inland Long-eared Bat P4 (DPaW)	Resident/ Recorded (BCE, 2011a)	Spinifex sand plains. May roost in tree hollows in *E. gypsophila* woodland.	**Minor.** Species is widespread but important regional roosting habitat may be in the *E. gypsophila* woodland. Potential impacts include loss of habitat, change in fire regime, dust, light, noise and vibration. Management measures include implementation of a management plan for fire, use of directional lighting and the avoidance of hollow-bearing E. *gypsophila* wherever practicable and where not practicable, the collection and re-affixing of suitable hollows to trees that would be retained.
Conservation Significance 3 (CS3)			
Burhinus grallarius Bush Stone-curlew	Resident/ Recorded (BCE 2011a; 2015a)	*E. gypsophila* woodland, dense Acacia shrublands, gnamma holes and Casuarina woodland.	**Minor.** Species is widespread and suitable habitat is extensive outside the study area, but population is small and uses habitat in the study area. Potential impacts include increased mortality, loss of habitat, increase in feral predators, changes in hydroecology, change in fire regime, dust, light, noise and vibration. Mitigation measures include implementation of management plans for fire and feral animals (including stray stock).

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Lophoictinia isura Square-tailed Kite	Resident/ Recorded (BCE 2011a)	*E. gypsophila* woodland and Mulga shrubland.	**Negligible.** Potential impact includes loss of habitat. Mitigation measures include implementation of management plans for fire, and clearing controls.
Neophema splendida Scarlet-chested Parrot	Irregular visitor/ Not recorded.	*E. gypsophila* woodland and Mulga shrubland.	**Minor.** Recorded at Wanjarri Nature Reserve (DPaW 2015). Negligible impact as only an irregular visitor to the fauna study area. Potential impacts include loss of habitat, loss of breeding habitat (Eucalypt tree hollows), changes in hydroecology, fire regime, dust, light, noise and vibration. Mitigation measures include implementation of management plans for fire and clearing controls. Where not practicable, the collection and re-affixing of suitable hollows to trees that would be retained.
Polytelis anthopeplus Regent Parrot	Vagrant/ Not recorded.	Woodland.	**Negligible.** Recorded at Wanjarri Nature Reserve (DPaW 2015). Potential impact includes loss of habitat. Management measures include management plan for fire.
Conopophila whitei Grey Honeyeater	Resident/ Not recorded.	Mulga shrubland.	**Negligible.** Recorded at Wanjarri Nature Reserve (DPaW 2015). Potential impacts include change in fire regime, dust, light, noise and vibration. Management measures include implementation of a management plan for fire.
Stipiturus ruficeps Rufous-crowned Emu-wren	Resident/ Not recorded.	Spinifex sandplains.	**Minor.** Probably not present in area but suitable habitat present. Recorded at Wanjarri Nature Reserve (DPaW, 2015). Changed fire regimes could lead to local extinction however the successful implementation of the fire management plan would minimise this loss. Potential impacts include loss of habitat, change in fire regime, dust, light, noise and vibration. Management measures include implementation of management plans for fire and dust.
Antichinomys laniger Kultarr	Resident/ Not recorded.	Open plains.	**Negligible.** Species is widespread and suitable habitat is largely outside the fauna study area. Recorded at Mount Keith. Potential impacts include increased mortality, loss of habitat, increase in feral predators, change in fire regime, dust, light, noise and vibration. Mitigation measures include management plans for fire and feral animals (including stray stock).

Species (Conservation Status)	Status in area	Habitat	Potential impact and management
Aprasia picturata Legless lizard	Unknown/ Not recorded.	Rocky ridges.	**Negligible.** Habitat outside the Project Area. Recorded at Wiluna. Management measures include implementation of a management plan for fire.

Table 9-34: Impacts on conservation significant invertebrate species

Species (Conservation Status)	Collected outside disturbance footprint?	Habitat	Potential impact and management
Mygalomorph Shield-backed Trapdoor Spider *Idiosoma nigrum* (Vul - EPBC; S1 - WCA)	Yes	Sandplain	**Minor.** Potential impacts to this species relate to dust generation from nearby activities as suitable habitat is outside direct impact areas. Minimise indirect impacts, such as dust suppression along roads through implementation of a dust management plan.
Isopod Platyarthridae/ Bathytropidae (Confirmed SRE)	No but habitat present outside footprint	Calcrete, Outwash, Hardpan Mulga.	**Moderate**. Potential impacts include loss of habitat, changes to hydro-ecology and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Isopod *Pseudolaureola* sp. (Confirmed SRE)	No but habitat present outside footprint	Calcrete, Outwash	**Moderate.** Potential impacts include loss of habitat, changes to hydro-ecology and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Carabidae Tiger Beetle *Pseudotetracha helmsi* (Confirmed SRE)	Yes	Playa	**Negligible.** Potential impacts include loss of habitat, dust generation and changes to surface water. Restrict vehicle traffic at the Yeelirrie Playa to a minimum and keep to existing tracks. Manage dust, surface water, and implement clearing controls.
Mygalomorph *Aganippe* sp. (Confirmed SRE)	Yes	Hardpan Mulga	**Negligible.** Potential impacts to this species relate to dust generation from nearby activities. Mitigation measures include suppression of dust and surface water management.
Mygalomorph Aname 'MYG170' (Potential SRE)	No but habitat present outside footprint	Calcrete, Hardpan Mulga	**Minor.** Potential impacts include loss of habitat and changes in hydroecology and dust. Mitigation measures include suppression of dust, surface water management and clearing controls.

Species (Conservation Status)	Collected outside disturbance footprint?	Habitat	Potential impact and management
Mygalomorph Aname 'MYG212' (Potential SRE)	Yes	Calcrete Outwash, Sandplain	**Moderate.** Potential impacts include loss of habitat and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Mygalomorph Barychelidae (Potential SRE)	No but habitat present outside footprint	Calcrete Outwash	**Moderate.** (Insufficient data). Potential impacts include loss of habitat and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Pseudoscorpion Cheridiidae (Potential SRE)	No but habitat present outside footprint	Calcrete Outwash	**Moderate.** (Insufficient data). Potential impacts include loss of habitat and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Isopod *Cubaris* sp. 1 (Potential SRE)	No but habitat present outside footprint	Calcrete	**Minor.** (Insufficient data). Potential impacts include loss of habitat and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Isopod *Cubaris* sp. 2 (Potential SRE)	Yes	Hardpan Mulga, Sandplain	**Negligible.** Potential impacts to this species relate to dust generation from nearby activities. Mitigation measures include suppression of dust, surface water management and clearing controls.
Centipede Chilopod Geophilida (Potential SRE)	No but habitat present outside footprint	Hardpan Mulga	**Minor.** (Insufficient data). Potential impacts include loss of habitat, changes to hydro-ecology and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.
Mygalomorph *Kwonkan* 'MYG171' (Potential SRE)	No but habitat present outside footprint	Hardpan Mulga	**Minor**. (Insufficient data). Potential impacts include loss of habitat, changes to hydro-ecology and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.

Species (Conservation Status)	Collected outside disturbance footprint?	Habitat	Potential impact and management
Mygalomorph *Kwonkan* 'MYG172' (Potential SRE)	No but habitat present outside footprint	Calcrete	**Minor.** (Insufficient data). Potential impacts include loss of habitat and changes to hydro-ecology. Mitigation measures include suppression of dust, surface water management and clearing controls.
Mygalomorph *Kwonkan* 'MYG210' (Potential SRE)	Yes	Hardpan Mulga	**Negligible.** Potential impacts to this species relate to dust generation from nearby activities. Mitigation measures include suppression of dust, surface water management and clearing controls.
Mygalomorph *Kwonkan* 'MYG211' (Potential SRE)	Yes	Hardpan Mulga	**Negligible.** Potential impacts to this species relate to dust generation from nearby activities. Mitigation measures include suppression of dust, surface water management and clearing controls.
Scorpion *Urodacus* 'yeelirrie' (Potential SRE)	Yes	Hardpan Mulga	Potential impacts include loss of habitat and dust generation. Mitigation measures include suppression of dust, surface water management and clearing controls.

Table 9-35: Summary of potential impacts on key fauna values and proposed actions

Fauna Value	Nature and Significance of Impact		Proposed Actions
	Potential Impacts	Significance	
Fauna assemblage	Increased mortality, loss of habitat and species interactions.	Minor as impacts very localised in a regional context	Minimise impact footprint, rehabilitate where possible, manage ongoing mortality, monitor / manage impacts from evaporation ponds. Minimise hydrological impacts to maintain fauna assemblage.
VSAs	Loss of habitat, altered hydroecology, habitat degradation through weed invasion or altered fire regimes.	Minor as these are widespread in the region except Calcrete VSA	Minimise footprint especially in Calcrete VSA, monitor vegetation condition and minimise hydrological impacts to maintain phreatophytic VSAs.

Fauna Value	Nature and Significance of Impact		Proposed Actions
	Potential Impacts	Significance	
Significant fauna	Ongoing mortality, loss of habitat and species interactions. Changes to fire regimes and hydrological flows. Disturbance from dust, noise and light spill. Fauna consuming water from evaporation ponds.	**Vertebrate Fauna** Minor as impacts are localised but consideration needed for Malleefowl and Black-flanked Rock-Wallaby. **Invertebrate Fauna** Minor to Moderate as impacts are localised but consideration needed for *Idiosoma nigrum*, Pseudolaureola, Platyarthridae/ Bathytropidae and Cheiridiidae.	Minimise footprint, retain / manage areas of importance for conservation. Monitor important populations of conservation significant fauna. Retain tree hollows for birds. Manage feral species as required. Monitor / manage impacts from evaporation ponds and dust. Minimise hydrological impacts to maintain phreatophytic VSAs.
Patterns of biodiversity	**Vertebrate Fauna** The most significant VSAs in terms of biodiversity are watercourses and areas of spinifex on sandy-loam soil, and these are largely outside areas of direct impact. The most-impacted VSA is low in biodiversity within the context of the region, although rocky hills and watercourses within the VSA may be of interest for some taxa. **Invertebrate Fauna** The most significant VSAs are the calcrete habitats. Some SRE species were only recorded in such habitats but these also occur away from the mine footprint.	Minor as impacts very localised	Minimise footprint where possible. Monitor / manage impacts from evaporation ponds. Minimise hydrological impacts to maintain phreatophytic VSAs
Ecological processes	Potential impacts on hydrology. Some possible impacts on fire regimes and feral predators.	Minor but changes to hydrology could be a concern.	Management to prevent any impacts to local hydrology. Manage fire and feral species where necessary.

9.3.5.4 Assessment of Impacts from Dust and Radiological Effects to Fauna

This section discusses the potential dust and radiological effects of the operation on fauna. The assessment considers the primary pathway for impacts outside the operation, which is the release of airborne dusts and their deposition in the environment. The operation is designed to prevent release of water off site therefore this pathway is not considered here.

The deposition of operation originated dust results in the deposition of radionuclides onto soils and the subsequent incorporation into the soils. The assessment utilises the ERICA software tool and the change in soil radionuclide concentrations to make a qualitative assessment of potential risk to a set of standard fauna species. The ERICA assessment was conducted for the full set of reference animals. In addition, an assessment was conducted for kangaroos which utilised the recently published concentrations ratios in APRANSA 2014. To take account of the difference in physical dimensions of the kangaroo (compared to the reference animals), Cameco has utilised the functionality within the ERICA software to create a kangaroo model (based on an ellipsoid). Note that ARPANSA 2014 does not provide concentration ratio values for thorium for kangaroos, therefore the default ERICA value for large mammals is used in the assessment.

Dust

Air quality modelling has been conducted for the Project and is discussed in detail in Section 9.8.

To assess the impact of dust emissions on fauna and habitat, the emissions of total suspended particulates (TSP) resulting from the operation of the Project (predicted operationally contributed annual average ground-level concentration of TSP) were considered.

There are currently no known measurements of TSP in the region. The standard conversion ratios detailed in the United States Environmental Protection Agencies (US EPA's) Compilation of Air Pollution Emission Factors Volume 1 (AP-42) and in the NPI Handbooks, have found that PM10 is usually 50% of the TSP concentration. In accordance with standard industry practice, this ratio has been employed for this assessment.

The New South Wales Environmental Protection Authority (NSW EPA) has set dust deposition impact assessment criterion to prevent impacts to residential amenity. The impact assessment criterion is expressed as an incremental increase in dust deposition levels over background due to the operation of a facility of 2.0 g/m^2/month (DEC, 2006). Due to the absence of dust deposition monitoring data in the vicinity of the proposed Yeelirrie Uranium Project, the impact assessment criterion specified by the NSW EPA has been used in this assessment.

Modelling predicts that the operation contribution of the Project to is less than 1g/m^2/month (see Table 9-68). At this level, it is unlikely that dust deposition from the Project will impact fauna and habitat.

Radiation

The ERICA Tool

The ERICA assessment tool was developed under the European Commission to provide a method of assessing the impact of radiological contaminants on the natural environment. The ERICA tool and assessment process which is conducted in three "tiers" is discussed in Section 9.1.5.

The ERICA tool presents the results as the dose rates to the organisms, and also in terms of the "Risk Quotient" (i.e. the ratio of the dose rate to the screening rate).

Soil Radionuclide Concentrations

Soil radionuclide concentrations are discussed in Section 9.1.5. As noted, the modelled change in soil radionuclide concentrations at the project boundary is 45Bq/kg for each radionuclide in the uranium decay series and after 15 years of deposition.

Concentration Ratios

For animals, the concentration ratios represent the ratio of organism whole body radionuclide activity concentration in fresh weight, compared to the activity concentration of that radionuclide in the media (soil or water) where the organism lives. For a terrestrial assessment this is the Becquerels per kilogram (Bq/kg) whole organism (fresh weight) per Bq/kg soil (dry weight).

Cameco has analysed kangaroo and soil data collected by BHP Billiton at Yeelirrie to develop local concentration ratios (see Technical Appendix J1). A summary of the values, together with recently published Australian concentrations ratios (ARPANSA 2014) and the ERICA default concentration ratios (for large mammals) can be seen in Table 9-36.

Table 9-36: Comparison of whole organism concentration ratios

Sample Type	Concentration Ratio (Bq/kg [fresh weight] per Bq/kg [soil])		
	U238	Ra226	Pb210
Uranium	0.005	0.005	0.007
Thorium	0.000	0.0086	-
Radium	0.044	0.062	0.041
Lead	0.037	0.016	0.020
Polonium	0.089	0.031	0.55

ERICA Kangaroo

The ERICA software provides the opportunity to expand the assessment beyond the reference animals and plants when necessary. The recent ARPANSA 2014 publication provides concentrations ratios for kangaroos and, as noted, the assessment has been conducted using this recent data. As the kangaroo is dimensionally different from the ERICA default large mammal, an ellipsoid for an additional ERICA reference species was developed. The species was termed "Kangaroo" and was given the following attributes; mass 50kg, height 1.5m, width 0.75m, depth 0.75m.

Table 9-37: Tier 2 ERICA assessment

Organism	CR Origin	Risk Quotient (expected value)	Risk Quotient (conservative value)
	Default	0.04	0.11
Organism	CR Origin	Risk Quotient	0.10
(expected value)	Risk Quotient	0.04	0.12
(conservative value)	Default	0.03	0.08
Arthropod - Detritivore	Default	0.04	0.11
Flying insect	Default	0.03	0.10
Mollusc - Gastropod	Default	0.04	0.12
Bird	Default	0.03	0.08
Amphibian	Default	0.05	0.14
Reptile	Default	0.05	0.15
Kangaroo (Cameco generated ellipsoid)	ARPANSA 2014	0.10	0.31
Mammal (large)	Default	0.04	0.13
Mammal (small burrowing)	Default	0.04	0.13

A Tier 2 ERICA assessment was conducted using a soil radionuclide concentration of 45 Bq/kg (each uranium series radionuclide) and using a combination of default concentration ratios and derived ratios for different organisms and the resulting risk quotients shown in Table 9-37.

Note that the ERICA assessment was conservatively conducted using the ARPANSA 2014 concentration ratios for kangaroos and the ERICA default figure for thorium.

No species exceeded the screening level of 10µGy/h.

The Risk Quotient is the ratio of the derived dose rate to the screening level. When the risk quotient is less than 1, no additional assessment is required.

Impact from Radon and Radon Decay Products

An impact assessment on fauna from radon and its decay products was conducted using the tool of Vives i Batlle et al. (2008;2012). The default values were used and the input radon concentration was 10Bq/m^3, based on the modelled average annual radon concentration at the project boundary.

The output of the calculator indicated that none of the 70 species assessed would be exposed to more that 10uGy/hr under the default conditions, with the highest being less than 1uGy/h. Further assessment was therefore not deemed to be necessary.

In summary, the risk to fauna from operation originated dust and radionuclides is very low.

9.3.5.5 Summary of Management Measures

Cameco will develop a Fauna Management Plan to minimise, manage and monitor potential impacts from the Project on native fauna. Management measures are likely to include the following:

General - Avoid and Minimise

- Cameco will minimise ground disturbance and clearing activities in accordance with a Flora and Vegetation Management Plan to be developed for the Project. The ground disturbance protocol will ensure that areas to be cleared are first inspected by qualified environmental personnel to determine if there are any significant habitats or signs of significant fauna activity.
- If populations of significant species are identified within Project boundary (e.g. lay down areas or storage areas), alternative areas must be considered and evaluated where practicable.
- If populations of significant species are identified within Project boundary and disturbance to those areas cannot be avoided, a specialist zoologist will be consulted prior to ground disturbance.
- A site vegetation clearing permit will be completed and authorised by site environmental personnel prior to ground disturbance.
- There will be no unauthorised driving off tracks, night driving will be limited and vehicle speeds will be restricted around the Project and sensitive habitats. Dust suppression along access roads will be managed under site management procedures.
- Waste disposal areas around the site will be maintained to a high standard. Inert and putrescible waste will be disposed of to an authorised landfill on site which will be fenced to prevent access by native and introduced fauna. The presence of introduced fauna species and pests will be monitored and appropriate control measures implemented if necessary.
- The evaporation pond will be inspected daily for fauna and bird access. Should fauna visitations to the facilities be considered significant, measures will be taken to deter fauna.
- Changes to surface water flow regimes will be managed in accordance with a Surface Water Management Plan to be developed for the Project.
- Cameco is committed to the removal of stock and decommissioning of existing stock watering points (in consultation with relevant stakeaholders) across the entire Yeelirrie Station, which will reduce trampling, weed infestations and competition from abundant native and introduced species. Cameco will develop a whole of Pastoral Lease management plan to ensure that areas of high conservation value are managed accordingly.
- Feral fauna management measures will also be implemented which take into consideration the role of dingoes in suppressing foxes.

- A fire management plan will be developed and implemented for the Project, with hot work permits required prior to commencing any activity that may create an ignition source. Fire extinguishers will be available in all hot work areas and personnel will be trained in their use. Cameco will have an emergency response plan for the Project, which will include response to bushfires, and a plan for controlled burning around the Project Area.
- Hydrocarbons and chemicals will be transported, stored and used in accordance with Australian standards and guidelines. Spill kits will be made available on site and hydrocarbon and chemical spills will be immediately cleaned up and the incident reported.

General - Rehabilitate

- Disturbed areas that are no longer required will be progressively rehabilitated over the life of the mine in accordance with the Mine Closure and Rehabilitation Plan.
- The pit will be progressively backfilled and rehabilitated from year 11.

Conservation Significant Species - Avoid and Minimise

- Training on the identification and reporting of conservation-significant fauna species will be included in the Cameco site induction.
- The ground disturbance guideline will ensure that areas to be cleared are first inspected by qualified environmental personnel to determine if there are any significant habitats or signs of significant fauna activity. Training on vegetation clearing procedures will be included in an environmental induction.
- Work with DPaW and local indigenous groups to assist in the implementation of a landscape scale fire management program.
- Cameco will work with DPaW and local indigenous groups to assist in the implementation of a landscape scale fire management program to manage habitat for conservation of significant species.

9.3.6 Outcomes

Taking into account the project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.

9.3.7 Commitments

Cameco commits to:

- Develop and implement a Fauna Management Plan.

9.4 Hydrological Processes and Inland Water Quality (Surface Water)

9.4.1 EPA Objective

The EPA's objective with regards to hydrological processes for surface water is:

- To maintain the hydrological regimes of surface water so that existing and potential uses, including ecosystem maintenance, are protected.

The EPA's objective with regards to inland water quality for surface water is:

- To maintain the quality of surface water, sediment and biota so that the environmental values, both ecological and social are protected.

9.4.2 Relevant Legislation and Policy

The WA *Rights in Water and Irrigation Act 1914* (RIWI Act) makes provision for the regulation, management, use and protection of water resources, and for related purposes. Surface waters within and around the Project Areas are ephemeral and not considered suitable for drinking water supply, stock watering or irrigation, and therefore there are no specific licensing requirements relating to surface water for the Project, under the RIWI Act.

The EPA has developed a number of policies relevant to the protection of surface waters in WA. These include EPA (2004a) *Position Statement No. 4: Environmental Protection of Wetlands, Pert*h, EPA (2004b) *Position Statement No 5: Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia*, and EPA policies.

The DoW has developed a number of operational policies and guidance. The policy most relevant to surface water management is DoW (2009) *Operational Policy No. 1.02 – Policy on water conservation/ efficiency plans*, Perth, Western Australia.

The Australian and New Zealand Environment Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) have developed the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). The main objective of these guidelines is:

> "to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values [uses] for natural and semi-natural water resources in Australia and New Zealand."

The water quality guidelines were prepared as part of Australia's National Water Quality Management Strategy (NWQMS). They are based around the protection of various environmental values (or uses) of surface waters. Environmental values that apply to surface waters within and around the Project Area are:

- aquatic ecosystems;
- cultural and spiritual values.

Surface water that is captured within the Project Area would be considered 'industrial water' and retained for use by the Project. No water quality guidelines are provided for industrial water within the ANZECC/ARMCANZ guidelines.

Associated with each environmental value are trigger values for substances that might affect water quality. If these values are exceeded they may be used to trigger an investigation or initiate a management response. Where two or more agreed environmental values apply to a water body, the more conservative, or stringent of the associated guidelines would be selected as the water quality objective.

Once the environmental values to be protected have been selected, the level of environmental protection or water quality necessary to maintain each value is determined. Management goals that describe how this will be achieved can then be developed following consultation with relevant stakeholders.

9.4.3 Studies and Investigations

A Surface Water Study for the original project was undertaken by BHP Billiton between 2009 and 2011. Cameco commissioned URS to undertake a review of this work and update it where appropriate for the revised Project (URS 2015a). An assessment of the overall site water balance was also undertaken for the Project (URS 2015b). The surface water report and water balance study are presented in Appendix H1 and Appendix H2 respectively.

9.4.3.1 Surface Water Study

The overall objectives of the surface water study were to characterise the existing surface water environment; assess potential changes to the surface water environment resulting from the proposed Project; and identify mitigation and management strategies to minimise potential changes to surface water hydrology. This study included:

- characterisation of the baseline hydrological regime, including stream flows, flood patterns, water chemistry, and water quantity and quality;
- analysis of rainfall data to inform project design elements necessary to manage storm rainfall events;
- assessment of the changes to the hydrological regimes including, water levels, water chemistry, stream flows, flood patterns, and water quantity and quality, as a result of implementation of the Project, under a range of climatic scenarios including probable maximum precipitation (PMP);
- calculating the duration of flooding within the development envelope under pre-construction, mining and post closure conditions; and.
- assessment of potential erosion and sediment transport within the Project envelope before disturbance, during operation and post closure.

Baseline Site Investigations

As part of the surface water study undertaken by URS for BHPB between 2009 and 2011, several site investigations were undertaken to support both the surface water and groundwater studies. The following site investigations were undertaken:

- reconnaissance survey (March 2009) with a walkover of the development envelope and local reaches of the Yeelirrie Catchment;
- infiltration tests conducted in June 2009 (winter) and January 2010 (summer);
- soil sampling (in June 2009 and January 2010); and
- opportunistic surface water sampling during two rainfall events in 2009 and 2010.

Baseline Surface Water Hydrology and Drainage Characterisation

Characterisation of the baseline surface water flows within the study area was based on:

- the results of a literature review;
- available topographic data to delineate the local catchments, inform drainage patterns and channel characteristics;
- analysis of available datasets from both historical records and recent site investigations including land system information from the Department of Agriculture & Food Western Australia (AgWA 1994 & 1998); and
- review of rainfall data and development of design rainfall data for the Yeelirrie (Playa) Catchment and the Lake Miranda Catchment for selected Average Recurrence Interval (ARI) events (1, 2, 5, 10, 20, 50, 100 and 1,000 years).

From this, hydrological modelling was undertaken to simulate the rainfall-runoff, surface water drainage and flow characteristics of the study area for a range of rainfall events.

Baseline Flood Characterisation and Simulations

The baseline hydraulic flood model was used to characterise the surface water flow along the main flow paths of the Lake Miranda and Yeelirrie Playa Catchments and determine the:

- extents of flooding for selected ARI events;
- depths of flood water for selected ARI events;
- natural attenuation of flood waters;
- flow velocities; and
- potential surface water flows out of the Lake Miranda Catchment.

Baseline Interactions between Surface Water and Groundwater

The interaction between surface water and groundwater was described by investigating the:

- observed water table responses to rainfall and flooding;
- surface water flux actually reaching the water table (recharge) and its predictability based on recently monitored ARI events;
- depth to the water table, groundwater salinity and position within the catchment; and
- comparing the observed recharge rises to local stratigraphy to determine whether event-based recharges are significant to event-based groundwater flow.

Environmental Change Assessment during Operations

Hydrological modelling was undertaken to assess the changes between the baseline hydrology and the modelled hydrological conditions resulting from the proposed Project.

To prevent the inflow from surface water runoff into the mine site area, Cameco is proposing to construct a surface water diversion bund to divert surface water runoff and stream flow around the active mining area during operations. The diversion bund, designed to protect against a 1,000-year ARI flood event, will be constructed in two stages in order to minimise the amount of precipitation and surface water runoff that would collect within the mine area and require management.

The baseline hydraulic flood model was adapted to incorporate key elements of the proposed Project infrastructure that potentially influence the surface water environment.

Hydraulic flood modelling was undertaken on the Lake Miranda Catchment to predict the effects of the surface water diversion bund on surface water flows during 1-, 5-, 20-, 100- and 1,000- year ARI events. The predictive assessments of changes to flood depths, extents and velocity of flow were undertaken at three different scales, with a hydraulic flood model developed for each:

- Regional Scale: Lake Miranda Catchment outside of the surface water diversion bund.
- Local Scale: Yeelirrie Playa Catchment outside of the surface water diversion bund.
- Minesite Scale: Area inside the surface water diversion bund forming the predominant disturbance footprint.

Changes to erosion and sediment characteristics were examined. Changes to surface water and groundwater interactions as a result of the Project were also investigated.

Change Assessment after Mine Closure

Changes to surface hydrology after mine closure were assessed based on the following closure concepts:

- Backfill of the pit area and build-up of the proposed disturbance area of the mine site to a 1:100 year ARI flood level. The area above this level would be shaped to be free draining.
- The diversion bunds would be removed and the northern watercourse would be reinstated by means of a channel along the northern side of the mine backfill area, with a capacity to convey the 1:100 year ARI flood flow without overtopping the site.
- Small areas on the northern upstream side of the surface water diversion bund will be filled to ensure hydraulic smoothness.

The change in flood characteristics from baseline conditions due to the post-closure landform were modelled and focussed on change in flood water depth / levels around the mine site; and change in flow velocities.

Changes to erosion and sediment characteristics post-closure were assessed. Changes to surface water and groundwater interactions, including alterations to groundwater recharge post-closure were also investigated.

Further detail on the methodology for the Surface Water Study is presented in URS (2015a) (Appendix H1). Further information on groundwater is provided in Section 9.5.

9.4.3.2 Project Water Balance

The ESD requires Cameco to assess the overall site water balance and management of affected surface water to ensure onsite containment. A water balance model was developed for the original project by URS in 2011. This was updated for Cameco's Project in 2015. The key components of the water balance model are:

- climate inputs (rainfall and evaporation);
- water demand.
- water supply
- water storage and distribution; and
- water recycling.

From the water balance model, a proposed Water Management Strategy (WMS) was developed. The WMS was tested under a range of climatic conditions (Monte Carlo simulations) based on historical data.

Further detail on the methodology for the Water Balance Study is presented in URS (2015b) (Appendix H2) and Section 6.6.

9.4.4 Existing Environment

The climate and surface water environment of the study area is described in detail in URS (2015a; Appendix H2) and summarised below.

9.4.4.1 Climate

There are no permanent surface water features in the region and rainfall is the primary source of surface water within the study area. The average annual rainfall for Yeelirrie Homestead is 238 mm with a minimum annual rainfall of 43 mm and a maximum annual rainfall of 507 mm (BoM 2015). The rainfall frequency and total annual rainfall is widely variable with a dependability of only 40%. Yeelirrie receives 61% of mean annual rainfall in the summer months (November to April) and the remainder during winter, generally at low intensity, producing limited surface water runoff.

Summer rains are normally of high intensity, caused by localised thunderstorm activity or much larger weather systems associated with tropical lows and cyclones. Cyclones and associated rain-bearing lows are the source of the majority of extreme rainfall events that are likely to generate surface runoff within the Yeelirrie Catchment. Data from the Bureau of Meteorology (BoM) indicates that 13 cyclones have passed within 200 km of Yeelirrie Homestead between 1970 and 2000.

No evaporation data is available from the BoM Yeelirrie Meteorological station. In the absence of evaporation data at Yeelirrie, long term SILO synthetic rainfall and evaporation data were generated for the Yeelirrie Catchment. Mean annual pan evaporation is estimated to be about 2,260 mm. Mean annual rainfall at Yeelirrie is about 10% of the mean annual pan evaporation.

Design rainfall

Design rainfall events were estimated to support the baseline surface water assessments within the Lake Miranda Catchment. Design rainfall quantities were estimated for a range of ARI events (1- to 1,000-year ARI) and Probable Maximum Precipitation (PMP). Design rainfall for selected ARIs is presented in Table 9-38.

Table 9-38: Design rainfall for selected ARIs (mm)

ARI (year)	Rainfall Duration (hrs)					
	1	6	12	24	48	72
Yeelirrie (Playa) Catchment						
1	12.5	20.8	25.2	31.2	37.4	40.3
5	15.6	29.9	39.5	49.7	63.6	71.8
20	22.5	46.2	63.1	79.9	104.8	116.8
100	36.0	78.5	107.0	139.2	177.8	198.8
1,000	NC	NC	NC	197.4	242.9	257.7
PMP	NC	NC	NC	650	860	1,030
Lake Miranda Catchment						
20	20.9	43.0	59.7	76.7	100.9	114.0
100	34.1	75.2	103.0	134.5	173.9	194.6
1,000	NC	NC	NC	193.5	239.4	254.5
PMP	NC	NC	NC	560	740	900

Note: For selected events the design rainfall have not been calculated (NC) as these are non-critical events and therefore not required.

9.4.4.2 Regional Drainage Characteristics

The Project is located within the Lake Miranda Catchment (7.560 km^2) which is a closed drainage area for typical rainfall events. During extreme rainfall events sufficient runoff may be generated for flood waters to fill Lake Miranda and flow across a low topographic saddle east into Lake Darlot. Lake Darlot is part of the larger Lake Carey Catchment (114,000 km^2) which is a surface runoff catchment within the Salt Lake Basin (441,000 km^2) of the Western Plateau Division. The regional drainage catchments are shown on Figure 9-20.

Figure 9-20: Regional drainage basins

9.4.4.3 Catchment Characteristics

The Yeelirrie Study Area has a gentle relief with the exception of sand dunes and granite breakaways. The total elevation range within the catchment is approximately 100 m from about 480 m AHD in the centre of the catchment near the Yeelirrie Homestead, to a maximum of about 580 m AHD on the granite breakaways, which mark the divide between the catchments. The topographic relief within the proposed Project Area is in the order of about 20 m.

The Yeelirrie catchment (upstream of the Yeelirrie Playa) drains to the southeast into Lake Miranda (Figure 9-21). The Yeelirrie catchment is further divided into a number of sub-catchments (Figure 9-22). The Project is located in the valley floor of the Yeelirrie Playa catchment drainage line on the confluence of two main drainage lines which drain the Yeelirrie Playa catchment upstream of the mine site with a total catchment area of 2,915 km^2. The northern drainage line which passes along part of the northern side of the pit drains sub-catchments A1-4 (2,449 km^2). The southern drainage line which is mostly south of the pit, drains sub-catchment B (466 km^2). Sub-catchment C (222 km^2) drains into the Yeelirrie Playa drainage line along the length of the proposed mine site, both north and south.

There are no known hydrological records for the study area, such as stream flow measurements or gauged run-off events. There is also no known record of a major flood in the main valley, although sheet-flooding has been observed nearby at the Yeelirrie Homestead. The hydrology of the study area has been described in several technical reports, predominantly hydrological studies for the Yeelirrie feasibility and environmental impact assessment studies from 1976 to 1982.

Surface runoff within the Yeelirrie Catchment occurs only occasionally following intense rainfall. Sheet runoff may shed from the upper margins of the catchments, flow rapidly to the central drainage line and generate short-lived stream flow. Typically, the stream flow terminates in playas (including clay pans). On the larger playas, water may remain for several weeks following large rainfall events (Western Mining Corporation 1978).

Surface water infiltration into the ground depends on a number of factors including rainfall intensity, duration, frequency, hydraulic conductivity of the soil and moisture characteristics during and between rainfall events. Recharge responses to rainfall during have been noted following the review of six climatic events since 2010. Typically, the infiltration rate was noted to be high where sandy soils are present in areas of low relief and where calcrete (and related “crab holes”) are present in low-lying areas where runoff accumulates. Infiltration was also higher in areas that are subject to inundation even if the underlying soils are clayey (e.g. clay pans). These areas accumulate clay and silt from the runoff, and salt derived from natural sources within the catchment.

Groundwater may also influence surface water where the water table is close to or above the ground surface. Evaporation draws salt from the water table where it accumulates at the surface along with salt derived from runoff. Salt lakes such as Lake Miranda and other smaller features in the Albion Downs area are examples of this.

Springs resulting from conditions where the water table is above the surface can also affect the surface water quality due to the accumulation of salt and other naturally-occurring solutes. There is only one spring in the region, Palm Springs located 54 km east southeast of the Project.

Also present are small rock holes and pools which fill after rainfall and evaporate shortly afterwards. These occur on granitic outcrops to the northeast and southwest of Yeelirrie Homestead and have cultural significance.

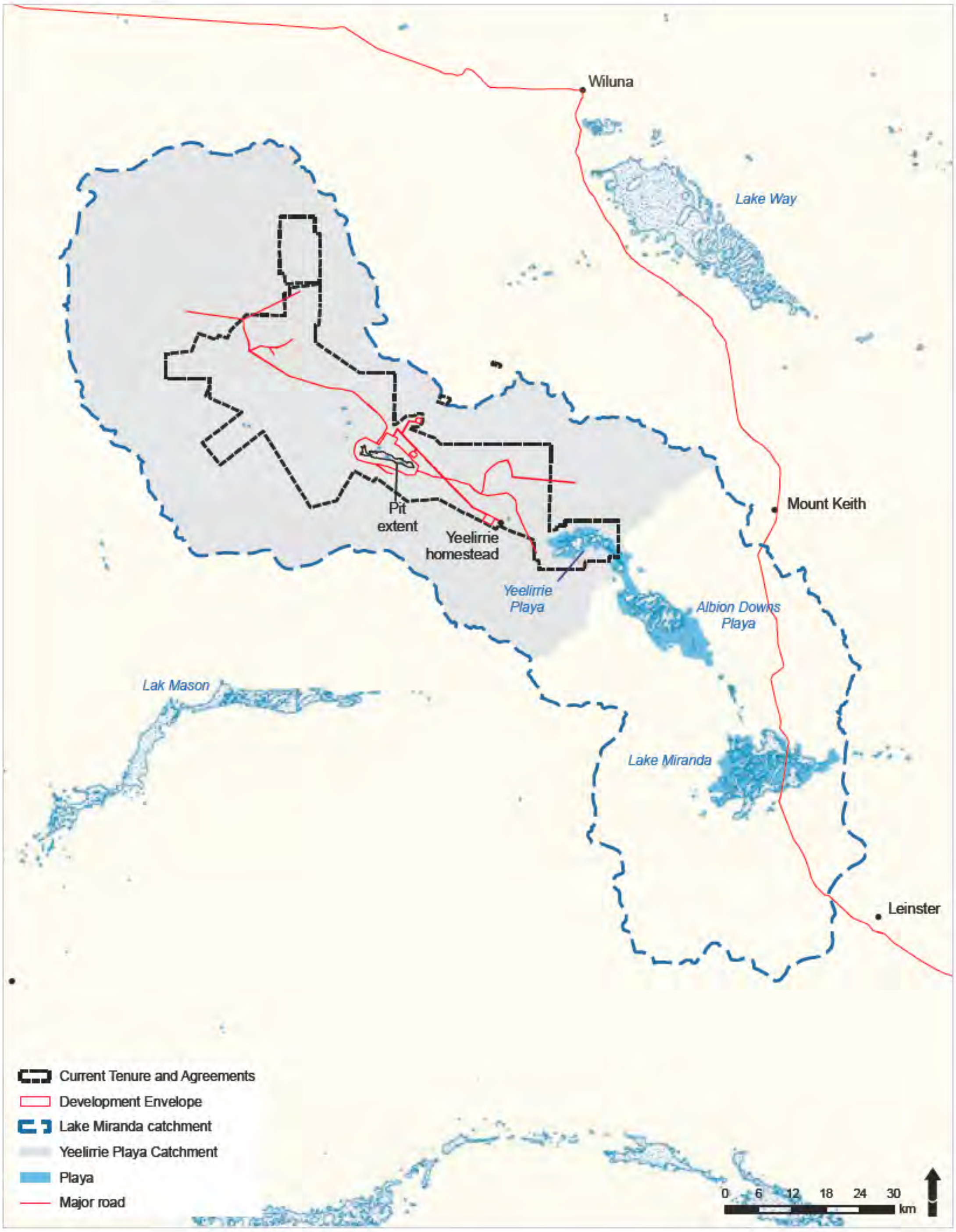


Figure 9-21: Lake Miranda catchment drainage

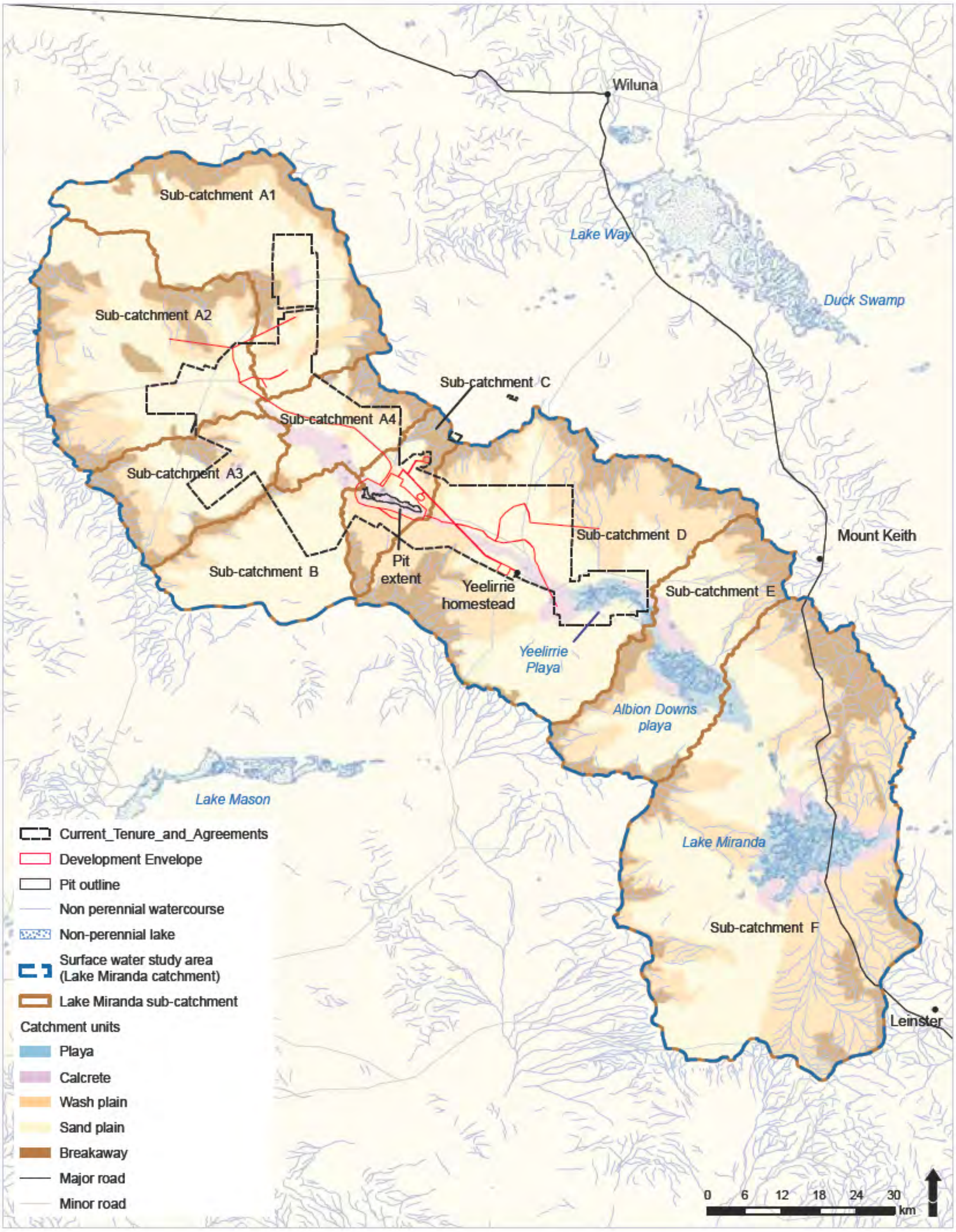


Figure 9-22: Lake Miranda catchment and sub-catchments

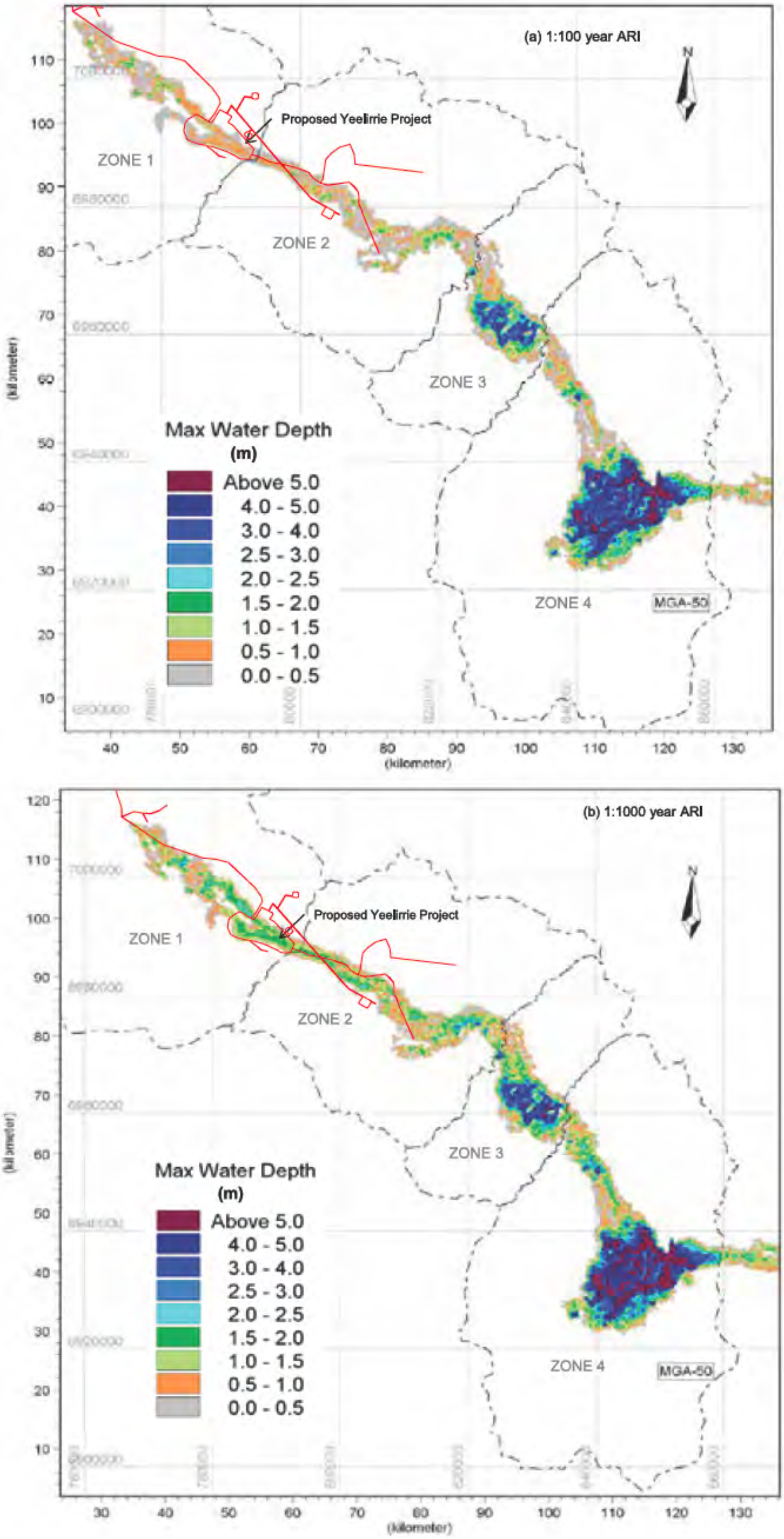


Figure 9-23: Regional baseline flood maps maximum water depths

Baseline Flood Simulations

The hydrological modelling of baseline conditions indicates:

- Rainfall events smaller than 1:20 year ARI generate localised sheet flow runoff. No interconnected flows are predicted to occur within the catchment valley.
- Larger rainfall events (1:20 to 1:100 year ARI) generate interconnected runoff in the valley floor throughout the Lake Miranda catchment terminating in the playas.
- Extreme rainfall events (1:100 year ARI and greater) generate runoff throughout the Lake Miranda catchment, with Lake Miranda spilling over into the Lake Carey catchment.

Simulated maximum flood water depths in the Lake Miranda catchment are presented in Table 9-39 and shown in Figure 9-23.

Table 9-39: Simulated baseline maximum water depths in the Lake Miranda catchment

Zone	Simulated Maximum Flood Water Depths (m)		Cyclonic Rainfall
	ARI Rainfall Event		
	100-year	1,000-year	Trixie (1975)
1	6	3.5	1.8
2	3.5	4.3	2.6
3	5.5	6.3	2.7
4	8.2	9.4	2.9

Simulated peak flood depths in the Yeelirrie Playa catchment indicate a maximum flood depth of 3.4 m for Zone 1 and 3.7 m for Zone 2.

Table 9-40 shows the baseline simulated maximum flood depths on the watercourse reaches immediately upstream and downstream of the proposed Project Area and on the Yeelirrie Playa. Stream flows along the main channel and into the Yeelirrie Playa start to occur during the 20 year ARI event. The maximum flood depths occur where the stream flow slows and pools at low points along the main valley floor flow paths.

Table 9-40: Simulated baseline maximum flood water depths on selected watercourse reaches

Event ARI (years)	Simulated Maximum Flood Water Depths (m)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
1	<0.1	<0.1	<0.1
5	0.1 – 0.25	0.25 – 0.5	0.25 – 0.5
20	0.25 – 0.5	0.5 – 0.75	0.5 – 0.75
100	0.75 – 1.0	0.75 – 1.0	0.75 – 1.0
1,000	2.0 – 2.5	1.5 – 2.0	1.5 – 2.0

Simulated regional baseline maximum flow velocities range up to 1 m/s. However, due to the natural attenuation in the catchment area, the simulated flow velocities have relatively little variation across the catchment.

Surface Water Quality

Opportunistic surface water sampling was completed during two rainfall events that occurred on 24 June 2009 (9.2 mm) and 21 – 22 March 2010 (42.6 mm). Due to the lack of physical access from isolated flooding during the rainfall events, only six surface water samples were collected from the following locations:

- SW4: Upstream Central Valley Playa Land System
- SW3: Northern Flank – Wash Plain Land System
- SW6: Northern Flank – Downstream Wash Plain Shedding to Yeelirrie Playa
- SW2: Southern Flank – Downstream Breakaway Land System
- SW5: Yeelirrie Playa
- SW1: Outskirts Albion Downs Playa

Surface water sampling results are provided in Table 9-41.

Table 9-41: Indicative surface water quality parameters

Parameter	Units	SW4	SW3	SW6	SW2	SW5	SW1
Physical Parameters							
TDS	mg/L	23	<5	123	824	16,800	4,130
Selected Ions							
Na	mg/L	1	<1	2	45	119	26
Cl	mg/L	<1	<1	1	61	97	13
SO_4	mg/L	3	<1	2	11	10	2
Total Alkalinity (as $CaCO_3$)	mg/L	5	4	2	27	314	56
Selected Metals (Dissolved)							
Al	mg/L	0.11	0.28	0.04	-	6.28	-
Fe	mg/L	0.07	0.27	<0.05	<0.05	1.43	3.66
Mn	mg/L	0.04	0.014	0.05	-	0.079	-
Zn	mg/L	0.03	<0.005	0.07	<0.005	0.020	0.012
Sr	mg/L	0.01	0.002	0.005	0.022	0.022	0.006
V	mg/L	<0.01	<0.01	<0.01	<0.01	0.080	<0.01

The data from the available surface water samples (measured in the short-term after rainfall) indicate the surface water is fresh, with relatively low concentrations of chloride, sodium, sulphate and bicarbonate. Samples collected from the Yeelirrie Playa and Albion Downs Playa had comparatively high levels of total dissolved solids (TDS) of 16,800 and 4,130 mg/L, respectively. The measured TDS concentrations, however, are known to include suspended sediments.

The measured chloride concentrations of < 1 to 1 mg/L occur within the upper catchment reaches of watercourses and align with low TDS measurements. These measurements may reflect both low chloride contents in rainfall and limited dissolution and mobilisation, of stored salts either on the surface or in shallow soils.

Measured chloride concentrations in the vicinity of the Yeelirrie and Albion Downs Playas, are indicative of fresh waters at the time of sampling. However, the measured chloride concentrations are not aligned with the TDS concentrations. This indicates there is likely to be evaporation concentration processes and dissolution of stored salts that influence the salinity of infiltrates reporting to the water table.

9.4.5 Potential Impacts

9.4.5.1 Surface Water Impacts

Surface water diversion

To prevent the inflow of surface water runoff into the proposed mine site area, a surface water diversion bund would be constructed to divert surface water runoff and stream flow around the active mining area during the operations. The diversion bund, which has been designed to protect the mine site from a 1,000 year ARI flood event, will be constructed in two stages to minimise the amount of runoff and rainfall that would collect within the mine area and require management (Figure 9-24 and Figure 9-25). The baseline streamflow paths (northern and southern channel) would be partially blocked due to the construction of the surface water diversion bund. Therefore, a diversion channel would be required to drain the flood waters from the northern watercourse, around the minesite and into a combined watercourse (which approximately aligns with the existing southern watercourse) along the western and southern perimeters of the mine, protected by a surface water diversion bund.

Diversion of natural surface water drainage lines will alter the baseline hydrology during a significant flood event. However, the modelling indicates that water would not flow within the catchment as a connected watercourse, unless a storm event in excess of a 20 year ARI occurred. The modelling predicts that for the duration of the mine operation, and up to a (hypothetical) 1,000-year ARI event, the surface water diversion bund would:

- prevent external catchment surface water from draining into the proposed Project mine site area, and
- prevent the surface water runoff that collects interior of the surface water diversion bund from discharging uncontrolled outside the bund into the natural environment.

Hydrological changes outside the diversion bund

The modelling indicates that outside the surface water diversion bund the predicted changes resulting from a (hypothetical) flood event include a temporary:

- increase in the water depth immediately upstream of the mine due to ponding;
- increase in the stream flow velocity of water draining around the western and southern perimeter of the mine area (through the proposed diversion channel and between the minesite and southern valley slope);
- increase in the baseline water depth and flow volume immediately downstream of the mine area due to retardation of stream flow upstream of the mine site.

Changes to inundation and water depths

Simulated flood water depths and differences from the baseline are shown in Table 9-42.

Changes to flow velocities

The simulated stream flow velocities along the valley floor are variable and comparatively low (< 1 m/s). This is as a result of the wide and flat valley floor with intermittent attenuation in local depressions, clay pans and playas. There are predicted to be only subtle changes in stream flow velocities for events greater than a 20-year ARI. The simulated differences in stream flow velocity as a result of the Project are not considered significant.

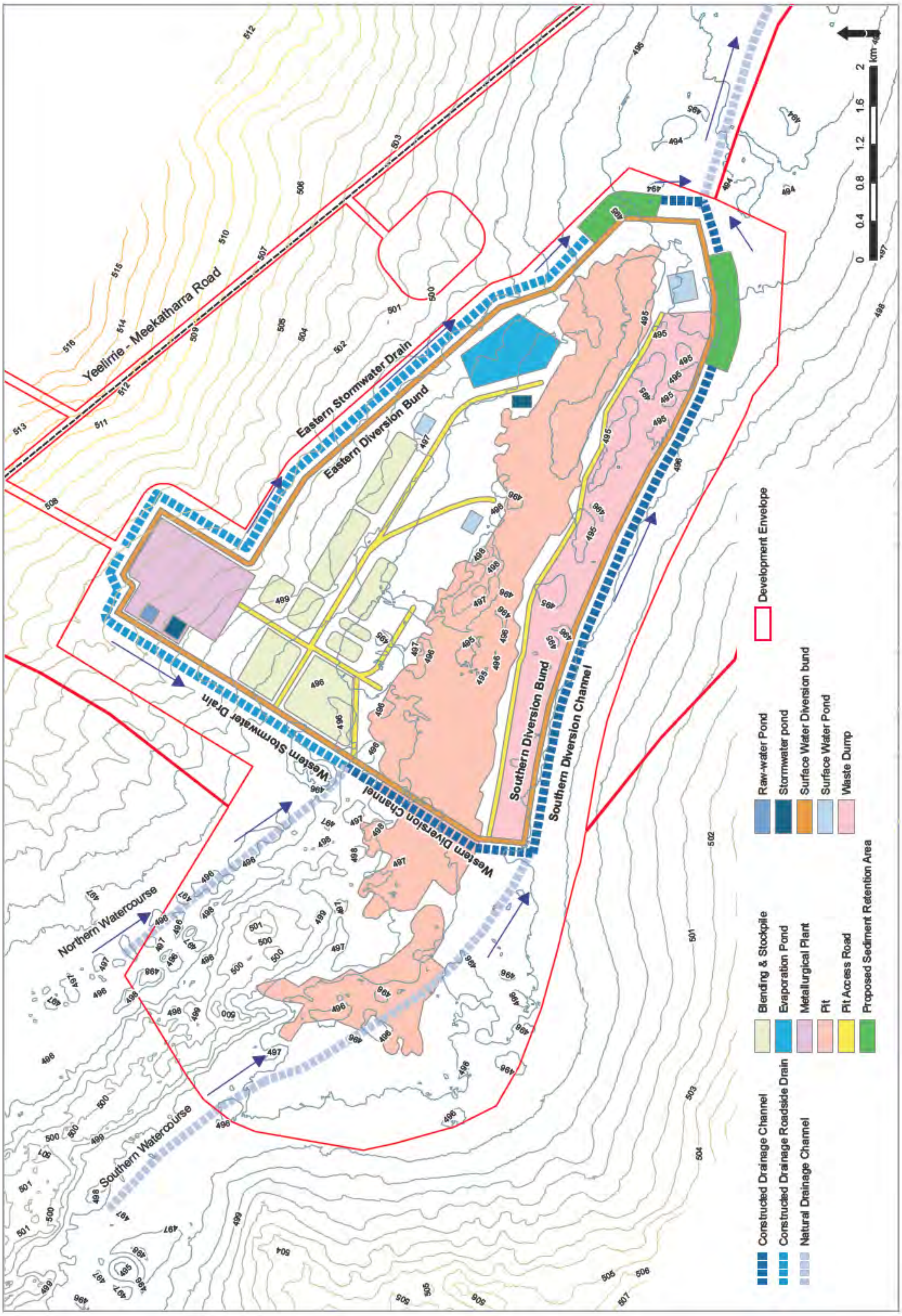


Figure 9-24: Conceptual diversion bund layout Stage 1 (year 1 to 7)

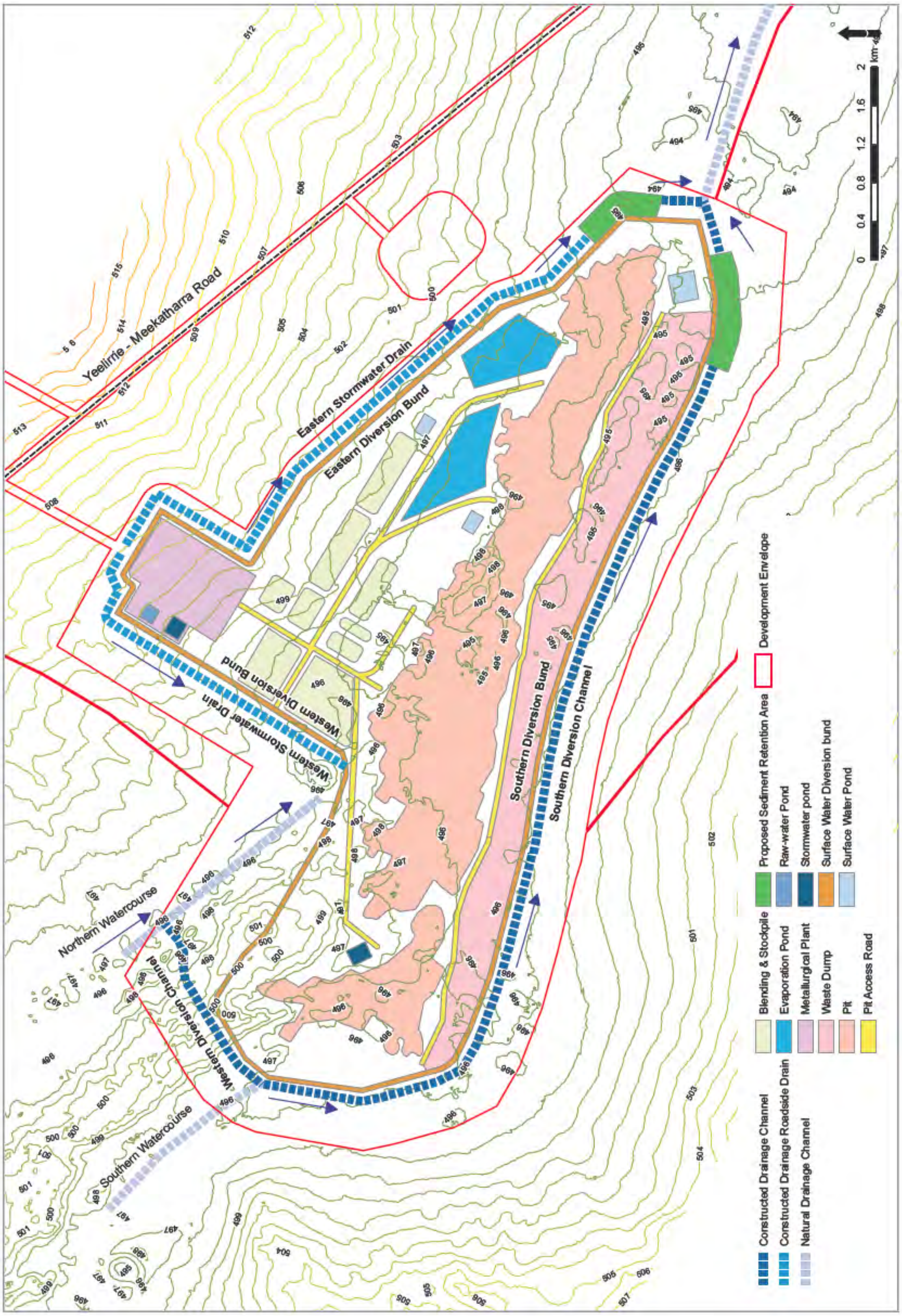


Figure 9-25: Conceptual diversion bund layout Stage 2 (year 8 to 22)

Table 9-42: Simulated flood water depths and differences from baseline

Event ARI	Simulated Maximum Flood Water Depths (m)			Simulated Maximum Difference from Baseline (m)		
	Upstream Reaches	Downstream Reaches	Yeelirrie Playa	Upstream Reaches	Downstream Reaches	Yeelirrie Playa
Stage 2 – Year 8-22 Yeelirrie Playa Catchment Model						
1	0.1	<0.1	0.5	0.1	-0.1 – 0.1	-0.1 – 0.1
5	0.5	0.25 – 0.5	0.25 – 0.5	0.25	-0.1 – 0.1	-0.1 – 0.1
20	0.5 – 0.75	0.50 – 0.75	0.50 – 0.75	0.5	-0.1 – 0.1	-0.1 – 0.1
100	1.5 – 2.0	1.0 – 1.5	1.0 – 1.5	1.25	0.25 – 0.5	0.25 – 0.5
1,000	4.5 – 5.0	1.5 – 2.0	2.0 – 2.5	2.5	-0.1 – 0.1	-0.1 – 0.1

Changes to streamflow hydroperiods

The altered hydrology is predicted to change the surface water availability on watercourse reaches upstream and downstream of the surface water diversion bund. The attenuation of flood waters on the upstream reaches of the surface water diversion bund may increase the hydroperiods for stream flow. Six sites were selected as points of interest and the Yeelirrie Playa hydraulic model was used to simulate flood depths at these locations.

At the three sites upstream of the surface water diversion bund, the simulated hydroperiods during Stage 1 showed no significant change from baseline. During Stage 2 of the Project (years 8-22) the simulated hydroperiods were extended by more than 200 hours for a 20 year ARI event and more than 500 hours during a 100 year ARI event. This indicates that the surface water diversion bund resulted in flood waters backing up, upstream of the bund which causes attenuation of flows. At sites downstream of the proposed Project, there were no changes in simulated hydroperiods during Stage 1 and minor changes during Stage 2.

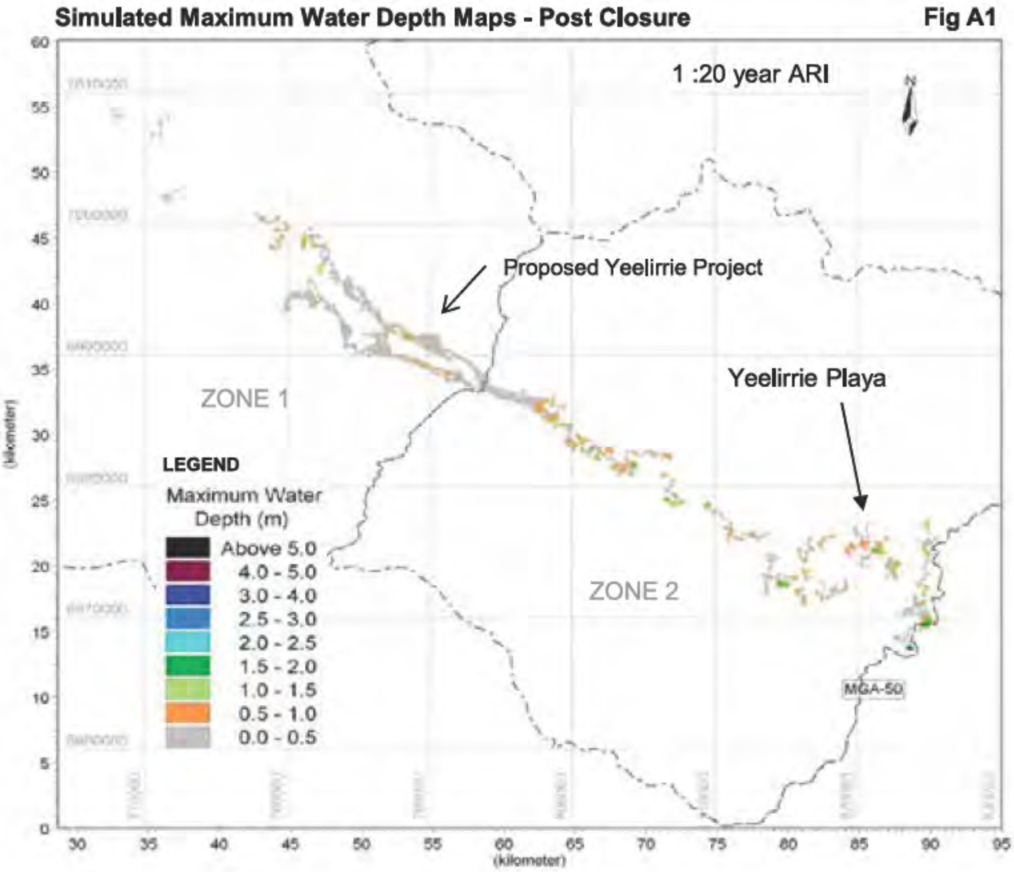
Changes to erosion and sedimentation characteristics

Based on the predicted changes in stream flow velocities along the valley floor, changes to erosion and sedimentation characteristics as a result of the Project were assessed. During more frequent flow events (up to 20 year ARI) the catchment runoff drains to the valley floor and ponds locally in valley depressions. As there is little stream flow there is little to no sediment transportation along the valley floor and therefore no changes in the erosion and sedimentation characteristics predicted as a result of the Project.

During the less frequent and more extreme events that result in stream flow along the valley floor there is the potential for change in the erosion and sedimentation characteristics of the catchment as a result of the Project. The predicted ponding of surface water flows upstream of the Project as a result of the flood bunds is expected to result in sediment deposition, although it is not considered to be significant. The resultant overall change to downstream sediment loads is also considered to be insignificant.

Model predictions for the more extreme events indicate that the streamflow velocities along the southern flood protection bund could reach up to 2 m/s and may result in localised erosion along this stretch of the bund. The eroded sediments are expected to drop out downstream of the Project in areas where stream flows start to pond, or once stream flows are reduced after the rainfall event (e.g. in valley floor depressions and playas).

Maximum water depths and difference from baseline for 20-, 100-year and 1,000-year ARI events are presented in Figure 9-26, Figure 9-27 and Figure 9-28.



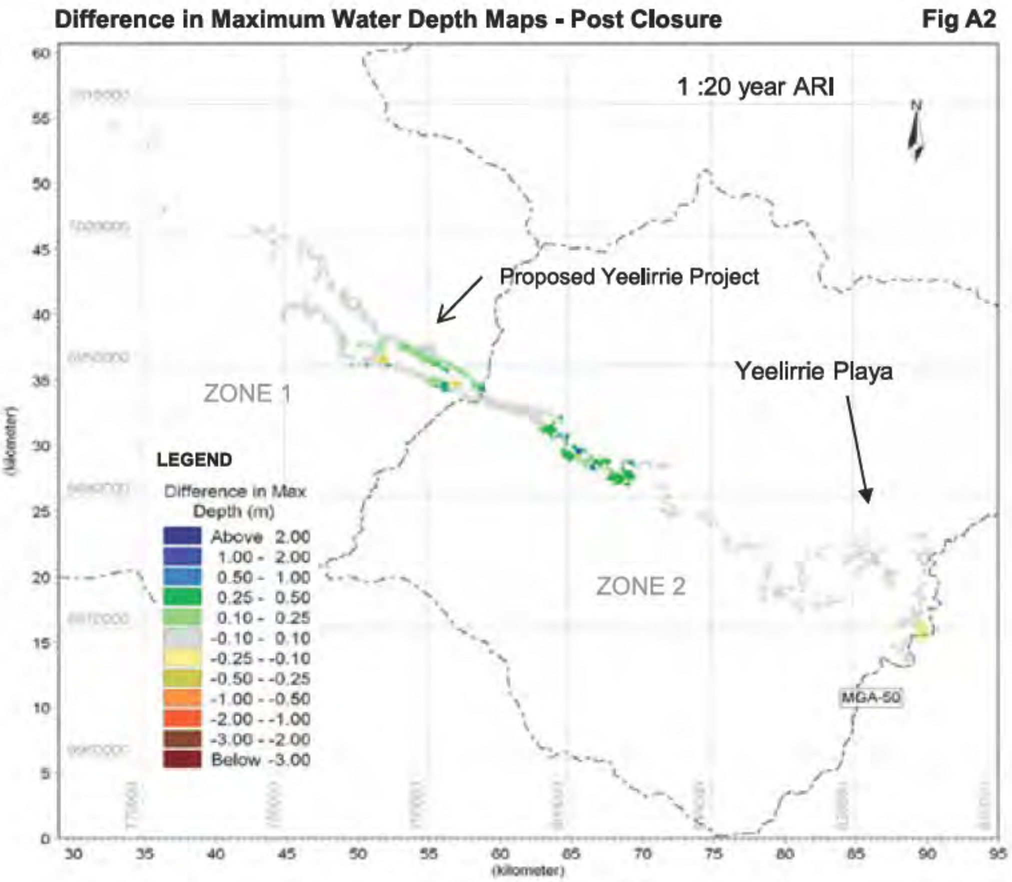
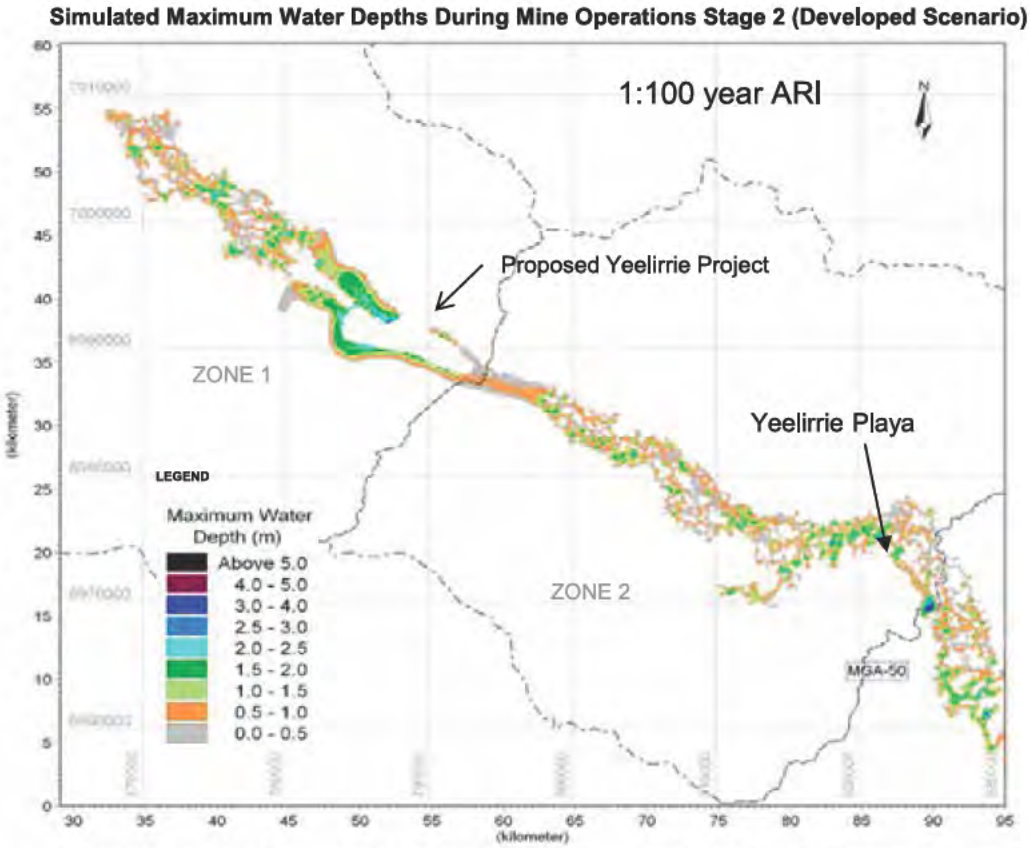


Figure 9-26: Maximum water depths and difference from baseline for 20 year ARI events



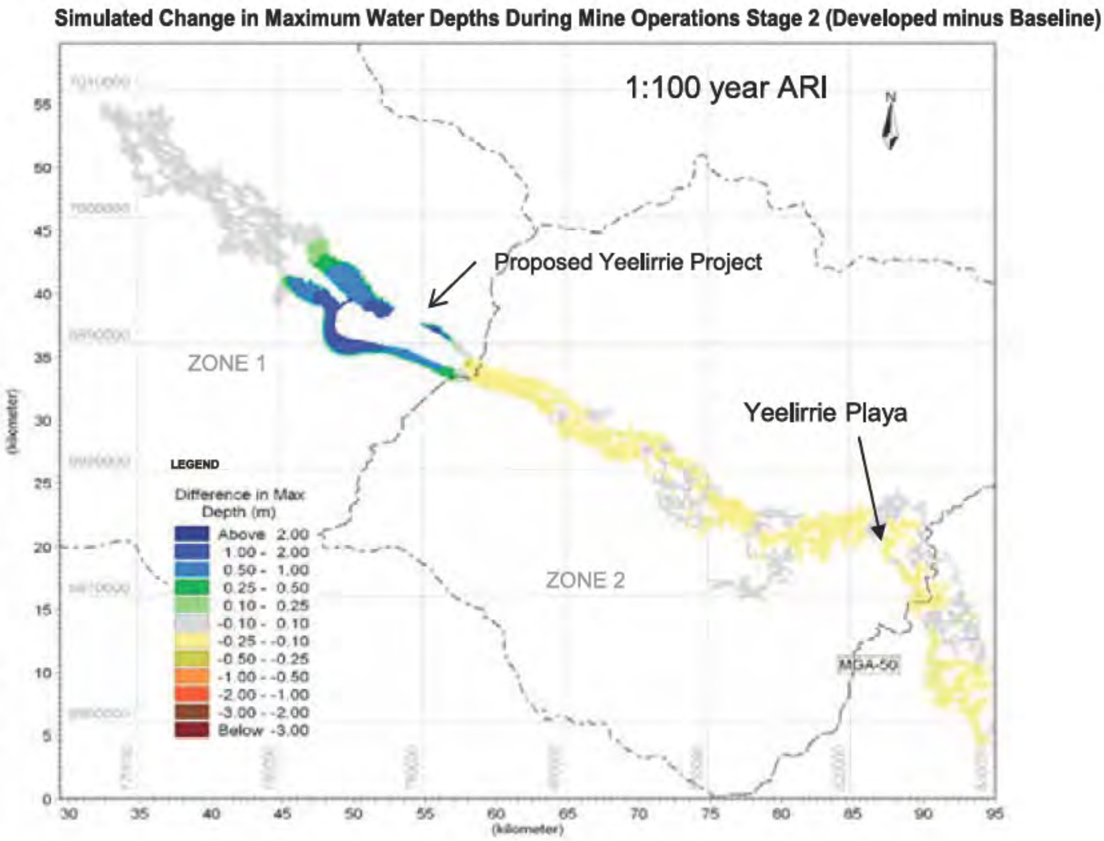


Figure 9-27: Maximum water depths and difference from baseline for 100 year ARI events

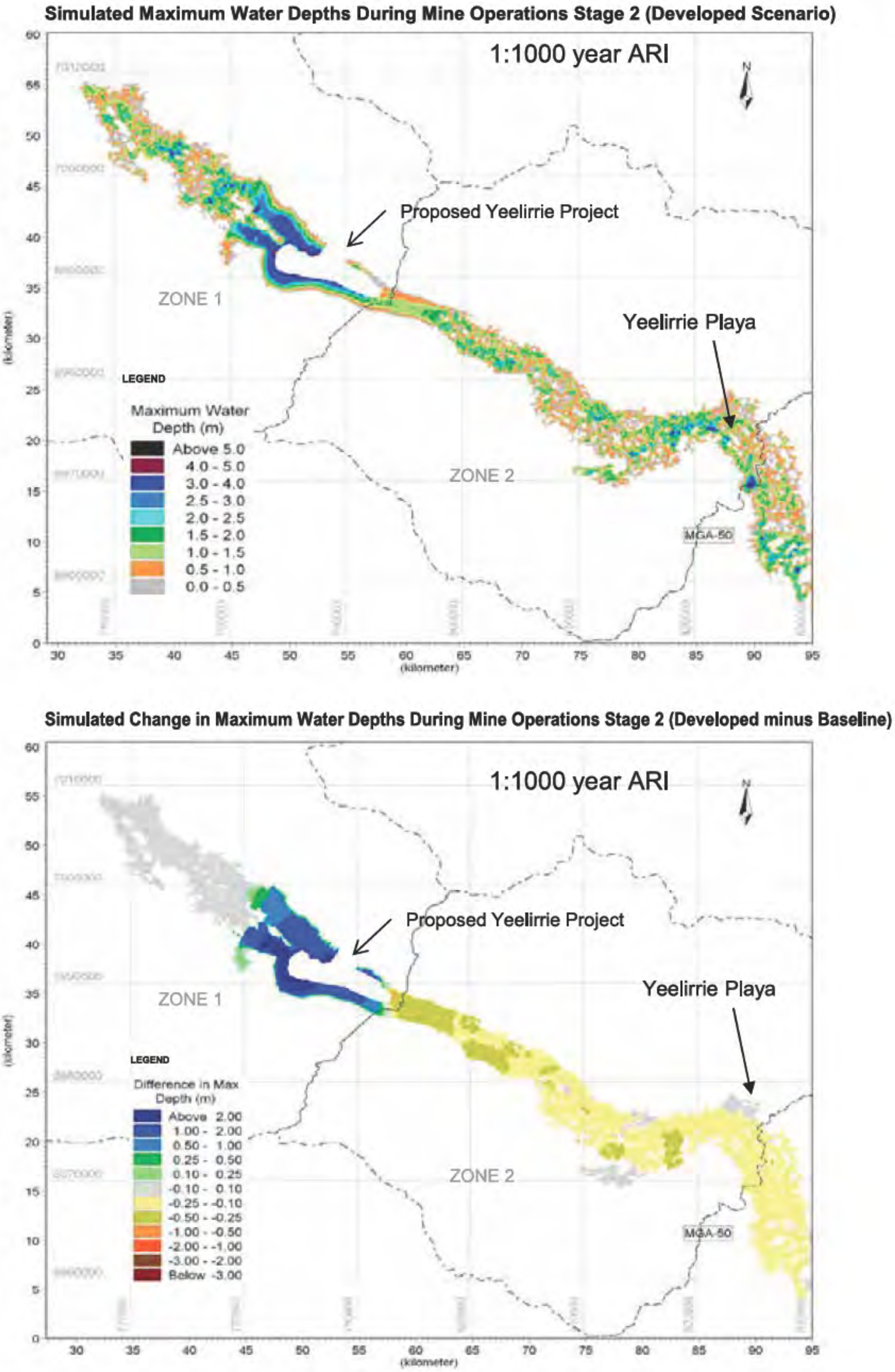


Figure 9-28: Maximum water depths and difference from baseline for 1000 year ARI events

Hydrological changes inside the diversion bund

Stormwater runoff will be captured in stormwater ponds located within the minesite. The ponds will be designed to capture runoff from a 20 year ARI event. If however the rainfall exceeds design capacity, the stormwater pond would be discharged to other storage facilities including the Evaporation Pond, the tailings storage facilities and ultimately into inactive pits. The capacity of the minesite to contain excess water under 1:20, 1:100 and 1:1,000 year ARI rainfall events has been assessed.

The assessment indicates that providing the far eastern section of the flood protection bund is of sufficient height (i.e. 3 m high) and engineered to retain flood waters on site (and keep external floodwaters out) the minesite is able to contain the in-bund stormwater runoff for a 1:1,000 year ARI rainfall event. Therefore, the minesite is expected to operate as a no-discharge site. However, depending on the development stage of the mine, there will be operational requirements to manage and discharge excess water.

Hydrological changes on mine closure

Details on proposed mine closure are provided in Section 9.12. Following mine closure and removal of the diversion bund, the simulated maximum water depths and difference from the baseline maximum water depth for the 1:20, 1:100, 1:1,000 year ARI rainfall events and PMP are shown in Figure 9-29 to Figure 9-32. The simulations show that:

- For the 1:20 year ARI event there is no significant change from baseline. The backfilled pit area would not be subject to inundation.
- The significance for the 1:100 year ARI event is assessed based on Figure 9-30. The difference in maximum water depth is due to a shift in flow path from the baseline location and therefore does not indicate additional ponding.
- For the 1:100 year ARI event the localised increase in flood water depths around the post-closure minesite are a little more significant, especially in the northern watercourse. However, a significant part of the water depth rise is due to the flow constriction of the flow through the northern water course channel. The backfilled pit area would not be subject to inundation.
- The significance for the 1:1,000 year ARI event is assessed based on Figure 9-31. The inundation of the backfilled area occurs during the peak flow period of the flood event and will recede as soon as the flood hydrograph recedes. During this relatively short period of inundation infiltration into the closed landform would potentially occur.
- For the 1:1,000 year ARI event the localised increase in flood water depths around the post-closure minesite appears more significant in both the north and south watercourses. However, a significant part of the water depth rise is due to the constriction of the flow through the northern water course channel. This change is considered relatively small and limited to the immediate vicinity of the post-closure landform. Changes upstream and downstream of the post-closure landform are considered insignificant. Under the 1,1000 year ARI scenario, the post-closure backfilled pit area would be subject to inundation for the duration of the event and surface water would potentially infiltrate the closed landform.
- The significance for the PMP event is assessed based on Fig 9-32. The assessed significance is based on the relatively small change compared to baseline conditions under this most extreme and unlikely event.
- For the PMP event the localised increase in flood water depths around the post-closure landform appears more significant immediately upstream of the minesite. This is due to the constriction of the flow through the site. A predicted flood level change of less than 0.5 m in a limited area upstream of the minesite is predicted and not significant. Under the PMP scenario, the backfilled pit would be subject to significant inundation for the duration of the event and surface water would potentially infiltrate the closed landform.

- The areas and extend of temporary pooling are shown on the difference in maximum water depth maps for each of the flow events. This indicates the maximum extend of the change in water depth at the time of peak discharge. The increase in water level should not be interpreted as pooling as although the water depth has increased, the water is flowing as indicated by the flow velocity figures (not shown). The areas indicate a temporary increase in water depth compared to baseline (green and blue is pooling).

9.4.5.2 Water Balance

Water balance modelling was undertaken for the Yeelirrie Project to validate the performance of the Project Water Management Strategy (WMS). The methodology and key assumptions for the water balance assessment are outlined in URS (2015b) (Appendix H2). The water balance for the Project is summarised below. A schematic figure of the water balance model is presented in Figure 9-33.

The modelling indicates that peak water supply demand during mining will be 8,750 kL/day and required for years 4 to 18. Water supply for the Project will be obtained from the following sources:

- groundwater dewatering / abstraction (to Raw Water Pond 2 [RWP2]);
- brackish wellfields (to Raw Water Pond 1 [RWP1]);
- saline wellfields (to RWP2);
- pit floor dewatering (to RWP2); and
- stormwater runoff (collected at 7 stormwater ponds located at natural low points within each of the sub-catchments within the mine site[1]).

The TDS concentration of water from the TSF is expected to reach 350,900 mg/L and therefore only about 10% (853 kL/day) of the decant water from the TSF can be reused in the processing plant. The remaining water will be sent to the Evaporation Pond to be evaporated as part of the brine management strategy. The Evaporation Pond will be constructed with multiple cells and have a surface area of 50 ha. The salt in the Evaporation Pond will be removed and transferred to the TSF to maintain the salinity of the pond below 200 g/L.

During high rainfall events, transfer of water from the TSF to the Evaporation Pond will cease with excess water retained on the TSF, or pumped to an open pit for temporary storage. In this event, abstraction from the borefields would cease until excess water was used.

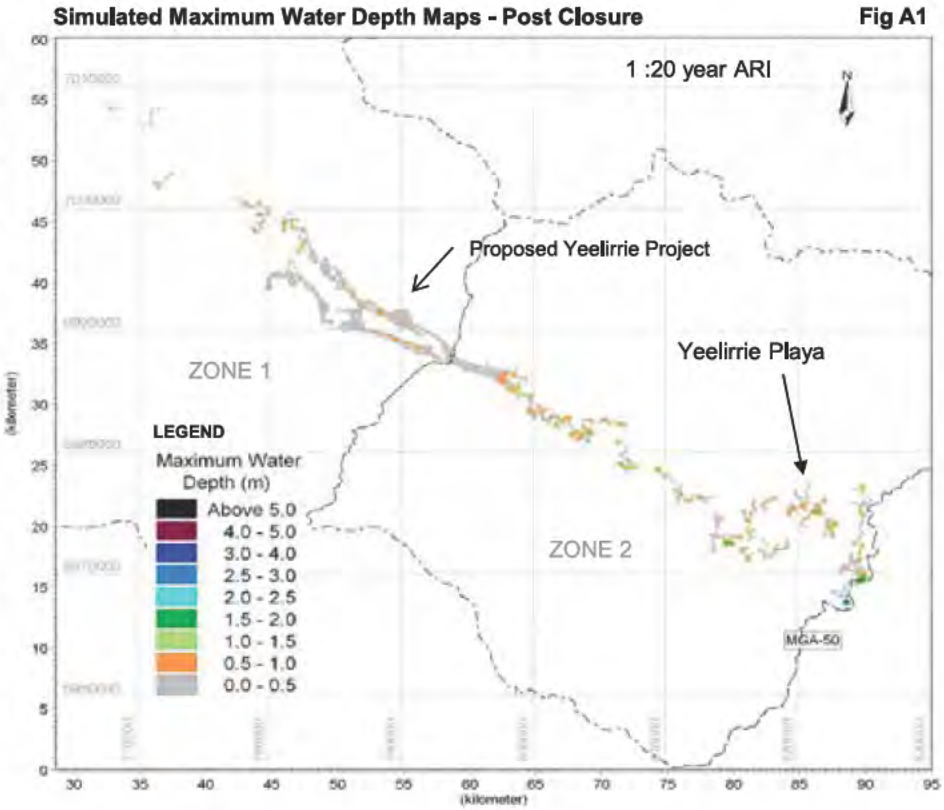
Groundwater dewatering will flow to Raw Water Pond 2 (RWP2) and is estimated to be 18,610 ML throughout the LoM.

Based on the brackish water demand and proposed operating rules (e.g. maintaining four-day operational storage for Raw Water Pond 1 [RWP1] which has 10 ML capacity) the model estimated that between 980 and 1,110 ML/year (16,860 – 16,920 ML) of brackish water will be required throughout the life of mine (LoM).

Based on the saline water demand and proposed operating rules (e.g. maintaining four-day operational storage for RWP2 which has 25 ML capacity) it is estimated that 510 to 1,280 ML/year (16,100 – 16,480 ML) of saline water will be required throughout the LoM.

The water balance assessment indicated that the proposed WMS is adequate to contain mine water onsite.

1. The stormwater runoff ponds were not represented in the GoldSim model for the reasons outlined in URS (2015b).



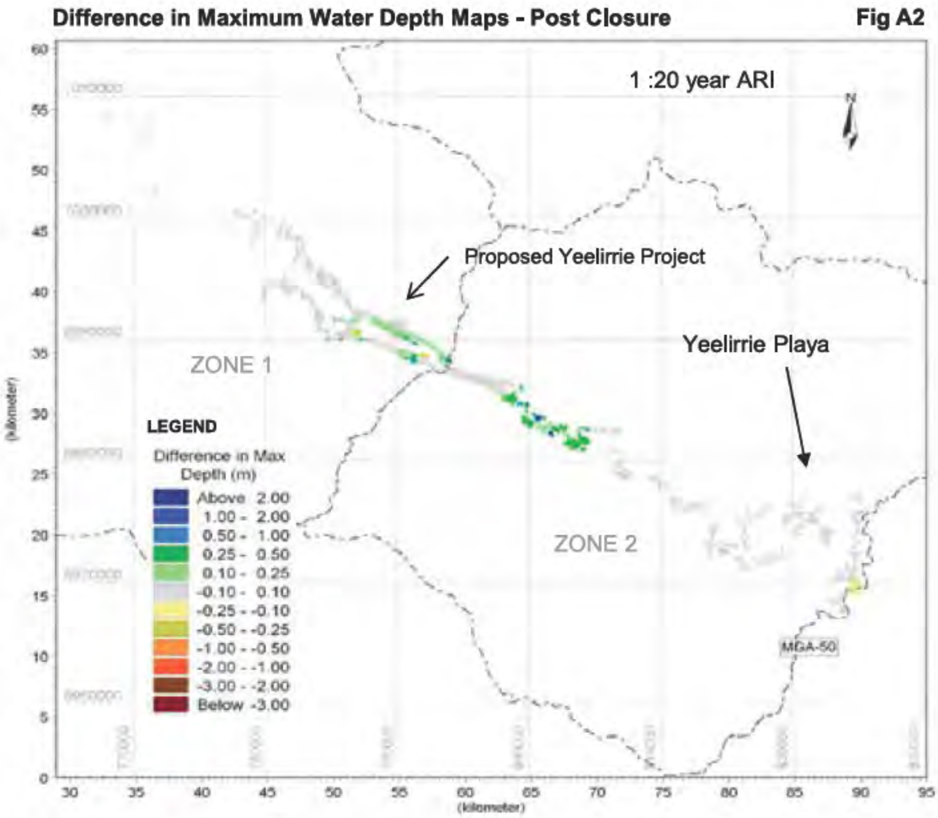


Figure 9-29: Basecase conceptual landform design difference in maximum water depths from baseline (20-year ARI)

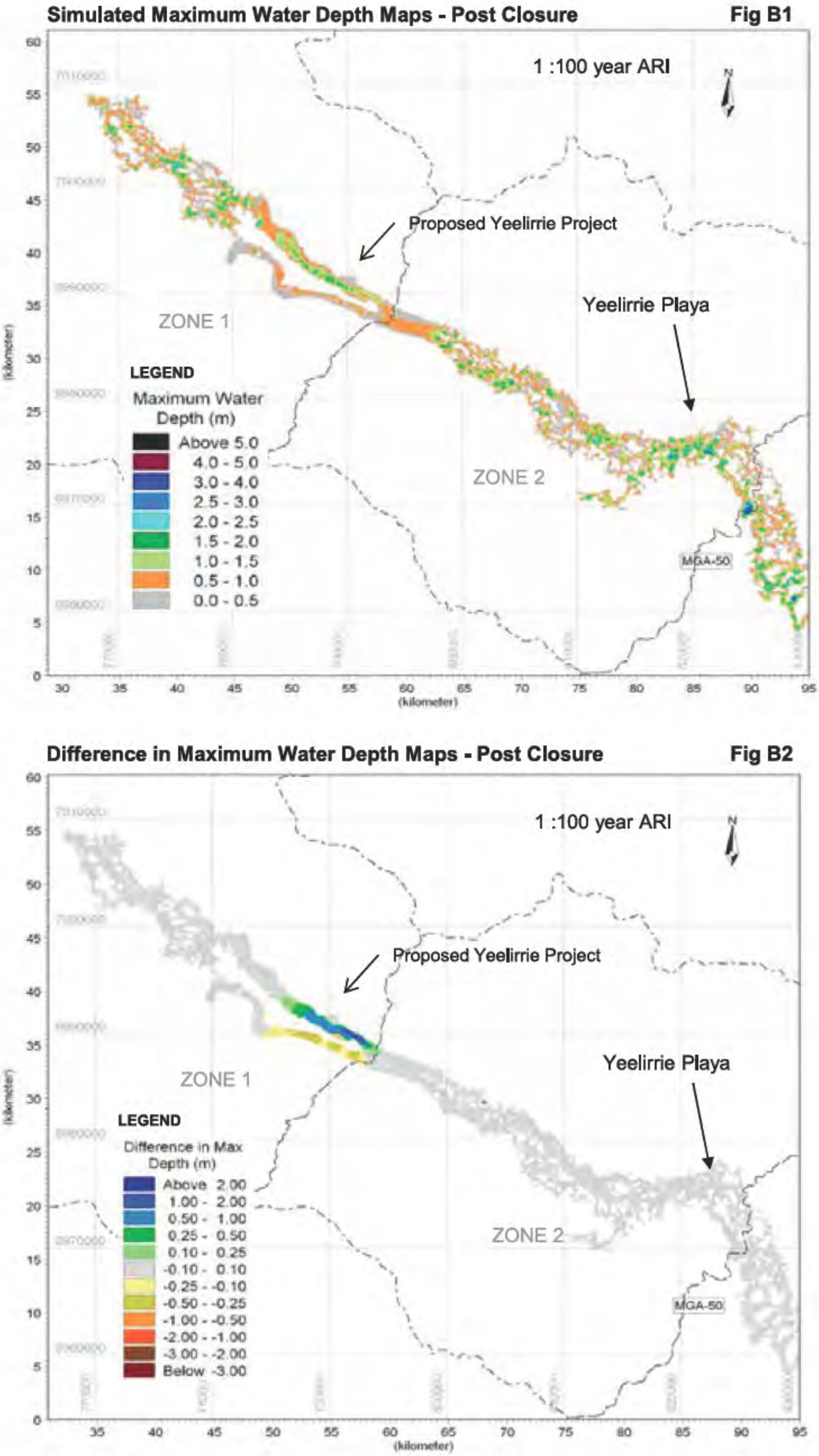


Figure 9-30: Basecase Conceptual Landform Design Difference in Maximum Water Depths from Baseline 100 yr ARI

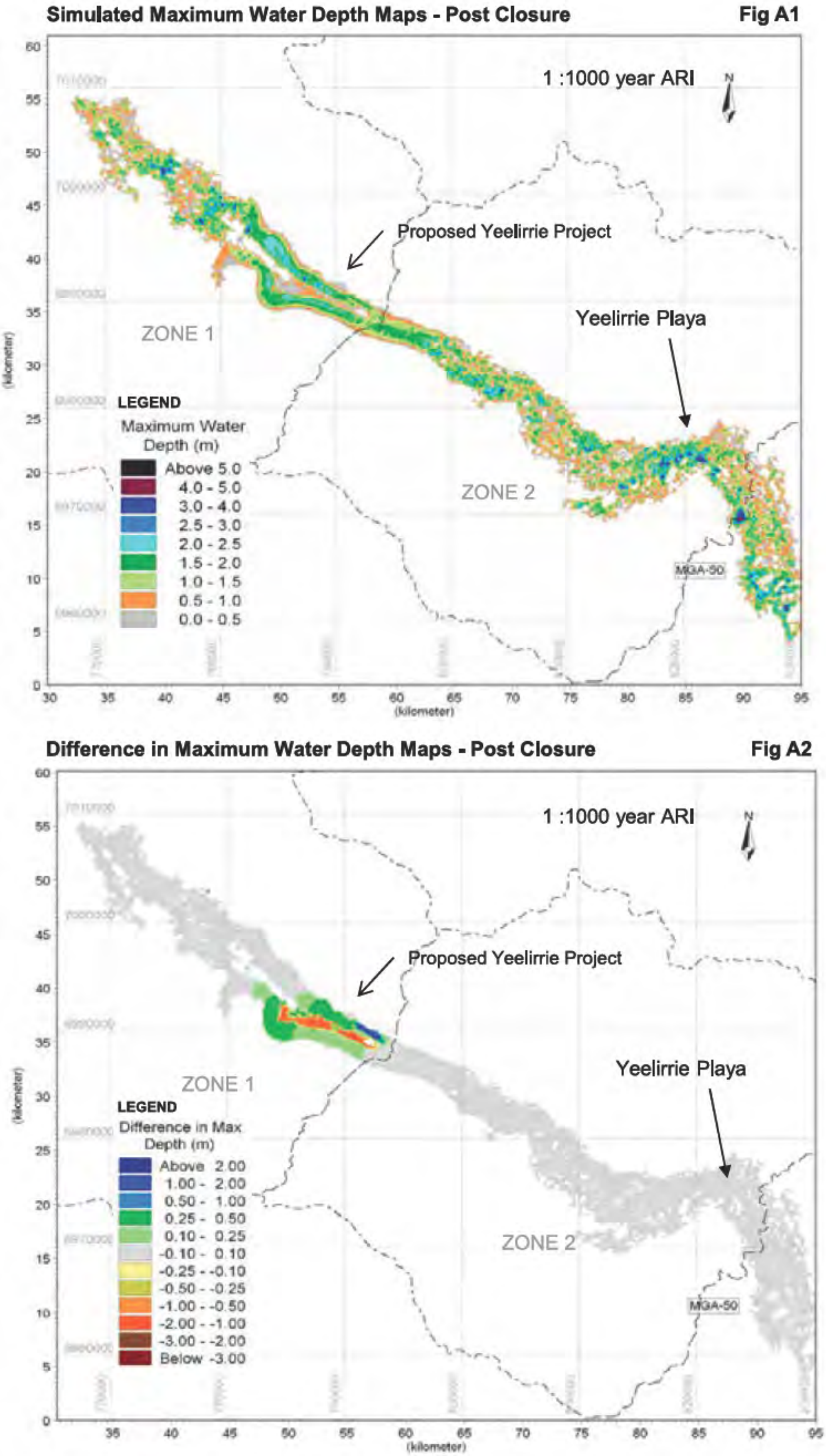


Figure 9-31: Basecase Conceptual Landform Design Difference in Max Water Depths from Baseline 1000 yr ARI

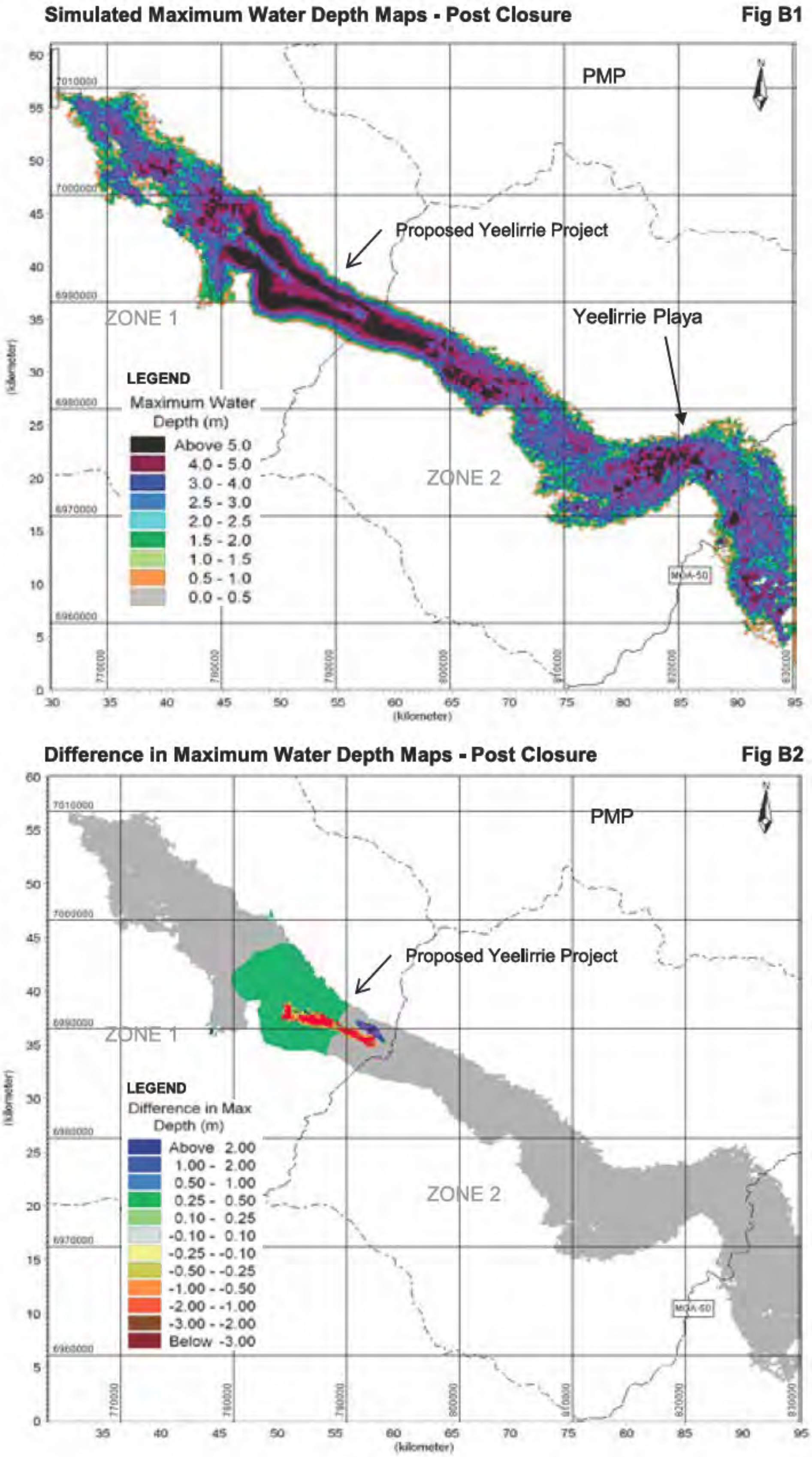


Figure 9-32: Basecase Conceptual Landform Design Difference in Max Water Depths from Baseline PMP

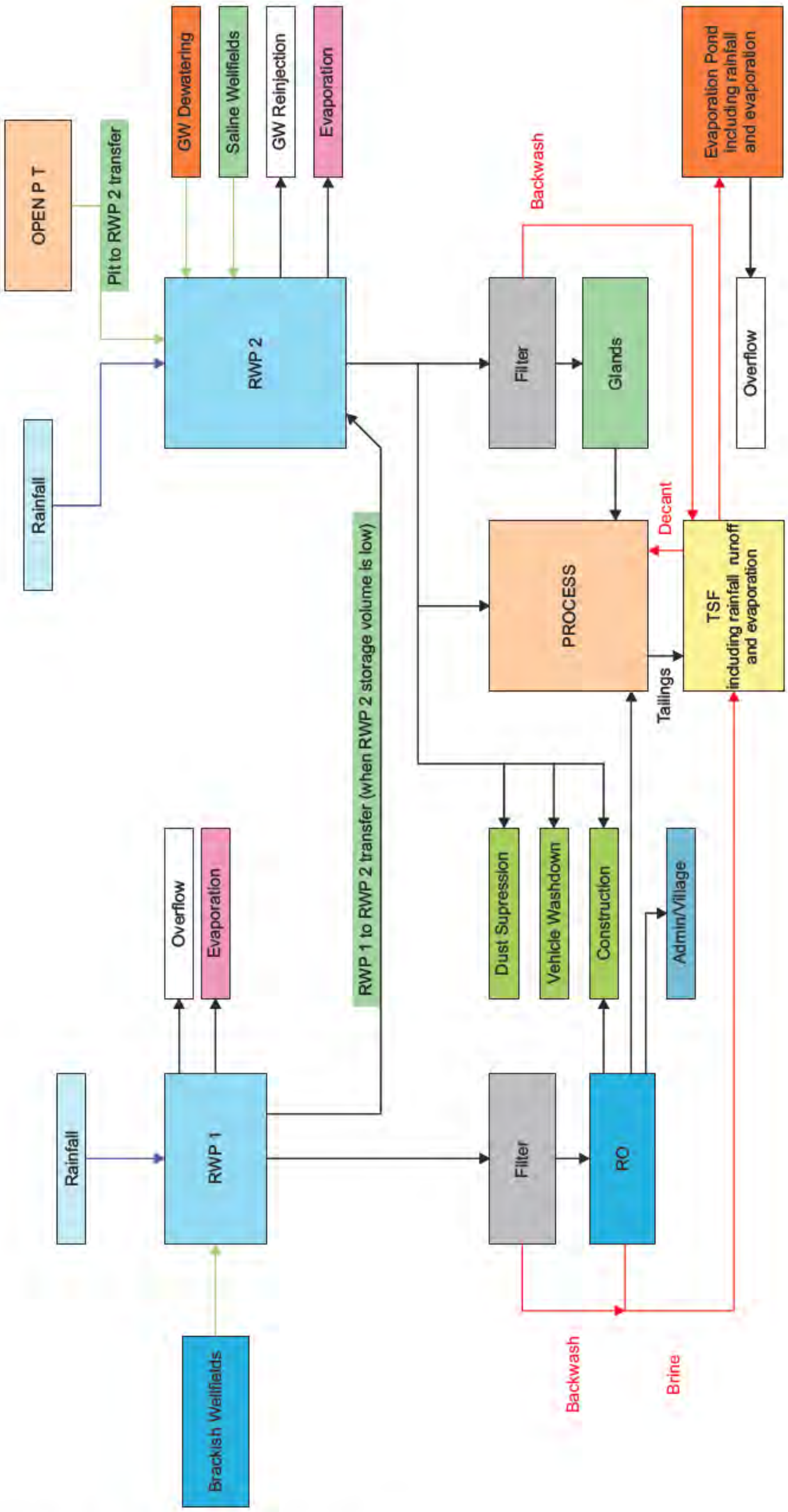


Figure 9-33: Water balance model schematic

9.4.6 Management

Avoid and Minimise

Cameco will develop and implement a Surface Water Management Plan to minimise the impacts on surface water and ensure no release of contaminants to the environment.

The proposed Project would be developed in two stages chiefly to minimise the development foot print and disturbance area, as well as minimise the volume of surface water runoff inside the bund that requires management.

Cameco will construct the surface water diversion bund and diversion channels as showing in Figure 9-24 and Figure 9-25.

To manage and mitigate the potential sediment in the diversion channels, the Project allows for the construction of sedimentation basins at the downstream (eastern) ends of the diversion channel. These basins will slow down the surface water flows in the diversion channels thereby dropping out the suspended sediments before discharging into the surface water environment downstream.

The surface water diversion bund has been designed to protect the mine site and retain floodwater within the bund, from a 1-in-1,000 year ARI flood event. Therefore the site has been designed to operate as a 'no release' site.

Stormwater runoff will be captured in a series of stormwater ponds located within the mine site designed to capture a 1-in-20 year ARI event. If however, rainfall exceeds design capacity, the stormwater would be directed to inactive pits.

The ROM pad and other stockpile areas would be compacted to control seepage and would be graded so that runoff and seepage would be directed to a storm water runoff pond. Water captured in the ponds would be used to supplement the water supply for the processing plant.

Storage areas for process chemicals and liquors will be sealed and bunded to ensure that and process spills can be contained and easily cleaned up.

Rehabilitate

On closure, all mineralised material will be processed or placed back into the open pit which will be backfilled and an engineered cover constructed over the in-pit TSF. Surface water drainage patterns will be reinstated around the final landform.

9.4.7 Commitments

Cameco commits to development and implementation of a Surface Water Management Plan.

9.4.8 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objectives with regards to Hydrological Processes and Inland Water Quality (Surface Water).

9.5 Hydrological Processes and Inland Water Quality (Groundwater)

9.5.1 EPA Objective

The EPA's objective with regards to hydrological processes for groundwater is:

- To maintain the hydrological regimes of groundwater so that existing and potential uses, including ecosystem maintenance, are protected.

The EPA's objective with regards to inland water quality for groundwater is:

- To maintain the quality of groundwater and biota so that the environmental values, both ecological and social are protected.

9.5.2 Relevant Legislation and Policy

The DoW draft guideline on the management of water in mining in Western Australian (DoW 2012) provides guidance on water management issues that need to be considered by mining projects and the type of information the department may require as part of the licence assessment process.

In WA, the DoW issues licenses and permits under the *Rights in Water and Irrigation Act 1914* (RIWI Act) that protect the State's water resources and promotes the sustainable and efficient use of water. Cameco will apply for a 5C licence to take water under the RIWI Act.

The DoW has also released a state-wide Environmental Water Provisions Policy (Water and Rivers Commission 2000). The primary objective of this policy is to provide for the protection of water dependent ecosystems whilst allowing for the management of water resources for their sustainable use and development to meet the needs of current and future users. It outlines the guiding principles to be followed by DoW when making decisions related to the provision of water to the environment.

The ANZECC and the ARMCANZ have developed the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). The objective of these guidelines is to provide a national framework for the protection of water bodies from contamination as part of Australia's NWQMS. The scope of the documents includes a set of actions currently in practice all over Australia, and recommendations on how to implement or adapt new strategies to any groundwater body localities.

9.5.3 Studies and Investigations

9.5.3.1 Overview

The required work relating to groundwater is outlined in the ESD under Hydrological Processes / Inland Waters Environmental Quality (Appendix A1).

The hydrogeology of the proposed development area and catchment has been extensively studied since the early 1960s. The understanding of the groundwater regime and the assessment of potential groundwater impacts presented in this chapter is based on the knowledge gained from these previous studies and on other detailed work undertaken by Cameco. Essentially, the previous studies undertaken were used to develop a conceptual hydrogeological model and a numerical groundwater flow model (URS 2011). Cameco adapted this model to simulate the groundwater behaviour under the proposed operating conditions. Cameco also undertook further studies (concentrations of contaminants that could be released in solute [referred to as 'source terms'] of tailings and mine waste that would be generated) and modelling (solute transport modelling) to simulate the likely movement of contaminants in the groundwater over time following mine closure.

An independent external consultant has undertaken a review of the groundwater modelling undertaken by Cameco. A copy of the review is provided as Appendix I3.

The DoW has advised in writing (email dated 29th April 2015) that the work presented by Cameco to assess groundwater impacts meets the requirements of a H3 level of assessment as outlined in DoW Operational Policy No. 5.12 (DoW, 2009).

A summary of key studies used to inform this assessment is provided below.

9.5.3.2 Previous studies

Slot 1 mining trial

In 1972, WMC conducted an extensive trial mining operation, referred to as the Slot 1 trial, to support a pilot scale metallurgical testing program. This trial provided 'real' data for understanding of the mining site's underlying hydrogeological regime, the required dewatering rate and the water table drawdown in the surrounding area.

The Slot 1 excavation had dimensions of 457 m [l] x 46 m [w] x 9.1 m [d]. Dewatering, via excavated trenches, was undertaken to determine the upper limit of groundwater abstraction required to dewater the slot. During the mining trial, transient groundwater levels within the main water bearing aquifer in the catchment area (calcrete and transition calcrete successions) were measured in numerous mineral exploration monitoring wells. This trial enabled the assessment of the local aquifer responses to groundwater abstraction over a period of 98 days. The results of this trial were used subsequently to construct and calibrate the numerical groundwater flow model (URS, 2011).

Groundwater studies prior to 2009

In the early 1970s and 1980s numerous groundwater investigations were commissioned for the Yeelirrie Catchment. These studies included groundwater level monitoring, groundwater quality analyses, hydrogeological investigations and water supply studies.

The key reports reviewed and prepared as part of the baseline studies include the following:

- Australian Groundwater Consultants Pty Ltd. (1972): A preliminary study of water supply that included a census of 22 wells in the Yeelirrie Catchment, providing information on depths, groundwater levels and salinity and catchment lithology.
- Western Mining Corporation (1978): A report that included investigating groundwater contours and groundwater quality. The groundwater quality data are sourced from 26 windmills, 25 geological exploration wells, and two deep groundwater wells.
- Australian Groundwater Consultants Pty Ltd. (1981): A comprehensive study of water supply options to inform feasibility of supply, inclusive of site investigations to indicate aquifer storage, hydraulic characteristics and groundwater quality within selected potential source areas.
- Australian Groundwater Consultants Pty Ltd. (1982): This study assessed the effects of mine dewatering on regional groundwater levels. A numerical groundwater model was used to predict the cumulative impacts of concurrent pit dewatering and process water supply abstractions together with the disposal of excess groundwater at times when the pit dewatering exceeds process supply demands. In addition, a solute transport model was used to estimate transient variations in salinity of the process water supply sources during the proposed development.
- AGC Woodward-Clyde Pty Limited (1996): This report presents geological cross-sections of the Yeelirrie Palaeochannel and the findings of groundwater exploration drilling and aquifer testing investigations from the early 1970s to the 1990s to develop process water supplies for the Mt Keith Operation.
- Stentiford and Berry (2008): Annual production and monitoring report for the Albion Downs Wellfield, approximately 50 km south east of the Project Area, the period 1 July 2006 to 30 June 2007. The report hosts historical abstraction, groundwater level data, groundwater quality data and an assessment of source performance.

- URS (2011): Report on a conceptual hydrogeological model which, in turn, formed the basis for developing a numerical groundwater flow model.
- Cameco (2015): Report completed by Cameco hydrologists on the amended hydrogeological model. (Appendix I1)

Development of Yeelirrie Catchment Model

In 2009 and 2010, BHPB commissioned several groundwater related field investigation programs in support of establishing a conceptual hydrogeological model which, in turn, formed the basis for developing a numerical groundwater flow model, termed the Yeelirrie Catchment Model (URS, 2011). The fieldwork conducted included:

- Construction and monitoring of groundwater monitoring wells:
  - 143 single groundwater monitoring wells;
  - seven multi-level monitoring wells (typically three monitoring wells were completed in a single borehole at each of the multi-level sites);
  - eight test production wells;
  - 95 wells for characterising stygofauna; and
  - 77 wells for troglofauna characterisation.
- Pumping tests:
  - Short-term pumping tests (50 monitoring wells) and longer term tests (eight test production wells) were conducted to obtain an estimate of the hydraulic conductivity and transmissivity of the various hydrostratigraphic units at the site.
- Laboratory test
  - conducted on eight undisturbed core samples from the clayey alluvium to determine the vertical hydraulic conductivity.
- Groundwater quality:
  - data were collected from 215 sampling sites;
  - groundwater was analyzed for major ions, metals (dissolved and total), nutrients and radiochemicals.

9.5.3.3 Studies undertaken by Cameco

Cameco Model

Cameco developed a numerical model (the Cameco Model) to model groundwater flow (drawdown and recovery) and solute transport movement from the TSF (Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit (Cameco, 2015a) presented in Appendix I1).

The development of the Cameco Model was based on the Yeelirrie Model but was modified (to consider the mining and processing rates, and groundwater abstraction locations proposed by Cameco) and expanded to include solute transport modelling.

The groundwater flow and solute transport modelling report:

- presents the characteristics of the baseline hydrogeological environment;
- assesses water supply options;
- provides a water balance for the proposal;
- evaluates the impacts of abstracting groundwater to meet Project water demand;
- presents the predicted extent and magnitude of groundwater drawdown; and
- outlines the simulated impact on the environment of solute transport of selected constituents of concern (COC) originating from the tailings (determined in the Source Terms analysis described below).

Cameco has used a conservative approach to modelling the groundwater flow and solute transport, including:

Groundwater flow modelling

- using a water supply demand which is 26% more than required for the Project;
- assuming a low (10%) recovery of water from tailings and processing;
- using low abstraction intensity from the wellfield; and
- making no allowance for harvesting of rainfall and runoff;

Solute Transport Modelling

- determining site specific distribution coefficients for the various subsurface mediums (ability of the medium to attenuate a contaminant) and conducting sensitivity analyses to understand the effect on transport and
- increasing the source terms by 20%.

Further detail on the methodology and assumptions is presented in Cameco (2015a) in Appendix I1.

Source Terms

Cameco also undertook a detailed analysis of the source terms of the tailings and stockpiled materials (Cameco 2015b). This work built upon previously commissioned work that included a geochemical assessment of tailings and mine waste (SRK Consulting, 2011a) and an assessment to determine the tailings' and mine waste's source terms (SRK Consulting, 2011b). SRK Consulting's work included chemical characterisation of Yeelirrie materials and laboratory leach tests. The source terms were then applied in the solute transport modelling described above to simulate the potential impacts to the groundwater over time following project closure. The steps involved in developing the source terms were as follows:

1. A review of a SysCAD process model with a production rate of 2.4 million tonnes of ore per year. The process model provided geochemical information of the tailings discharge slurry.
2. A review of the tailings aging data from the SRK Consulting investigations. Statistical parameters of the tailings aging data in conjunction with geochemical modelling predictions were used to determine the tailings source terms.
3. The sensitivity of the source terms was investigated by varying the pH and redox potential. Evaporation and the resulting effects on salinity and constituent porewater concentrations were also modelled.

Geochemical modelling using the software program Geochemist's Workbench was then undertaken using thermodynamic data held in various databases.

Further detail on the methodology for this study is presented in Cameco (2015b) in Appendix I2.

TSF design and management

Cameco has also prepared a report for the Yeelirrie TSF design and management (Cameco, 2015c; Appendix D) which is relevant to the management of impacts on groundwater.

9.5.4 Existing Environment

9.5.4.1 Physical setting

The Yeelirrie uranium deposit occurs in the Cenozoic aged drainage channel of a wide, flat and long drainage valley (Yeelirrie Catchment) flanked by granitic breakaways of low topographic relief; including the Barr Smith Range to the north-east and the Montague Range to the west.

The drainage channel is incised into the crystalline, Archaean aged basement rocks of the northern Yilgarn Craton.

The valley has a northwest to southeast orientation. The valley floor has an elevation of about 500 mAHD, while the breakaways are 50 to 100 m higher. In the vicinity of the deposit, the valley is 25 to 30 km wide. From the Yeelirrie deposit, the valley extends at least 50 km to the north-west and approximately 80 km to the southeast, where it joins the Lake Miranda basin at 460 mAHD.

Regionally there are a number of important features that relate to the groundwater regime in the Yeelirrie Catchment. These include the Yeelirrie and Albion Downs Playas and the Albion Downs Wellfield. The Yeelirrie and Albion Downs Playas are small playa lakes that exist in topographic depressions in the lower reaches of the catchment. They are located on or adjacent to the channel axis approximately 20 km and 30 km south east of the Project Area, between the Yeelirrie deposit and Lake Miranda. The Albion Downs Wellfield is described in Section 9.5.4.5.

The climate in the Yeelirrie catchment area is classified as arid with a variable temporal and spatial rainfall distribution. The average annual rainfall of 239 mm is overwhelmed by the large evaporation rates that exist in the area. The Wiluna BoM Station No. 013012 (1957 to 1985) (the closest official site to Yeelirrie) recorded an average pan evaporation rate of 2,412 mm a year.

9.5.4.2 Aquifer systems

The aquifer systems within the Yeelirrie Catchment have been determined based on a conceptual hydrogeological model developed by URS (2011). The interpreted hydrostratigraphical setting is shown in Table 9-43.

Calcrete Aquifers

The calcrete deposits form the most significant water table (unconfined) aquifers in the central valley areas of the region, with transmissivity enhanced by karstic secondary porosity characteristics. Well yields in calcrete are known to be widely variable, due to the karst development. Yields at Depot Springs (located 75 km south from the Project) ranged from 300 to 5,000 kL/day in massive and strongly karstic calcrete (WMC, 1978).

Alluvial Aquifers

The majority of the alluvial aquifers occur between the base of the carbonated clay-quartz unit and above the unconformity marker horizon (Table 9-43). The alluvial sediments commonly form an unconfined water table aquifer with a saturated thickness from 5 to 15 m. Typically, the water table is comparatively shallow at depths of 2 to 10 m beneath the valley-floor and foot-slope areas. Water yields of 50 to 330 kL/day occur within the Albion Downs Wellfield downstream of Yeelirrie.

Basal Palaeochannel Sand Aquifer (Woolubar Sandstone)

The basal sands form important regional aquifers capable of providing substantial groundwater supplies. Based on aquifer tests the hydraulic conductivity of this aquifer is in the range of 1 to 40 m/day (average 10 m/day).

Archaean Basement

Basement rocks within the Yeelirrie Catchment are typically considered to have a low transmissivity, consistent with assessments made in other similar geological settings. Weathered and fractured fault/shear zones may be associated with localised aquifer zones but these zones would have relatively a low transmissivity. The weathered granite is interpreted to form a hydraulic link between the Early Tertiary sediments and the near surface alluvial/calcrete aquifers. Fresh granite forms the base of the groundwater flow system within the Yeelirrie Catchment.

Table 9-43: Regional and Yeelirrie Catchment Stratigraphy

Hydrostratigraphic Unit		Potential Aquifer Description	
		Storage Characteristics	Broad Lithology
Quaternary/Recent Superficial Formations			
Hard Pan		Unconfined	Loam and Hard Pan
Calcrete			Calcrete
			Transitional Calcrete
			Carbonated Clay-Quartz
Alluvium		Unconfined to Semi-Confined	Sandstone
			Sandy Alluvium
			Clayey Alluvium
Early-Tertiary Successions – Yeelirrie Palaeochannel			
Upper Channel	Unconformity Marker Bed	Confined	Ferricrete/Desiccated Clay
	Carbonaceous Marker Bed		Dark Grey Clay
	Upper Palaeochannel Sands		Palaeochannel Sand
Lower Channel	Perkolilli Shale		Lacustrine Clay
	Wollubar Sandstone		Palaeochannel Sand
Archaean - Yilgarn Shield			
Weathered Bedrock		Confined	Granite, Greenstone and Dolerite
Fresh Bedrock		Confined Fractured Rock	Granite, Greenstone and Dolerite

Units considered potential aquifers

Source: Cameco (2015a) after URS (2011)

9.5.4.3 Groundwater levels

Baseline (pre-development) water table elevations were reported by URS (2011).

The interpreted water table topography closely reflects the land surface topography. Groundwater is predicted to move from the catchment divides towards the valley floor areas and then in a general southeast direction towards the Yeelirrie Playa, Albion Downs Playa and Lake Miranda. With elevations ranging from 530 to 610 mAHD, the groundwater levels are the highest in the northwest (headwaters) of the Yeelirrie catchment. Down-gradient, across the deposit, it ranges from 490 to 492 mAHD and is about 480 mAHD at the Yeelirrie Homestead. In the vicinity of Miranda Lake the water table is about 460 mAHD. Along the valley floor the hydraulic gradients are flat, reflecting the high transmissivity of the calcrete and sandy alluvium aquifers.

The greatest depths to the water table are found in the headwater area of the catchment and along the flanks. In these areas the depth to the water table ranges from 10 to 20 m below ground surface and locally is greater than 20 m. Along the valley floor, the depth to the water table is typically less than 5 m. Within the area of the deposit the depth to the water table is in the 3 to 5 m range. Regional groundwater level data also show that the range of water level fluctuations is less than 0.2 m with no evidence of seasonality fluctuations.

Interpreted pre-development water table elevations are shown in Figure 9-34.

Water fluxes within the Yeelirrie Catchment are likely to be complex and variable. A simplified interpretation of the system of recharge and discharge is that recharges occur in the breakaways and in the flanks for the catchments via directed infiltration, while discharges occur from the playas and lakes through evaporation and/or transpiration processes. As a result of the concurrent occurrence of several processes, the water table salt concentrations sporadically increase and decrease down the valley in response to reoccurring discharge and recharge occurrences.

Surface runoff occasionally occurs within the Yeelirrie Catchment following intense rainfall. Sheet runoff from the upper margins of the catchments flows to the central drainage line and generates ephemeral stream flow. Typically, the stream flow terminates in playas (including clay pans). Water may remain on the larger clay pans and playas for several weeks after large rainfall events, however groundwater recharge is not understood to occur at these locations due to the underlying clay which prevents infiltration.

9.5.4.4 Groundwater quality

The geochemical characteristics of the groundwater in the catchment have evolved over geologic time due to processes including:

- precipitation;
- runoff and ponding of runoff;
- infiltration of precipitation and runoff;
- geochemical interactions between infiltrating water and the sediments through which the water flows;
- groundwater flow patterns (recharge and discharge areas, as developed over time); and
- evaporation and evapotranspiration.

Reported groundwater quality data (URS, 2011) indicate:

- Groundwater in the Yeelirrie catchment typically is of the sodium-chloride (Na-Cl) type.
- Areas with low total dissolved solids (TDS), which is suitable for the beneficial use ‘stock watering’ under the ANZECC guidelines, coincide with zones where the depth to the water table is the deepest. These areas represent the weathered granite, clayey and sandy alluviums along the flanks of the valley floor.
- High TDS groundwater is found along the valley floor, in areas where the water table is at shallow depth.
- The quality of shallow groundwater in the area of the Yeelirrie deposit is highly variable. The average and standard deviation of the TDS in the eastern part of the deposit (32,700 ± 14,900 mg/L) is higher than in the western part (15,800 ± 10,300 mg/L).
- Within the palaeochannel aquifer low TDS water (average 3,800 mg/L) is found west of the deposit but increases eastward to 87,400 mg/L near the Albion Downs wellfield.
- Dissolved uranium is present in all of the hydrostratigraphical units. Overall, the concentration ranges from less than detection limit (<0.001 mg/L) to 2.4 mg/L. Within the deposit the average is 0.29 mg/L (± 0.32 mg/L) and in the palaeochannel sediments it is 0.74 mg/L (± 0.69 mg/L).
- The dissolved vanadium concentration is typically less than the detection limit (0.01 mg/L).
- Bromide is present in significant concentrations (up to tens of milligrams per litre) in all hydrostratigraphical units.

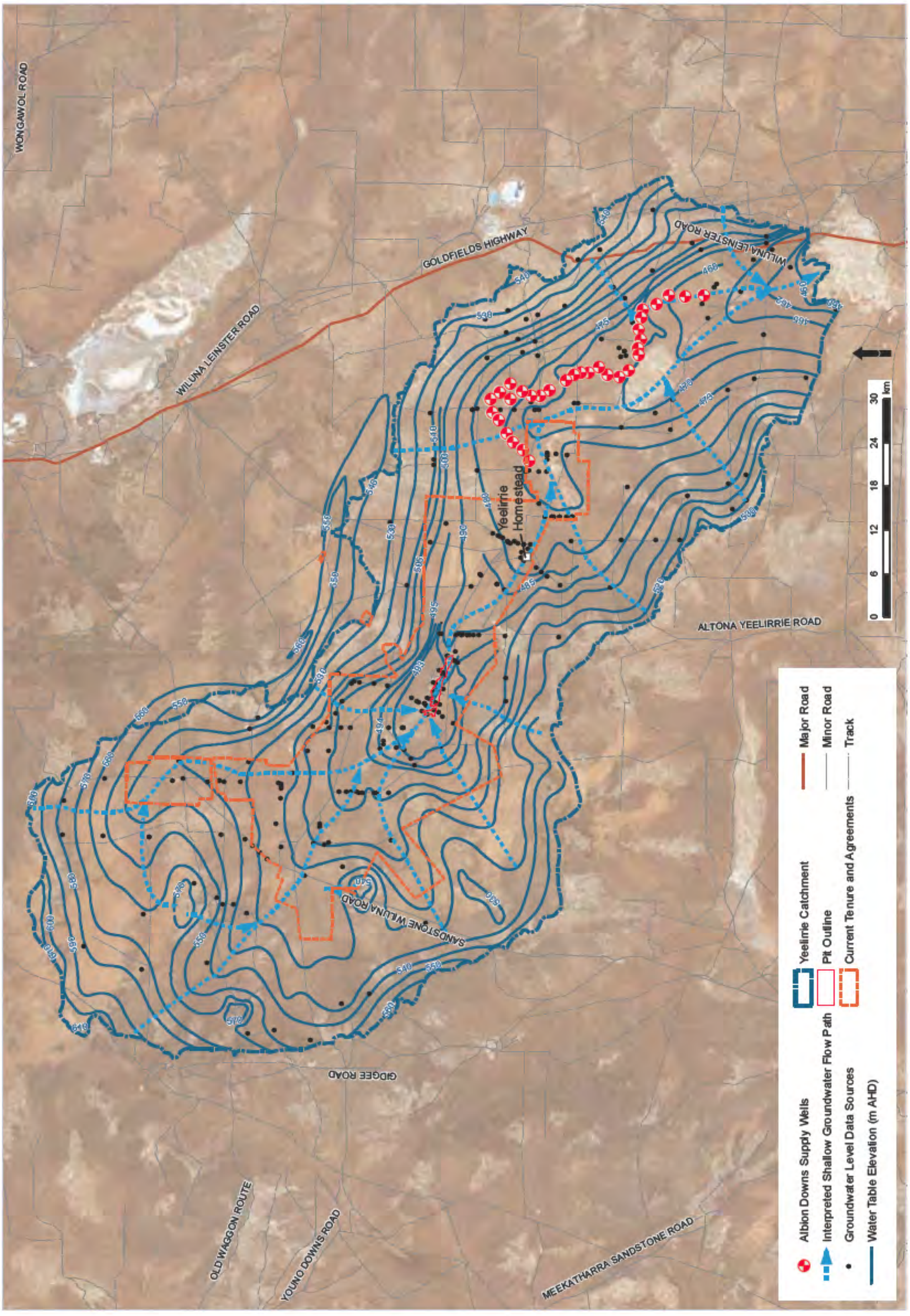


Figure 9-34: Interpreted pre-development water table elevations

9.5.4.5 Existing groundwater users

There are a significant number of existing groundwater bores (wells) in the region. These include pastoral wells, groundwater investigation and monitoring wells, and production wells related to the Albion Downs Wellfield.

The historical land use in the Yeelirrie Catchment has been fenced pastoral activities. URS (2011) noted that many of the pastoral wells have not been used in recent times. An exception is the Big Mill well which is used by the Yeelirrie Homestead (located approximately 10 km south east of the proposed mining lease area) as a water supply source. Farther away from the Yeelirrie deposit several pastoral wells related to the Albion Down pastoral lease are likely to be in use.

The Albion Downs Wellfield is located about 30 km east of the Yeelirrie deposit, and consists of 32 production wells, spaced about 1.6 km apart, stretching over a linear distance of approximately 51 km. The wellfield produces on average approximately 20,000 kL/day (about 7.5 GL/yr) for the BHP Billiton Nickel West Mt. Keith Operation.

9.5.5 Potential Impacts and Management

The Project will result in local and temporary changes to the groundwater regime in the Project Area. Without appropriate measures in place, proposed activities that are most likely to affect the groundwater regime are:

- Groundwater abstraction, mine pit dewatering and aquifer recharge, could potentially impact groundwater availability to groundwater dependent ecosystems (refer to Sections 9.1 and 9.2) and other groundwater users.
- Storage of ore and mine waste in stockpiles, and tailings in the TSF, could result in changes to water chemistry and contamination of the groundwater.
- Potential precipitation of solids due to mixing of groundwater chemistry during the re-injection process.

9.5.5.1 Project Water Balance

Methodology

Water is needed throughout each phase of the Project. The water need, or water demand, would be met by a supply of groundwater.

Water demand

The Project's total water demand is predominantly the amount of water required to process ore in the processing plant. Detailed process modelling of the processing plant has been undertaken to determine the volumes of water required to process a proposed 2.4 Mt/yr of ore using alkaline extraction to extract uranium from the ore. Water demand for vehicle washing and dust suppression (adopted from URS 2011) and for domestic use in the mine camp and administration facilities (estimated based on Cameco's previous experience) are also components of the total water demand calculation. The total water demand for the Project was presented in Section 6.6 and is estimaged on an average annualised basis to be approximately 8.7 ML/day.

Water supply

Groundwater would be sourced from the following:

- mining pit dewatering; and
- proposed water supply wellfields.

As described in Section 6, dewatering of the mine pit would need to be undertaken to allow the ore to be mined. The water sourced from this dewatering will meet the initial Project demand.

When ore processing commences in year four, the Project water demand exceeds the supply from dewatering and groundwater would be abstracted from the proposed wellfields.

Conversely, prior to the commencement of processing, the dewatering volumes will exceed the water demand and surplus water would be re-injected.

The groundwater supply wellfields were previously identified (URS 2011) and are located within and outside the Project Area and the Yeelirrie catchment. Figure 9-35 shows the locations of the proposed wellfields.

The proposed wellfields are:

- Western Brackish Wellfield; comprising wells that intercept the alluvium aquifer.
- Northern Brackish Wellfield; comprising wells that intercept the alluvium and weathered bedrock aquifers.
- Eastern Brackish Wellfield; comprising wells that intercept the alluvium and weathered bedrock aquifers, and
- Saline Wellfield; comprising wells that intercept the alluvium and Yeelirrie Palaeochannel aquifers, and wells that intercept the weathered bedrock aquifer.

The volume of groundwater that would be supplied from dewatering which was based on the previous work done at Yeelirrie was determined using a numerical groundwater flow model (Appendix I1).

Other (minor) sources of water supply would include:

- Reagents: Water naturally contained in the reagents. This source is included in the Water Balance for the processing water needs.
- Opportunistic rainfall runoff: Water collected from within the mine pit and disturbed areas. This water would be sporadically available and therefore cannot be quantified or consistently relied upon.
- The groundwater naturally contained in the mined ore would also offset processing water needs.

Water within the tailings would also be recycled from the TSF. This water would be available during the period that ore is milled, and will offset demand from the wellfields.

Total project water balance

The water demand modelling shows the indicative total demand for water is estimated to be in the order of 53.35 GL over the life of the project (Table 9-44). The indicative maximum total daily demand for water is estimated to be in the order of 8,724 kL. The results of the groundwater modelling predict that the total amount of water derived from dewatering would be 18.9 GL. The modelled volume of withdrawals from aquifers is 50.72 GL (Table 9-44).

Groundwater Reinjection

Prior to the commencement of the operation phase (operation of the processing mill in Year 4), dewatering would result in excess water for the project. When this occurs it is proposed to re-inject the excess water back into the underlying calcrete aquifer just north of the proposed pit. The numerical groundwater flow modelling shows, the total amount of water to be re-injected over the life of the Project is estimated to be 2.27 Gl.

The highest rate of reinjection occurs in Year 3 of the Project. During this year of operation, groundwater extracted from the Pit from dewatering operations will be reinjected at the rate of approximately 1.28 Gl/a (3.5 Kl/d).

Table 9-44: Water Demand and Groundwater Abstraction

Year	Estimated water demand (Gl/a)	Predicted annual dewatering abstraction (Gl/a)	Simulated annual well abstraction (Gl/a)
1	1.04	0.85	0.66
2	1.44	1.14	0.82
3	1.44	2.23	0.82
4	3.18	2.73	2.14
5	3.18	1.26	2.93
6	3.18	0.95	3.18
7	3.18	0.79	3.21
8	3.18	0.97	3.2
9	3.18	1.41	3.2
10	3.18	0.8	3.2
11	3.18	1.33	3.21
12	3.18	0.77	3.2
13	3.18	0.66	3.2
14	3.18	0.67	3.2
15	3.18	0.59	3.21
16	3.18	0.55	3.2
17	3.18	0.52	3.2
18	3.18	0.5	3.2
19	0.42	0.04	0.44
20	0.42	0.04	0.44
21	0.42	0.05	0.44
22	0.42	0.05	0.44
Total	53.35	18.90	50.72

Note: The simulated abstraction figures include a level of conservatism of 26 % (i.e. 26 % more than is required).

Source: after Cameco (2015a)

Modelling predicts that during reinjection, the height of groundwater levels will rise by approximately 1.1 m and that this increase will be limited to an area of radius of approximately 525 m from the reinjection point or an area of approximately 86 ha. At the reinjection point natural groundwater levels are approximately 8 m below ground level and reinjection is therefore unlikely to cause groundwater levels to rise to such an extent as to cause waterlogging and impact on vegetation.

In year 4, reinjection is predicted to reduce to approximately 0.24 Gl/a and modelling predicts that the groundwater levels in the mound caused by reinjection is reduced back to normal levels by Year 5.

All of the area affected by reinjection occurs within the area where groundwater will subsequently be lowered by dewatering and groundwater abstraction and therefore does not contribute to an increased area of impact.

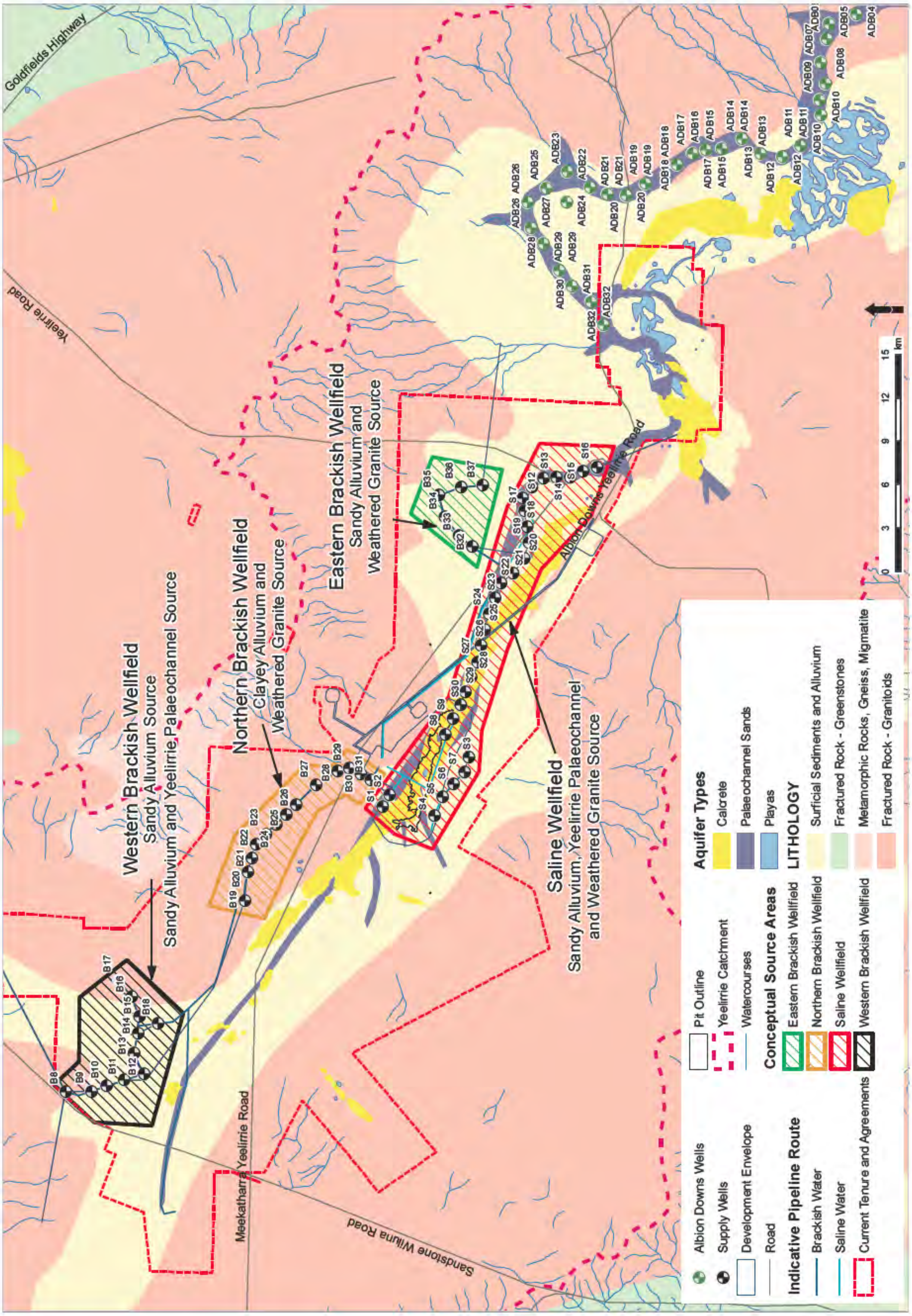


Figure 9-35: Location of proposed wellfields

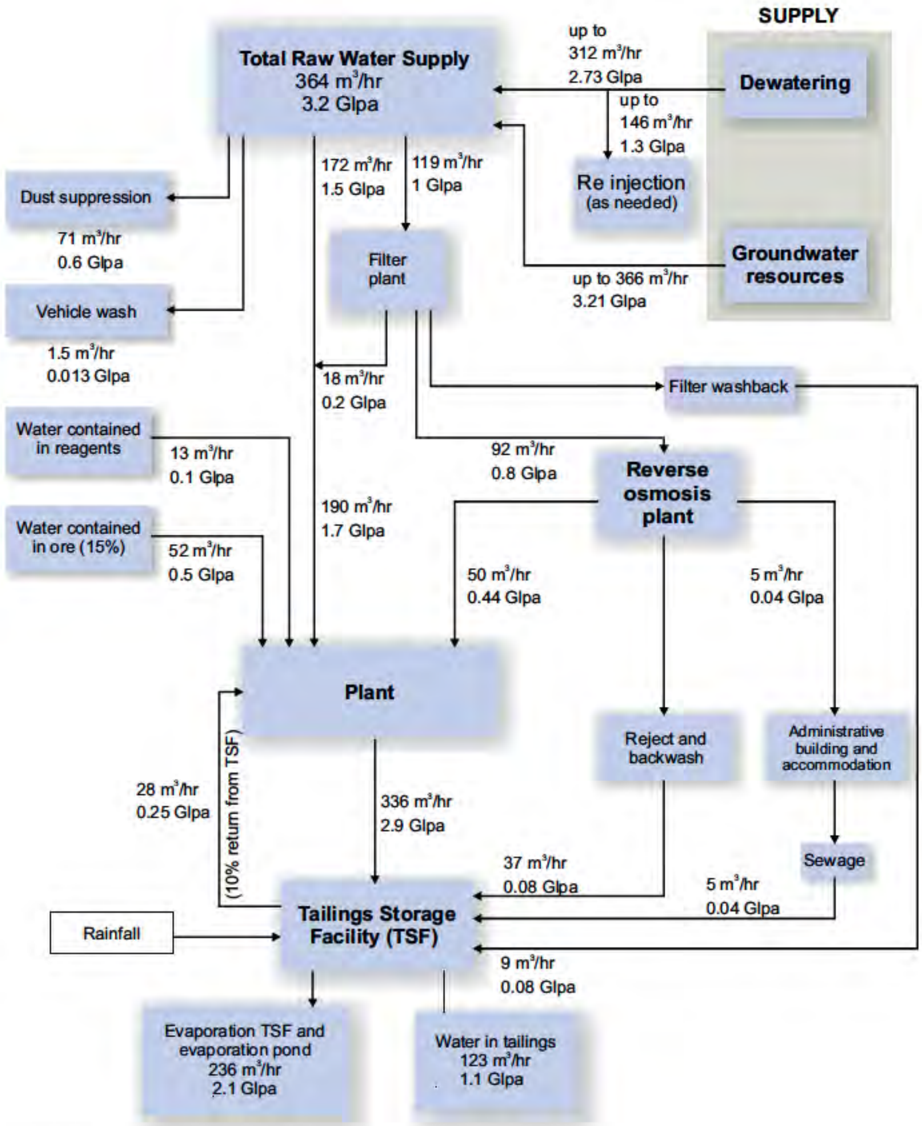


Figure 9-36: Project water balance

A detailed indicative water balance for the operational (milling phase) phase of the project is shown in Figure 9-36. A detailed water balance model was completed by URS, (2015) using the GoldSim modelling package to validate the performance of the Project water management strategy. The water balance model report is provided in Appendix H2. The assessment showed that within the assumptions adopted the proposed water management strategy is adequate in containing the mine impacted water onsite.

Groundwater abstraction throughout the project

As groundwater abstraction from the proposed wellfields is determined by the project phase and the amount of water sourced from mine pit dewatering, the volumes extracted from this source will vary with time. Modelling was undertaken to determine daily groundwater abstraction volumes thought the Project life. The results of this modelling are shown in Figure 9-37.

The modelling determined the individual volumes of groundwater abstraction from each of the four wellfields. The results of this modelling are shown in Figure 9-38.

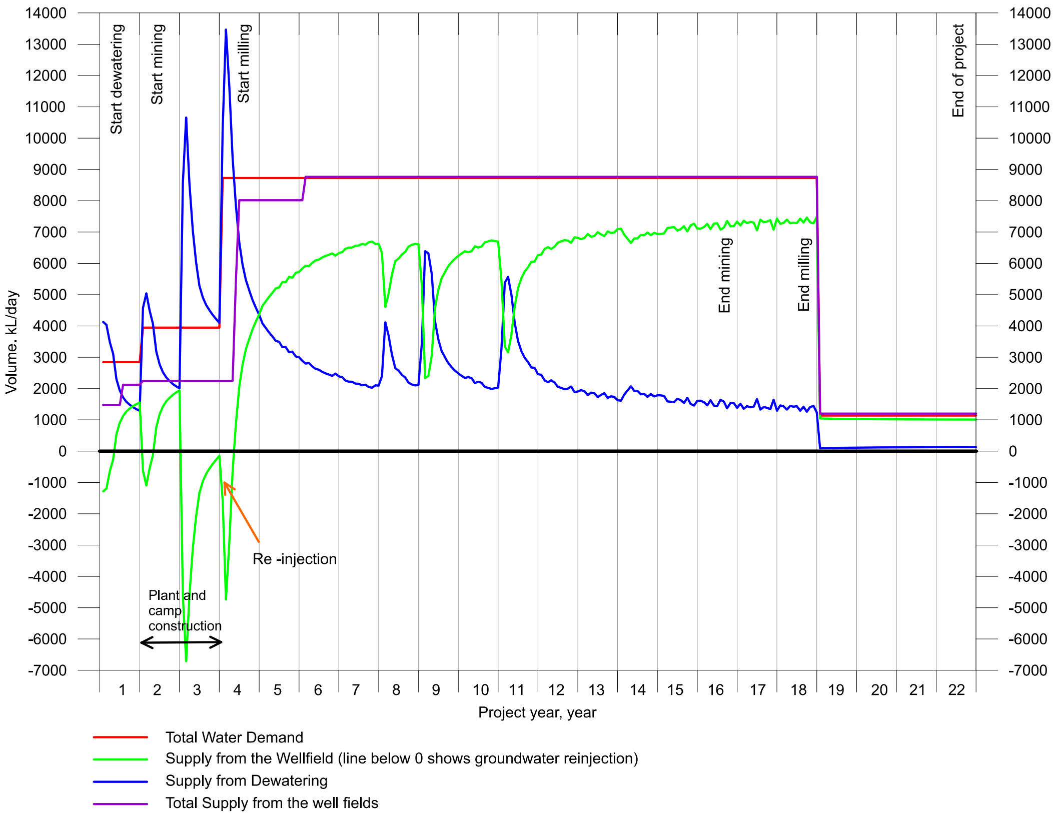


Figure 9-37: Simulated water demand and supply over time

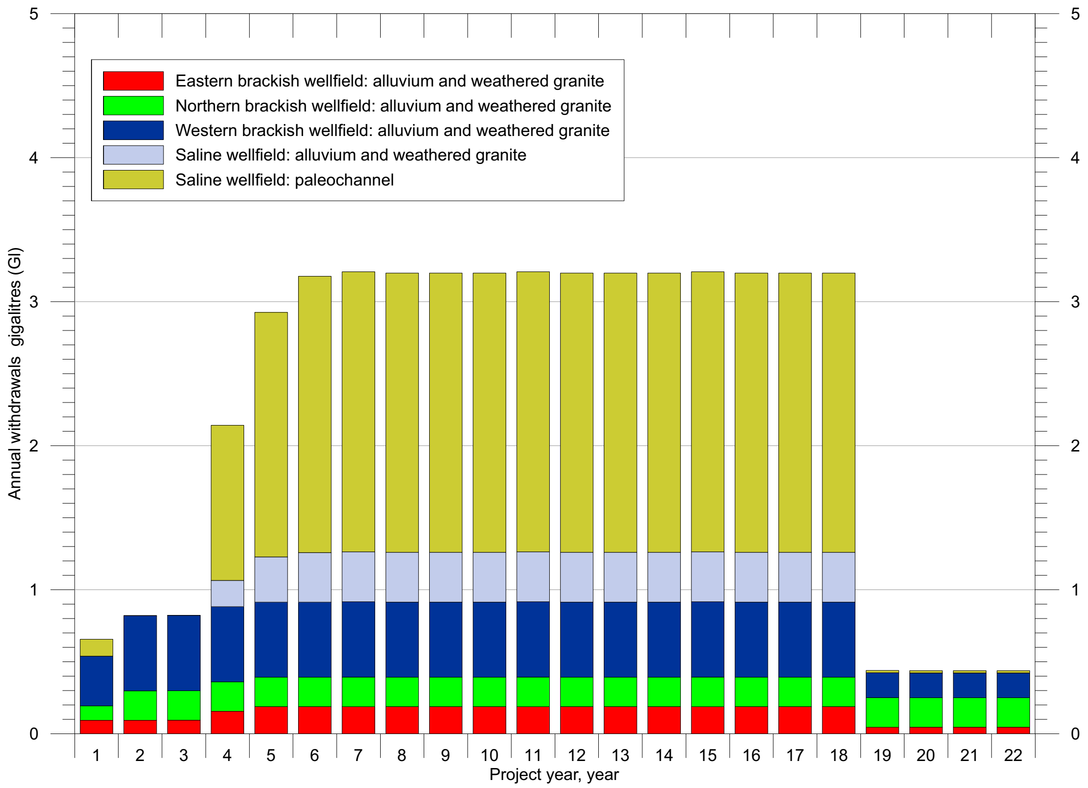


Figure 9-38: Annual abstraction of groundwater by wellfield

9.5.5.2 Groundwater drawdown

Methodology

The numerical groundwater flow and solute transport model was used to predict the extent of water table drawdown and recovery and the transport of solutes from the TSF. Computer modelling packages Groundwater Vistas (version 6.7) with MODFLOW-SURFACT Version 4 (HydroGeoLogic, Inc.) were used for groundwater flow and solute transport modelling.

The computer model required input of topographical, stratigraphic, recharge, climatic, geochemical and hydrogeological data, all of which were obtained from the previous studies as detailed in URS (2011). The model was calibrated using dewatering data from the Slot 1 trial (referred to in Section 9.5.3), catchment wide water table elevations, observed drawdown of the water table associated with the long term abstraction by the Albion Downs Wellfield and observed salinity concentrations at discharge zones.

The model was used to simulate operations, closure and long term solute transport to:

- define the pre-project groundwater regime;
- predict the drawdown caused by dewatering;
- predict the drawdown caused by groundwater abstraction;
- estimate the groundwater mounding effect caused by the aquifer recharge system;
- assess the impacts on other groundwater users such as pastoral wells and the Nickel West Mt Keith operation Albion Downs wellfield;
- predict the groundwater level recovery process after mine decommissioning; and
- conduct solute transport modelling to predict the movement of contaminants from the TSF and stockpile areas into the local groundwater system and their potential impact on environment.

In the modelling conservative approaches were adapted. For example, as noted in Section 9.5.3, the modelled supply is 26% greater than the estimated demand. Similarly, the solute transport source terms were increased by 20%.

Extent of drawdown

The results of the modelling undertaken to predict the cumulative water table drawdown from proposed pit dewatering, wellfield abstraction and aquifer recharge are shown in Figure 9-39 to Figure 9-42. The figures show drawdown contours at the end of Project year three (immediately prior to milling), year 18 (end of milling) and year 22 (end of project) respectively. Figure 9-43 shows a transverse cross section in the northwest corner of the pit and illustrates the modelled maximum drawdown across the palaeochannel.

The water table drawdown modelling shows:

- Groundwater re-injection through the aquifer recharge system causes groundwater mounding around the injection well, with a predicted maximum groundwater level increase of approximately 1 m. The injection ceases at the beginning of year four and the groundwater mound disappears by the end of that year.
- The groundwater mound from reinjection (greater than 0.1 m) does not extend past the area affected by drawdown greater than 0.5m, from the operation of the production wellfield.
- Drawdown in the vicinity of the proposed wellfields increases over time and is the greatest at the end of year 18 (end of milling). The typical drawdowns in the Western, Northern and Eastern brackish wellfields are approximately 2, 5 and 3 m, respectively. Around the mine pit the drawdown typically exceeds 7 m.

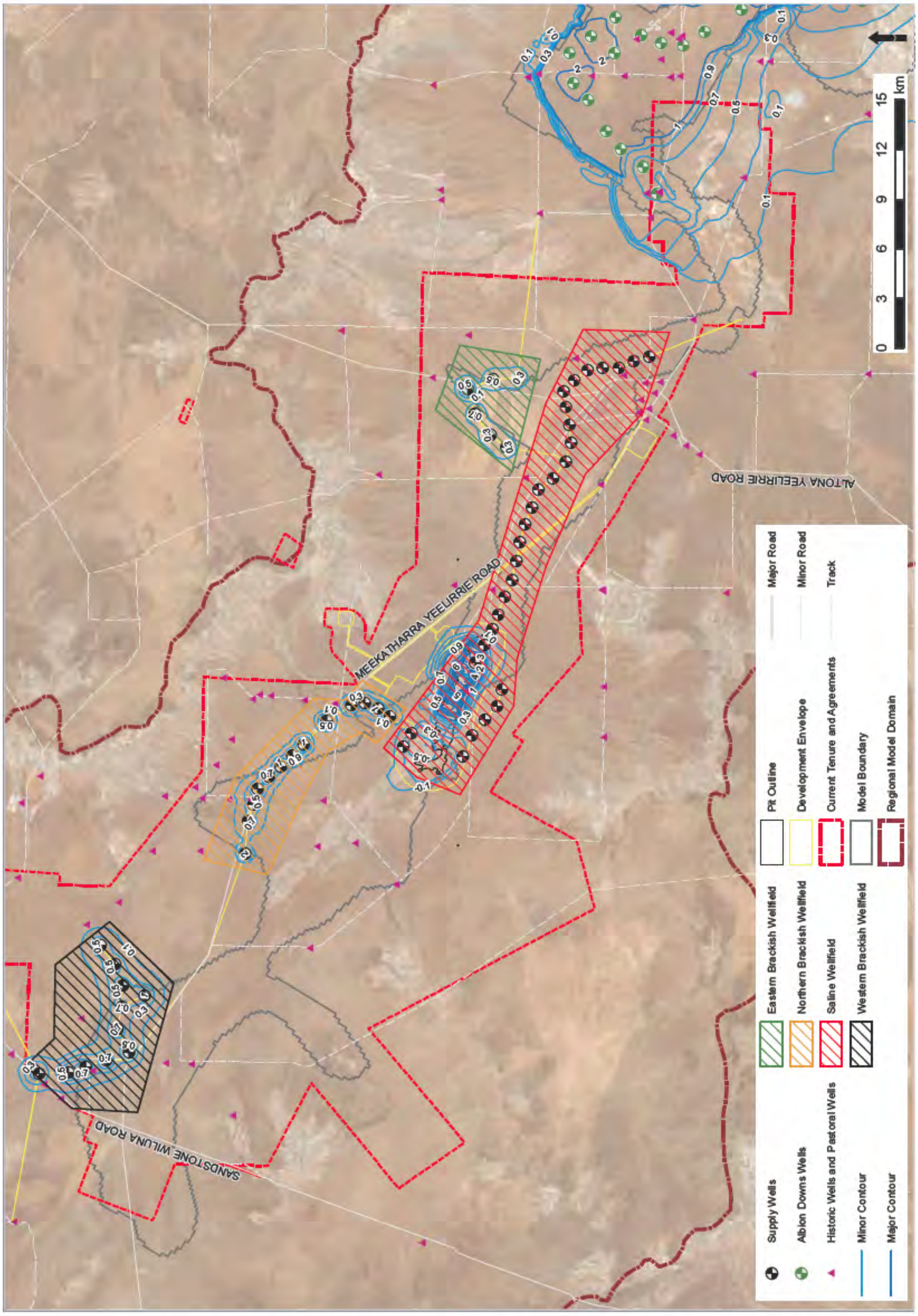


Figure 9-39: Drawdown contours at end of year 3

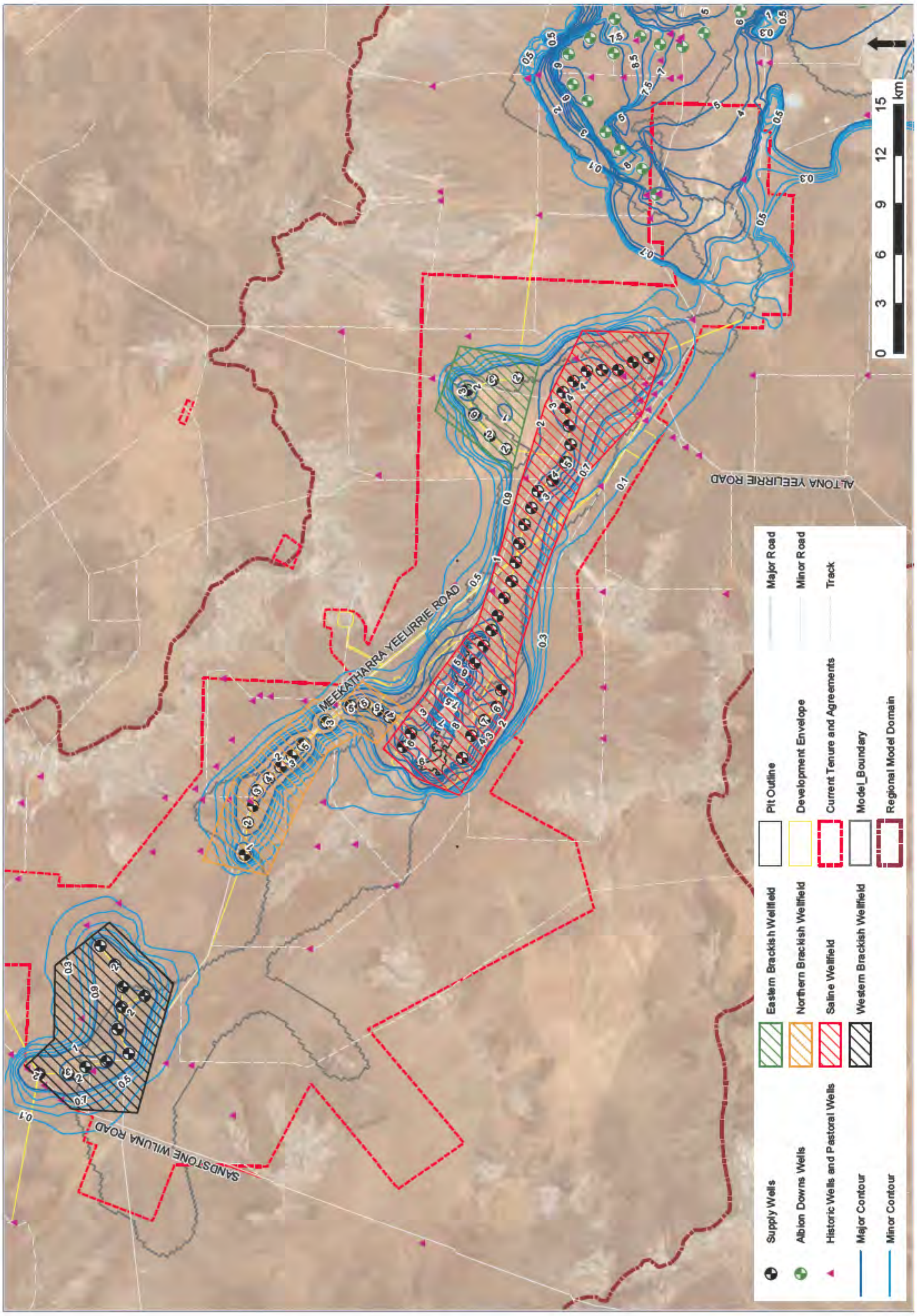


Figure 9-40: Drawdown contours at end of year 18

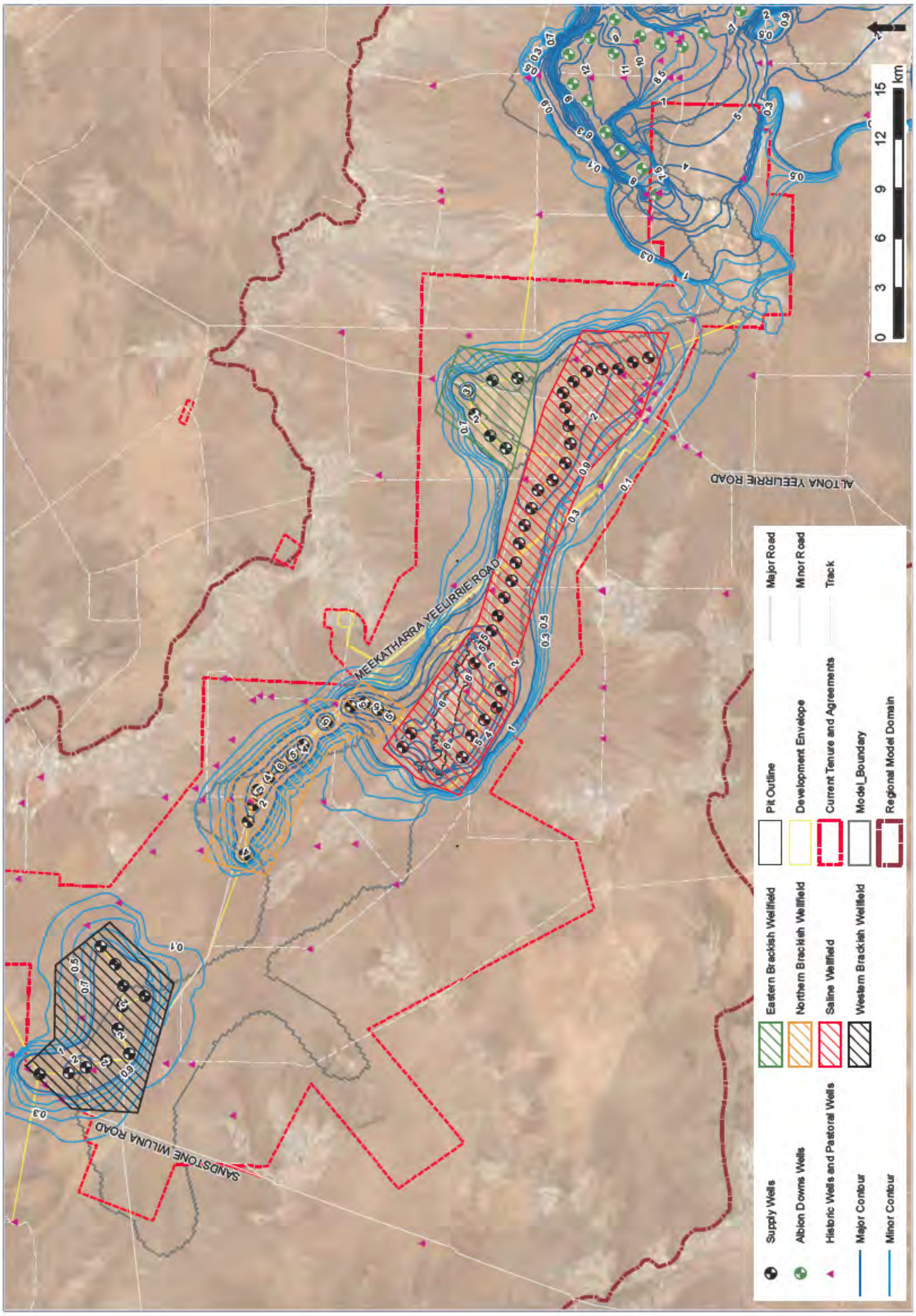


Figure 9-41: Drawdown contours at end of year 22

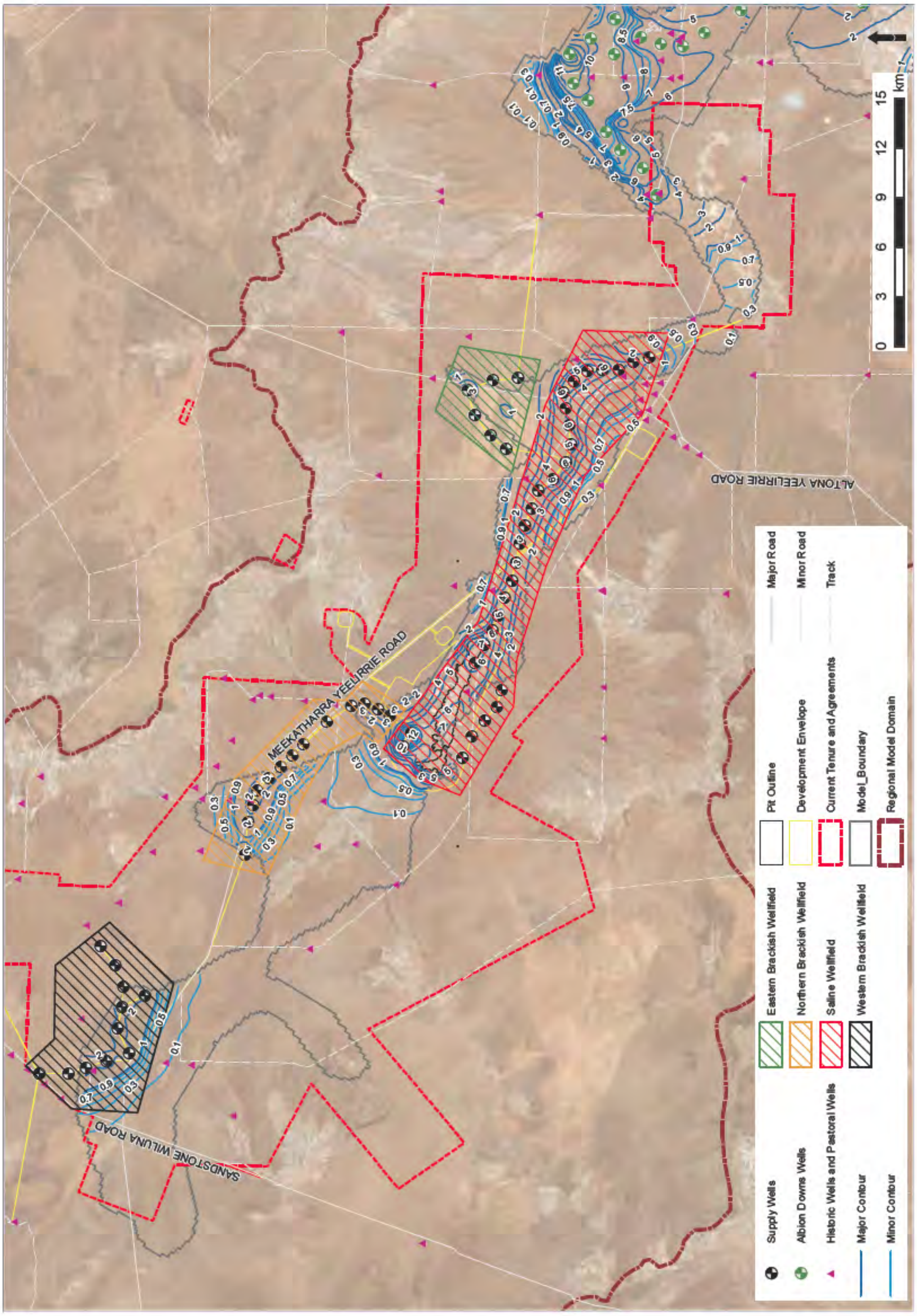


Figure 9-42: Predicted water level drawdown in palaeochannel aquifer after end of milling (Year 18)

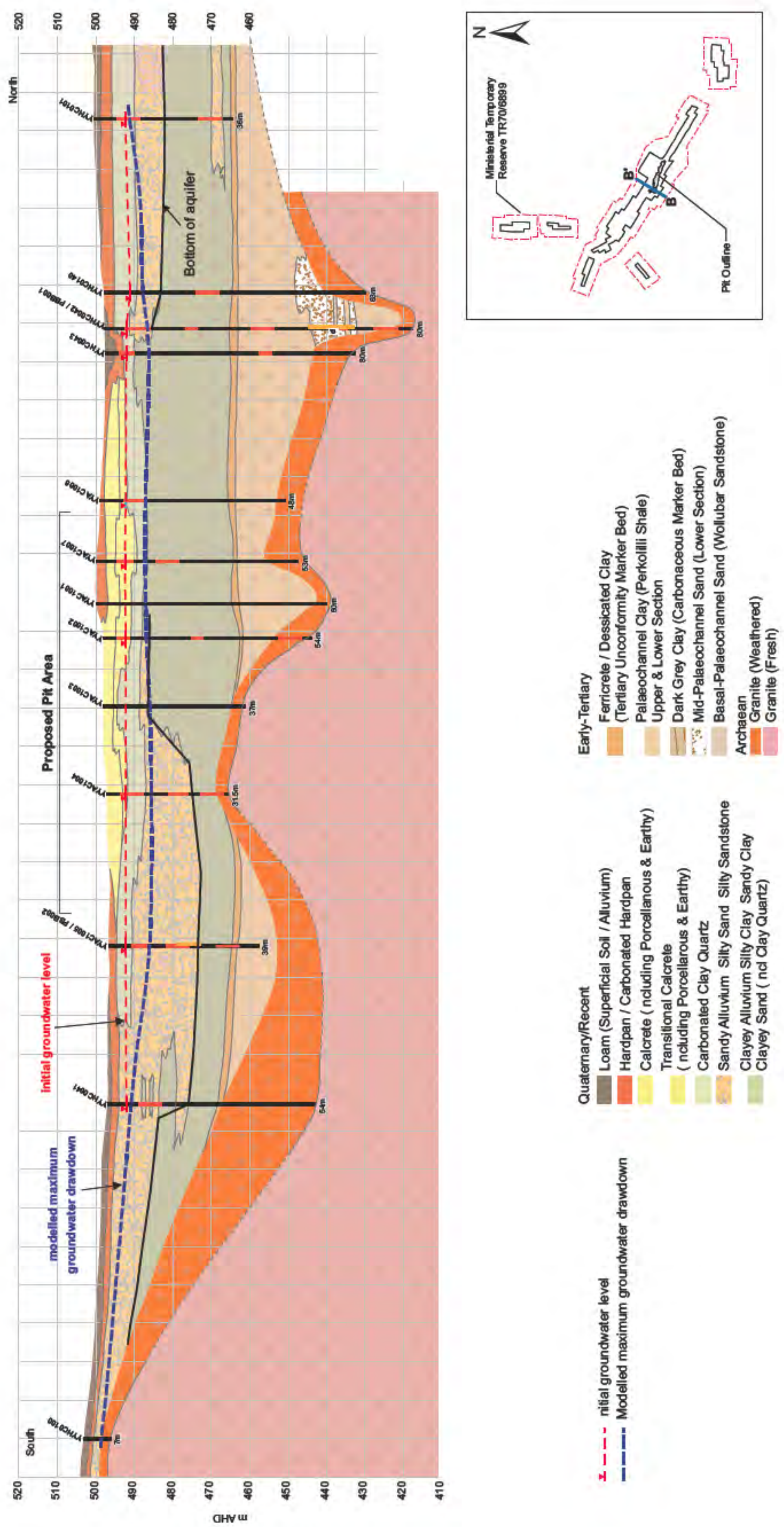


Figure 9-43: Transverse cross section

- Slow expansion of the drawdown cone indicates that the groundwater sources in the proposed wellfields are relatively abundant compared to the extraction rate suggesting a sustainable yield.
- The drawdown from pit dewatering, the Saline, Eastern and Northern wellfields overlap, which broadens the overall drawdown footprint and increases the magnitude of the associated drawdown.
- The model-predicted water table drawdown cone caused by the proposed saline wellfield has a limited overlap with the water table drawdown cone caused by the Albion Downs wellfield. This slight hydraulic interference starts to occur from year 12. It is noted that, depending on future production from the Albion Downs wellfield, this interference may not happen.

Water table recovery

The results of the modelling undertaken to predict the recovery of the water table following the end of the proposed project are shown in Figures 9-44 to 9-46. The figures show regional drawdown contours after 50, 100 and 200 years of recovery (i.e. after the close of the proposed project). The results predict the following:

- Groundwater levels recover significantly within 50 years following cessation of the Project.
- The water table at the pit/TSF location recovers to baseline levels within 100 years, but small residual drawdowns of 0.3 to 0.5 m below the baseline elevations would persist in the area of the nearby eastern and northern wellfield for more than 200 years.
- Within the TSF area, the water table eventually recovers to levels about 0.5 m below the baseline elevations. This suggests a new steady state would occur locally due to the different geological properties of the TSF.
- There would be some change in the down-valley groundwater flow path at the local scale in the vicinity of the pit; however, no discernable change in groundwater flow is expected at the catchment scale.

Impacts to existing users

Big Well bore (Yeelirrie Homestead)

The modelling shows a slight drawdown (0.3 m) of the water table at the Yeelirrie Homestead at year 18 after the end of milling. A residual drawdown (0.1 m) remains for approximately 150 years after the end of the Project.

Existing wellfields and pastoral wells

After year 12 there is a slight interference between the water table drawdown due to the proposed development and the water table drawdown caused by the operation of the Albion Downs Wellfield. This assumes that the Albion Downs Wellfield would continue to be operated indefinitely at historical pumping rates. If abstraction rates are reduced in the future, the proposed project is unlikely to cause interference between the wellfields.

As shown in Figure 9-37, there would be no notable interference between the proposed withdrawals from the palaeochannel and the drawdown in the palaeochannel due to pumping from the Albion Downs Wellfield.

The modelling shows there would not be an impact of the proposed development on existing pastoral wells.

Groundwater dependent ecosystems

The impact of the proposed project on groundwater dependent ecosystems is described in Sections 9-1 and 9-3.

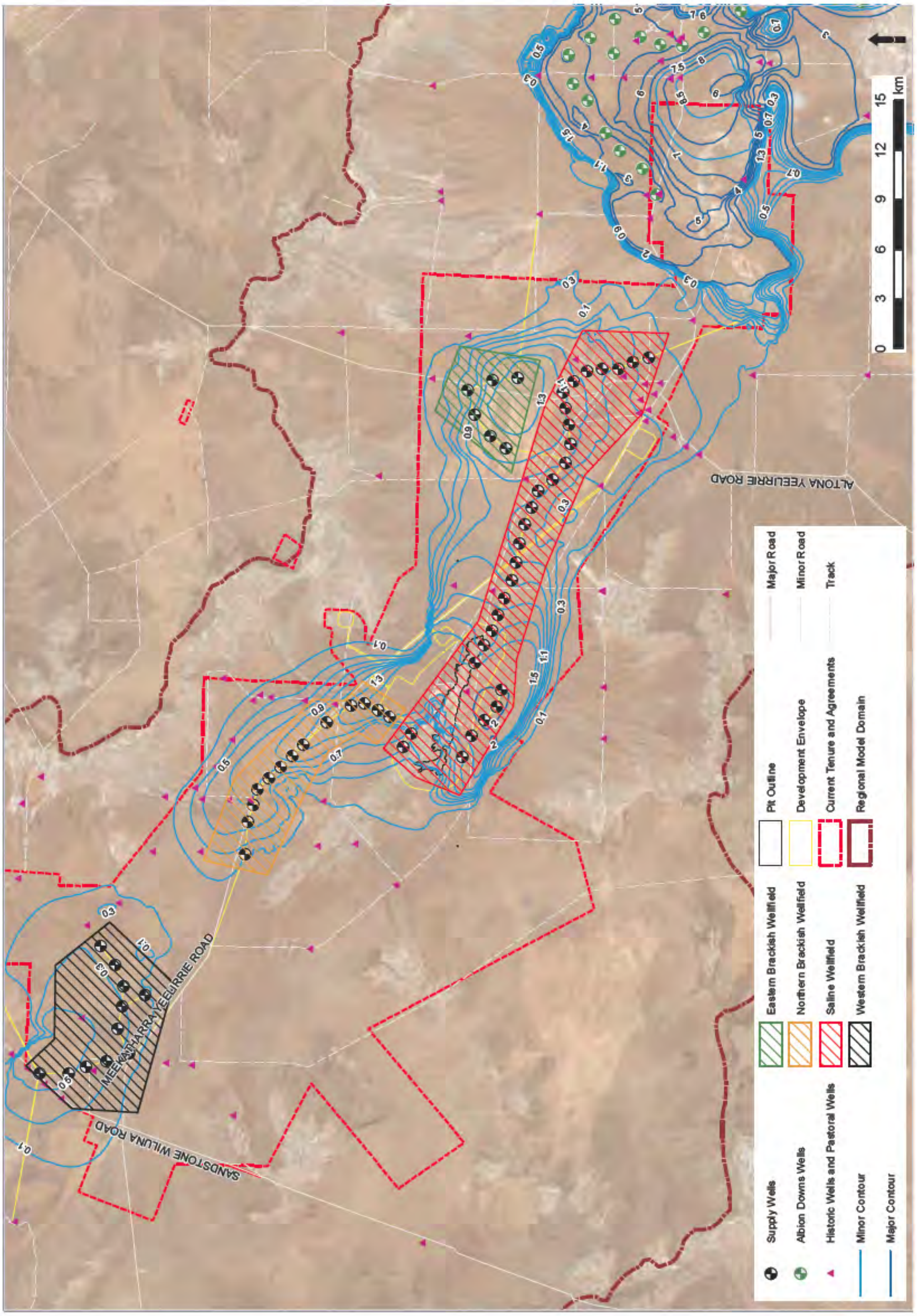


Figure 9-44: Predicted water table drawdown after 50 years of recovery

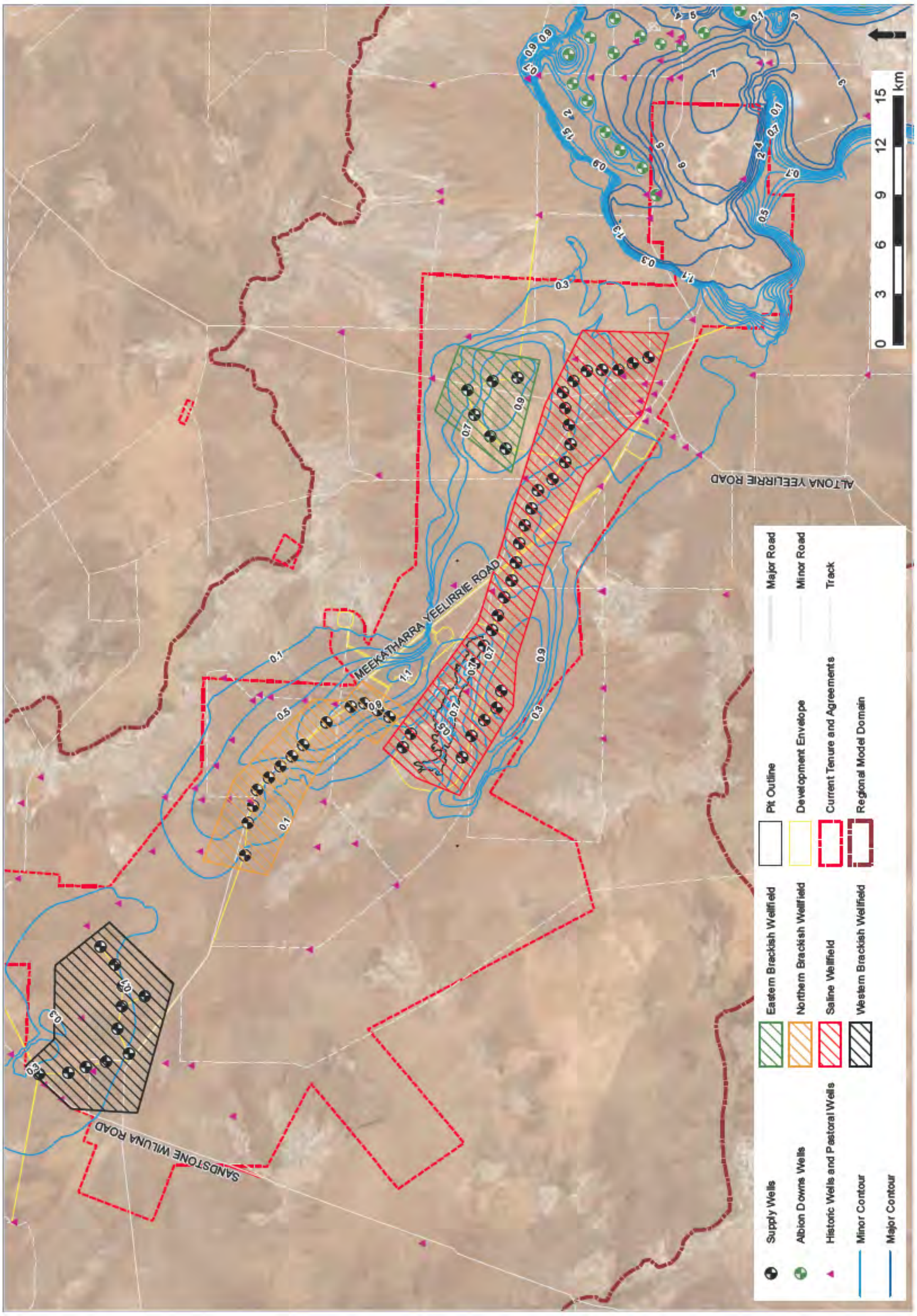


Figure 9-45: Predicted water table drawdown after 100 years of recovery

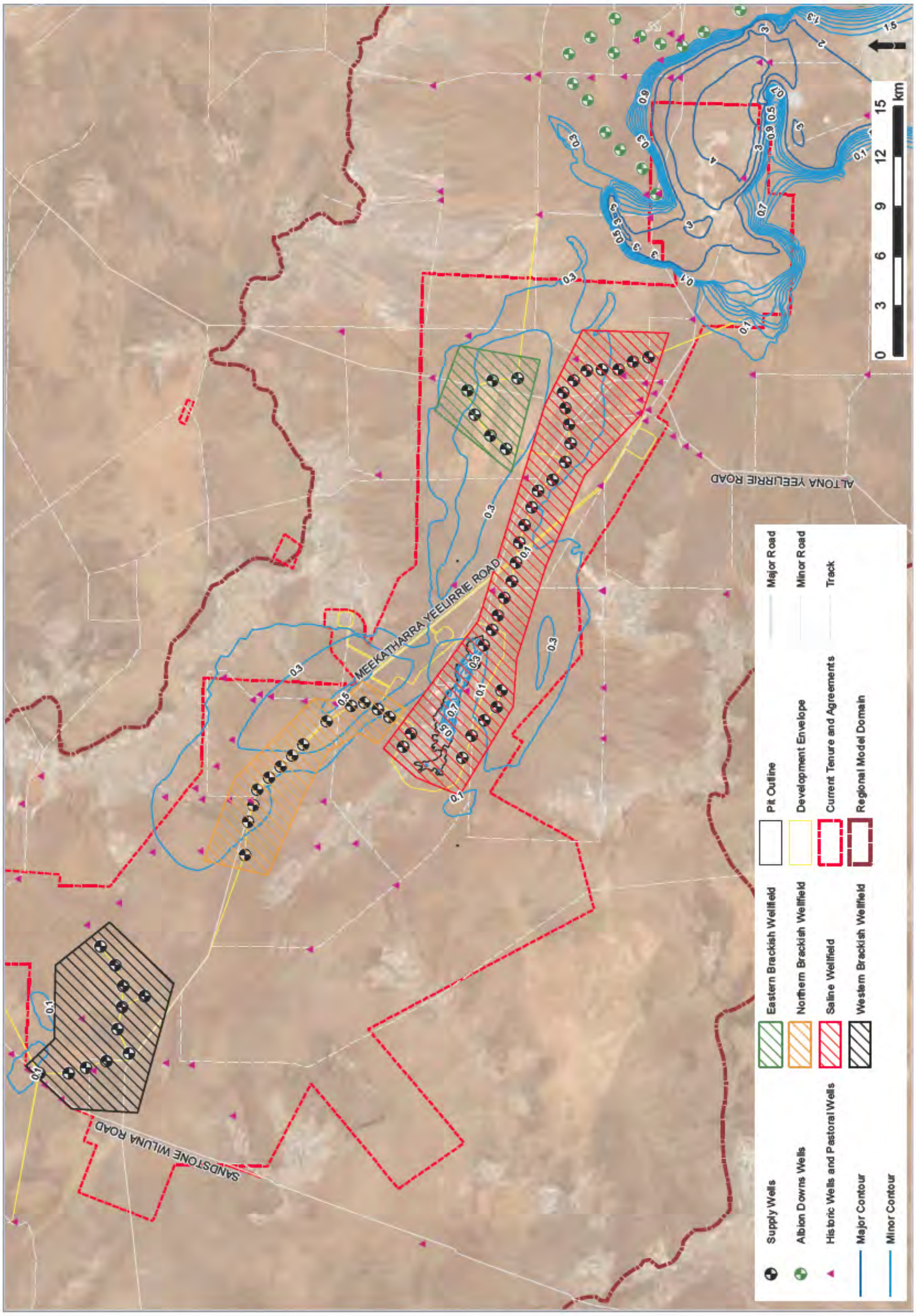


Figure 9-46: Predicted water table drawdown after 200 years of recovery

Contingency Water Supply

At this stage of the Project, Cameco has not investigated a contingency water source for a number of reasons.

Firstly, the extraction intensity of water proposed to be supplied from Yeelirrie Borefield is relatively low at approximately 0.80 GL/km. The proposed extraction intensity is less than 30% of other similar paleochannel aquifers in the region that have significant operational history (i.e. the Albion Downs Borefield at 2.92 GL/km and the Leinster Process Borefield at 2.72 GL/km).

Based on the high level of definition achieved in the water studies completed to date and the relatively low extraction intensity proposed for the Yeelirrie Borefield, Cameco considers a supply shortfall unlikely.

Secondly, following presentations to the DoW, they advised that the hydrogeological studies more than satisfy the requirements for Operational Policy 5.12 – Hydrogeological reporting associated with a groundwater well licence (DoW, 2009) at a H3 Level of Assessment. The DoW also advised that the hydrogeological studies provide sufficient rigour and accuracy to enable an adequate assessment of impacts on the environment, other users and the aquifer system. After receiving this feedback from the DoW Cameco was further satisfied that the DoW had no concern with the proposed extraction intensity from the perspective of a potential supply shortfall and Cameco did not consider that a contingency plan was necessary at this stage of the Project.

Furthermore, the Yeelirrie Agreement Act provides a contingency regime (both prior and subsequent to the granting of water licences) for water supply. This contingency regime provides rights of land access and State involvement in contingency investigations, as well as the granting of water licences in respect of water supplies. This contingency regime therefore removes potential risks regarding access to alternative water sources that would otherwise be suitable for the project. Therefore, Cameco is of the view that it was not necessary to include a separate contingency plan within the PER.

As previously discussed in Section 9.2, prior to the commencement of the Project, Cameco will undertake a definitive feasibility study. During the study and in consultation with the State, Cameco will consider potential contingency water supplies as required.

9.5.5.3 Groundwater quality

Methodology

Tailings and mine waste source terms

Solute transport modelling predicts the movement of contaminants from the TSF and stockpile materials into the local groundwater system, tailings and mine waste source terms (i.e. the concentrations of contaminants likely to be released in solute from the mine waste and tailings). A summary of the work undertaken to determine the source terms are described below.

Tailings

This involved conducting geochemical analysis of ore and field simulated mine waste and tailings, to determine contaminants of concern and their ability to be released in solute. Aged tailings tests in conjunction with thermodynamic geochemical speciation modelling were used to develop the source terms that would describe conditions in the TSF in the long term.

Solute transport model

The potential for solute release from tailings in the short and long term was evaluated primarily based on aging tests on fresh tailings slurries from various categories of ore material. In addition, the chemical composition of potential stockpile material was evaluated by performing leach tests (deionized water and 'barren liquor' solution) on selected samples in order to determine the solute loadings that could result from these materials.

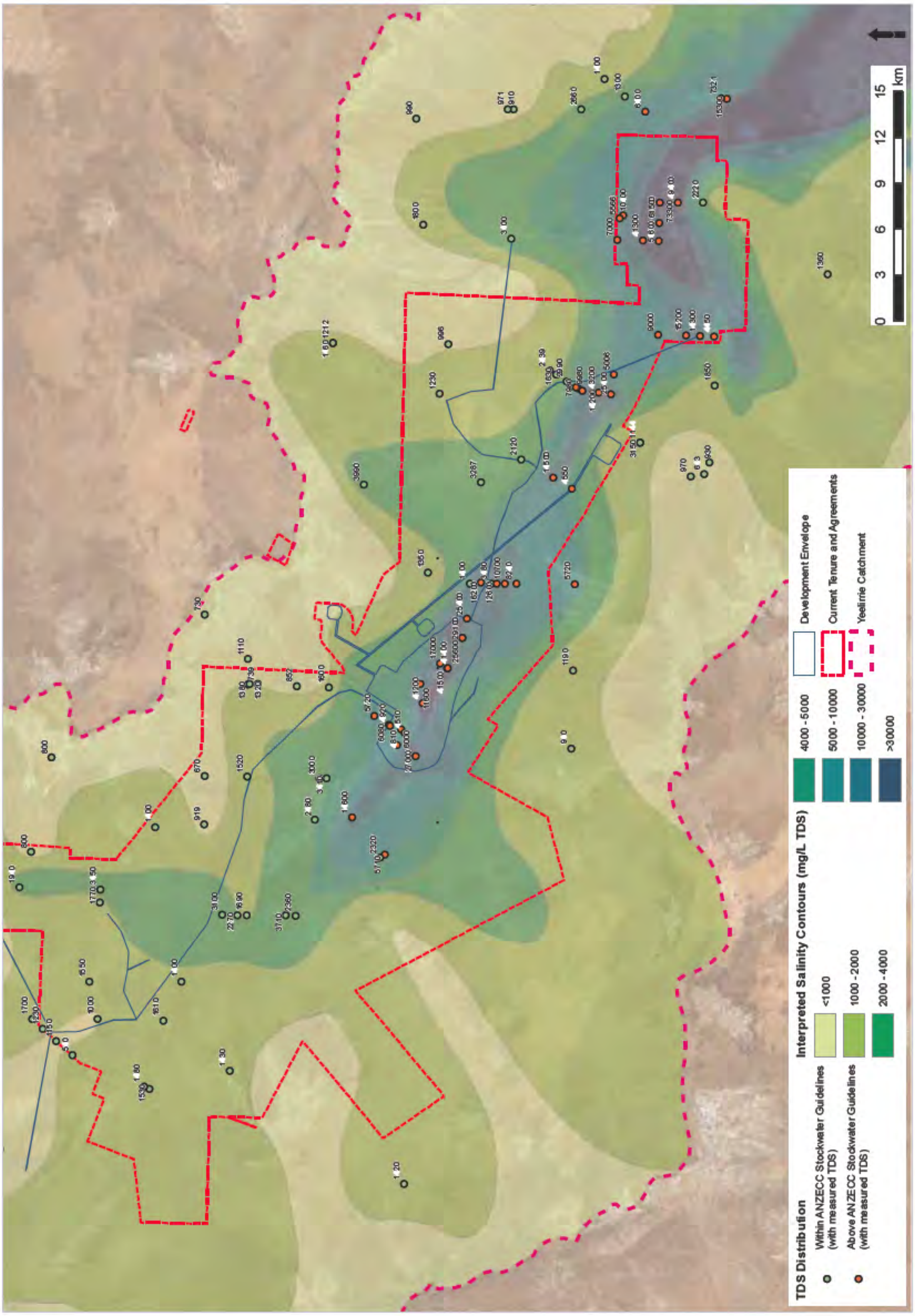


Figure 9-47: Distribution of total dissolved solids (TDS) at the water table

The thermodynamic data used were those contained in the thermo.dat database for Geochemist's Workbench with modifications. The database was updated with data from the Harwell/Nirex Thermodynamic Database for Chemical Equilibrium Studies (HATCHES), version 20 released in July 2013 as well as recent publications that improve thermodynamic data for relevant species. The HATCHES database is based on the database provided with the US Geological Survey computer program PHREEQC and is used, in conjunction with chemical and geochemical computer programs, to simulate a wide variety of reactions in aqueous environments. The database is currently maintained by the company AMEC (HATCHES, 2013) for the Radioactive Waste Management Directorate of the Nuclear Decommissioning Authority (Cameco, 2015b).

The aged tailings tests in conjunction with thermodynamic geochemical speciation modelling were used to develop conservative source terms that would describe conditions in the TSF in the long term. Sorption controls were not considered in the development of tailings source terms as a further conservative measure despite the presence of significant ferruginous soils available as a sorbent for tailings contaminants of concern.

The source terms data was used in the long term solute transport modelling to determine the extent of movement of the contaminants of concern 15,000 years after the closure of the project. The long term solute transport modelling is described in Appendix I1.

Figure 9-47 shows the majority of the groundwater from the wellfields will be low quality water (high salinity) from the palaeochannel aquifer.

Contaminants of concern

Based on the geochemical analyses undertaken, chloride, uranium, vanadium, arsenic, and molybdenum were selected for solute transport modelling. These contaminants of concern (CoCs) were chosen as they are expected to be the least retarded in the Yeelirrie environment because they exist as negatively charged species (arsenic and molybdenum), and uranium and vanadium because they are of particular concern because of the geochemistry of the carnotite deposit. Chloride was included because it is a non-retarding conservative tracer.

Contaminant transport

Mass transport involves the following processes:

- advection;
- hydrodynamic dispersion (including mechanical dispersion and diffusion); and
- chemical, nuclear and biological processes.

The results of the modelling of the transport of chloride and uranium are shown in Figures 9-48 to 9-51. The results are presented pictorially as increases (on a logarithmic scale) in concentrations of COCs above the baseline (pre-development condition) after Project closure.

Chloride

- Along the valley, the predicted plume is expected to travel up to 50 km eastward. Concentration increases above pre-development conditions within the plume are typically < 10 mg/L. Elevated concentrations (>10 mg/L above pre-development conditions) occur only in a limited number of locations. Given that high concentrations of chloride occur naturally in the Yeelirrie Catchment, predicted increases in chloride concentrations beyond approximately 1,000 m east of the TSF are considered negligible.
- Chloride could migrate up to 600 m northward from the TSF due to local northward groundwater flows north of the TSF cells and transverse dispersion. Southward migration is limited.
- In the vertical direction, the downward transport of chloride is limited to diffusion in the presence of an upward hydraulic up-gradient. Therefore, the downward transport is limited, but could reach the weathered granite.

Figure 9-48: Simulated chloride transport plume in model layer 1 at year 15,000

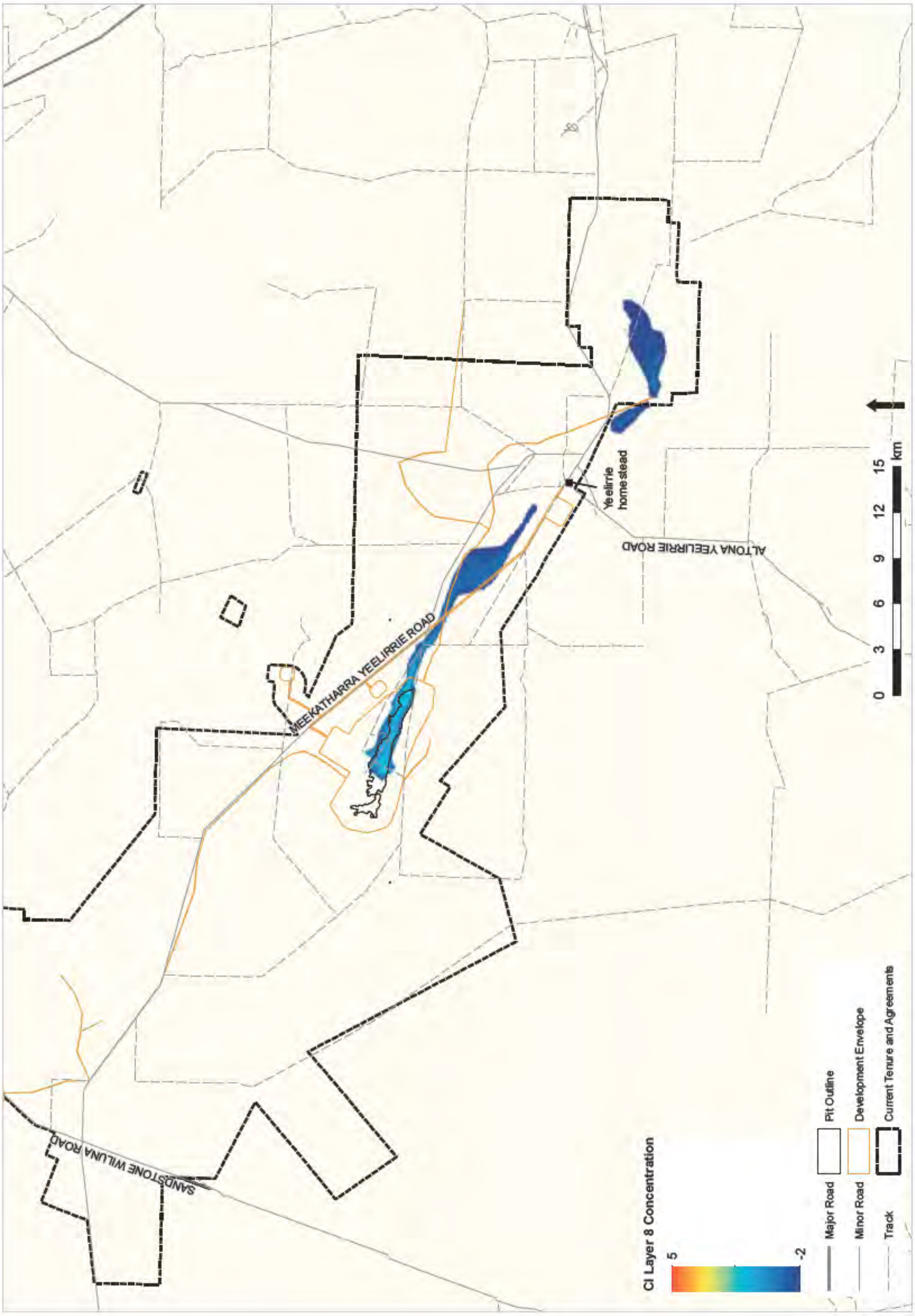


Figure 9-49: Simulated Chloride transport plume in model layer 8 at year 15,000

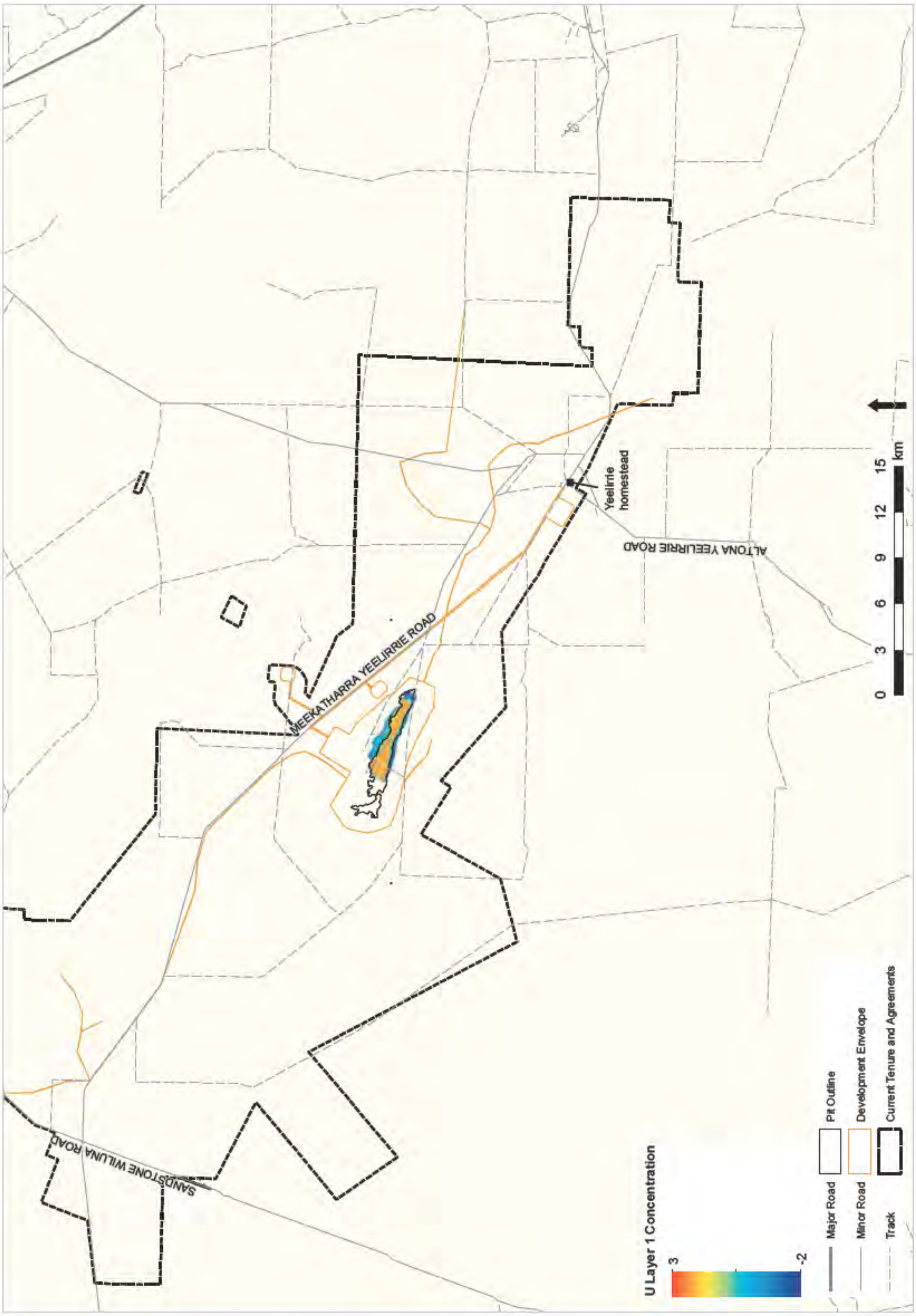


Figure 9-50: Simulated uranium transport plume in model layer 1 at year 15,000

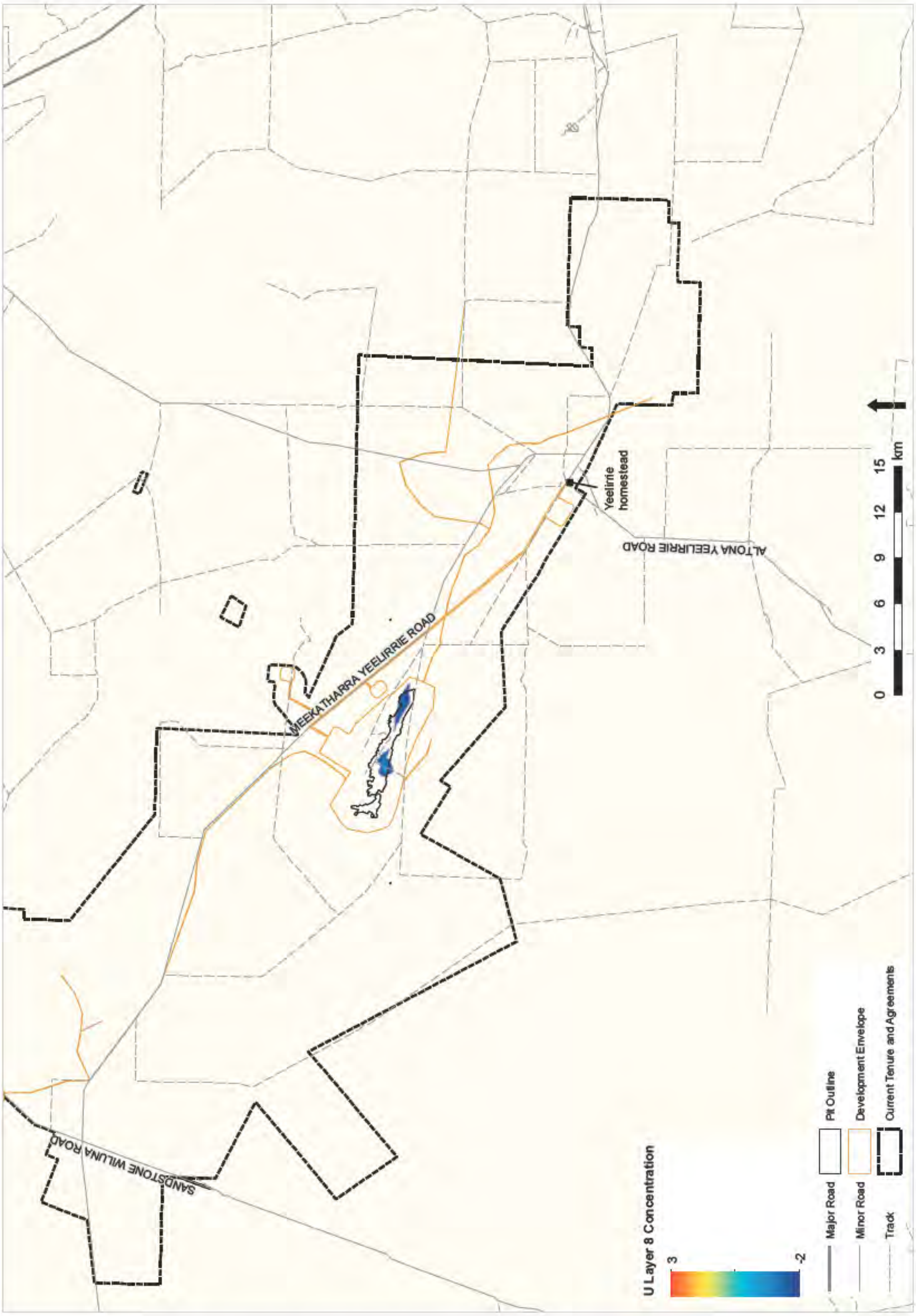


Figure 9-51: Simulated uranium transport plume in model layer 8 at year 15,000

Uranium

- In the east-west direction, the likely resultant uranium plume front (threshold of 0.2 mg/L) is predicted to remain within the mine-waste backfill (i.e. stay within the mine pit).
- In the north-south direction, the plume front (0.2 mg/L) could travel northward in the calcrete by as much as approximately 500 m.
- In the vertical direction, the predicted uranium plume could reach the weathered granite.

Vanadium

- In the east-west direction, the likely resultant vanadium plume front (0.01 mg/L) is predicted to remain within the mine-waste backfill (i.e. stay within the mine pit).
- In the north-south direction, the plume front (0.01 mg/L) could travel northward approximately 600 m, and southward approximately 200 m.
- In the vertical direction, the plume front could reach the weathered granite in a limited area.

Arsenic

- In the east-west direction, the likely resultant arsenic plume front (0.01 mg/L) is predicted to remain within the mine-waste backfill (i.e. stay within the mine pit).
- In the north-south direction, the plume front (0.01 mg/L) could travel northward in the calcrete by approximately 600 m.
- In the vertical direction, the plume front could reach the sand/clay lower paleo-channel formation and the weathered granite in a limited area.

Molybdenum

- In the east-west direction, the likely resultant molybdenum plume front (0.01 mg/L) is predicted to remain within the mine-waste backfill (i.e. stay within the mine pit).
- In the north-south direction, the plume front (0.01 mg/L) could travel northward in the calcrete by approximately 500 m.
- In the vertical direction, the plume front could reach the sand/clay lower paleo-channel formation and the weathered granite in a limited area.

Sensitivity analysis

The sensitivity analyses undertaken indicate that COC transport is more sensitive to the diffusion coefficient (Kd), infiltration through tailings and backfill cover, and the extinction depth, rather than the source concentration in the respective simulated range of these parameters.

This, along with the uncertainty in characterising Kd, infiltration through tailings cover, extinction depth and source concentration, has been taken into account in considering the transport simulation results presented in this report. High site-specific Kd values are supported by field evidence, gamma radiation surveys obtained after the removal of stockpiled materials during rehabilitation activities in 2004 at the Yeelirrie site showed very low readings after removal of the stockpile indicating a very limited release during the stockpiles lifetime (20 to 30 years) (Cameco, 2015a).

9.5.5.4 Summary of Management Measures

In summary, based on the detailed groundwater investigation and modelling of the Yeelirrie aquifers since 1978, Cameco has a high level of confidence that the required water demand can be met without any unacceptable environmental impact. Cameco will prepare and submit a detailed Groundwater Operating Strategy including a Groundwater Management Plan as part of the application of a 5C groundwater licence.

Design - Avoid

Cameco has designed the Project to enable in-pit storage of tailings, thereby avoiding additional groundwater impacts from an above-ground facility.

The in-pit TSF will incorporate an under-drainage system to capture and return any seepage to the metallurgical plant.

General - Avoid and Minimise

- Groundwater abstraction rates will be maintained at the minimum required for safe operation and for Project water supply.
- Groundwater abstraction rates and groundwater levels will be monitored to confirm predicted drawdown levels.
- Cameco will continue baseline monitoring of groundwater wells to increase levels of confidence around the response of groundwater to rainfall events.
- Continue baseline monitoring of groundwater wells to increase levels of confidence around the response of groundwater to rainfall events.

9.5.6 Commitments

Cameco will prepare and implement a detailed Groundwater Operating Strategy including a Groundwater Management Plan.

9.5.7 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes the Proposal will meet the EPA's objectives with regards to Hydrological Processes and Inland Water Quality (Groundwater).

9.6 Human Health - Radiation

Summary

This section discusses the radiological environment of the Project. It includes a summary of the natural levels of background radiation and considers the impacts from operating the Project on human health, including occupational exposures to radiation. As the section introduces radiation terms and units that some readers may not be familiar with, an introduction to radiation is included as Appendix J1.

Cameco will design, construct and operate the proposed Project to ensure that human radiation exposures comply with Australian standards, codes of practice and guidelines. The Project will be managed in accordance with an approved Radiation Management Plan to ensure compliance with the radiation dose limits for workers outlined in the Radiation Safety (General) Regulations 1983 and limit radiation exposure to members of the public to less than 1 mSv per year above background.

9.6.1 EPA Objectives

The objectives agreed to within the ESD with regards to radiation exposure are:

- To ensure that human health is not adversely affected.

9.6.2 Relevant Legislation and Policy

The exploration, mining, use, and transportation of radioactive substances are regulated at State, Federal, National and International levels of government. Key pieces of legislation relevant to the Project are outlined in Section 3.1 of this document.

In Western Australia the current regulatory framework for the management of radioactive substances is the Radiation Safety Act (RSA) 1975 with three subsidiary regulations; Radiation Safety (General) Regulations 1983, Radiation Safety (Qualifications) Regulations 1980, and Radiation Safety (Transport of Radioactive Substances) Regulations 2002.

The Radiological Council is an independent statutory authority appointed under the RSA to assist the Minister for Health to protect public health and to maintain safe practices in the use of radiation. The RSA regulates the possession, storage, use, handling or disposal of, or other dealing with, any radioactive substances, irradiating apparatus and certain products that use radiation, through its registration and licensing system. The Act applies to both ionising and non-ionising radiation.

Under the current system a licence must be issued by the Radiological Council to mine or mill radioactive substances. The RSA also states that a premise, at which radioactive substances are manufactured, used or stored, must be registered. Through subsidiary legislation like the Radiation Safety (General) Regulations 1983, specific guidance is given for radiation safety officers, codes used and a framework for radiation management plans.

Transport of substances is regulated by the State through the Radiation Safety (Transport of Radioactive Substances) Regulations 2002 which requires any person who transports radioactive substances to be licensed or work under the direction and supervision of a licensee. A Radiation Protection Programme is also necessary, which outlines a transport management plan as well a source security transport plan.

The *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) complements State legislation by regulating agencies and departments which fall under Commonwealth jurisdiction. As with State legislation, the ARPANS Act creates its own regulatory authority, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The ARPANS Act promotes uniformity between all Australian jurisdictions in the Commonwealth, States, and Territories, through the Radiation Health Committee (RHC), which is made up of representatives from each jurisdiction. ARPANSA is recognised as the national authority on radiation protection in Australia.

Two main international bodies provide guidance on radiation protection; the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). The ICRP is an advisory body providing recommendations and guidance on radiation protection which are unilaterally adopted around the world. The IAEA is aligned to the United Nations with a mandate to promote the peaceful use of uranium for nuclear power and provides standards and codes of practice which are generally adopted in local regulations.

Radiation legislation specific to mine sites in Western Australia is regulated through the Mines Safety and Inspection Act 1994 and the Mines Safety and Inspection Regulations 1995 administrated by the DMP. Radiation safety on mine sites is addressed by Part 16 of the Mines Safety and Inspection Regulations. The regulations include requirements for authorised limits, preparation of a radiation management plan, control of exposure to radiation, mining of radioactive material, stockpile management, waste management and mine closure.

In regards to nuclear safety, Australia is a signatory of the international agreements on nuclear materials; the Non-Proliferation of Nuclear Weapons or Non-Proliferation Treaty (NPT) which is enforced in conjunction with Australian Nuclear Safeguard Agreements. This ensures that any nuclear material produced in Australia can only be used for peaceful purposes. Australia has 22 bilateral Safeguard Agreements, covering 39 countries.

9.6.3 Studies and Investigations

Radiation monitoring has been conducted periodically at Yeelirrie since the late 1970s when WMC undertook monitoring for its environmental impact assessment. More recently, BHP Billiton conducted background monitoring for radiation from 2009 to 2011 for its proposed ERMP. Cameco has continued to monitor the background radiation in the region since it acquired the Project at the end of 2012.

The principal purpose of undertaking background monitoring is to understand natural variation in radiation and the impact that an operation might have on this. It is also useful when setting rehabilitation targets. In parallel with direct measurements of various radiation parameters, the background monitoring program included several parameters that are known to influence the radiation environment such as meteorological conditions and groundwater flow.

Background radiation monitoring to date has included:

- activity concentration of long-lived, alpha-emitting radionuclides in dust (LLA);
- concentration of radon in air (Rn);
- concentration of radon decay products in air (RnDP);
- gamma dose rate in air 1 m above ground surface;
- gamma dose rate in air (derived from aerial gamma surveys);
- concentration of radionuclides in soil;
- concentration of radionuclides in groundwater; and
- concentration of radionuclides in surface waters.

Parameters from other data sets that assisted with the description of the background radiological conditions were:

- meteorological data (from on-site weather station and Bureau of Meteorology regional stations), in particular, wind speed, wind direction and atmospheric stability class; and
- traditional food gathering.
- To assess the radiological impacts from the Yeelirrie operation, the potential doses to workers and members of the public from the Project have been calculated.

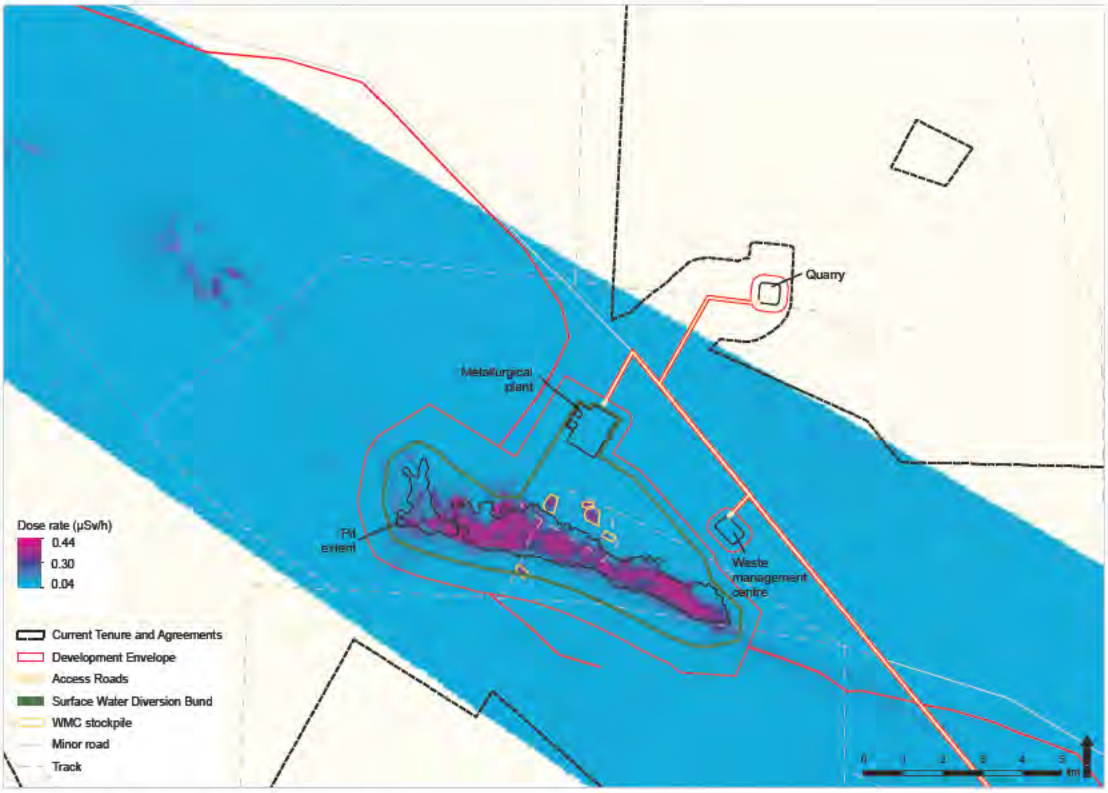


Figure 9-52: Aerial gamma results

Reference is also made to the Air Quality Assessment (Section 9.8), where the sources, methods and results of dust and radon modelling are presented.

9.6.4 Existing Environment

The existing radiological environment at Yeelirrie and in the general region has been monitored and characterised periodically over a period of more than 30 years. Over this period, techniques and technology have improved with measurements becoming more accurate and more precise.

The first radiation monitoring results are from the 1978 WMC Environmental Impact Statement, which were based on a report by the Australian Atomic Energy Commission (AAEC 1978). The main finding in this report was that the Yeelirrie deposit exists in an area of naturally occurring elevated radiation levels.

Between 2009 and 2011 BHP Billiton conducted extensive background monitoring. The raw results from this work have been reviewed and analysed and are used in this assessment. When Cameco acquired Yeelirrie in 2012, some monitoring continued in locations consistent with the BHP Billiton monitoring. The detailed results of this monitoring are provided in the radiation appendix (Appendix J1) and a summary is provided below.

9.6.4.1 Gamma Dose Rates

Surface gamma dose rates arise principally from soil radionuclides and cosmic rays. As the cosmic ray flux is generally quite uniform, the gamma dose rates provide a measure of the underlying soil radionuclide concentrations.

An airborne gamma survey of the Project Area was conducted in 2011. The results of the survey are shown as Figure 9-52.

The figure shows the gamma signature in the Project Area in units of µSv/h, together with the conceptual Project layout superimposed. In addition to the aerial survey, gamma monitoring using a handheld gamma detector was conducted. A survey of 1,900 measurements over the orebody gave an average dose rate of 0.85 µSv/h (range 0.1 to 6.3 µSv/h).

Results off the orebody were much lower, with average levels of approximately 0.09 µSv/h and 0.07 µSv/h at the proposed accommodation area and Yeelirrie homestead respectively. These off site results are consistent with average background gamma dose rates observed elsewhere in Australia (inferred from ARPANSA 2012).

9.6.4.2 Radionuclides in Soils

Sampling and analysis of radionuclides in soils occurred in 2010 with results provided in Table 9-45. (Note that <10 km refers to samples within 10 km of the centre of the proposed pit and >10 km refers to samples beyond this).

Table 9-45: Radionuclide concentrations in different soil types

Soil Sample Location	Radionuclide Concentration Average and Range (Bq/kg)				
	U^{238}	Th^{230}	Ra^{226}	Pb^{210}	Po^{210}
All samples	50 (6-370)	62 (57-210)	129 (7.5-960)	182 (13-1,060)	88 (15-165)
>10 km samples	50 (6-370)	78 (57-123)	85 (7.5-560)	144 (40-590)	42 (15-110)
<10 km samples	51 (10-131)	124 (37-210)	208 (11-960)	249 (13-1,060)	114 (62-165)

The results indicate that radionuclides in soil (apart from uranium) are higher closer to the orebody..

9.6.4.3 Airborne Dusts

A program of sampling airborne dusts was undertaken at Yeelirrie during the second half of 2010, with analyses of radionuclide concentrations conducted. Both total suspended particles (TSP) and particles less than 10 microns in equivalent aerodynamic diameter (PM10) were sampled. The average activity concentration can be seen in Table 9-46.

Table 9-46: Summary of high volume dust results at Yeelirrie

Location	Sample Type	Radionuclide Concentration (µBq/m^3) (Average and range)			
		U^{238}	Th^{230}	Ra^{226}	Pb^{210}
South Gate	PM_{10}	8.3 (4-15)	67 (18-100)	4.5 (1.8-7)	518 (360-730)
Yeelirrie Homestead	PM_{10}	2.9 (2-3.7)	34 (11-50)	3.2 (0.7-6.4)	305 (85-570)
Proposed Accommodation Area	TSP	27.4 (3-90)	107 (14-300)	9.3 (1.7-15)	278 (90-560)

9.6.4.4 Radon

Radon concentration monitoring has been conducted in the region using real time monitoring equipment and passive radon detectors.

The real time monitoring indicates that there is locational, seasonal and diurnal variation in radon concentrations. Higher average and peak radon concentrations occur:

- closer to the orebody;
- during the winter months of the year;
- during stable atmospheric conditions, mainly at night.

The 2010 monitoring results confirmed the findings of the 1978 monitoring which noted that the "undisturbed orebody affects the quality of air in its immediate neighbourhood" (AAEC 1978). The orebody has a significant radon signature when compared to surrounding areas. A summary of the real time monitoring results from 2010 can be seen in Table 9-47.

Table 9-47: Radon concentrations (Bq/m^3)

	Above Orebody		3 Mile Bore (10 km east of orebody)	
	July	November	July	November
Average	127	33	46	30
Median	23	8	18	11
Maximum	1720	783	320	304

Fifty passive radon monitors were placed into the region for a three month period during 2010. The results vary between approximately 10 and 65 Bq/m^3 and again show higher levels closer to the orebody. The average concentrations are as follows:

- 0 to 25 km from the orebody – 37$Bq/m^{3;}$
- 25 to 40 km from the orebody – 30$Bq/m^{3;}$
- > 40 km from orebody – 22$Bq/m^{3.}$

9.6.4.5 Radon Decay Products

Radon decay products (RnDPs) behave in a similar manner to radon, exhibiting large concentration variation depending upon the stability of the atmospheric conditions. This results in seasonal and diurnal variations. Higher concentrations are also noted closer to the orebody. A summary of background monitoring can be seen in Table 9-48 and in Figure 9-53.

Table 9-48: Radon decay product concentrations ($\mu J/m^3$)

	Above Orebody		Adjacent to Yeelirrie Homestead (15 km east of orebody)	
	July	November	July	November
Average	0.21	0.06	0.06	0.03
Median	0.05	0.03	0.03	0.02

The diurnal and seasonal variation is naturally occurring and recorded elsewhere (Cameco 2013, BHP Billiton 2009). The diurnal variation is due to a reduction in atmospheric mixing of radon emitted from the ground as a result of temperature inversions and very stable conditions. This causes the radon to effectively be trapped in layers in the atmosphere, until turbulent conditions return.

Seasonal variations are usually aligned to the broader weather patterns with lower Radon Decay Product Concentrations being associated with periods of higher mixing especially during the

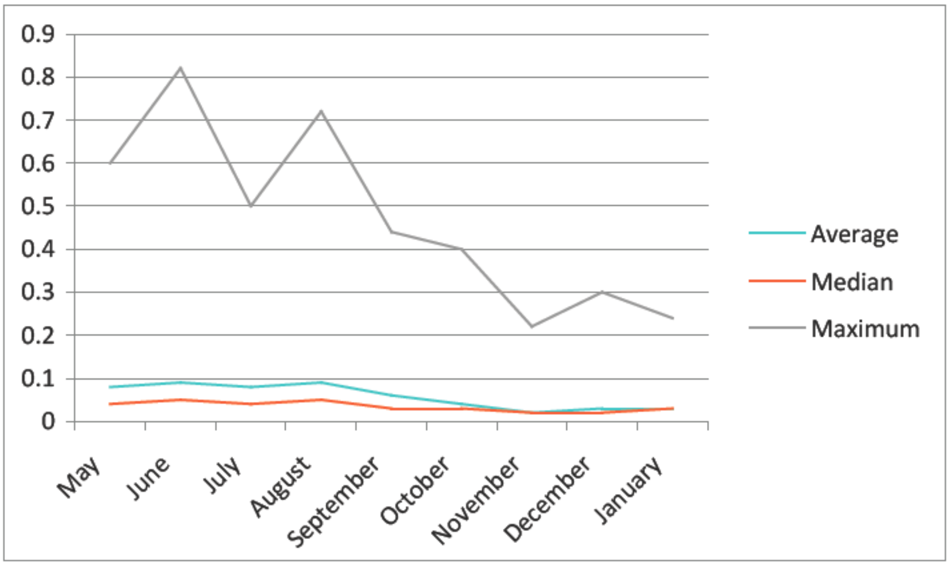


Figure 9-53: Radon decay product concentrations at Yeelirrie Homestead

summer months where there is an increase in thermal turbulence (primarily due to more daylight hours and strong solar radiation).

9.6.4.6 Radionuclides in Groundwater

Earlier monitoring results (AAEC 1978) indicated a high level of variability in groundwater Ra226 concentrations, between 0.02 and 33 Bq/L, together with U^{238} concentrations varying between 3.8 and 17.4 Bq/L within the orebody region and levels between 0.02 and 2.2 Bq/L within the broader catchment area.

An extensive program of groundwater monitoring was conducted during 2009 and 2010 with over 150 samples taken from drill and bore holes from across the region. The data have been grouped and a summary is provided in Table 9-49.

The grouping of data is as follows and as shown in Figure 9-54:

- results from within the outline of the mineralised area (referred to as ‘pit’);
- results from within the area just outside the mineralised area (referred to as ’outline’);
- results from within the valley, (referred to as ‘valley’);
- results from within the south eastern area, (referred to as ‘SE area’);
- any other results from the broader region (referred to as ‘regional’).

Note that the analysis was conducted on each discrete set of data (for example, the ‘outline’ results are only results from that area and exclude results from the ‘pit’ area). This way, it is possible to see how the radionuclide concentrations change as the distance from the mineralised zone increases.

In each category there is a wide range of results, however, the average results show that concentrations of radionuclides in groundwater are generally lower further away from the mineralised zone.

9.6.4.7 Radionuclides Surface Water

Surface water flow in the Yeelirrie region is intermittent, usually only flowing through the broader valley after major rainfall. Drinking water for humans is not sourced from the region, although there are two fresh water pools in the breakaways to the north and upstream of the Project Area that may occasionally be used as a source of drinking water.

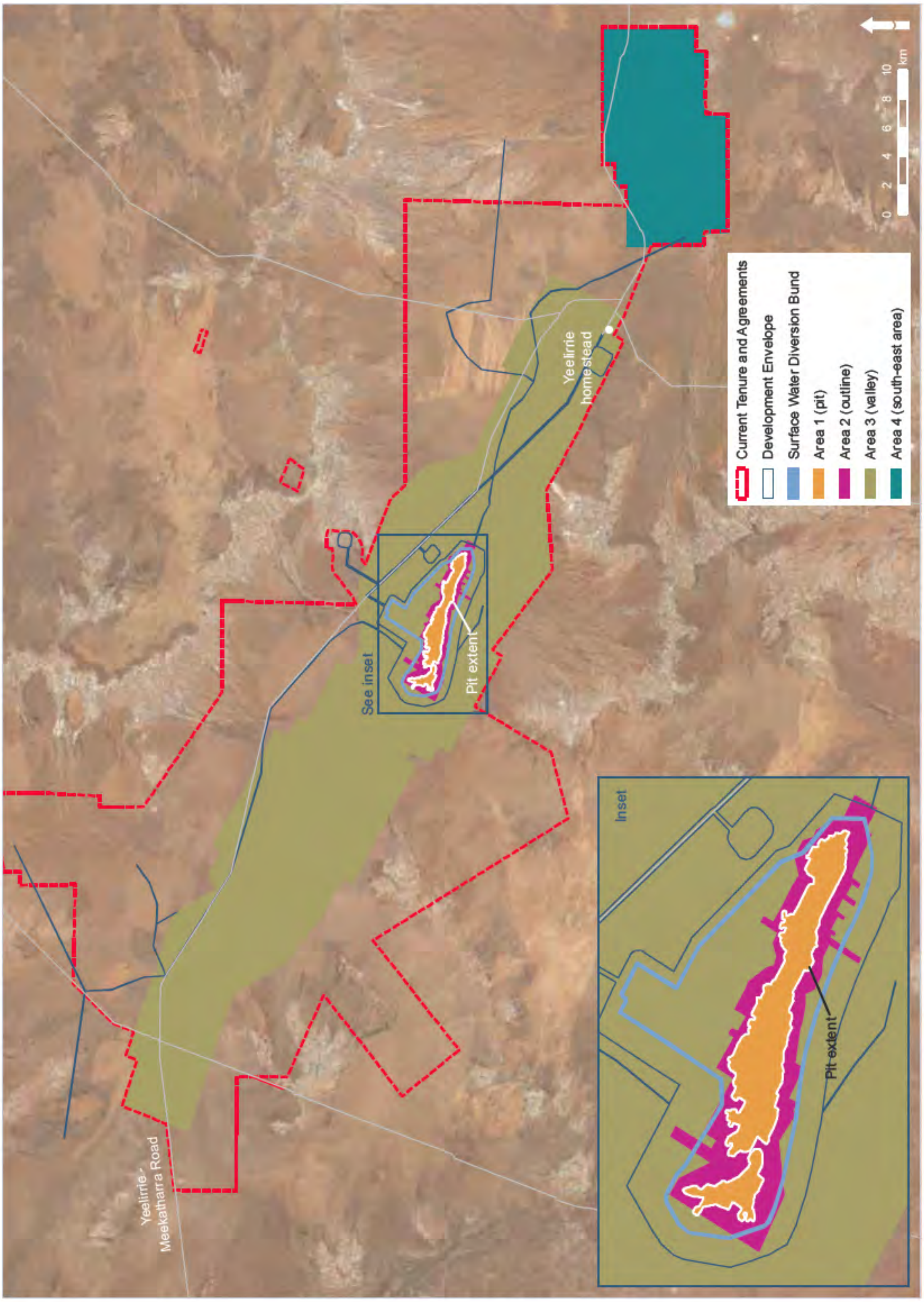


Figure 9-54: Categories of groundwater results

Table 9-49: Average and range of radionuclides in groundwater for different regions

Region	Radionuclide Concentration in Groundwater, Average and Range (Bq/L)				
	U^{238}	Th^{230}	Ra^{226}	Pb^{210}	Po^{210}
Pit	8.6 (1.5 - 31)	17.1 (0.1 – 63.6)	36 (0 – 447)	723 (7.3 – 4210)	2.29 (0.1 – 11.8)
Outline	6.2 (0.1 – 24.3)	0.07 (0.05 – 0.1)	5.9 (0.1 – 19.3)	86.3 (0.003 – 356)	6.8 (0.1 – 39.5)
Valley	5.9 (0.03 – 28.5)	7.5 (0.1 – 24.3)	5.0 (0.1 – 58.2)	77.6 (0.94 – 198)	2.0 (0.1 – 22.9)
SE area	1.6 (0.13 – 8.69)	0.57 (0.1 – 0.87)	2.8 (0.1 – 27.8)		1.1 (0.1 – 18.4)
Regional	0.7 (0.06 – 2.4		0.95 (0.1 – 1.82)	98.3 (1.14 – 491)	5.9 (0.1 – 29)

During the 2009 - 2010 regional water sampling program, a limited number of surface water samples were taken when water was present and results are presented in Table 9-50.

Table 9-50: Summary of radionuclides in surface water samples (Bq/L)

Sample Location	U^{238}	Ra^{226}	Pb^{210}
Breakaway region (upstream)	<0.06	<0.1	4.63
Albion Downs region (downstream)	0.2	< 0.1	3.24

Note that surface water is not generally used permanently for human or stock consumption due to the lack of availability and salinity.

9.6.4.8 Summary

Measured radioactivity levels in environmental media (water, soils, air and biota) in the vicinity of the Yeelirrie deposit are generally higher than those observed from the wider region. The orebody affects the quality of air in its immediate neighbourhood, with "peaks" in radon and RnDP concentrations during stable atmospheric conditions.

Radioactivity in soils and vegetation along the central drainage channel is elevated locally but generally much less elsewhere.

9.6.5 Potential Impacts

9.6.5.1 Radiation Exposure of Workers

As discussed in more detail in Appendix J1, there are three main pathways for radiation exposures of workers: external gamma exposure, inhalation of radioactive dusts and inhalation of radon decay products. This section discusses the estimated doses that will received by Cameco's Yeelirrie workforce.

Miners

Assessment of doses to miners has been based on a mining rate of 8 Mtpa of ore and waste rock, of which 3 Mtpa is ore. The average uranium grade of the mined ore is expected to be 1,600 ppm and 100 ppm for the waste rock, giving an average mined material grade of 660 ppm. Mining will be from shallow "cells", approximately 10 m deep with areas of approximately 50 ha.

Mining is expected to occur for 15 years, and the mine will be operated on a continuous roster for 24 hours/day, seven days a week.

External Gamma Exposure

Mine workers will be exposed to gamma radiation from the uranium mineralisation in the rock on which they work. The expected dose rate from standing on mineralised material can be expressed as 65 µSv/h per 1% of uranium in the material (Thomson and Wilson 1980).

For the mine as a whole, the average concentration of uranium in all excavated material is 660 ppm (0.066%). Therefore the calculated dose rate is 4.3 µSv/h. A worker who spends 2,000 hours per year on "average" material is expected to receive an annual dose of about 8.6 mSv.

This estimate does not take into account shielding that is provided by the mining equipment or the fact that miners do not spend all of their time in the mine (for example truck drivers, mine surveyors and other workers would likely only spend about half of their time in the mine). Therefore, the calculated dose is a worst case estimate. Actual doses are expected to be no more than half the maximum estimated dose.

On this basis the maximum probable gamma dose to mine workers is estimated to be approximately 4.3 mSv/year.

Inhalation of Radionuclides in Dusts

Drilling, blasting and handling of the ore and waste rock produces dusts containing radionuclides which have the potential to result in exposure to workers. The dust generating activities at the Project will be similar to those found at any open pit mining and quarrying operation. Data from dust monitoring in open pit uranium mining is limited, and an estimate of dose may be made based on dust levels recorded at other mining operations and calculating the radiation dose.

For this assessment, a conservative estimate of the long term average dust concentrations in the mine has been made. Published data of 3,000 personal dust samples from 157 quarrying operations has been used (Creely et al., 2006). From this data 99% of the 3,000 measurements taken were of a concentration less than 3 mg/m^3.

Assuming that the uranium content of dust is that of the average of all mined material (660 ppm uranium), then the radionuclide content of the dust is calculated to be 25 mBq/m^3. If it is assumed that the radionuclides are in secular equilibrium, then the activity of each radionuclide in the U^{238} decay chain is 25 mBq/m^3. Assuming a breathing rate of 1.2 m^3/h for 2,000 hours per year, the radionuclide dust intake is calculated to be 19.2 Bq/y (per radionuclide). Using the recognised dust conversion factors (ICRP 1994), the resulting dose received from inhaling that dust cloud for a full (working) year is approximately 3.6 mSv on the basis that the dust concentration being on average 3 mg/m^3 for the full year.

Again, this estimate is considered to be worst case as most mine workers are not exposed to dusty conditions for the full working day. Most spend much of the day in air-conditioned equipment. It is also unlikely that dust levels remain at the estimated concentrations for a full year. Cameco will ensure that dust suppression strategies will be a priority during operations as part of an overarching occupation health and hygiene program.

Inhalation of radon decay products

Exposures to radon decay products are dependent on two main factors: the amount of radon that is being introduced into the mine air and the rate of ventilation.

The radon release rate from the Yeelirrie deposit has been estimated to be 50 $Bq/m^2/s$ per %U (Mason 1982, BHP Billiton 2009, ERA 2014). For an average uranium grade of ore of 1,600 ppm U, the radon emission rate is 8 $Bq/m^2/s$. (Note that the uranium grade of ore is used because it is assumed that the base of the open cell from which the radon is emitted is ore).

For a mining void area of 50 ha, the emanating surface area is 50 ha plus the wall surface area. Assuming the void is square, the walls of the cell will be approximately 700 m long and the design depth is 10 m. This gives a total surface area of 528,000 m^2.

For an average ore grade of 1,600 ppm uranium, and an emanation rate factor of 50 $Bq/m^2/s$ per %U, the total emanation into the cell of 4.2 MBq/s.

The ventilation rate was calculated from the following expression (Thompson 1994):

$$T=33.8*(V/U.L.W)*(0.7\cos(x) +0.3)$$

where T is the air residence time;

- V is the pit volume (m^3);
- U is the wind velocity (m/s);
- L and W are the pit length and width (m); and
- x is the angle between the mine axis and the wind velocity.

The annual average wind speed for the region is 2.7m/s. Using the above formula, together with the mine dimensions, gives a ventilation rate approximately 29 times an hour.

The radon equilibrium concentration is calculated using the following equation (derived from Cember 2009):

$$\text{Radon concentration } (Bq/m^3) = ER/ (PV \times VR)$$

where ‘ER’ is the radon generation rate for the pit in Bq/h, ‘PV’ is the pit volume and ‘VR’ is the number of air changes per hour. This gives an average concentration of 104 Bq/m^3. Assuming that the equilibrium factor between radon decay products (RnDP) and radon is 0.4 (based on the results from baseline monitoring) then the resulting annual average RnDP concentration is 0.24 $\mu J/m^3$. Using the dose conversion factor in ARPANSA (2005), the RnDP dose for a miner in the mine for a full working year is approximately 0.7 mSv.

The baseline monitoring indicated that there are periods of very stable atmospheric conditions which cause atmospheric radon (and RnDP) concentrations to increase, although these conditions would be taken into account in the annual average calculation. However, an additional calculation was undertaken to consider the potential dose under very stable atmospheric conditions

Using the ratio of stable condition RnDP concentrations and the overall average RnDP concentrations from the baseline monitoring, an estimate of the dose under stable atmospheric conditions when the mine is operating can be made. The calculated scaled dose for stable conditions was 1.5 mSv/y.

The total RnDP dose for a miner is therefore conservatively calculated as the weighted sum of the dose from average conditions plus the dose from stable conditions. Assuming 50% of the time in each, the total RnDP dose is calculated to be 1.1 mSv/y.

It is noted that the ICRP (ICRP 2015) has recently recommended a new dose conversion factor for RnDP, which is equivalent to 2.8 Sv/J and is an increase by a factor of 2.4 over the current dose conversion factor. While the new factor has yet to be adopted in Australia applying the new factor to the estimated doses for the Yeelirrie worker dose estimates, results in an estimated dose of 2.6 mSv/y.

Total Dose - Miners

The estimated average annual dose to miners is 4.3 mSv from gamma, 3.6 mSv from inhalation of radioactive dust, and 2.6 mSv from inhalation of radon decay products, resulting in a total of approximately 10.5 mSv/year.

The assumptions used in this assessment are very conservative. A minimal allowance for such factors as shielding of gamma radiation by heavy equipment has been allowed for and it is expected that a lower dust exposure due to cab air-conditioning would occur. In practice it is expected that the maximum probable dose to miners will be approximately 5 mSv/year, similar to doses measured at other uranium mines.

Cameco commits to achieving a very high standard of exposure management to maintain gamma doses at acceptable levels. Using the radiation management experience developed over 20 years of mining uranium in Canada, Cameco will establish a series of control processes which are discussed further in this section to ensure that doses remain well controlled.

The radiation dose history of all Australian uranium mine workers are recorded on the Australian National Radiation Dose Register (ANRDR). More than 31,700 individual workers from the uranium mining industry are recorded on the database which is maintained and managed by ARPANSA.

The register tracks a workers cumulative dose based on data provided by the employer. It assists in minimising the possibility of a worker receiving a dose greater than the Australian dose limit when moving from one employer to another. The data is available to workers and is also used to generate annual statistics relating to exposure trends to assist in the optimisation of radiation protection.

In 2013, approximately 95% of workers received a dose less than 3.5mSv/y and 67% of workers received a dose below 0.5 mSv/y. (ARPANSA, 2013)

Processing Plant Workers

The processing plant will be located to the north east of the mine. Ore will be trucked to the plant from the mine for treatment. The processing facility will consist of three main areas and doses were estimated for workers in these areas as follows:

- concentrator section which consists of ore handling, ore crushing and grinding areas;
- hydrometallurgical section, which consists of alkali leach circuits and precipitation of final product uranium; and
- final product handling.

Maintenance personnel doses will be estimated from averages of all area estimates.

The Yeelirrie processing facilities will be practically identical to existing facilities currently in operation, for example, at Olympic Dam and Ranger. Actual doses from these facilities provide the best estimate of the potential doses to Yeelirrie processing plant operators.

For this dose assessment, a combination of actual doses from other operations and estimates based on modelling has been used.

External Gamma Exposure

Gamma radiation exposures have been based on reported gamma doses of 2.4 mSv/y for processing plant workers at Olympic Dam.

The Yeelirrie uranium ore grade is approximately three times higher than the Olympic Dam uranium grade, however, gamma doses for workers in the hydrometallurgical area and final product handling areas are expected to be similar to the dose received by Olympic Dam hydrometallurgical plant workers. This is because the concentration of radionuclides in these process streams is similar.

Inhalation of Radioactive Dusts

For the assessment, average annual dust concentrations of 2 mg/m^3 have been assumed to exist in the crushing area. This assumption is based on dust concentrations in modern processing facilities being generally low because there is a focus on dust minimisation in design and operations and during actual operations, process materials are usually in slurry form (also known as wet processing).

For the wet processing part of the concentrator and in the hydrometallurgical section, it has been assumed that average dust concentrations are less than for the crushing and ore handling parts of the concentrator area (due to process materials only being in a slurry form). The dust dose in this area is conservatively assumed to be 1 mg/m^3.

In the final product packing area, dust doses have the potential to be high due to the high specific activity of the final product. However, the technology used for handling and packaging of final product ensures that these workplaces are practically dust free. Cameco would utilise standard technology for the packaging of uranium oxide which includes a totally self-contained packing facility, with safety interlocks to prevent access into the packing area during actual packing of product into drums. Therefore dust concentrations are expected to be minimal with low doses as a result.

Inhalation of Radon Decay Products

The estimated doses from inhalation of RnDP for plant workers are based on the modelled radon concentrations from the air quality modelling. This shows an annual average radon concentration of 100 Bq/m^3 at the processing plant location.

For a working year of 2,000 hours, the dose to processing plant workers is calculated to be 0.6 mSv/y using the dose conversion factor from ARPANSA (2005). Using the proposed new ICRP dose conversion factor (ICRP 2105), the estimate dose is 1.5 mSv/y.

Any RnDP variation that may occur at night is accounted for by using the air quality modelling results which are annual averages.

Total Dose – Processing Plant Workers

- The maximum probable annual doses to processing plant workers (using the new ICRP RnDP dose factor) are as follows;
- concentrator ore handling workers – 6.8 mSv;
- concentrator other workers – 5.6 mSv;
- hydrometallurgical plant workers – 3.0 mSv;
- maintenance personnel – 5.2 mSv.

Other Workgroups

Administration workers

The main exposure pathway for administration workers is via inhalation of RnDP. The administration area is located to the north of the processing facility and the air quality modelling indicates that annual average radon concentrations would be 50 Bq/m3. Using the new ICRP dose factors, the calculated RnDP dose is 0.7 mSv/y. Therefore it is expected that total doses to administration workers would be less than 1 mSv/y.

Construction workers

A construction workforce of up to 1,200 workers would be employed to build the accommodation village, processing plant and associated infrastructure. While some mine pre-stripping and mining will occur during construction, it will be away from the construction activities and therefore doses to construction workers are expected to be negligible. If construction activity is to occur within the designated radiation areas once operations commence, then the construction workers would be managed and monitored, as per the production workforce.

Regular area monitoring would be conducted during construction to ensure that construction worker doses remain well below the public limit of 1mSv/y.

Transport workers

The final uranium oxide product is to be trucked to Port Adelaide for export. All final product would be contained in sealed drums in sealed containers during transport and therefore not present a potential dust source. The main exposure pathway during routine transport operations will be from gamma radiation. Gamma dose rates in truck cabins have been measured to be 1uSv/h (BHP Billiton 2009). Based on the exposure time, and the number of typical trips that a driver would make each year, the calculated annual doses to drivers would be approximately 0.5 mSv/y.

Note that potential doses to the public during transport are addressed later in this section.

Camp workers

The accommodation village will be located approximately 16 km to the southeast of the orebody, adjacent to the Yeelirrie homestead. Cameco will employ a catering contractor to manage the camp. Doses to the camp workers would be approximately one half of the calculated doses for residents of Yeelirrie homestead because of the limited time that they would be present there. For example, camp workers would work 2,000 hours per year at the camp and reside there for up to another 2,000 hours per year, compared to full time occupants of the homestead who would reside there for 8,760 hours per year. Doses to camp workers are expected to be approximately 0.1 mSv/y.

Comparison with Other Projects

Appendix J1 provides a comparison of occupational doses received at other similarly configured uranium mines around the world.

Rossing uranium mine is a large open pit mine in Namibia. The average dose to equipment operators in the mine is 2.2mSv/y.

In Canada, the McLean Lake open pit mine has been operating for a number of years and the average measured dose to pit workers is less than 1mSv/y.

Doses to workers at the Olympic Dam are reported as averaging 4mSv/y for underground workers and 2.4mSv/y for processing plant workers. Exposure situations are different for open pit and underground operations.

In Australia, the best comparison is with the Ranger mine in the Northern Territory which is an open pit uranium mine which has operated since 1980. The grade of ore in the mine is higher than that at Yeelirrie, however actual measured doses are relatively low.

Annual occupational dose data from Ranger Mine for the period 2009 to 2011 show that average doses to miners is 0.81 mSv/y, with the maximum being 2.3 mSv/y. For the miners, on average, gamma made up approximately 50% of the total dose and approximately 30% of the dose coming from inhalation of radon decay products (ERA, pers. comm., September 2012).

9.6.5.2 Off-site Exposure

Exposure to members of the public occur when emissions from inside the operation impact upon people outside the operation. Assessments have been conducted for representative people located at:

- the Yeelirrie homestead, (also the location of the project accommodation village) and located approximately 16.4 km to the southeast of the orebody;
- Ululla homestead, located approximately 28.5 km north of the orebody;
- Yeelirrie Pool, located approximately 10.2 km north east of the orebody; and
- Palm Springs located approximately 50.4 km east-south east of the orebody.

Potential pathways

The primary potential exposure pathways for members of the public are:

- irradiation by gamma radiation
- inhalation of the decay products of radon;
- inhalation of radionuclides in dust; and
- ingestion of water, animals or plants that have come in contact with emissions.

Sources

Gamma Radiation

Gamma radiation exposure to members of the public from sources within the project area is considered to be negligible due to the distance between the sources and the public. The sources of gamma radiation (for example ore stockpiles) are well within the project boundary and at least 1km from the closest publicly accessible area (the Yeelirrie Meekatharra Road).

Appendix J1 shows that potential dose to a member of the public at this location, for a full year, is 0.03µSv/y.

Dust Inhalation

Dust emissions from the Project are expected to be primarily generated from mining and materials movement, such as, drilling, excavating, stockpiling and materials movement. Dust may also occur from ore crushing in the processing plant.

The estimated emission of radionuclides (for each work area) was calculated from the dust emission rates and is shown in Table 9-51.

Dust emissions are not expected to be generated from tailings deposition because it will be deposited to a series of cells in the in-pit TSF, as a slurry. Deposition of tailings to TSF cells would be rotated to allow for sufficient consolidation before the next round of deposition. The TSF will be actively managed in accordance with the TSF Operating Plan. If necessary a moist cover will be maintained over the tailings to minimise the risk of dust generation. Final drying and closure of the in-pit TSF will be undertaken to minimise dust generation as outlined in Section 9-12.

Table 9-51: Estimated radioactive dust releases

Dust source	Emission Rate (Bq/s)
Mining - Ore	286
Mining - Overburden	30
Mining - Unmineralised Topsoil	0

Dust source	Emission Rate (Bq/s)
Processing Plant	93
Other (quarry, roads)	0

Exhaust gases from the product drying building will be scrubbed before release to the atmosphere, therefore emissions of concentrated uranium bearing dusts are expected to be negligible.

Radon

The main radon sources for the operation are the mine and tailings. The amount of radon released during operations is based on a radon emission rate of 50 Bq/m^2/s per %U for uranium bearing rocks and ore. For tailings, since the source of radon is radium and the majority of radium in the ore reports to the tailings, the emission rate is also estimated to be 50 Bq/m^2/s per %U. The estimated radon releases are shown in Table 9-52.

Table 9-52: Estimated radon releases

Dust source	Emission Rate (MBq/s)
Mine Pre-strip	12.3
Mine	27.5
Tailings	14.0
Stockpiles	7.1
Processing Plant	0.0

Dispersion modelling

Dust Concentrations

The dust sources identified were used as sources in the air quality modelling and a contour plot of dust concentrations can be seen in Figure 9-49.

The predicted annual average dust concentrations at the main receptor locations can be seen in Table 9-53. The ground level radionuclide activity concentrations have been calculated from the average of all mined material (including ore and overburden). This gives an activity concentration of 9.4 Bq/g for each radionuclide in the uranium decay chain.

Table 9-53: Annual TSP ground level concentrations

Location	Distance from Orebody	Ground Level Concentrations Dust (µg/m^3)	Ground Level Concentrations Radionuclide activity (µBq/m^3)
Yeelirrie Pool	10.2 km northeast	1.1	10.3
Accommodation Village	16.4 km southeast	0.1	0.9
Yeelirrie Homestead	16.4 km southeast	0.1	0.9
Ululla Homestead	28.5 km north	0.2	1.9
Palm Springs	50.4 m east-southeast	0.01	0.1

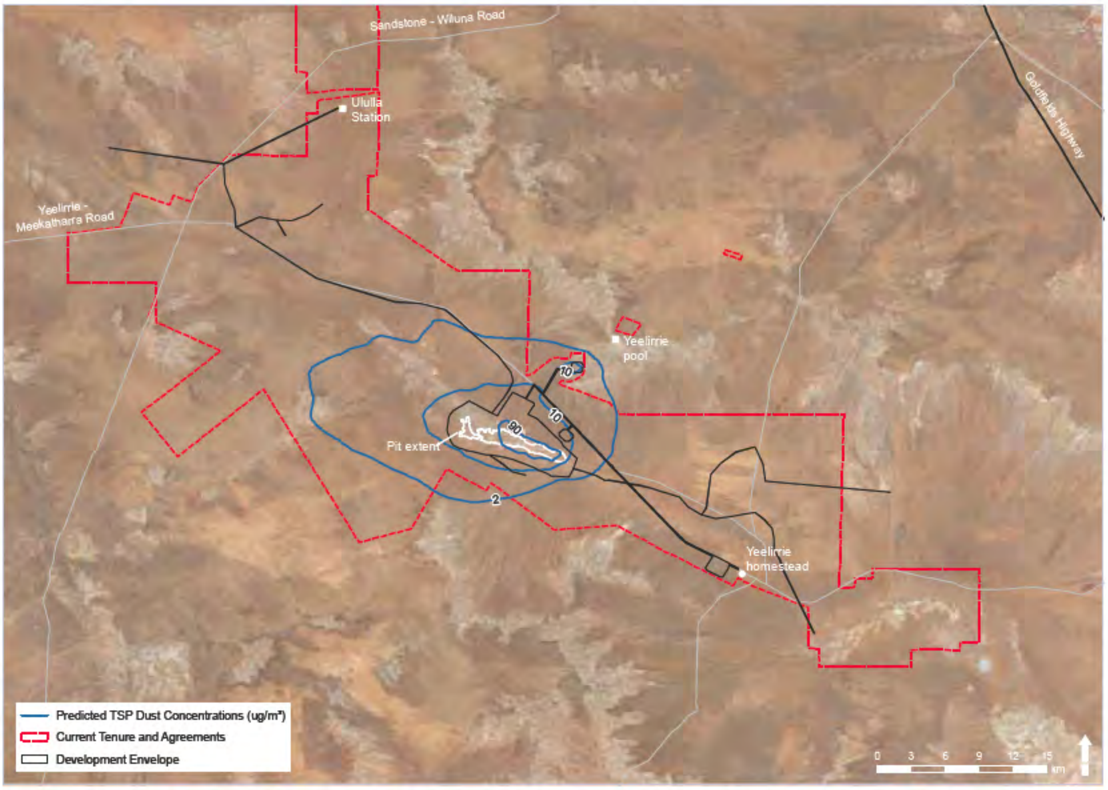


Figure 9-55: Predicted TSP dust concentrations (µg/m³)

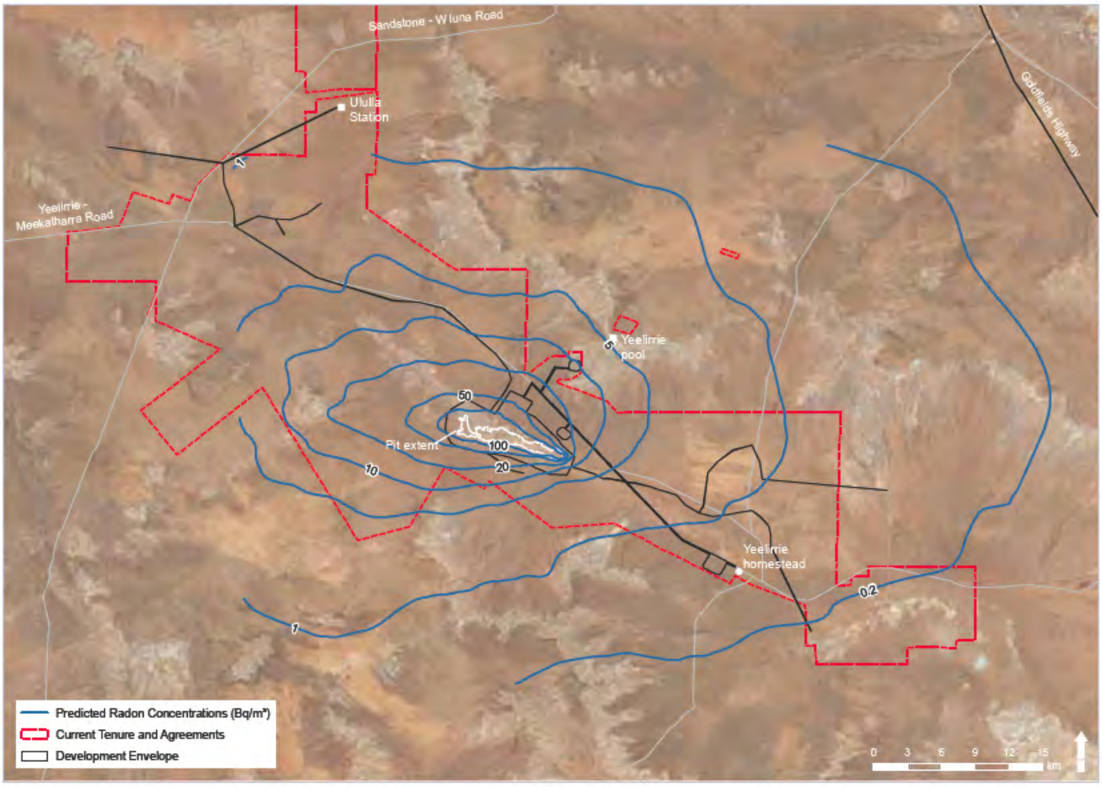


Figure 9-56: Predicted annual average radon concentrations Bq/m³

Radon Concentration

The air quality modelling provides contours of average annual radon concentrations as shown in Figure 9-56.

The predicted annual average ground level concentrations at the main receptor locations can be seen in Table 9-54, together with the calculated RnDP concentration based on an equilibrium factor of 0.4.

Table 9-54: Annual radon and RnDP ground level concentrations

Location	Distance from Orebody	Ground Level Annual Average Radon Concentrations (Bq/m^3)	Ground Level Annual Average RnDP Concentrations (μJ/m^3)
Yeelirrie Pool	10.2 km northeast	10.0	0.022
Accommodation Village	16.4 km southeast	0.4	0.001
Yeelirrie Homestead	16.4 km southeast	0.4	0.001
Ululla Homestead	28.5 km north	1.2	0.003
Palm Springs	50.4 km east-southeast	0.06	0.0001

Dust Deposition

The air quality modelling provides contours of average annual average dust deposition as shown in Figure 9-57, and deposition rates (for dust and radionuclides) as shown in Table 9-55. The radionuclide deposition (per radionuclide) is based on a dust specific activity of 9.4 Bq/g.

Table 9-55: Annual dust deposition rates

Location	Distance from Orebody	Average Annual Ground Level Dust Deposition (g/m^2.month)	Average Annual Ground Level Radionuclide Deposition (Bq/m^2/month)
Yeelirrie Pool	10.2 km northeast	0.013	0.122
Accommodation Village	16.4 km southeast	0.002	0.019
Yeelirrie Homestead	16.4 km southeast	0.002	0.019
Ululla Homestead	28.5 km north	0.006	0.056
Palm Springs	50.4 km east-southeast	0.0004	0.004

Total Inhalation Dose Estimates

The radionuclide concentrations in air and RnDP concentrations are used as the basis for the calculation of inhalation dose using the dose factors and methods recommended by the IAEA (IAEA, 1996) and ARPANSA (ARPANSA 2005). The method is outlined in detail in Appendix J1. A summary of the results can be seen in Table 9-56.

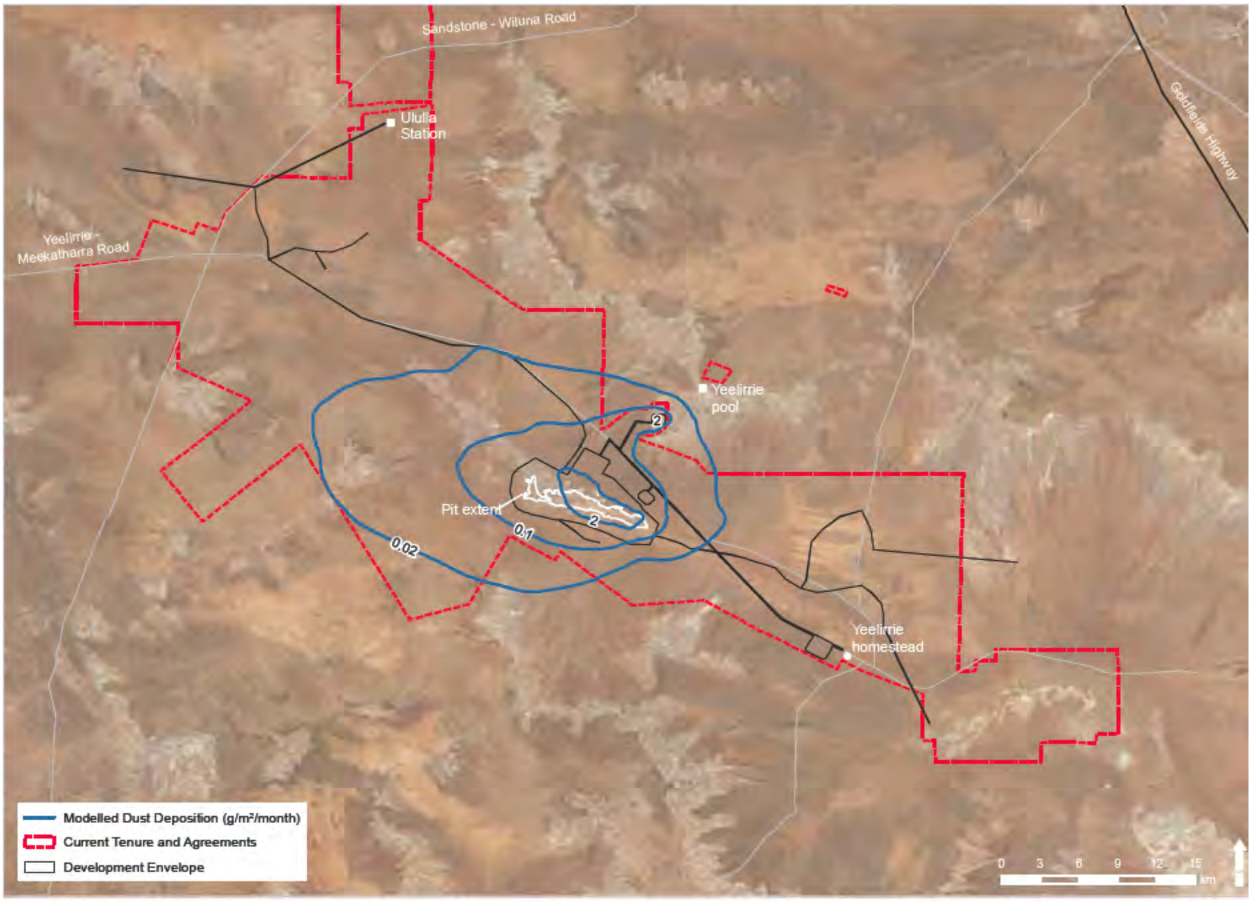


Figure 9-57: Predicted dust deposition (g/m²/month)

Table 9-56: Public inhalation dose estimates

Location	Dose (mSv/y)	
	Radionuclides in Dust	Radon Decay Products
Yeelirrie Pool	0.006	0.210
Accommodation Village	0.0005	0.009
Yeelirrie Homestead	0.0005	0.009
Ululla Homestead	0.0009	0.026
Palm Springs	0.00005	0.0001

Ingestion Dose Estimates

A potential pathway of exposure is through ingestion of food that has been in contact with or contaminated by emissions from the operations. This has been assessed for two types of diets as follows:

- locally cultivated produce; and
- locally sourced bush tucker.

For this assessment, it has been assumed that a person would consume both diets in one year. This will significantly overestimate the calculated potential exposure.

For the cultivated produce, the assessment is based on the following annual food type consumption:

- 30 kg of non-leafy vegetables;
- 30 kg of leafy vegetables;
- 30 kg of root vegetables;
- 100 kg of meat.

The annual rates of consumption are estimates only. The vegetable consumption rates are based on information published by the Food and Agriculture Organization of the United Nations, which notes that the world annual average consumption of vegetables in the year 2000 was approximately 100kg. The meat consumption rates are based on information provided at https://sustainabletable.org.au which notes that in Australia people consume approximately their own weight in meant every year.

The calculated doses from the cultivated diet at each of the main receptor locations are shown in Table 9-57.

Table 9-57: Data for cultivated diet

Location	Vegetation Ingestion Dose (mSv/y)	Meat Ingestion Dose (mSv/y)	Total Ingestion Dose (mSv/y)
Yeelirrie Pool	0.006	0.0009	0.007
Accommodation Village	0.001	0.0001	0.001
Yeelirrie Homestead	0.001	0.0001	0.001
Ululla Homestead	0.002	0.0004	0.003
Palm Springs	0.0002	0.0	0.0002

The bush tucker assessment was based on a survey during 2011, involving Traditional owners of the area. The edible vegetation sampled is shown in Table 9-58.

The consumption rate of traditional bush foods is assumed to be 155 kg/y of plant material and 125 kg/y of animal material based on figures for traditional owners of the Maralinga lands (AAEC 1985). The bush tucker assessment is based on:

- 125 kg/y meat (assumed to be all 110 kg kangaroo flesh and 15 kg kangaroo liver)
- 155 kg/y vegetable (assumed to be 40 kg/y seeds, 115 kg/y berries and fruit)

Table 9-58: Sampled bush foods

Common name	Part eaten	Part sampled
Mulga	Seeds, edible gum, edible insects and galls	Seed pods
Bowgada	Seeds and young seed pods	Seed pods
Ruby Salt bush	Ripe berries	Fruit
Berrigan	Fruit	Green fruit
Australian Boxthorn	Berries	Berries
Quandong	Nut (seed of fruit) and fruit	Fruit
Bush Plum	Flesh of fruit	Fruit
Kangaroo	Flesh, liver	Flesh, liver

Note that this is considered to be a very conservative assessment because it is unlikely that all food consumed would be just from the Yeelirrie area alone. However, this does provide a "worst case" assessment.

From the estimates of bush tucker diet, the intakes of radionuclides are calculated. The intakes are then converted to dose using the IAEA recommended ingestion dose conversion factors (IAEA 1996).

To determine the impact of the operation on bush foods, the dust deposition figures were used to determine the percentage increase in soil radionuclide concentrations after 15 years of dust deposition (compared to baseline). The percentage increase was then factored against the existing dose to provide an estimate of the potential incremental operation originated dose from consumption of bush tucker.

The results in Table 9-59 show the incremental increase in dose after 15 years of operation due to emissions from the Project.

Table 9-59: Bush tucker dose estimates

Location	Distance from Orebody	Estimated Annual Dose (mSv/y)
Yeelirrie Pool	10.2 km northeast	0.040
Accommodation Village	16.4 km south east	0.006
Yeelirrie Homestead	16.4 km southeast	0.006
Ululla Homestead	28.5 km north	0.017
Palm Springs	50.4 km east-southeast	0.002

For transient visitors to the area, the potential dose would be proportionally lower. For example, over a two month period, a visitor to the area would receive 1/6 of the predicted doses.

Total Dose Estimates

The total dose estimates at the sensitive receptors can be seen in Table 9-60. Note that the doses are based on 100% occupancy (that is 8,760 hours per year) at these locations.

Table 9-60: Public Total Dose Estimates

Location	Exposure Pathway Dose ((mSv/y)[1]			
	Dust	RnDP	Ingestion	Total Dose
Yeelirrie Pool	0.003	0.210	0.007	0.215
Accommodation Village	<0.001	0.009	0.001	~0.011
Yeelirrie Homestead	<0.001	0.009	0.001	~0.011
Ululla Homestead	<0.001	0.026	0.003	~0.028
Palm Springs	<0.001	<0.001	0.000	<0.003

Note 1: As noted, the gamma dose is negligible (<0.001mSv/y).

Public Doses During Transport

During the routine trucking of final uranium product to Port Adelaide, there is the potential for members of the public to be exposed to gamma radiation. The exposure is limited due to relatively low gamma dose rates and also the limited exposure situations.

Based on gamma dose rates of 5µSv/h at 1m from a container of uranium oxide, and 1µSv/h and 0.2µSv/h at a distance of five and 10 metres respectively from a container (BHP Billiton 2009), doses for the following exposure scenarios were estimated:

- The dose to a person in a car travelling behind a product container on a truck for six hours at a distance of 5m is calculated to be 0.006mSv.
- The dose to a person standing on side of road as every truck passes in a year (assume 50 occasions and one minute per occasion for the truck to pass, and a distance of 1 m from truck) is calculated to be 0.004mSv/y.

In the event of an accident and a release of radioactive material, an emergency response plan (ERP) would be initiated. The priorities of the ERP are first aid and containment of any product spillage. The area would be segregated and any spilled product covered.

The potential dose from such an incident is expected to be low due to the relatively short exposure period.

9.6.6 Proposed Management

Cameco has extensive experience in managing uranium mining, and is committed to maintaining high standards of radiation protection. The basis of the approach is the corporate Radiation Protection Programme which will be used to set minimum requirements for radiation protection at Yeelirrie. Cameco’s Corporate operation provides services and technical advice to support the radiation protection programs of individual operations.

As part of the approval and authorisation process, a draft Radiation Management Plan (RMP) will be developed for the Project, which will be provided to the DMP and Radiological Council prior to construction. The RMP would include details of radiation protection and radioactive waste management specific to the plant and addresses the requirements of the Western Australian NORM Guidelines (DMP 2010) and the ARPANSA Mining Code (ARPANSA 2005)

A Transport Radiation Management Plan (TRMP) would also be developed which will include an Emergency Response Assistance Plan (ERAP). The transport carrier will be required to develop a plan consistent with Cameco’s ERAP.

This section sets out the principles that will be applied in managing radiation exposure and radioactive waste, and outlines the way these principles will be applied to the Project, including an outline of the radiation control methods and an overview of the proposed monitoring.

Note that the management plans will be consistent with the plans developed for Cameco’s Kintyre operation (Cameco 2013).

9.6.6.1 Principles for the Management of Radiation

The overall approach by Cameco towards the management of radiation is consistent with the recommendations of the ICRP (ICRP 2003), in particular, the principle of optimisation, which aims to ensure that radiation doses to workers and the public are As Low As Reasonably Achievable (social and economic factors taken into account). This is also known as the ALARA principle.

This approach is also applied to the environment, where a priority is to minimise releases which may result in radiological impacts to the natural environment.

Radiation and radioactive waste will be optimally managed and controlled at Yeelirrie through good design and appropriate ongoing operational management systems. The final design detail is yet to be decided, however, the Cameco approach is to establish design criteria and minimum requirements to ensure that radiation is properly managed.

9.6.6.2 Radiation Control in Design

Hazards and risks, including radiation, are most effectively controlled through good design decisions. Cameco will undertake a design optimisation (or ALARA) process, which will be based on risk assessments to identify areas and situation where radiation controls will be required.

This will involve:

- reviewing the initial plans of plant and equipment to determine where radiation protection may be required;
- quantifying the potential radiation impacts; and
- determining and developing options for control.

The options will be examined for the degree of protection they afford, and the optimum option will then be identified. Further refinements of control measures will then be considered before the final design is produced.

In addition to the risk reviews, Cameco has a formal set of design standards that will be used as the basis for certain plant and equipment.

A similar approach will be used in the development of operating procedures. The specific work and tasks will be examined to identify what tasks may require protection measures, the options will be identified and considered and from these an optimum procedure will be developed.

The ALARA principle will also be applied during operations. Radiation data will be collected via the regular monitoring program and will be examined to determine if there are ways in which radiation levels can be reasonably reduced. Where such changes can be identified, the physical project and the management measures will be adapted to incorporate these.

9.6.6.3 Radiation Control in the Mine

Access to the main mining areas will be restricted to ensure that only appropriately trained and qualified personnel enter the main mine work area.

Gamma radiation levels will be relatively low in the mine, however estimates for workers spending all of their working hours for a full year on ore, are up to 8 to 9 mSv/y. However, this is highly unlikely to occur in practice due to shielding from equipment and work areas and because mine workers do not spend their full shift in locations where they are exposed to ore.

For production drill operators and charge up crews who may be required to spend extended time directly on the ore, a workplace exposure plan will be developed based on actual dose rate measurements. The plan would estimate doses (based on exposure time and dose rate) and if necessary require a pad of inert material to be placed to provide some shielding during drilling and charging activities

Worker gamma doses will be monitored and rostering and scheduling of workers will occur if necessary.

Workers will be monitored with TLD gamma monitors and direct-reading personal electronic dosimeters will be issued to workers who may be in higher exposure situations, allowing real-time readout and dose assessment. The results of this monitoring will be regularly reviewed and individuals whose doses may be approaching the target levels will be assigned to other duties. Results will also be used to improve other radiation management measures where necessary.

Active radon (and therefore RnDP) control in the mining areas is unlikely to be necessary during mining operations. The evidence for this is the reported doses to mine workers in the Ranger mine. The Ranger mine is deeper and contains a higher uranium grade than the proposed Yeelirrie project, and the doses are a maximum of 2.3mSv/y (see earlier in this chapter).

However, during stable atmospheric conditions (night time in winter months), RnDP concentrations can increase due to natural processes (e.g. formation of temperature inversions) and these are not directly amenable to control. However, measures will be taken to limit the exposures arising from such situations. All heavy equipment operating in the pit will have air-conditioned cabs. Continuous RnDP monitors will be installed in the pit at times when stable atmospheric conditions are likely to occur. Should essential work be required when high concentrations exist, then respiratory protection will be utilised.

Routine mine dust suppression measures will minimise doses from inhalation of radioactive dust.

9.6.6.4 Radiation Control in the Processing Facility

The plant will be designed for ease of access so that spillages can be effectively cleaned up before they become dust sources. Ample wash-down water points and hoses will be supplied for spillage clean-up.

The main areas of the processing facility that will require particular attention to radiation protection are the crushers and associated facilities, and the uranium product handling.

For dust, crushers and conveyor systems will be fitted with appropriate dust control measures, including dust extraction at dust generating sources, and cleaning of the exhaust air using scrubbers or bag houses. During commissioning, the area will be subject to dust monitoring, to establish exposure levels and to identify dust sources. Based on the results of monitoring, additional dust control measures may be implemented. In situations where engineering solutions cannot be found, procedures will be used (such as work permits) and as a final measure, respiratory protection will be utilised.

After crushing, water will be added to the ore to produce a slurry. At this stage spillage control becomes important and all areas will be bunded. Spilled material will be collected and pumped back to vessels or to the tailings management system as required. Tanks containing radioactive process slurries will be suitably bunded to capture at least the volume of the tank in the event of a catastrophic failure. The tailings pipeline corridor will bunded, and designed to contain spillage from tailings pipeline failures. Pressure sensors will be installed on pipelines to give early warning of failure and to automatically cut-off flow to affected areas.

The uranium precipitation, drying and packing section of the plant handles a product of up to 85% uranium concentration, requiring specific radiation protection measures, particularly dust control. The technology for the safe and secure packing of uranium concentrate into drums has been used for many years at uranium production facilities in Australia. It consists of a totally enclosed packing booth with an automated drum filling process operating under negative pressure to prevent any releases of dust. The negative pressure is maintained by an extraction ventilation system, and all air is scrubbed prior to release. Typically, uranium product packing scrubbers remove more than 99% of exhausted dusts and particulates.

The standard operating procedure requires all product packing workers to change into dedicated overalls prior to entry to the area, and then change when leaving the area.

Access to the product drying and packing area will be by 'swipe-card', with only authorised personnel allowed access. The swipe-card system will also log entry and exit and will record names of personnel and the total amount of time each person spends in this controlled area.

During operations, the emission of dust and radon from tailings cells will be controlled by the inherent moisture levels within the tailings. Elevated moisture levels reduce the amount of radon that is emitted because the radon is unable to escape from the pore space of the tailings particles. The moisture also prevents dusting. As the tailings itself dries and becomes competent and safe to drive on, it will be progressively covered. The dose estimates to workers and the public have been based on the conservative assumption that all cells are uncovered. This provides a worst case assessment of potential dose.

9.6.6.5 General Management Measures

The following section outlines the general management controls that would be applicable across the whole site.

Access Control

Access to operating areas will be controlled to ensure that only those who have been properly trained in specific radiological protection measures can be admitted. As part of this process, controlled and supervised areas will be established for radiation control purposes. A supervised area is one in which working conditions are kept under review but in which special procedures to control exposure to radiation are not normally necessary. The supervised areas will include offices, laboratories and administrative areas, the hydrometallurgical plant (except for controlled areas listed below), the waste rock landforms, and the mineralised overburden stockpile.

A controlled area is one in which employees are required to follow specific procedures aimed at controlling exposure to radiation. Controlled areas are likely to include the mine (both mining areas and tailings management areas), ore handling, crushing and grinding circuit and product precipitation drying and packing areas.

To facilitate the control of people, vehicles and contamination, the operations area will be divided by fencing into 'clean' and 'potentially-contaminated' areas. Access to the potentially-contaminated area will be via a security gate.

Change-room facilities will be established which will have a clean side and a dirty side. Workers will come to work through the clean side and change into work clothes and exit through the dirty side into the "potentially-contaminated' areas. At the end of shift workers will enter the dirty side, remove their work clothes and shower, then proceed to the clean side where they will change back into clean clothes before returning to camp. All work clothes will be laundered on site.

Egress from the potentially contaminated area by vehicle will be via a wheel-wash to ensure that contaminated material will not be transported off-site by vehicles. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation (for example mine vehicles) will be kept within the contaminated area. Equipment that must be taken off-site (for example for specialist servicing or repair) will be required to be cleaned and then checked for contamination by suitably trained staff.

Radiation Safety Expertise

Cameco has access to suitably qualified and experienced radiation safety professionals to assist it during the design, construction and operational phases of the Project. Cameco is the world's largest producer of uranium, and has considerable corporate experience that it brings to the Yeelirrie Project.

Qualified radiation protection personnel would be employed to implement the RMP.

Induction and Training

All employees will receive an induction informing them of the hazards associated with the workplace, of which radiation is one hazard. Area inductions will provide further information on the radiation risks associated with the particular work area. For example, workers who will work in the mine will receive more detailed information on radon, radon decay products and controls. Specific training will be provided to personnel involved in the handling of uranium concentrates.

Managers and supervisors will receive additional training in the recognition and management of situations that have the potential to increase a person's exposure to radiation. This is similar to the Hazard Observation (HAZOB) reporting system, and will also contribute to the annual review of performance of the plans.

A specific radiation safety work permit system will be implemented for use before any non-routine work in a potentially high exposure situation is undertaken. This includes work such as maintenance in the product packing area, where the work permit would list all controls and instructions on radiation protection.

Record Keeping

A computer-based data management system will be used to store and manage all information relating to radiation management and monitoring.

The system will allow the recording of 'raw' and processed data and all relevant supplementary information such as calibration records, dose conversion factors, formulae used to estimate doses and employee occupation, work area, and time spent in various exposure situations.

Information that can be used to identify a person is considered confidential, and only authorised personnel will be able to access such data (including the relevant authorities).

Periodic and statutory reports will be prepared from information stored in the electronic database. Dose reports would be provided to individuals as a matter of course.

Worker radiation monitoring records would be made available to the CEO of ARPANSA via the Australian National Radiation Dose Register (ANRDR), in accordance with confidentiality requirements.

Incident Response

It is not expected that radiological emergencies would arise. However, plans for incidents or accidents that may result in exposure radiation or loss of containment of radioactive material will be prepared as part of the overall site emergency response plan and include:

- immediate response to medical conditions;
- evacuation of non-essential personnel;
- stabilisation of the source(s) of radiation;
- assessment of the likely source(s) of radiation exposure and the types of radiation; and
- contamination of the person(s) and the area.

The plan will also include requirements for post-incident response, including counselling of all people involved or affected by the incident, detailed investigation of the incident, including root-cause analysis to prevent recurrence, and procedures for estimating any radiation doses that may have arisen. Appropriate external experts will be used to assist as required.

Review of Performance

Radiation monitoring results will be reviewed on an ongoing basis to determine the adequacy and effectiveness of engineering and management controls to reduce radiation exposures of people and the environment.

Targets for the following year will be set and progress towards these targets will be monitored (at quarterly intervals).

Monitoring

An occupational and environmental radiation monitoring program would be developed and implemented. The final programs will form part of the RMP and would be submitted to the appropriate authority for approval prior to operations. The plans would include support systems such as servicing and calibration of monitoring instruments.

Occupational Monitoring Programme

Occupational radiation monitoring will be conducted to fulfil two major aims:

- to provide data to assess the doses received by workers, and
- to determine the effectiveness of radiation protection controls.

Table 9-61 provides an outline of a conceptual occupational monitoring program.

Table 9-61: Conceptual occupational monitoring program

Pathway	Measurement method	Area of operations
Direct (external) gamma	Thermo-luminescent dosimeter (TLD)	Individual monitoring for people working in areas where their total annual dose is likely to exceed 5 mSv/y.
Direct (external) gamma	Personal electronic dosimeter	Workers in higher dose rate areas.
Direct (external) gamma	Hand-held, calibrated gamma survey meter	Periodic spot measurements to detect changes in gamma dose rate.
Direct (external) gamma	Hand-held, calibrated gamma survey meter	Periodic spot measurements to detect changes in gamma dose rate.
Inhalation of dust containing long-lived, alpha-emitting radionuclides	Personal dust monitors Alpha counters	Individual monitoring for people working in areas where their total annual dose is likely to exceed 5 mSv. Representative monitoring of work groups
Inhalation of radon decay products	Continuous radon decay product monitor	In mine during periods of very stable atmospheric conditions
	Grab sampling	Representative (audit) monitoring of work groups.

As part of the operational ALARA program, a series of action levels would be established to ensure that exposures remain controlled. Action levels are a management tool for reducing exposures, and are not a regulated limit. An action level system requires that personnel take specified remedial action when monitoring results exceed the specified level. In some cases, the action would be a formal reporting and investigation procedure. It can also involve moving an individual from one task to another to reduce exposure. Table 9-62 provides an indication of action levels that may be set, and the remedial actions that would be required.

Table 9-62: Proposed radiation action levels

Radiation	Action Level	Actions
Gamma dose rates	5 µSv/h	Review occupancy, consider relocation if occupied, consider shielding if practicable.
Surface Contamination	4000 Bq/m^2	Immediate cleanup

Radiation	Action Level	Actions
Dust Concentrations	3 mg/m³	Identify source and suppress (e.g. water suppression, housekeeping and ventilation)
Personal electronic dosimeter	100 µSv in one week	Review tasks, review occupancy of high exposure situations, consider job rotation.
TLD - (¼ly result)	1 mSv	Investigate and identify source. Redesign workplace or tasks to reduce exposure. Shield if necessary.
RnDP Concentrations	3 µJ/m³	Limit occupancy to air conditioned cabins, require respiratory protection

Environmental Radiation Monitoring Programme

In addition to the occupational monitoring program, an environmental radiation monitoring program will be developed and implemented. The basis of the program will be the establishment of a number of environmental radiation monitoring locations (ERML's) taking into account current baseline monitoring locations. The aims of this program are to provide data for the assessment of doses to the public, to provide data for non-human biota impact assessment, to measure any radiological impacts on the off-site environment, and to ensure that the radiation controls for off-site impacts are effective.

A detailed environmental monitoring plan will be prepared for approval prior to construction commencing. A conceptual plan is shown in Table 9-63.

Table 9-63: Proposed environmental radiation monitoring program

Environmental Pathway	Measurement Method	Location and Frequency
Direct (external) gamma	Handheld environmental gamma monitor	Annual survey at perimeter of operational area.
Radon Decay Product Concentrations	Real time monitors	Monitors will rotate between off-site ERMLs
Dispersion of dust containing long-lived, alpha-emitting radionuclides	High volume samplers	Monitors will rotate between off-site ERMLs.
Dispersion of dust containing long-lived, alpha-emitting radionuclides	Dust deposition gauges	Establishment of permanent samplers at the nominated ERMLs.
Samples composited for one year then radiometrically analysed.	Groundwater sampling from monitoring bores	A network of monitoring bores will be sampled quarterly and analysed for radionuclides and other constituents.
Seepage of contaminated water	Groundwater sampling from monitoring bores	A network of monitoring bores will be sampled quarterly and analysed for radionuclides and other constituents.
Run off of contaminated water	Surface water sampling	Opportunistic surface water sampling will occur following significant rainfall events.
Radionuclides in potable water supplies	Sampling and radiometric analysis	Annually

Environmental Radiation Monitoring Network

A network of environmental radiation monitoring sites has been established as part of the broader environmental monitoring program.

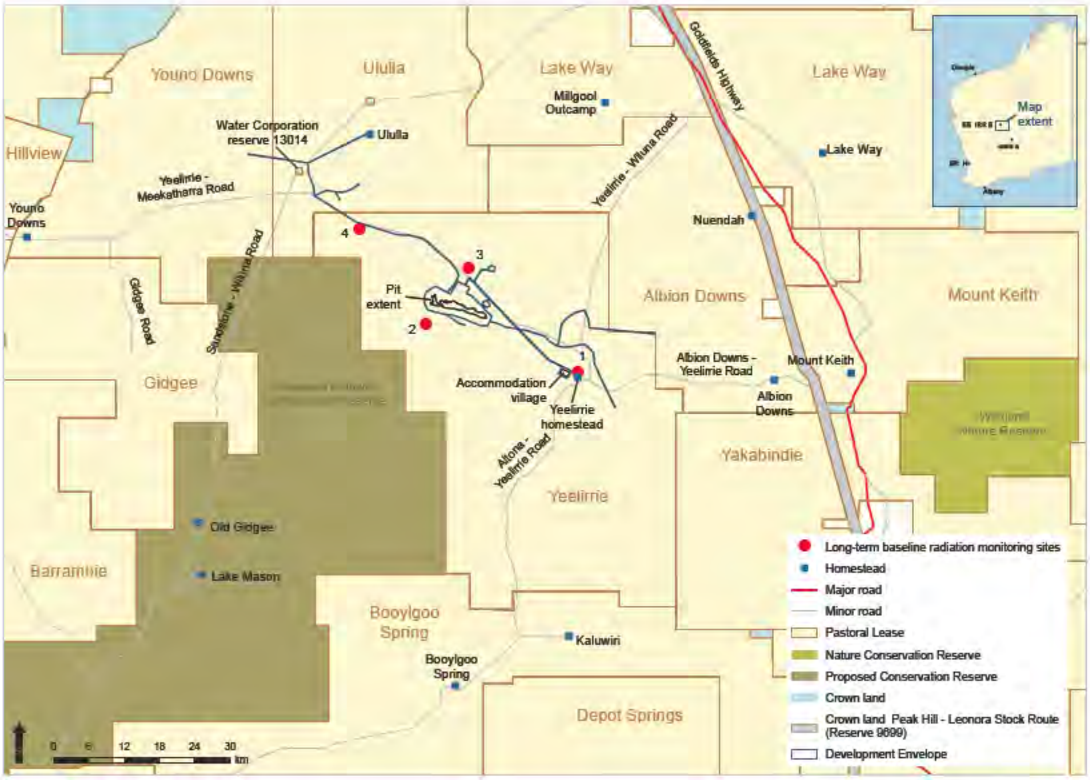


Figure 9-58: Location of longterm baseline environmental radiation monitoring sites

The four radiation monitoring sites have been installed and located based on their proximity to sensitive receptors and to provide even coverage around the orebody.

The locations of the four sites are shown on Figure 9-58. Each site consists of the following:

- Dust Deposition Gauge (set up to AS/NZS 3580.10.1:2003) - to be analysed annually for Total Solids, Insoluble Solids, Soluble Matter, Dust Weight, Gamma Spec and Mass Spec (10-12 metals);
- Environmental TLD badge - installed to measure long term average gamma doses over time; and
- Alpha-track radon gas detector (installed in protective canister to reduce exposure to heat) - installed to measure long term average radon concentration over time.

The dust deposition bottles, TLD badges and radon gas detectors will be collected and replaced on a monthly and quarterly basis (depending upon the requirements). TLD badges and the radon gas detectors will be sent to an approved laboratory for analysis on a quarterly basis.

Support Systems

The support system for the monitoring programs will include:

- recognised sampling methodologies that are documented and regularly reviewed;
- routine instrument calibration programs, including auditing of calibration sources;
- instrument maintenance and repair programs;
- the purchase and use of appropriate monitoring equipment;
- provision of appropriately trained and qualified monitoring personnel;
- review of new equipment; and
- regular external audits of the monitoring program and system.

9.6.6.6 Radioactive Waste Management

Overview

There are four main categories of radioactive waste that will be generated at Yeelirrie:

- mineralised waste material that contains uranium at an average grade of less than 670 ppm which may be blended with higher grade ore and processed or may be returned to the open pit for long term storage at the conclusion of mining;
- process tailings, which is the residue from processing, being material that has passed through the processing plant and had uranium extracted, leaving the remaining radionuclides in the uranium decay series;
- water that may have come into contact with radioactive materials including surface run off, from areas which may contain uranium bearing materials, and leachate that has infiltrated such materials; and
- miscellaneous wastes that may have become contaminated through contact with ores and process residues (referred to as contaminated waste), including discarded conveyor belts, rubber lining material, pipes, filter media and used protective equipment.

All radioactive waste produced by the project is naturally occurring radioactive material (NORM) waste and therefore classified as low level radioactive waste. The Project would not produce any intermediate level radioactive waste streams.

Waste Rock Management

Standard grade-control methods will be used to identify the general type of material during mining. Overburden will be trucked to the waste rock facility. At the end of mining, mineralised waste (very low grade ore) will be returned to the open pit mine as part of the closure program and then capped with unmineralised waste material to minimise radiation at the surface of the rehabilitated open pit.

Tailings Management

Tailings will be disposed of into the mined out voids. The tailings will be allowed to dry sufficiently within the mined out voids and then covered with inert waste rock to a depth agreed to minimise the emanation of radon. A detailed closure plan for the TSF is included in the Mine Closure Plan (Appendix O1).

Radionuclide assessments of tailings have been conducted and are summarised in Table 9-64. The processing of the ore will use a standard milling, leaching and precipitation process and the deportment of radionuclides through this flowsheet are well known, with the majority of uranium reporting to final product and remnant radionuclides reporting to tailings.

Tailings handling will be similar to other uranium mines. Tailings will be pumped from the processing plant to an empty mine cell and deposited in thin layers. The tailings discharge points will be rotated around the cell with a cycle time of several weeks, which will allow some drying but will retain the tailings in a damp state to reduce dust generation. Excess liquor will collect near the centre of the facility and will be reused in the plant or pumped to lined evaporation ponds.

The philosophy of maintaining a moist beach surface during operation is leading practice for radon emanation control from tailings storage facilities, with trials conducted at Ranger Mine showed that the radon emanation from tailings kept below the air entry point were similar to submerged tailings (Cameco, 2015, Appendix D).

Table 9-64: Radionuclide analysis of tailings

Tailings Material	Radionuclide Concentration							
	U^{238}	U^{234}	Th^{230}	Ra^{226}	Pb^{210}	Po^{210}(3)	U^{235}	Ac^{227}
Solids (Bq/kg)[1]	1,600	1,600	13,000	10,000	14,000	9,000	<100	90
Liquor (Bq/L)[2]	1,520	1,520	<130	17	<20	40	90	<2

Note 1: The testwork was conducted on material containing approximately 1,100 ppm of uranium.

Note 2: The activity concentration for solid tailings is in units of Bq/kg for volumetric comparison with the liquor portion of the tailings.

Note 3: The Po^{210} concentration was not analysed for this particular sample. However an estimate has been made based on the analysis of Cameco Kintyre ore. The processing of both ores is similar and it is expected that the radionuclides would behave in a similar manner (which is the case for U^{238}, Th^{230}, Ra^{226} and Pb^{210}).

During March 2010, BHP Billiton conducted drying tests on tailings samples to investigate the drying behaviour of the tailings, and in particular the 'air entry point', which indicates the moisture content at which the tailings begin to de-saturate. This is important for determining the moisture content at which the tailings should be kept to minimise radon emanation.

The results of this work will be used during operations to minimise radon emanation.

Waste Water Management

Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or from the mineralised overburden stockpile may contain entrained radioactive dusts and sediments. The site will be designed to retain surface water runoff from a 1-in-100 year 72-hour storm event on site. The method of control will involve the construction of sedimentation and evaporations ponds, and appropriate collection bunds and channels.

All operational areas in the plant will be bunded. Spillage will be collected and returned to the processing vessels or to the tailings management system.

Waste water from washdown areas and cleanup water would also be captured for treatment and evaporation.

Contaminated Material Waste Control

Material including contaminated equipment and wastes from operational areas would be disposed in an approved manner. A system of separate collection of potentially contaminated wastes from operational areas will be instituted. Where practical, potentially contaminated wastes will be decontaminated and disposed of with normal waste streams. Contaminated waste will be collected and initially held in a secure, bunded area. Depending on the nature of the waste several disposal options will be available. These include:

- disposal within the TSF during mining; or
- disposal into the mine pit at the end of operations.
- In all cases records of the disposal, including type of material, quantities and locations will be kept.

Rehabilitation and Decommissioning

A Mine Closure Plan has been developed for the Project and will be submitted to DMP for approval before commencement of operations (Section 9.12 and Appendix O1). The radiation closure design aim is to ensure that all radioactive material is contained in the long term so that radiation exposures are low and well below the member of public dose limit.

At the end of mining, all equipment will be tested for contamination. Where recycling is practicable, items will be decontaminated to approved radiation levels before leaving site. Items that cannot be properly decontaminated, or where recycling is impracticable, will be buried in the open pit in an approved manner.

The site will be monitored after rehabilitation to ensure that it is free of contamination. Monitoring, including surface monitoring and monitoring of groundwater would continue for a period of time post-closure until agreed Completion Criteria had been achieved to the satisfaction of the regulators.

It is expected that under those conditions radiation exposures to the public would be minimal, and certainly significantly less than those during operation.

Assessment of radon exhalation from the TSF post closure

In the Mine Closure Plan (Appendix O1), Cameco proposes to cover the completed tailings cells with at least 1 m of capillary break material and at least 2 m of growth medium. The capillary break will be constructed from compacted coarse material, likely to be calcrete and local loamy material while the growth medium will be local soils and previously stored mine overburden.

The completed cover provides an effective barrier to radon by increasing the diffusion time of radon through the cover material to the surface and then into the atmosphere. A longer diffusion time increases the chance that the radon decays within the cover material itself.

The rate of radon movement through the cover is proportional to the diffusion characteristics of the cover material and the depth of material. Canadian work (Chambers 2009) has been used to determine the rates of radon penetration through various depths of various materials. This work shows that one metre of soil reduces radon emission rates to 25% of their input rate. One metre of compacted soil is estimated to reduce radon emission rates to 16% of the original input (average of soil and compacted moist soil values). Therefore, for the proposed Yeelirrie tailings cell cover, the radon emission rates would be reduced to 1% of the radon input into the cover material. (Note that 1% is obtained by multiplying the reduction rate of each layer.)

Cameco will commit to undertaking test work during operations to accurately determine the attenuation rate of various covers.

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

Appendix O1 identifies that erosion of the in-pit TSF cover may occur at rates that exceed the natural background rates. The modelling indicates that the natural erosion rates in the region over 10,000 years are less than 0.5m over approximately 80 to 85% of the former TSF area, with the potential for gullying up to depths of 1.5m for the remain area.

Based on an initial cover of 1m of capillary break (compacted soil) and 2m of soil, the radon emission rate was reduced to less than 1% of the un covered emission rate and calculated to be approximately 0.08Bq/m^2/s (see section 9.6.6.7 of this document).

If it is assumed that 0.5m of the soil cover is eroded over all of the TSF, then the total emission rate is reduced to approximately 2% of the uncovered emission rate. To account for gullying, if it is assumed that 20% of the cover has gullies that are 1.5m deep (compared to the original depth of cover), then the total emanation rate can be calculated to be reduced to 4% of the uncovered emission rate. This gives an areas emission rate of approximately 0.3Bq/m^2/s. As noted during earlier site assessment work by the AAEC (AAEC 1978), naturally occurring radon emission rates were measured to be 3.7 Bq/m^2/s (atop the orebody) and 0.37 Bq/m^2/s (away from orebody).

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

9.6.6.7 Summary of Management Measures

General - Avoid and Minimise

- Cameco will develop a Radiation Management Plan and obtain approval to implement the Plan prior to commencement of the Project. Incident response planning will be included as part of the overall site Emergency Response Plan.
- Qualified radiation protection personnel would be employed to implement the management plan.
- Operations will be divided into 'clean' and 'potentially contaminated' areas. Access to controlled areas will ensure that only those who have been properly trained in radiological protection measures are admitted.
- Movement of vehicles from the potentially contaminated areas will be via a washdown bay to remove all mineralised material. Generally vehicles that are likely to be regularly in contact with higher grade uranium mineralisation will be kept within the contaminated area.
- All personnel will be appropriately trained.
- A specific radiation safety work permit system will be implemented.
- A data management system will be used to store and manage all information relating to radiation management and monitoring.
- The time spent in high dose areas by individual workers will be limited, through careful rostering and scheduling of those workers operating ore recovery equipment, backed up by detailed monitoring.
- Radiation monitoring results will be reviewed on an ongoing basis to determine the adequacy and effectiveness of engineering and management controls and reduce radiation exposures of people and the environment.
- As part of the operational ALARA program, a series of action levels would be established to ensure that radiation exposures remain controlled.

Mining

- All heavy equipment operating in the pit will have air-conditioned cabs with effective air filtration systems.
- Dust management measures will be implemented in accordance with the Dust Management Plan.

Process Plant

- Crushers and conveyor systems will be fitted with appropriate dust control measures, including dust extraction at dust generating sources.
- The process plant uses wet processing which minimises dust generation.
- All operational areas in the plant will be bunded. Spillage will be collected and returned to the processing vessels or to the tailings storage facility.

Mineralised Waste Management

- Stockpile areas will be compacted to minimise infiltration and bunded to capture potentially contaminated surface water, which will be transferred to the process plant.
- Dust management measures will be implemented in accordance with the Dust Management Plan.

Tailings Management

- Tailings will be pumped from the processing plant to the TMF in a slurry form. Tailings will be kept moist during operations to prevent dust lift off.

Waste Water Management

- Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or from the mineralised overburden stockpile will be captured and transferred to the process plant.
- Runoff will drain to sedimentation and evaporation ponds which will be designed to retain runoff from a 1-in-100 year 72-hour storm event. The surface water retention bund will be capable of retaining runoff within the mine area from a 1-in-1,000 year ARI event.
- Waste water from washdown areas and cleanup water would also be captured for treatment and evaporation.

General Waste

- A system of separate collection of potentially contaminated wastes from operational areas will be instituted.
- All equipment will be tested for contamination. Where recycling is practicable, items will be decontaminated to approved radiation levels before leaving site. Items that cannot be properly decontaminated, or where recycling is impracticable, will be buried in an approved manner.

Transport

- The dried UOC product would be top-loaded into 205-litre steel drums and sealed with lids and ring-clamps. The drum-filling station would be located in an airlock that maintained negative pressure to prevent uranium entering the work areas. The outside of the drums would be subsequently washed to remove any residual product from the lids and surfaces before labelling and loading into shipping containers for transport and export.
- All consignments would have extensive safety, operational, emergency response and security arrangements in place.

Closure and Rehabilitation

- All mineralised material will be backfilled to the pit with an engineered cover (refer to Section 9.12).
- The post-closure landform will be monitored in accordance with the Mine Closure Plan (Appendix O1) to ensure that it meets surface contamination criteria.

Management Measures

- Comply with Australian standards, codes of practice and guidelines regarding human and ecological radiation exposure.

9.6.7 Commitments

- Develop and implement a Radiation Management Plan.
- Develop and implement a Transport Radiation Management Plan including an Emergency Response Plan.

9.6.8 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Human Health (Radiation).

9.7 Amenity - Noise

9.7.1 EPA Objective

The ESD requires Cameco to address noise impacts as part of its assessment of the key environmental factor 'human health'. The EPA's objective with regards to human health is:

- To ensure that human health is not adversely affected.

9.7.2 Relevant Legislation and Policy

The Project is subject to the requirements of the Environmental Protection (Noise) Regulations 1997 (Noise Regulations). The assigned levels of acceptable noise exposure are specified under Regulation 8, according to the type of premises receiving the noise. The Noise Regulations define all premises, other than commercial or industrial premises, as 'noise sensitive premises'. As mining and processing at the Project would be a 24 hour per day operation, noise received at neighbouring noise sensitive premises from the mining and processing plant would need to comply with the assigned L_{A10} noise level of 35 dB(A) for the night period.

Additionally, the Noise Regulations require that noise received at noise sensitive premises be free of annoying characteristics including tonality, modulation and impulsiveness. If the annoying characteristic cannot be practically removed and noise received at the premises is deemed to contain an annoying characteristic, then an adjustment needs to be made to the calculated level of noise received at that premises by adding 5 dB(A) where tonality or modulation is present or adding 10 dB(A) where impulsiveness is present.

Noise emissions from mining equipment and processing plants are normally tonal in nature. Given the distance from the Project to the neighbouring noise sensitive premises, it is likely that the tonal nature of the noise received at these premises would be masked by the natural background noise level, and the +5 dB(A) penalty for a tonal component would not be applied. However, to be conservative it has been assumed that noise received at the neighbouring noise sensitive premises would contain a tonal characteristic and the 5 dB(A) penalty would be applied to the calculated level of noise received at a premises.

The EPA released Environmental Assessment Guideline No. 13 for consideration of environmental impacts from noise in September 2014 (EPA, 2014). This guideline outlines how the EPA considers the impacts from noise emissions. The EPA expects project proponents to:

- use best practice noise management, for all noise forms, to minimise impacts on human health and amenity;
- achieve compliance with the requirements of the Environmental Protection (Noise) Regulations 1997 or State Planning Policy 5.4 (SPP 5.4) Road and Rail Transport Noise and Freight Considerations in Land Use Planning where applicable, and other accepted standards; and
- address their contribution to cumulative noise emissions.

9.7.3 Studies and Investigations

An Environmental Noise Assessment was undertaken for BHP Billiton, and reviewed for Cameco's Project (Herring Storer Acoustics, 2011a; Appendix K1). The objectives of this study were to:

- Determine, by modelling, noise propagation from the mining operations.
- Assess the predicted noise levels received at the closest noise sensitive premises, for compliance with the Environmental Protection (Noise) Regulations 1997.
- If exceedances are predicted, investigate possible noise control options that will reduce noise emissions to achieve compliance with the regulations.

An assessment of noise along the transport route was also undertaken by the BHP Billiton and reviewed for Cameco's Project (Herring Storer Acoustics, 2011b; Appendix K2).

These studies indicated that due to the remoteness of the site, the potential noise impacts from the original project were negligible (Section 9.7.5). Review of the results for Cameco's Project indicated noise impacts from the amended Project were expected to be similar to those assessed for BHP Billiton. For this reason, noise modelling was not redone for Cameco's Project.

9.7.4 Existing Environment

The Project is located in a remote area on the Yeelirrie pastoral station. Surrounding pastoral leases include Ululla station, Yuono Downs, Kaluwiri, Yakabindie and Albion Downs (Figure 7-2).

The closest noise sensitive premises is the Yeelirrie homestead, located approximately 14 km south east of the proposed mine. Ululla homestead is located approximately 30 km to the north west of the proposed mine.

The proposed transport route for product from site is along the Albion Downs-Yeelirrie Road, then to the Port of Adelaide in South Australia via the Goldfields Highway and the Eyre Highway. In Western Australia the transport route would pass through Leonora, Menzies, Kalgoorlie, Kambalda, Norseman and Border Village. Transport of construction and mining equipment, workforce and major commodities is likely to be required from Port Hedland, Geraldton, Perth and Kalgoorlie.

9.7.5 Potential Impacts and Management

9.7.5.1 Impacts from Mining and Processing

The following section presents the results of the modelling of the BHP Billiton proposal as presented by Herring Storer Acoustics (2011a, 2011b). A review of the current Project indicates the results are expected to be similar.

At the Yeelirrie homestead, the noise received from mining and processing has been calculated to be 8 dB(A). If calculated noise levels were increased by 5 dB(A) to account for tonality, then the assessable noise level would be 13 dB(A); this complies with the assigned noise night-time L_{A10} level at sensitive premises of 35 dB(A).

Although not required to comply with the requirements of the Environmental Protection (Noise) Regulations 1997, noise received at the proposed accommodation camp (approximately 15 km south east of the mine) has been calculated at 8 dB(A), or 13 dB(A) if tonality is taken into account. This complies with the assigned night-time noise level of 35 dB(A).

Modelling of noise likely to be received at the Ululla homestead shows an assessable noise level of 0 dB(A).

As noise emissions will comply with the Noise Regulations, no additional noise controls will be required. Cameco will, however, minimise noise emissions from the Project by operating and maintaining equipment and machinery in accordance with manufacturers' requirements.

9.7.5.2 Impacts from Transport

An assessment of noise impacts from the anticipated number of vehicle movements was undertaken for the BHP Billiton proposal and reviewed for the Project.

Given the anticipated number of vehicle movements, it is expected that overall traffic movements on the Goldfields Highway could increase by around 9%. This is expected to result in an increase in the level of noise received at residences located along the transport route of 0.4 dB(A). This increase in noise would be considered negligible and therefore, noise emissions from vehicle movements to and from site are not required to be assessed in detail in accordance with SPP5.4.

Whilst no additional noise controls will be required to comply with SPP5.4, Cameco will require its transport contractors to regularly maintain and operate vehicles in accordance with manufacturers' requirements to minimise noise emissions.

9.7.5.3 Summary of Management Measures

General - Avoid and Minimise

- Cameco will minimise noise emissions from the Project by operating and maintaining equipment in accordance with manufactures requirements.
- Cameco will require its transport contractors to regularly maintain and operate vehicles in accordance with manufacturers requirements to minimise noise emissions.

9.7.6 Commitments

Cameco commits to;

- Complying with the Environmental Protection (Noise) Regulations 1997.

9.7.7 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Amenity (Noise)

9.8 Air Quality

9.8.1 EPA Objective

The EPA's objective with regards to air quality is:

- To maintain air quality for the protection of the environment, human health and amenity and to minimise atmospheric gases through the application of best practice.

9.8.2 Relevant Legislation and Policy

The key air emissions of concern for the Project are:

- dust (or particulates) from land clearing, mining, haulage, stockpiling, processing (including crushing and milling); and
- sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulates from diesel-fired power generation.

Dust is generally defined as particles that can remain suspended in the air by turbulence for a period of time. Dust or particulate matter is commonly defined by the size of the particles, measured as:

- total suspended particulates (TSP), which refers to all particulate matter but typically associated with particles that have an equivalent aerodynamic diameter below 50 µm. (The term equivalent aerodynamic particle is used to reference a spherical shaped particle and a density of 1 g/cm^3);
- PM_{10}, particulate matter of 10 µm or less in equivalent aerodynamic diameter; and
- $PM_{2.5}$, particulate matter of 2.5 µm or less in equivalent aerodynamic diameter.

TSP, which contains both the PM_{10} and $PM_{2.5}$ fractions, is normally associated with nuisance impacts such as dust fallout and impacts on amenity. PM_{10} and $PM_{2.5}$ are associated with the potential for health impacts as finer particle fractions can enter deeper into the lungs.

Air quality in WA is assessed against the standards specified in the National Environment Protection (Ambient Air Quality) Measure 1998 (Air NEPM) (National Environmental Protection Council, 1998). The Air NEPM standards for the most significant air pollutants that may arise from the Project are presented in Table 9-65.

Table 9-65: Air quality standards relevant to the Yeelirrie Uranium Project

Pollutant	Averaging Period	Air NEPM standard (µg/m^3)[a]	Air NEPM goal – maximum allowable exceedances
PM_{10}	24-hour	50	5 days per year
NO_2	1-hour	246	1 day per year
	Annual	62	None
SO_2	1-hour	571	1 day per year
	24-hour	229	1 day per year
	Annual	57	None
CO	8-hour	11,000	1 day per year

Note: a. Expressed at Standard Temperature and Pressure (i.e. 0 degrees Celsius and an absolute pressure of 101.325 kilopascals)

For impact assessment purposes, where air pollutants are not covered by the Air NEPM, the DER typically adopts the World Health Organisation's (WHO) Guidelines for Air Quality, or air quality guidelines from other jurisdictions where appropriate (Department of Environment and

Conservation 2004). For example, the Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1999 (Kwinana EPP) specifies a 24-hour average standard for total suspended particulates (TSP) of 90 µg/m³ (limit of 150 µg/m³) for a residential dwelling outside of the buffer zone (Area B). This standard has been applied in the air quality assessment undertaken for the Project by Katestone Environmental Pty Ltd (Katestone) (Katestone 2014a; Appendix L1).

In addition, the New South Wales Office of Environment and Heritage (NSW OEH) has defined dust deposition criteria. These guidelines are based on studies undertaken on coal dust deposition in the Hunter Valley in NSW by the National Energy Research and Demonstration Council (NERDC 1988) and take into account potential amenity impacts. While the dust deposition guideline is expressed as g/m²/month, the NSW OEH has indicated that the monthly average deposition (to be compared against the guideline value) is to be determined from data spanning no less than one year, so as to account for seasonal variations.

Other relevant air quality assessment criteria that are not covered by the Air NEPM are summarised in Table 9-66.

Table 9-66: Relevant air quality guidelines

Pollutant	Averaging period	Air quality guideline	Units [d]	Source
Total suspended particulates (TSP)	24-hour	90	µg/m³	Kwinana EPP
	Annual	90	µg/m³	NSW EPA
PM_{10}	Annual	25	µg/m³	WHO Guideline
$PM_{2.5}$	24-hour	25	µg/m³	Air NEPM advisory reporting standard
	Annual	8	µg/m³	Air NEPM advisory reporting standard
Dust deposition rate	Annual	2 [a]	g/m²/month	NSW EPA [c]
		4 [b]		

Notes:

[a] Maximum increase in deposited dust levels

[b] Maximum total deposited dust level

[c] Amenity dust guideline

[d] Concentrations expressed at Standard Temperature and Pressure (i.e., 0 degrees Celsius and an absolute pressure of 101.325 kilopascals)

Other relevant policies are:

- DEC (2006) Guidance Notes: Air Quality and Air Pollution Modelling, Perth, Western Australia.
- DEC (2010) A guideline for managing the impacts of dust and associated contaminants from land development sites, contaminated sites remediation and other related activities, Perth, Western Australia.

9.8.3 Studies and Investigations

An air quality assessment of the Project was undertaken by Katestone for Cameco's Project design. The complete air quality assessment report is provided as Appendix L1 (Katestone, 2014a).

The purpose of the air quality assessment as outlined in the report was to:

- characterise baseline air quality and describe the climate, local meteorology and existing air environment in the development area;

- quantify particulate emissions (TSP, PM_{10} and $PM_{2.5}$) from all Project related sources;
- quantify emissions of other air pollutants from all Project related sources, including onsite power generation;
- conduct air dispersion modelling using accepted techniques;
- evaluate the incremental and cumulative air quality impacts of the proposed project on the air environment;
- present the results in relation to relevant ambient air criteria; and
- recommend dust management and mitigation strategies where applicable.

The key air pollutants that were considered were dust from the project operations and SO_2, NO_2 and CO from power generation. Atmospheric dispersion modelling was carried out using the CALPUFF Version 6.4 dispersion model to predict the ground-level concentrations of SO_2, CO, NO_2, particulate matter (TSP, PM_{10}, $PM_{2.5}$) and dust deposition rates at sensitive receptors as well as contours across the modelling domain.

The results of dispersion modelling to predict radionuclide activities in airborne and deposited dust and radon emissions have been considered separately in Section 9.6 under Health Impacts (Dust and Radiation).

The assessment was generally conducted in accordance with the DER's Air Quality Modelling Guidance Notes (DER, 2006). Meteorological data for the assessment was generated by coupling TAPM (a prognostic mesoscale model) to CALMET (a diagnostic dispersion model). Data from the on-site automatic weather station was also assimilated into the TAPM model to improve the model's predictions. Katestone evaluated the performance of the TAPM model in simulating wind speed, wind direction and other meteorological parameters against meteorological measurements at the Yeelirrie Automatic Weather Station (AWS). The model was shown to accurately simulate the distribution of light and strong winds at the Yeelirrie AWS. Statistically the TAPM model performed well in regards to accurately reproducing wind speeds at the Yeelirrie AWS.

Dust emissions from the project were estimated based on representative emission factors from the National Pollutant Inventory (NPI) mining handbook, USEPA AP-42 documents and source characteristics and operational activity data provided by Cameco (refer to Katestone 2014a [Appendix L1]). Emissions from power generation were estimated based on engine manufacturer's specifications.

The ESD has requested that Cameco undertake physical and geochemical characterisation of process residues, waste rock and overburden including an assessment of the 'dustiness' of bulk materials to the relevant standards, with an early version of the ESD directing Cameco to undertake the assessment using EN150541 Workplace exposure - Measurement of the dustiness of bulk materials:

- Part 1: requirement and choice of test methods' and/or Workplace exposure - Measurement of dustiness of bulk materials.
- Part 2: rotating drum method.

Cameco has reviewed the European Standards associated with EN150541. Based on a review of the Standard, Cameco considers that it is not applicable as the test methods (rotating drum and continuous drop) do not apply to the mechanical handling of ore and waste at Yeelirrie.

Further the Standard is not applicable to dust releases during mechanical reduction of solid bulk materials (e.g. cutting or crushing) or to wheel generated dust, excavation of material or wind erosion. As these mechanisms (crushing, wheel generated dust, excavation of material or wind erosion) account for approximately 80% of the dust producing processes modelled at Yeelirrie, further testing pursuant to the Standard is unlikely to provide any additional information or improve the existing estimates.

9.8.4 Existing Environment

The Project is located in the East Murchison region in an area which is sparsely populated. The Project is located on the Yeelirrie pastoral lease and is located more than 10 km from the nearest receptors, which have been identified as the Yeelirrie Pool, Yeelirrie Homestead and the proposed Accommodation Village, located approximately 10.2 km, 16.9 km and 14.4 km, respectively, from the ore body.

The nearest sensitive receptors to the Project are presented in Table 9-67.

Table 9-67: Nearest sensitive receptors to the Project

Receptor	Distance and direction from ore body
Accommodation Village	14.4 km SE
Yeelirrie Homestead	16.9 km SE
Ululla Homestead	28.8 km N
Albion Downs Homestead	45 km WSW
Youno Downs	62.1 km WNW
Yeelirrie Pool	10.2 km NE
Palm Springs	50.4 km ESE

The National Pollutant Inventory (NPI) database identifies 15 emission sources within a 100 km radius of the Project. The reported emissions from these sources for the 2012-2013 reporting year are presented in the Katestone report (Appendix L1). The closest mining activity to the Project is at Mount Keith, approximately 70 km east of the proposed Yeelirrie Uranium Project.

The main regional and local dust source is wind erosion of exposed soil surfaces particularly during dry periods. Air quality in the vicinity of the site is also affected by occasional bush fires and scrub fires. Anthropogenic dust sources are primarily from pastoral activities and vehicular activity on unsealed roads. Daily background-levels of dust are expected to be low and will vary significantly depending on location, topography, meteorological conditions and proximity to sources. There are no significant anthropogenic gaseous emissions sources that could affect air quality in the vicinity of the Project.

9.8.4.1 Climatic Conditions

The inland areas of the Western Australian region show a predominance of east to southwest winds during spring and summer, shifting to a distinct alternating westerly and easterly flow during autumn and winter. The climate of the Project Area is described as arid with rainfall occurring mostly in winter. A detailed description of the climatic conditions is presented in Appendix L1.

The most important aspect of the Yeelirrie climate in terms of air quality is the frequency and intensity of hot, dry north-easterly winds as these are most likely to generate dust from the erosion of stockpiles and disturbed areas. Also of importance is the frequency and intensity of night-time inversions particularly in winter characterised by a stable atmosphere and the formation of a low level jet (Lyons *et al.*, 1981). These conditions can cause pollutants to remain suspended in the atmosphere for long periods of time (Katestone 2014a).

The meteorological modelling found that stable boundary layer conditions (Pasquil-Gifford F class) were likely to occur frequently (39% of hours in the period from February 2010 to January 2011). These conditions occur at night and are more prominent during the winter months when surface cooling is at a maximum (Katestone 2014a).

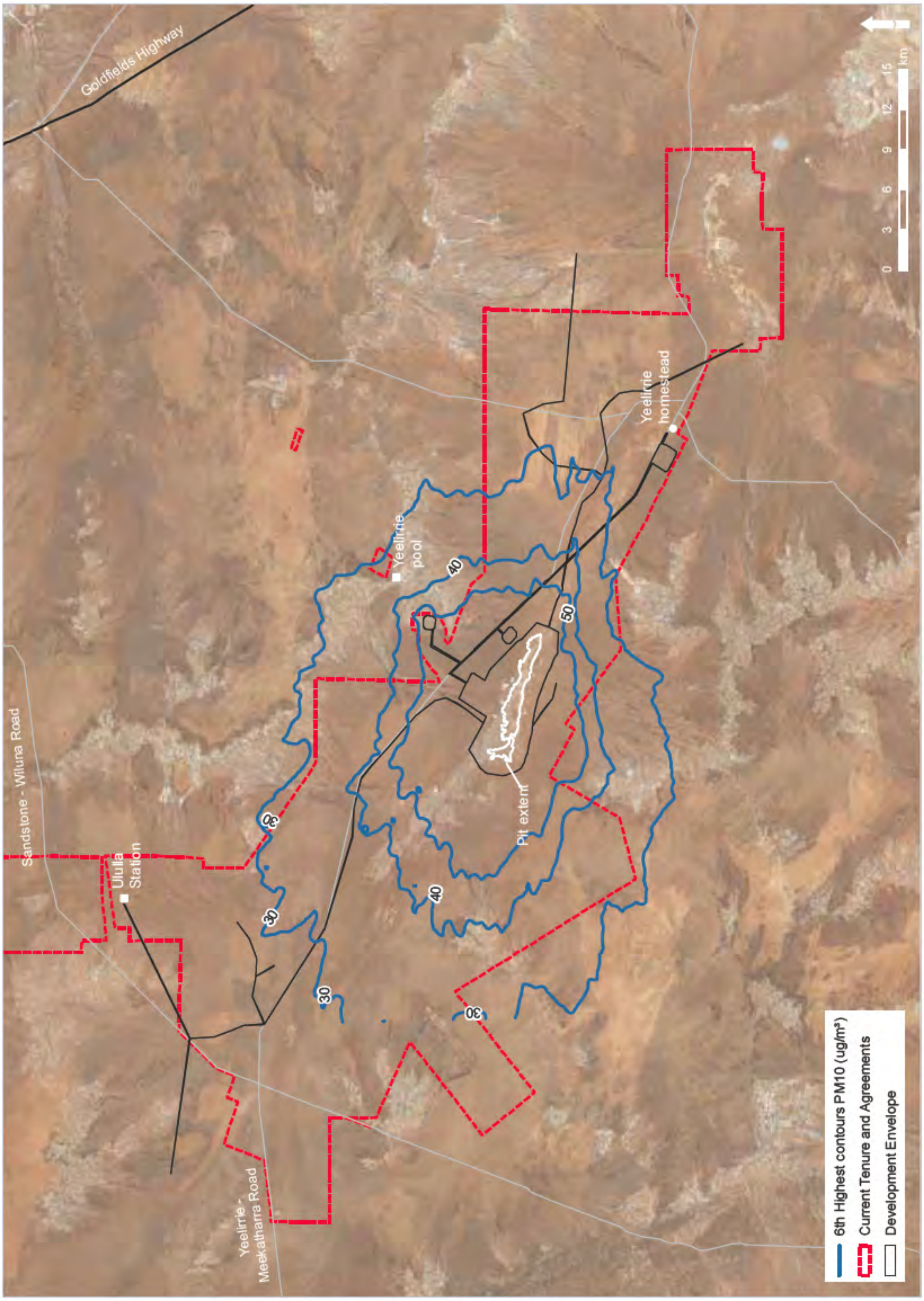


Figure 9-59: Predicted 6th highest 24 hour average ground level concentration of PM_{10}

9.8.5 Potential Impacts

The predicted maximum 24-hour average and annual average ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition from the Project at the nearest sensitive receptor locations are presented in Table 9-68. The maximum predicted ground level concentrations of these pollutants as a result of the Project are presented in Plates 1 – 13 of the Katestone report (Appendix L1).

These results indicate that:

- the predicted maximum 24-hour average ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ at the nearest sensitive receptors due to the Project comply with the relevant air quality criteria;
- the predicted annual average ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ at the nearest sensitive receptors due to the Project comply with the relevant air quality criteria; and
- incremental dust deposition rates outside the mining lease area boundary due to mine operations are predicted to comply with the air quality criterion of 2 g/m^2/month.

Figure 9-59 shows the predicted sixth highest 24-hour average ground level concentrations of PM_{10} with ambient background levels included (as noted in Table 9-68).

Figure 9-60 and Figure 9-61 show the predicted maximum 24-hour and annual average ground level concentrations of $PM_{2.5}$ respectively with ambient background levels included.

The predicted annual average dust deposition rate from the Project is presented in Figure 9-62.

Air emissions from on-site diesel power generators will principally consist of NO_2, CO, SO_2 and particulates. The predicted maximum and annual average ground-level concentrations for these pollutants at the nearest sensitive receptor locations are presented in Table 9-68.

The results of dispersion modelling of pollutants show:

- The maximum 1-hour average NO_2 concentration at Yeelirrie Pool is predicted to be greater than the Air NEPM criterion of 250 $\mu g/m^3$ (Figure 9-63) However, one exceedance day is allowed for by the Air NEPM. As the maximum 1-hour average concentration on the 2nd highest day is 157.5 $\mu g/m^3$, concentrations at this receptor comply with the Air NEPM criterion.
- The ground-level concentrations of 1-hour average NO_2 at all other sensitive receptors comply with the air quality criterion.

The ground-level concentrations of CO, SO_2, PM_{10}, and annual average NO_2 at all nearest sensitive receptors due to on-site power generation are predicted to comply with the relevant air quality criteria (Katestone, 2014a, Appendix L1).

The predicted maximum 1-hour average ground level concentration of NO_2, assuming no reduction of generator NO_x emissions, is shown in Table 9-69.

Table 9-68: Predicted ground-level concentrations (µg/m³) of TSP, PM_{10} and $PM_{2.5}$ and dust deposition rate (g/m²/month) due to the Yeelirrie Uranium Project

Pollutant	Averaging Period	Criteria	Accommodation village / Yeelirrie Homestead		Yeelirrie Pool		Ululla Homestead		Palm Springs	
			From operations	With background	From operations	With background	From operations	With background	From operations	With background
TSP	24-hour max	90	4.7	24.7	14.4	64.4	5.6	55.6	0.4	50.4
	Annual	90	0.1	25.1	1.14	26.1	0.2	25.2	0.01	25.0
PM_{10}	24-hour (6th highest)[1]	50	1.3	26.3	10.9	35.9	1.7	26.7	0.1	25.1
	Annual	25	0.1	12.6	1.0	13.5	0.2	12.7	0.01	12.5
$PM_{2.5}$	24-hour max	25	1.1	11.9	3.5	14.3	0.9	11.7	0.1	10.9
	Annual	8	0.01	7.7	0.2	7.9	0.04	7.7	0.002	7.7
Dust deposition	Annual	2 [2]	0.002	n/a	0.013	n/a	0.006	n/a	0.0004	n/a

Notes:

[1] 6th Highest 24-hour concentration presented for PM_{10} in accordance with the Air NEPM

[2] Dust deposition criterion of 2 g/m²/month (as an annual average) is maximum increase in deposited dust level above background

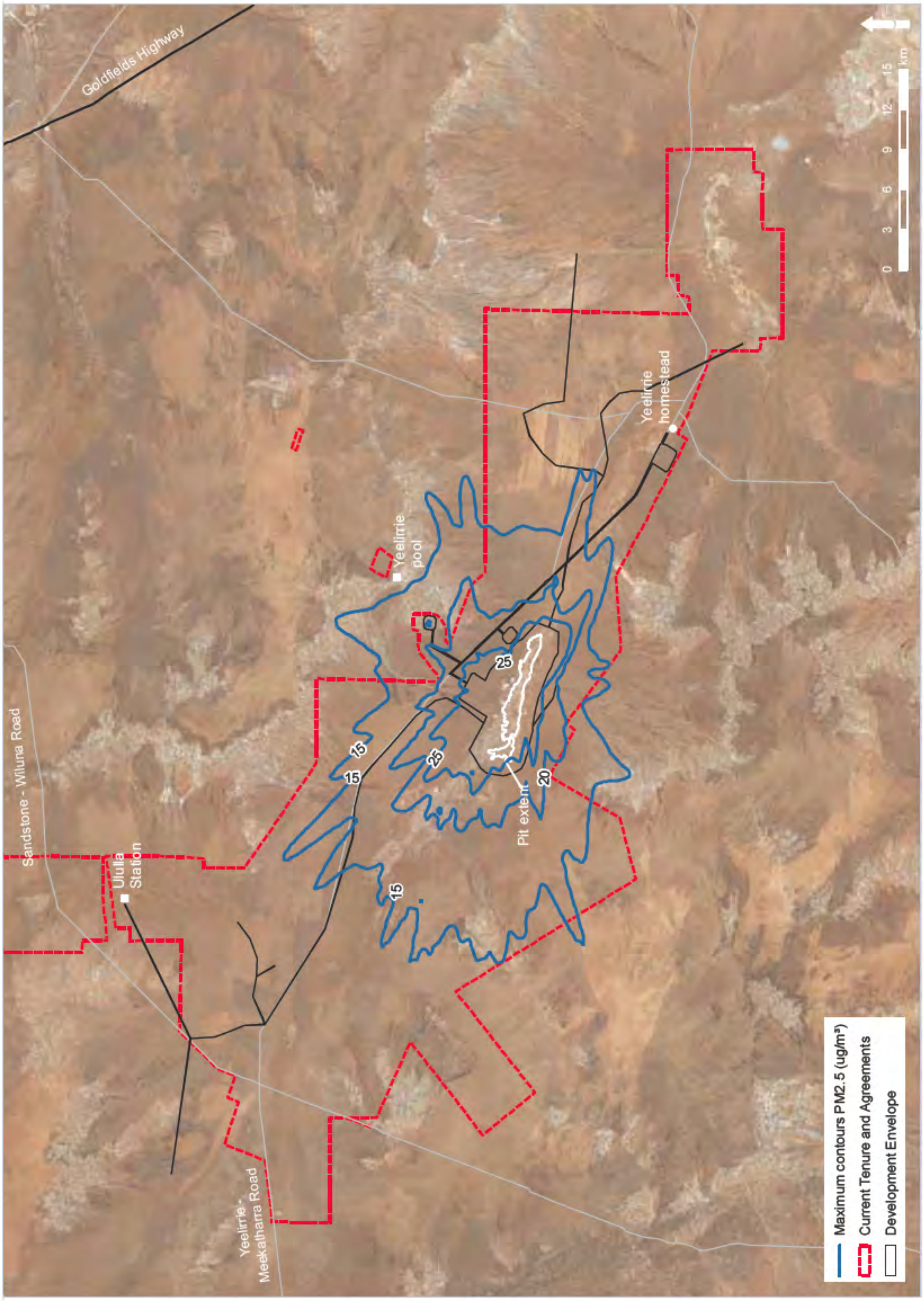


Figure 9-60: Predicted max 24 hour average ground level concentration of $PM_{2.5}$

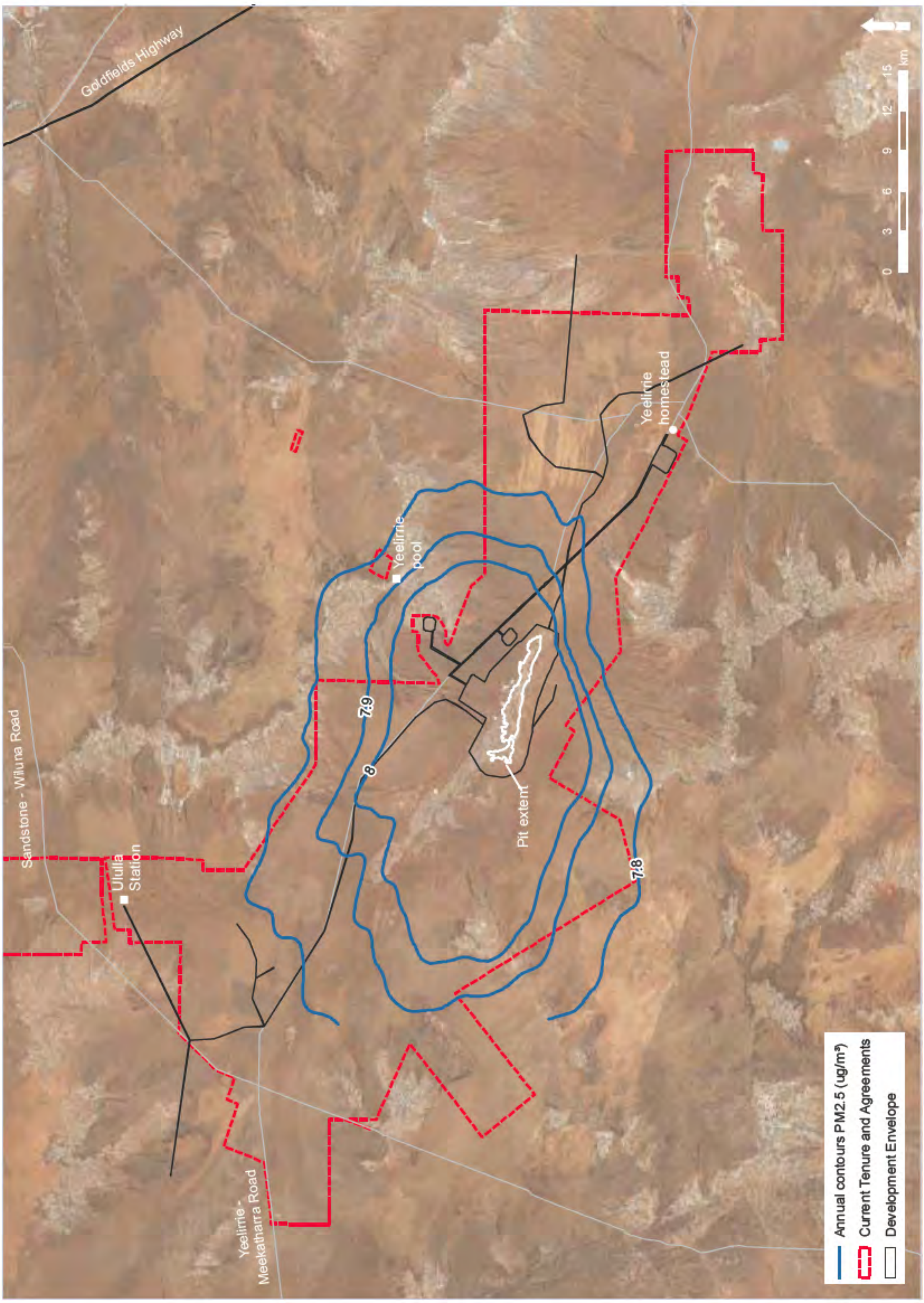


Figure 9-61: Predicted annual average ground level concentration of $PM_{2.5}$

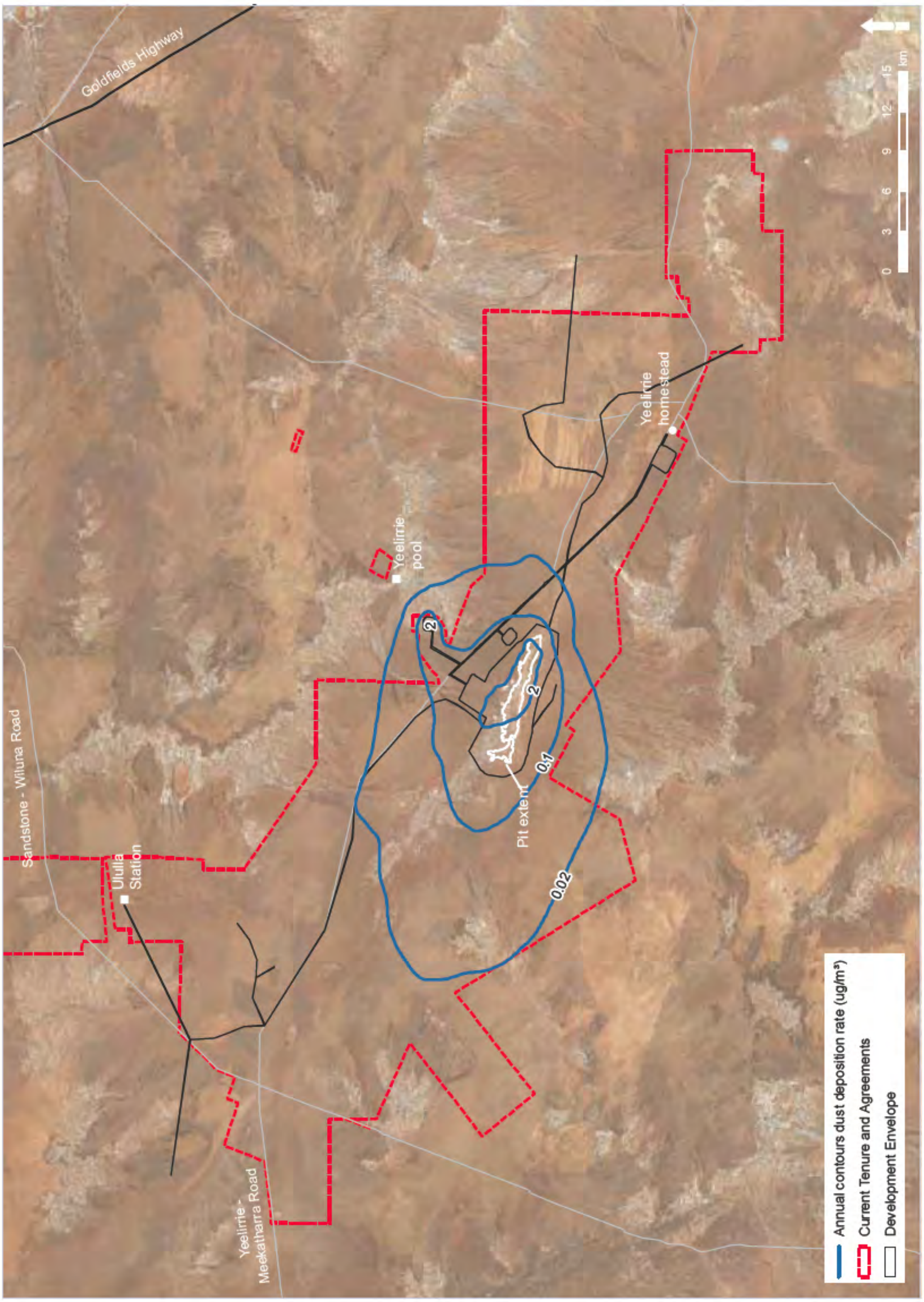


Figure 9-62: Predicted operationally contributed annual average dust deposition rate

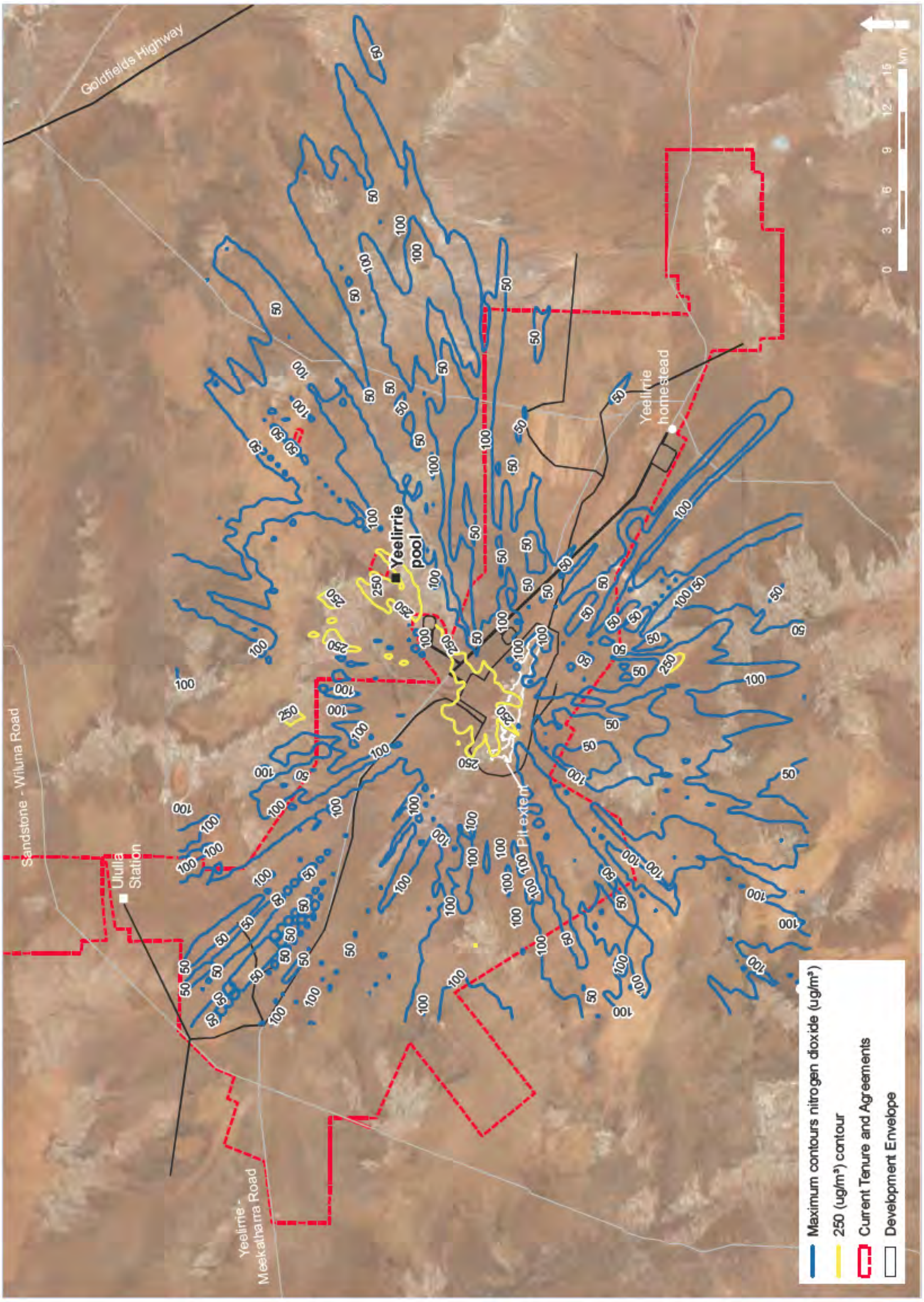


Figure 9-63: Predicted operationally contributed maximum 1-hour average ground-level concentration of nitrogen dioxide (assumes no capture of generator emissions)

Table 9-69: Predicted operationally contributed ground-level concentrations (µg/m³) due to diesel generators (Assume zero capture of generator emissions)

Pollutant	Averaging Period	Criteria	Accommodation village/ Yeelirrie Homestead	Yeelirrie Pool	Ululla Homestead	Palm Springs
NO_2	1-hour max	250	42.2	157.5 [1]	82.6	10.6
	Annual	62	0.02	0.6	0.2	0.03
CO	8-hour max	11,000	0.7	10.1	4.2	0.6
SO_2	1-hour max	570	1.7	17.0	3.6	0.5
	24-hour max	230	0.1	1.6	0.7	0.1
	Annual	57	0.001	0.024	0.01	0.001
PM_{10}	24-hour (6th highest)[2]	50	<0.01	0.07	0.02	<0.01
	Annual	25	<0.01	<0.01	<0.01	<0.01
$PM_{2.5}$	24-hour max	25	0.02	0.3	0.1	0.02
	Annual	8	<0.01	<0.01	<0.01	<0.01

Notes:

[1] Maximum 1-hour concentration on 2nd highest day in accordance with the Air NEPM

[2] 6th Highest 24-hour concentration presented for PM_{10} in accordance with the Air NEPM

The results of the dispersion modelling indicate that fugitive dust emissions from the Project are not likely to result in unacceptable air quality impacts at the sensitive receptors. The maximum predicted 24-hour and annual average TSP, PM_{10} and $PM_{2.5}$ ground-level concentrations and the monthly incremental dust deposition rates will comply with the relevant air quality criteria at each of the sensitive receptors. The air dispersion modelling results also indicate that emissions from the on-site diesel power generators will not result in unacceptable air quality impacts and the associated maximum and annual predicted ground-level concentrations of NO_2, CO, SO_2 and particulates will comply with the relevant air quality criteria at each of the sensitive receptors.

9.8.6 Management

A Dust Management Plan will be prepared for the Project. The Project has been designed with a strong focus on minimising dust emissions. Within the mining and stockpile areas traditional dust management techniques, including the use of water sprays, dust suppressants and progressive rehabilitation (where practicable), will be used to manage dust emissions associated with the Project. Similarly, a high level of control has been included within the plant design to minimise the particulate emissions (Section 9.6.6). Dust management measures are discussed further in Appendix L.

The Dust Management Plan will include ambient monitoring of PM_{10} concentrations and dust deposition rates. The results of the ambient monitoring program will be used to develop management targets for PM_{10} concentrations to allow an adequate response time to reduce the risk that concentrations greater than the 24 hour NEPM PM_{10} standard occur as a result of Project operations. In the event that target concentration criteria are not met, Cameco will investigate the likely causes and assess possible contributions from the Project's operations. If these are deemed to be significant then Cameco will implement remedial actions and contingencies targeting the identified Project related sources using actions that will be identifi ed in the Dust Management Plan.

General - Avoid and Minimise

- The Project has been designed to minimise atmospheric emissions as a result of its operations and comply with all relevant air quality standards and guidelines.
- The Dust Management Plan will be prepared for the Project. The plan will include ambient monitoring of PM_{10} concentrations and dust deposition rates. The results will be used to develop management targets for PM_{10} concentrations to allow adequate response time to reduce the risk of exceeding the NEPM standard.
- Within the mining and stockpile areas conventional dust management techniques, including the use of water sprays, dust suppressants and progressive rehabilitation, will be used to manage dust emissions.
- The process plant uses wet processing and the plant has been designed to minimise particulate emissions.
- Tailings will be deposited to the in-pit TSF as a slurry and kept moist throughout operations to prevent dust generation at the surface.
- The power station will be maintained to operate efficiently.
- Comply with all relevant air quality standards and guidelines.
- Developing limits and management targets for the Project by using the Ambient Air Quality NEPM.

9.8.7 Commitments

Cameco will:

- Develop and implement the Dust Management Plan.

9.8.8 Outcomes

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

9.9 Atmospheric Gases (Greenhouse Gas Emissions)

9.9.1 EPA Objective

The EPA's objective with regards to greenhouse gas emissions is:

- To minimise the emissions of greenhouse gases through the application of best practice.

9.9.2 Relevant Legislation and Policy

Gases such as water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), absorb and re-emit infrared radiation from the sun warming the Earth's atmosphere and these gases are called GHG. This GHG warming is a natural phenomenon and maintains temperatures suitable to support life.

However, concentrations of GHG have increased significantly since the Industrial Revolution in the 18th century and have been linked to warming of the global climate. The Fifth Assessment Report, produced by the Intergovernmental Panel on Climate Change (IPCC, 2014), states that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history". The report also states that "warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty that aims to limit atmospheric GHG concentrations to levels below those at which unacceptable impacts would occur. Australia has signed and ratified this treaty. Australia is also a signatory to the Kyoto Protocol which is an addition to the UNFCCC treaty and has powerful and legally binding measures including emission targets for developed nations.

The National Greenhouse and Energy Reporting System (NGERS), comprising the *National Greenhouse and Energy Reporting Act 2007* (Cwlth) (NGER Act), National Greenhouse and Energy Reporting Regulations 2008 (Cwlth) (NGER Regulations) and National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Cwlth) (NGER Measurement Determination, updated annually) was introduced to provide for the reporting and dissemination of information related to GHG emissions, GHG projects, energy production and energy consumption. The NGER framework contains mandatory reporting provisions for corporations who emit over 50,000 t of CO_2-e per annum or demand over 200 terajoules (TJ) of energy; or for individual facilities where these emit over 25,000 t of CO_2-e per annum or have an energy demand of greater than 100 TJ. Information from NGERS is used in the National Greenhouse Accounts to meet Australia's GHG reporting obligations under the UNFCCC and to track progress against Australia's target under the Kyoto Protocol. The NGERS framework provides information to Australian companies on how GHG emissions should be calculated.

The government of Western Australia's view is that the regulation of greenhouse gas emissions are primarily matters for the Australian Government. The Government of Western Australia has nevertheless prepared a statement outlining the key policies it will adopt in response to climate change (Government of Western Australia, Adapting to our changing climate, October 2012). The EPA has also released a guidance statement for minimising GHG emissions (EPA, 2002a). This guidance specifically addresses the minimisation of GHG emissions from significant new or expanding operations and outlines the information the EPA will consider when assessing proposals where GHG emissions is a relevant environmental factor in an assessment. The guidance recommends that best practice is applied to maximise energy efficiency and minimise GHG emissions, comprehensive analysis is undertaken to identify and implement appropriate offsets, and that proponents undertake an ongoing program to monitor and report emissions and periodically assess opportunities to further reduce GHG emissions over time.

9.9.3 Studies and Investigations

A GHG assessment was undertaken for Yeelirrie by URS (URS 2015). The report is attached in Appendix L2. The purpose of the assessment was to provide a GHG emission forecast for the proposed Project by applying consistent international and Australian methodologies.

For the purposes of the study, the following emissions were assessed:

- Scope 1 – Direct GHG emissions. Emissions occur from sources that are owned or controlled by Cameco, such as energy consumption for electricity and steam generation and fuelling of the mine fleet.
- Scope 2 – Indirect GHG emissions. Emissions arising from the generation of purchased electricity, steam, and/or heating/cooling by third party sources. Cameco is not proposing to purchase electricity, steam, heating or cooling and therefore no Scope 2 emissions were included in the assessment.
- Scope 3 – Other indirect GHG emissions. Emissions that arise as a consequence of the upstream and downstream corporate value chain, sources used by Cameco that are owned or controlled by third parties, such as air flights and off-site transport. Scope 3 emissions were limited to those activities within Australia that were a consequence of the proposed Project's activities, specifically:
  - diesel fuel for transport of construction materials to site;
  - diesel fuel for transport of UOC to port (Adelaide and/or Darwin);
  - aviation fuel (Avtur) associated with the fly-in, fly-out workforce; and
  - hazardous waste transported off-site for disposal by licensed third parties.

Due to significant uncertainty regarding the boundaries associated with life cycle assessments, and to allow comparison of development emissions with State, Federal and global GHG projections, emissions associated with the embedded energy of the materials used to construct the proposed Project infrastructure, were not included in the assessment. However, the URS report presents a discussion of the life cycle emissions associated with the mining, processing and use of uranium (Appendix L2).

The emissions generated from the following sources were used in the assessment:

- stationary energy emissions, such as from fuel burning equipment for steam and electricity generation;
- transport fuel emissions;
- emissions associated with changes to land use, such as land clearing; and
- emissions associated with chemical reactions within the tailings storage facility.

The emission factors used in this study were from the National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (DOE, 2014b) or, where NGER factors were not available, the National Greenhouse Accounts (NGA) Factors, 2014 were used (DOE 2014a). The NGA factors were also used to determine Scope 3 (indirect) emissions, where necessary.

The emissions for the proposed development were calculated by multiplying the volume or mass of a greenhouse gas-emitting fuel or process by an emission factor, to generate a value for the likely amount of CO_2-e emitted. The CO_2-e value accounts for the various greenhouse gases emitted, taking into account their respective Global Warming Potential (GWP) and the amount emitted. Land clearing emissions were estimated using the National Carbon Accounting Toolkit Full Carbon Accounting Model (FullCAM). Details regarding the inputs and assumptions associated with the use of this model are outlined in Section 3.1.1 of the URS Report (Appendix L2).

9.9.4 Existing Environment

The Project is located in the East Murchison region in an area which is sparsely populated. The nearest settlements are the accommodation village (14.4 km) and the Yeelirrie Homestead (16.9 km) and the Ulalla Homestead (28.8 km). The existing environment, relevant to air emissions is described in more detail in Section 9.8.

9.9.5 Potential Impacts

GHG emissions for the Project were calculated for the following phases of the Project:

- Land clearing
- Construction Phase – construction and pre-stripping;
- Operations Phase - mining and processing; and
- Decommissioning Phase.

The inventory of direct (Scope 1) GHG emissions is presented in Table 9-70 (URS, 2015).

Table 9-70: Inventory of estimated direct (Scope 1) GHG emission sources

Activity	Source	Estimated Annual Consumption (except where noted)
Land use change	Land clearing	Open pit – 726 ha over the life of the Project, with progressive rehabilitation from Year 12
		Infrastructure – 1,695 ha
Mining / light vehicle fleet	Diesel fuel	6,190 kL
Explosives	ANFO/ANE	70 t
Steam generation	Diesel fuel	26,440 kL
Electricity generation	Diesel fuel	39,260 kL
Process emissions	Absorption	CO_2-e generated from steam and electricity generation absorbed in process
TSF	Desorption	Absorbed CO_2-e is assumed, as a worst case, to be liberated from the TSF
Liquid waste	Anaerobic	24,400 kL (wastewater)
Putrescible solid waste	BOC	500 t of mixed solid wastes
Synthetic gases	Leakage	20% of capacity for mobile equipment, 35% of capacity for stationary equipment

Indirect (Scope 3) emission sources are presented in Table 9-71.

Table 9-71: Inventory of estimated indirect (Scope 3) GHG emission sources

Activity	Source	Estimated Annual Consumption (except where noted)
Materials transport	Diesel fuel	8,000 kL
Workforce transport	Avtur fuel	2,040 kg of Avtur per one way trip. 100 round trips per annum (412 t Avtur per annum)
On-site hydrocarbon scope 3 component	Grease/ lubricants	On-site oil/grease consumption of 28 tonnes

Estimated total GHG emissions for the Project are presented in Table 9-72 (URS, 2015).

Table 9-72: Estimated gross GHG emissions across the life of the Project

Emission Source	Estimated Total GHG Emissions (t CO_2-e)
Land clearing	31,380
Revegegation	-30,100
Construction Phase	316,630
Operations Phase	3,234,040
Decommissioning Phase	182,500

The predictive estimate calculated a total gross emission of approximately 3.76 x 10^6 t CO_2-e across the Project life of 22 years. When sequestration due to rehabilitation of the site is included into the calculated emissions, the net GHG emissions are estimated to be 3.73 x 10^6 t CO_2-e.

The breakdown of emissions during operations, by source are detailed in Table 9-73 (URS, 2015).

Table 9-73: Estimated annual GHG emissions during operations

Activity/Source	Scope 1	Scope 3
Steam generation	70,920	Not applicable (NA)
Electricity generation	105,330	NA
Mining and light vehicle fleet	15,590	490
Waste water treatment	370	NA
CO_2 absorption into liquor	-13,600	NA
TSF	13,600	NA
Explosives	10	NA
Waste	500	NA
Synthetic gases	620	NA
Materials transport	NA	21,590
Workforce transport	NA	80
CO_2 desorption from TSF	190	NA
Total	**193,530**	**22,160 (average)**

Diesel fuel consumption for electricity generation is the single largest source of total GHG emissions (49%) during the operations phase, followed by diesel fuel consumption for steam generation (33%) and diesel fuel use in off-site vehicles (10%).

Over the 23 year life of the proposed Project, Western Australian, Australian and global greenhouse gas emissions are predicted to rise from the current levels. The average annual greenhouse gas emissions from the proposed Project (215,690 tpa of CO_2-e) were compared against the projected future state, national and global emissions. As a proportion of these emissions, the contribution of the development to atmospheric GHG emission levels from the Project is very low. However, given the national and global importance of this issue, Cameco will investigate GHG emissions reduction initiatives throughout the life of the proposed Project.

9.9.5.1 Life Cycle Assessment

The end-product of uranium mining may be CO_2-free nuclear power but the extraction and conversion of the ore consist of activities that generate and emit GHG emissions to the atmosphere. A high-level GHG emission life cycle assessment of the Project was undertaken using available literature to estimate emissions associated with uranium production, use and disposal (URS, 2015).

Studies of the nuclear fuel cycle GHG emissions have shown that the generation of nuclear electricity produces about 66 grams of CO_2-e per kWh (g CO_2-e/kWh) of electricity generation (Sovacool, 2008; Lenzen, 2008). This emissions intensity is about 10 to 15 times less than that of other fossil fuel electricity generation and at the higher end of the range of renewable electricity generation emission intensities. The studies undertaken by Sovacool (2008) and Lenzen (2008) highlighted the various aspects of the nuclear fuel cycle that have the greatest influence on life cycle GHG emissions. Specifically these are:

- the grade of the uranium ore mined;
- the method of enrichment;
- the conversion rate of the nuclear fuel cycle (i.e., the amount of fuel recycling);
- the source (fossil, renewable or nuclear) of electricity used for the enrichment phase; and
- the overall GHG intensity of the electricity mix in the countries where fuel cycle activities are undertaken.

Approximately 8.49 kg of pure U_3O_8 from Yeelirrie is required to produce 1 kg of 3% U_{235} nuclear fuel-grade UO_2, sufficient to generate approximately 304 MWh of electricity. Given that 1 kg of uranium (U) is equivalent to 1.18 kg of 100% pure U_3O_8, and using the nuclear life-cycle information presented in the literature, it is estimated that 1 kg of pure U_3O_8 has the energy equivalence of approximately 9.3 kL of diesel that would generate 24.86 t of CO_2-e. Therefore, the CO_2-e saving is 24.81 t of CO_2-e per kilogram of U_3O_8 produced (URS, 2015).

9.9.6 Management

Avoid and Minimise

In term of management and reduction of GHG emissions, two main categories exist within the context of mining operations. Demand-side management relates to energy requirements throughout the site and supply-side management refers to how that energy is supplied. Cameco will minimise GHG emissions through management of both energy demand and energy supply via on-site management programs specifically designed through on-site studies. This may include the following measures:

- optimisation of the proposed mining fleet size (number of trucks versus size of trucks) in order to best meet the targets of the mine plan and optimise diesel demand;
- optimisation of the metallurgical process to reduce the electricity and steam requirements, including the capture and use of waste heat where possible, and thus reduce the site diesel demand; and
- incorporation of energy efficiency measures for the accommodation and administration facilities.

Measures to supplement energy supply:

- solar hot water systems and solar photovoltaic systems for the site administration and accommodation facilities;
- solar photovoltaic power systems for powering the remote groundwater wells and associated pumping stations; and
- consideration of biodiesel blends in the mining fleet and for the generation of on-site steam and electricity.

Cameco will continue to investigate GHG emission abatement projects throughput the life of the Project as technologies improve. The on-going monitoring, implementation and reporting of these abatement projects will be managed through a site based GHG and Energy Management Plan.

GHG emissions from the Project are as low as reasonably practicable for a Project of this scale and duration.

Rehabilitate

Disturbed areas that are no longer required for the operation of the Project will be progressively rehabilitated over the life of the mine to offset GHG emissions from clearing.

9.9.7 Commitments

Cameco commits to:

- Developing a GHG and Energy Management Plan.

9.9.8 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective with regards to Air Quality () Greenhouse Gas Emissions).

9.10 Terrestrial Environmental Quality

9.10.1 EPA Objective

The EPA's objective with regards to terrestrial environmental quality is:

- To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.

9.10.2 Relevant Legislation and Policy

The following documents are relevant in setting the framework for the identification and assessment of potential impacts to terrestrial environmental quality from the Project:

- Department of Industry Tourism and Resources (2007) Managing Acid and Metalliferous Drainage, Leading Practice Sustainable Development Program for the Mining Industry, Canberra, Australian Capital Territory.
- Department of Industry Tourism and Resources (2007) Guideline for Tailings Management, Leading Practice Sustainable Development Program for the Mining Industry, Canberra, Australian Capital Territory.

9.10.3 Studies and Investigations

The ESD outlines a series of studies and investigations required to be undertaken by Cameco to address Terrestrial Environmental Quality. These studies are also relevant to other factors as outlined in Table 9-74.

Table 9-74: Terrestrial environmental quality studies

ESD Requirement	Study	Also relevant to:
Characterisation of wastes, including intermediate wastes, tailings and decontamination waste, according to contaminant and leachable concentrations	Conceptual Mine Closure Plan for the Yeelirrie Uranium Project (Cameco 2015a; Appendix O1)	Rehabilitation and Decommissioning (Section 9.12)
	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit (Cameco 2015d; Appendix I1). Yeelirrie Tailings Storage Facility Design and Management (Cameco 2015e; Appendix D).	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)
Physical and geochemical characterisation of process residues, waste rock and overburden including an assessment of 'dustiness' of bulk materials to the relevant standards in consultation with DER	Soils and Soil Landscapes of the Study Area (Blandford & Associates 2011; Appendix M1). Landform Evolution Modelling (SWC 2015a; Appendix O2)	Rehabilitation and Decommissioning (Section 9.12)
	Atriplex sp. Yeelirrie Station Investigation (SWC, 2015b; Appendix E5)	Flora and vegetation (Section 9.1)

ESD Requirement	Study	Also relevant to:
	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Geochemical Assessment of Tailings and Mine Waste (URS, 2011) Assessment of Tailings and Mine Waste Source Terms (SRK, 2011)	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)
	Air quality assessment of the Yeelirrie Uranium Project (Katestone, 2014a; Appendix L1)	Air Quality (Section 9.8)
Contaminant pathways modelled to assess potential leaching of contaminants from waste dumps/stockpiles and risks of acid metalliferous and neutral drainage.	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit (Cameco 2015d; Appendix I1).	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)

Collectively, these studies provide the background to characterise waste rock, overburden, soils and process residues to understand potential pollution risk, and plan rehabilitation and closure of the Project.

9.10.4 Existing Environment

9.10.4.1 Soil Characteristics

D. C. Blandford & Associates Pty Ltd was engaged to conduct a soil and soil landscapes survey as part of BHP Billiton's studies for the original project (Blandford D.C. & Associates 2011; Appendix M1). The objectives of this survey were:

- to identify the major soil types and associated soil landscapes and to define soil and soil profile characteristics; and
- to identify the soil profile characteristics associated with individual vegetation communities to develop an understanding of the soil-landscape-vegetation systems present.

The soil resources of the Study Area were defined using a soil landscape approach, where the major landscape units were identified and the characteristics of soils from representative positions within each landscape were defined. Within the Study Area, three soil landscapes were defined:

- the Colluvial/Alluvial Sand Plain System;
- the Playa System; and
- the Calcrete System.

In addition the Granite Breakaway System was identified as occurring outside of the Study Area.

Colluvial / Alluvial Sand Plain System

The Colluvial / Alluvial Sand Plain System is an extensive soil landscape that extends from the central valley to the Granite Breakaway System. Soil gradients range from 0.3 – 0.4% on the lower surface of the plain to 3.5% on the northern valley side slope and 5% on the southern valley side slope. The system is underlain by weathering granitoids, with the saprolite zone ranging in thickness from tens of centimetres to zero. The surface of the plain is intruded by granitoid bedrock at isolated locations where it forms very low relief 'granite' rises. Throughout this soil landscape there is variability in soil profile characteristics.

The 'sands' of the sand plain, tend to contain a range of grain sizes from fine sand to gravel (up to 50 mm in size). These 'sands' demonstrate varying degrees of induration, which indicates high soil moisture retention at varying depths below the surface.

Ferricrete, occurs throughout the sand plain soils with the thickness of ferricrete horizons ranging from 0.25 m to 1.0 m. The ferricrete present ranges from a true ferricrete gravel with well sorted and well-rounded gravels to 35 mm in diameter, to ferricrete that is in the form of secondary cementation. Elsewhere, the ferricrete is typified by massive, recemented forms (Blandford D.C. & Associates 2011).

Playa System

The Playa System is a key soil landscape within the Study Area. The Playa System is a transition zone from the Sand Plain System to the Calcrete System and a major conduit for surface runoff along the valley.

This is a highly variable soil landscape, which reflects the complex interaction between the sand plain and central valley drainage with peripheral calcrete influence.

The Playa System comprises the following units:

- Depressions: Low relief shallow structures (< 0.5 m deep) varying in diameter from tens of metres to hundreds of metres;
- Flats with scalds: Areas devoid of vegetation where wind erosion is the major degradation factor. These areas tend to pond water temporarily; and
- Flats with sink holes.

Within the Playa System the depressions are not continually interconnected and there are no obvious preferred surface drainage routes. At the valley scale, surface discharge patterns pass both sides of the Calcrete System, which is topographically higher relative to the Playa System.

The soils of this system often show a complex stratigraphy due to a highly varied geomorphic pre-history. Some profiles contain silty clays at depth below the surface, which is usually a platy sandy loam. Gypsum is also present is some profiles as either crystal growths or as a massive, structureless material (Blandford D.C. & Associates 2011).

Calcrete System

This soil landscape, which occupies the central zone of the valley floor, generally comprises outcropping calcrete in its various forms and is quite variable. The Calcrete System comprises four units:

- Calcrete rises: discrete areas of outcropping, weathered calcrete. The weathered material is generally present as a discontinuous surface lag gravel. The calcrete rises are characterised by a thin veneer of residual soil overlying massive to platy calcrete;
- Depressions: In some areas, solution of the underlying calcretes has resulted in collapse of the surface, forming small-scale pseudo-karstic topography, while in other areas, low relief depressions are present. These tend not to be filled with sediment but are more typically small scale hollows in the surface, probably the result of differential collapse of underlying solution cavities;
- Flats: The surface of the calcrete may contain 'flats' where sediment is retained on the structure and where it generally forms a thin veneer of sandy loams to loam, fine sandy; and
- Clay flats: distinctive clay flats are present where the clays tend to be high ranking, self-mulching, and display seasonal cracking (Blandford D.C. & Associates 2011).

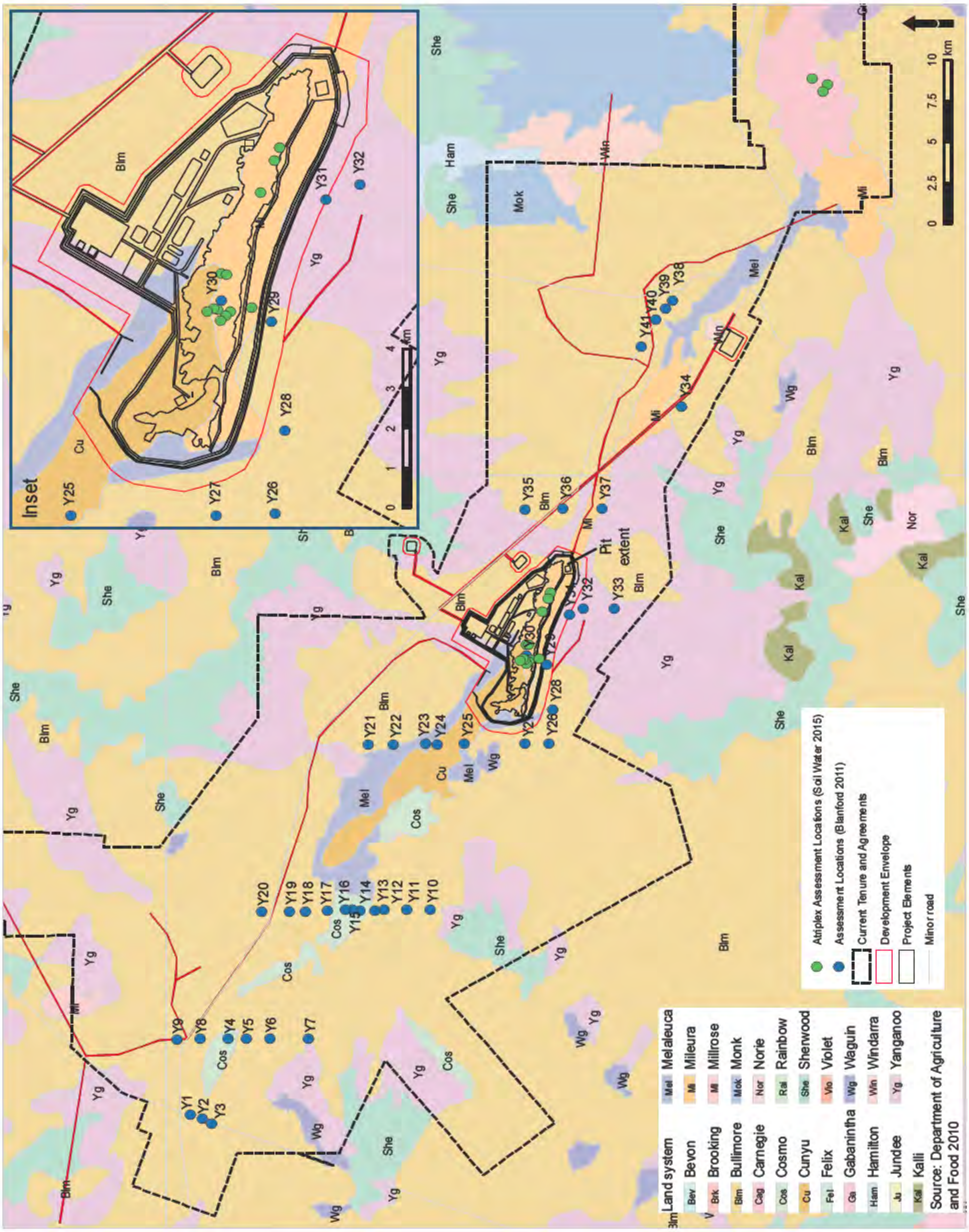


Figure 9-64: Soil landscapes and assessment locations

Aggregate Stability and Dispersion

Dispersive soils are present within the study area. However, they are generally associated with the Playa System, and with scald areas at the interface of the Sand Plain and Playa Systems. When dispersion occurs at or near the surface, and the dispersed clays dry in situ, they set hard. This hard, fine-grained layer results in differential permeability. Vertical permeability is greatly reduced resulting in increased horizontal permeability, or water ponding at the depth of the dispersed clay layer. If the hard clay layer occurs at the surface, accelerated runoff occurs due to decreased infiltration, and evaporation rates will increase, resulting in a reduction of effective rainfall (Blandford D.C. & Associates 2011).

Surface Infiltration Rates

Surface infiltration rates were measured at two locations using a constant head infiltrometer. The range of surface infiltration rates from zero to 756 mm/h which is considered within the normal range for these soil landscapes (Blandford D.C. & Associates 2011).

Soil Chemistry

Soil chemistry was investigated at nine sites to assess the trend in soil chemical status. The results are presented in Table 9-75.

Table 9-75: Summary of soil chemistry in the Study Area

Site ID	Depth (m)	pH	EC (mS/m)	TSS (% Salt)	Org C (%)	Soil Landscape
1	0.5	4.2	2.0	0.006	0.1	Sand Plain
2	0.95	4.7	1.0	0.003	0.08	Sand Plain
12	0.6	5.1	<1	<0.001	0.09	Sand Plain
13	0.8 – 1.5	5.3	11.0	0.035	0.08	Sand Plain
15	0.0 – 0.3	8.0	11.0	0.035	0.54	Calcrete
23	1.0	8.4	370	1.184	0.09	Playa
30	0.0 – 0.2	8.0	270	0.864	0.23	Calcrete
36	1.0	6.4	11.0	0.035	0.11	Sand Plain
41	0.3 – 0.4	5.7	2.0	0.006	0.08	Sand Plain

Soil Characteristics of *Atriplex* sp. Yeelirrie Station.

Soilwater Consultants were engaged in 2015 to conduct a soil investigation aimed at characterising the ecophysiological requirements of *Atriplex* sp. Yeelirrie Station. The study involved the excavation of 15 soil investigation trenches (Figure 9-64), with 12 of those trenches occurring within the proposed pit development. The study followed a similar field methodology to the survey conducted by Blandford and Associates (2011).

A typical soil profile encountered consisted of calcareous loam of variable thickness over transitional calcrete (Plate 9-5). The calcareous loam is rarely evident on the surface and is instead covered with either a variable thickness of clay (approximately 0.4 m) or a thin cover of loamy sand depending on the position within the landscape. These soils are indicative of the overburden (waste rock/soil) material that will be generated by the mining of the Yeelirrie ore.

Four distinct soil units occur within the calcrete system consisting of:

- Loamy Sand - This material occurs on the surface directly above the carbonated loam in areas outside of the clay flats and calcrete outcrops. It generally consists of a loosely packed, friable silty loam to loamy sand, with common gypsum crystals and rounded quartz grains. The material

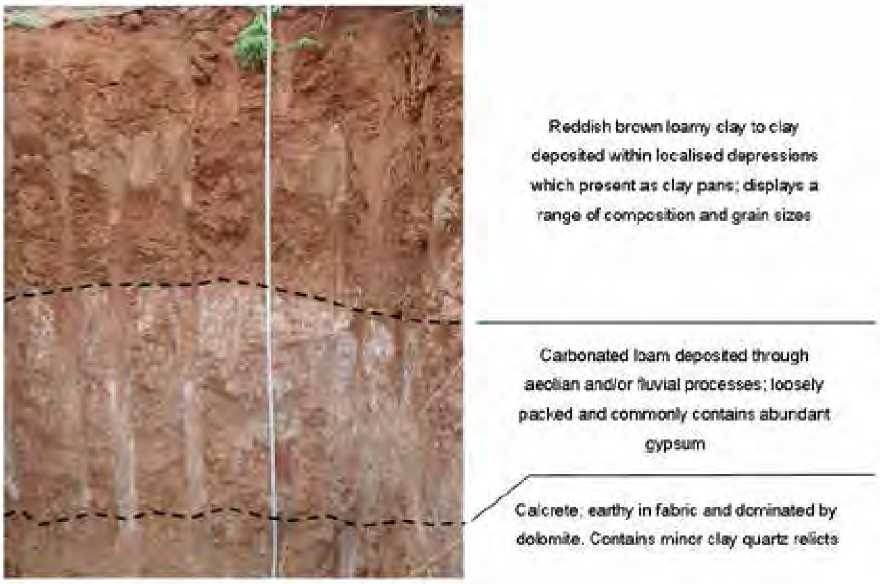


Plate 9-5: Typical soil profile encountered within the calcrete soil-landscape system

has an alkaline pH between 8 and 9 and low salinity < 100 mS/m. It generally exists in an unsaturated condition and is freely draining;

- Loamy Clay - This material occurs on the surface directly above the carbonated loam in the clay flats and depressions of the calcrete system. It consists of a cracking clay to clay loam, with high plasticity. The cation exchange capacity (CEC) indicates that the clay mineralogy is mostly likely to be made up a mixture of illite and chlorite, with minor kaolinite and smectite, and have a moderate to good structural resilience (i.e. shrink/swell potential). The material generally displays a slightly alkaline pH around 8 and highly variable salinity from < 100 to > 2000 mS/m. Significant rainfall had occurred prior to the time of investigation and the material displayed a dry, fluffy and sometimes crusty upper layer of aggregates approximately 5 to 10 cm thick, below which the clays retained more moisture and had not aggregated;
- Carbonated loam - This alluvial material underlies the loamy sand and clays and is aeolian and/or fluvial in nature. It consists of a very to moderately friable brownish white to pale brown loam with occasional pisolitic nodules and abundant carbonate nodules. It consistently displays an alkaline pH between 8 and 10 and generally has a moderate to high salinity, ranging from approximately 200 to 800 mS/m; and
- Calcrete - The upper calcrete material is earthy and composed of dolomite, calcite and smectite, with common amorphous black silica. It varies in hardness from soft to hard where porcelaneous silica alteration has occurred, but is dominantly medium to soft in hardness with < 10 % clay quartz present. Where the material has outcropped weathering has removed the finer fractions, leaving behind hardened and indurated gravel to sand size fractions.

A summary of the key physical characteristics measured from the various soil units identified within the calcrete landform system is provided in Table 9-76 whilst the key chemical characteristics are summarised in Table 9-77. The results highlight the abrupt changes in texture and structure that are present within the investigated soil profile, with large changes in sand and clay fractions between the different horizons. The majority of material contain low larger particle size or gravel fractions, with the exception of the blocky and sometimes vuggy transitional calcrete materials. Each of the three 'soil' materials was tested for water retention capacity using five point pressure plate analysis. The summarised results below show that the plant available storage capacity of the three materials tested are all substantial, with little difference between the carbonated loam and the loamy clay materials despite their different textural compositions.

Table 9-76: Summary of measured physical parameters within the calcrete landform system

Soil unit	Particle size distribution (< 2mm)			Gravel %(>2mm)	Plant Available Water (v/v)
	Sand %	Silt %	Clay %		
Loamy Sand	84.6	15.2	0.2	<1	12.1
Loamy Clay	53.0	11.2	35.8	<1	20.1
Carbonated Loam	74.2	9.5	16.3	5-10	23.1
Calcrete	68.5	10.1	21.4	50-90	na

Table 9-77: Summary of measured chemical parameters within the calcrete landform system

Soil-landscape	pH	EC mS/m	Exchangeable Cation meq/100g				CEC meq/100g	ESP (%)
			Ca	K	Mg	Na		
Loamy Sand	8.1	10-80	10	1.3	3.1	0.1	14	0.1
Loamy Clay	8.8	100-2000	14.7	3.3	7.6	4.9	30.6	0-50
Carbonated Loam	8.3	200-800	11.2	2.9	5.5	4.8	24.4	4-30

The measured pH of the various soil units was alkaline, reflecting the dominance of carbonate ions in the finer fractions. The salinity was widely variable and closely linked to landform position, with slightly elevated positions in the landscape generally recording significantly lower levels, particularly in the upper 40 – 50 cm of the profile. This suggests that these areas are very rarely inundated after rainfall events and so the surface salts have been leached from the profile. The exchangeable sodium percentage (ESP) is an indicator of a given materials tendency to disperse. In simple terms, dispersion is the movement of clay from an aggregated state to one where the clays move freely into suspension. In materials where the sodium ion dominates the cation exchange complex to such an extent that the ESP is larger than 6, they are considered to be vulnerable to dispersion. Salinity will act to limit dispersion (through the inclusion of Na as an electrolyte) to some degree by promoting flocculation of suspended soil particles. The wide ranges of ESP and salinity recorded throughout the various samples tested indicates that some portions of the Clay and Carbonated Loam materials are likely to contain dispersive properties.

9.10.4.2 Ore, Mineralised Waste and Tailings Characteristics

SRK Consulting was commissioned by BHP Billiton to complete a geochemical assessment of ore and mine waste material. The scope of assessment included detailed chemical characterisation of selected Yeelirrie materials (ore, mineralised waste and tailings), and the completion of a series of bottle roll contact and column tests including assessment of neutral drainage conditions procedures.

A total of 199 Samples were collected from a range of material types from the Yeelirrie site taken at various depths (max depth 30 m) from drill cuttings for drill holes located within and downstream of the proposed mining area. In addition to these 199 samples, two samples of palaeochannel sand from below the proposed pit (depths between 55 and 65 m).

Forty one samples of tailings (comprising both tailings and underlying sediments) were taken from the historic WMC tailings storage facility located at the Kalgoorlie Research Plant, where WMC undertook testing on tailings produced from mining and processing the Yeelirrie ore in the mid-1960s and early 1990s.

Twenty of the 199 samples from the proposed mining area along with all palaeochannel and tailings facility samples underwent detailed geochemical characterisation as follows:

- Bottle roll testing: Tailings and waste samples were contacted with solution (either de-ionised water or 'barren liquor' solution) for 72 hours. The tests were undertaken at a liquid- solid ratio of 3:1;

- Column testing: Four column pairs were set up to operate in series. The first column in each pair is open to air and operated such that the material drains down and becomes unsaturated between flushing events. The second column is not open to air and is maintained saturated with solution at all times. Effluent from the first column is used as inflow for the second column in that pair; and
- Aging tests (tailings): Fresh tailings slurries were placed in open and sealed flasks, to represent atmospheric as well as anoxic conditions respectively. After 1, 2, 4 and 8 months of contact time pore water from selected flasks was recovered for analysis.

In addition the following static geochemical test work was conducted:

- metal content via Inductively Coupled Plasma (ICP) analysis;
- mineralogical determination via X-ray Diffraction (XRD) analysis;
- mineral surface characterisation using the Brunauer–Emmett–Teller (BET) method for surface area, and Cation Exchange Capacity (CEC) testing;
- radiological investigation to determine key radionuclide concentrations.

The bulk chemistry of the ore and waste rock samples tested shows that U_3O_8 contents were significantly elevated in comparison with mean crustal abundances published by Bowen (1979).

All of the waste material samples tested by SRK had low overall sulphur contents ranging from 0.01 to 0.1 % (averaging < 0.05%) indicating the waste materials tested had a low potential to produce acid and cause acid mine drainage (AMD). These results were compared to the chemical assay database which has been generated from the drilling conducted over the Yeelirrie deposit. This comparison has shown that the samples selected for testing can be considered representative of each lithological unit.

Leach testings (Bottle leach, column and tailings age testing) was conducted on mine waste and tailings materials to simulate the onsite neutral drainage conditions. The results of leach testing on materials including various grades of ore showed that a number of readily soluble phases were released upon contact with water, with leachate dominated by salts such as halite and various sulphates. Contaminants which were released at appreciable concentrations included boron, barium, molybdenum, strontium, thallium, uranium, vanadium and zinc. Analysis of radionuclides showed that radium-226 could also be released during flushing of samples.

The testing of tailings material via leach testing showed that initial pore water quality within the tailings would be dominated by barren process water which is alkaline and contains elevated concentrations of dissolved uranium and vanadium.

These results were used to develop base-case and upper-bound (or worst case) source terms to be used in modelling of solute transport for the temporary stockpile areas and the in-pit TSFs (SRK, 2011, Cameco, 2015c) Development of the source terms for the stockpiled material contained two basic assumptions; the base case assumes that placed surfaces may leach solutes for up to one year, whereas the upper bound case assumes that all exposed surfaces remain active at all times.

The source terms for the tailings material were developed within the context of the conditions expected to develop after the cessation of operations. It was assumed that pore water release from the tailings, and therefore interaction with groundwater, could occur only after the tailings cells have been decommissioned. The tailings source terms were developed using 90th percentiles (i.e. representative of 90% of the data) from geochemical data and modelling to ensure conservative values.

Full details of the tests conducted and results are provided in Appendix I2, M2 and M3.

9.10.5 Potential Impacts and Management

Activities or aspects of the Project which have the potential to impact on terrestrial environmental quality include:

- managing topsoils to minimise erosion, sedimentation and for successful rehabilitation;
- haulage and process activities (including dust emissions) capable of spreading mineralised materials outside of mining areas;
- surface water runoff and seepage from stockpiled materials;
- seepage of pore water from the in-pit TSF's and stockpiled materials;
- flooding and / or overtopping of water storage facilities; and
- accidental spills of controlled materials.

9.10.5.1 Topsoil impacts and management

The physical and geochemical analysis of soil profiles across the deposit area provides the information to develop a detailed plan for topsoil and waste rock management for rehabilitation purposes.

The physical and chemical attributes of the loamy sand and loamy clay discussed above suggest these soil types would be suitable for use in rehabilitation and mine closure. The soils are alkaline with low to moderate salinity and the loamy clay exhibits good structure and water holding capability. The dispersive property of some of the clays and the carbonated loam make them less suitable for the final topsoil or surficial cover, so careful selection of soils will be required for rehabilitation purposes.

Topsoils will be mapped and preferentially stockpiled for use in rehabilitation and revegetation. Topsoil will be stored in low stockpiles to retain seed viability and will be protected from erosion. Topsoil will not be handled when wet to avoid damaging soil structure. Soils that are not suitable for use in rehabilitation or construction (e.g. dispersive, saline soils) will be buried within the final landforms.

Prior to commencement of construction, Cameco will have determined the availability and volumes of key materials required for rehabilitation. The results of these investigations will be presented in a revised version of the Mine Closure Plan (Appendix D1) to be submitted prior to the commencement of construction. Further detail on Mine Closure and Rehabilitation is provided in Section 9.12.

9.10.5.2 Haulage and processing impacts and management

If not appropriately managed, mineralised material may be spread out of the mine area on vehicles or machinery used in mining and processing, or through dust emissions from the mine area.

To facilitate the control of people, vehicles and contamination, the operations area will be divided by fencing into 'clean' and 'potentially-contaminated' areas. Access to the potentially-contaminated area will be via a security gate.

Egress from the potentially contaminated area by vehicle will be via a wheel-wash to ensure that contaminated material will not be transported off-site by vehicles. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation (for example mine vehicles) will be kept within the contaminated area (Section 9.6.6).

Dustiness of Bulk Materials

Cameco has reviewed the European Standards associated with EN15051 for the measurement of the dustiness of bulk materials and considers that it is not applicable as the two test methods (rotating drum and continuous drop) do not apply to the mechanical handling of ore and waste at Yeelirrie (Section 9.8.3).

Dust emissions from the Project were estimated based on representative emission factors from the National Pollutant Inventory (NPI) mining handbook, USEPA AP-42 documents and source characteristics and operational activity data provided by Cameco (refer to Katestone 2014a, Appendix L1).

Incremental dust deposition rates outside the mining lease area boundary due to mine operations ranged from 0.0004 g/m^2/month at Palm Springs to 0.013 g/m^2/month at Yeelirrie Pool, well below the air quality criterion of 2 g/m^2/month (Section 9.8.5).

The following measures will be implemented to manage dust sources from the Project:

- water sprays during clearing and mining activities;
- covered conveyors, transfer points and dust extraction on crushing circuits;
- wet processing plant;
- retaining tailings in a damp state until closure; and
- water sprays and dust suppressants on haul roads and stockpiles.

9.10.5.3 Ore and waste stockpile impacts and management

Runoff and seepage from ore and waste stockpile areas could affect the quality of surface and groundwater in the vicinity. However, the potential impacts of this are considered low due to the following:

- A surface water diversion bund will retain surface water runoff generated from within the proposed mine site, including stockpile areas, with water flowing to stormwater ponds for use in the processing plant (Section 9.4.5).
- During mining, the footprint of the stockpiles will be within the groundwater production drawdown area and any solute would remain within the affected footprint (Section 9.5.5); and
- Solute releases from stockpiles occur as a result of the first rainfall event related flushes and reduce thereafter.

In the event that Cameco needs to release stormwater to maintain a safe operating environment following an extreme rainfall event, the released water would need to be of sufficient quality to minimise the accumulation of solutes in groundwater along the valley floor. Surface water modelling indicates that stormwater releases during an event larger than 1:100 year ARI would be significantly diluted by local flood waters, and recharge-related loadings to groundwater outside this floodplain would be minimal. Receding floodwaters carrying any mine-sourced loadings would be concentrated along the valley floor where the baseline groundwater is not considered suitable for stock water. However, the proposed design of the flood retention bund is expected to be sufficient to retain a 1 in 1,000 year ARI event (Section 9.4.5).

A solute transport model has been developed to examine the movement of solutes from surface into groundwater. Stockpile source terms were assessed for ore and mine waste materials and were assessed for operations only, as all ore and waste materials will be either processed or disposed of within the pit at the end of the mine life. The main control on solute loading is the exposed surface area of each stockpile, which changes over time. To ensure conservative modelling, the solute loading calculations assumed that the footprint of each planned stockpile would remain constant at its maximum planned size throughout the lifetime of that particular stockpile.

The solute loading calculations have shown that the potential release of each constituent by the stockpiled material is finite as once the solute is released it is not regenerated. Experimental results of stockpile material aging indicated that solute release occurs quickly and at a rate that all available solutes that can be flushed from exposed surfaces within a year. A full description of the method of solute load estimation and the results of modelling are provided. (Appendix M2).

The ROM pad and other stockpile areas would be compacted to control seepage and would be graded so that runoff and seepage would be directed to a storm water runoff pond. Water captured in the ponds would be used to supplement the water supply for the processing plant (Section 9.4.5).

As all stockpiles will be removed for milling or placed back into the open pit at the conclusion of milling there will be no post mining impact to ground and surface water following mine closure. The pit will be backfilled and an engineered cover constructed over the in-pit TSF. Landform-evolution modelling of the final landform has shown that under the base case (constant erosion rate over 10,000 years) and the time varying scenario (erodability decreasing after 100 years), the majority of sediment loss is predicted to occur on the valley slopes and net deposition occurring in many areas of the valley floor near the rehabilitated landform.

Under these scenarios, there are predicted to be some rill erosion gullies that form over the in-pit TSF area after a period of 10,000 years. These features are predicted to be isolated and restricted to the outer edges of the cover system and will not have a negative impact on either the stability of the TSF cover system or sediment transport downstream (Section 9.12; Appendix O2).

9.10.5.4 Seepage from in-pit TSF

Based on the geochemical analyses undertaken, chloride, uranium, vanadium, arsenic, and molybdenum were selected for solute transport modelling. These contaminants of concern (CoCs) were selected based on the geochemistry of the carnotite deposit and because they exist as negatively charged species (arsenic and molybdenum). Chloride was included because it is a non-retarding conservative tracer.

The results of the modelling are discussed in Section 9.5.5 and in the modelling report in Appendix I1. The in-pit TSF long term solute transport modelling predicts:

- Simulated plume fronts (at a concentration of 0.01 mg/L) for uranium, vanadium, arsenic and molybdenum may travel several hundred metres longitudinally along the valley, but typically not beyond the eastern boundary of the pit.
- The uranium, vanadium, arsenic and molybdenum plume fronts (at 0.01 mg/L) may extend up to 600 m north and 200 m south of the in-pit TSF.
- Vertically the plume fronts (at 0.01 mg/L) may reach the palaeochannel underlying the TSF.
- The chloride (conservative constituent) plume (at 0.01 mg/L) could travel as far as 50 km from the in-pit TSF. However, beyond 1,000 m from the TSF, the concentration increases negligibly compared with baseline concentrations (Cameco 2015d).

9.10.5.5 Flooding and overtopping impacts and management

The potential for flooding and / or overtopping of water storage facilities and the proposed management measures is discussed in Section 9.4.5 and in detail in the surface water study (Appendix H1). As outlined above, a surface water diversion bund designed to 1:1,000 ARI will be constructed to:

- prevent external catchment surface water from draining into the proposed Project mine site area, and
- prevent the surface water runoff that collects interior of the surface water diversion bund from discharging uncontrolled outside the bund into the natural environment.

Stormwater runoff will be captured in a series of stormwater ponds located within the minesite. These ponds will be designed to capture runoff from a 20 year ARI event. If however the rainfall exceeds design capacity, the stormwater ponds would overflow and excess water would flow to the lowest point on the minesite, which would likely be inactive pits.

The assessment indicates that providing the far eastern section of the flood retention bund is of sufficient height (i.e. 3 m high) and engineered to retain flood waters on site, the minesite is able to contain the in-bund stormwater runoff for a 1:1,000 year ARI rainfall event. Therefore, the minesite is expected to operate as a no-discharge site. However, depending on the development stage of the mine, there may be operational requirements to manage and discharge excess water.

Following mine closure the backfilled pit would not be subject to inundation up to the 1:100 year ARI event. Under the 1:1,000 year ARI scenario and probable maximum precipitation (PMP) event, the post-closure backfilled pit area would be subject to inundation for the duration of the event and surface water would potentially infiltrate the closed landform (URS 2015b).

9.10.5.6 Spill control

As outlined above, the site would be designed and operated as a no-release site. Where process chemicals and liquors are present the process plant and process materials storage facilities will be sealed and bunded to ensure that any process spills can be contained and easily cleaned up. Personnel will be trained in the control and clean-up of spills, including the specific management of spills containing radioactive materials.

Cameco will have appropriate management measures in place to minimise the risk of spills outlined in a chemical and fuel storage management plan to be developed for the Project. Management of ore or process spills will also be referred to in the Radiation Management Plan as outlined in Section 9.6.6.

9.10.5.7 Summary of Management Measures

Avoid and Minimise

- Vehicle and equipment hygiene measures in accordance with the Radiation Management Plan to ensure that contaminated material is not transported off-site. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation will be kept within the contaminated area (refer to Environmental Factor 6).
- Minimise dust impacts in accordance with the Dust Management Plan (refer to Environmental Factor 8).
- Implement surface water management measures in accordance with the Surface Water Management Plan to prevent release of contaminated runoff (refer to Environmental Factor 4).
- Implement spill control procedures as required.
- Ensure that all ore or mineralised waste is either processed through the processing plant, or buried in-pit at the end of mine life.
- Implement vehicle and machinery hygiene measures.

Rehabilitate

- Topsoils will be mapped and preferentially stockpiled for use in rehabilitation and revegetation. Topsoil will be stored in low stockpiles to retain seed viability and will be protected from erosion. Topsoil will not be handled when wet to avoid damaging soil structure. Soils that are not suitable for use in rehabilitation or construction (e.g. dispersive, saline soils) will be buried within the final landforms.
- Prior to commencement of construction, Cameco will have ascertained the availability and volumes of key materials required for rehabilitation. The results of these investigations will be presented in a revised version of the Mine Closure and Rehabilitation Plan to be submitted prior to the commencement of construction (refer to Environmental Factor 12).

9.10.6 Commitments

Cameco commits to :

- developing and implementing a Surface Water Management Plan;
- developing and implementing a Radiation Management Plan;
- developing and implementing a Dust Management Plan.

9.10.7 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.

9.11 Heritage

9.11.1 EPA Objective

The EPA objective with regards to heritage is:

- To ensure that historical and cultural associations are not adversely affected.

9.11.2 Relevant Legislation and Policy

Both State and Federal legislation applies to the protection of Indigenous heritage within the Project Area including:

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cwlth) (ATSIPA);
- *Aboriginal Heritage Act 1972* (WA) (AHA); and
- *Native Title Act 1993* (Cwlth) (NTA).

The following policy documents are also relevant to the protection of Indigenous heritage within the Project Area:

- EPA Guidance Statement No.41. (Assessment of Aboriginal Heritage);
- Department of Aboriginal Affairs (DAA) guidelines regarding Section 18 and Risk Assessment; and
- The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance 1999 (Australia ICOMOS, 2000).

The *Aboriginal Heritage Act 1972* provides protection for all places and objects in Western Australia that are important to the Indigenous people of Australia. Proponents are required to apply for clearance from the Minister for Aboriginal Affairs under Section 18 of the Act if disturbance to an Aboriginal heritage site cannot be reasonably avoided. A report on the Aboriginal heritage surveys undertaken is also required to be submitted to the Aboriginal Cultural Material Committee (ACMC). Recent proposed amendments to the Act will clarify the way sites are assessed and recorded, provide simpler rules and increased penalties to protect registered sites, fast-track approvals when proposed activities will not impact a registered site and introduce some administrative changes.

The EPA Guidance statement provides guidance for the assessment of Aboriginal heritage as part of environmental impact assessments (EPA 2004a). This guidance considers Aboriginal heritage as a relevant environmental factor “in circumstances where the heritage values are linked directly to the physical and biological attributes of the environment, and when the protection and management of those attributes are threatened as a result of a proposed development.” The guidance indicates that the proponent should demonstrate that the relevant Aboriginal heritage issues have been identified and the proponent has considered how to minimise any adverse impact by the proposal on heritage values. The guidance provides a list of actions to be considered including undertaking an Aboriginal heritage survey.

9.11.3 Studies and Investigations

A number of heritage surveys have been conducted over the Project Area since 1976. The surveys are discussed in the following section.

9.11.3.1 Ethnographic Surveys

Liberman & WA Museum, 1976

A very comprehensive ethnographic investigation of the Yeelirrie Project Area was commissioned by Western Mining Corporation (WMC) and was conducted by the WA Museum. It involved a regional ethnographic study as well as a site survey of the proposed mine site and proposed township for the Yeelirrie project. The principal anthropologist was Liberman, who conducted the fieldwork in late 1976 and 1977. He lived temporarily in Leonora and consulted over many months with more than 30 Aboriginal informants, making trips to Yeelirrie and adjacent areas with people who had knowledge of the landscape and sites. Liberman also consulted and visited Yeelirrie with an initiated man who had worked on Yeelirrie Station and been given information on significant sites by a more senior lawman who was a custodian for the sites (Liberman 1977a, 1977b; WA Museum 1978). The ethnographic site survey covered a wider area than the designated Project Area, and in fact extended beyond the Yeelirrie Station lease.

A number of sites 'which have some mythological significance' were identified by Aborigines and recorded (WA Museum 1978). Five of these were features said to be part of Dreaming stories, and one of these also included engravings of the Panaramittee style (WA Museum 1978). The other three were rock shelters containing hand stencils. Some of the ethnographic sites included water sources, such as pools in gorges and soaks in creeklines or gnammas (rockholes) on granite outcrops. Seven other ethno-archaeological sites were also identified and recorded, including six ceremonial stone arrangements and a site for manufacturing spears.

The recorded ethnographic sites are almost all situated in hills and breakaways to the north or the south of the Project Area. None of the sites is within the Project Development Envelope. All of the recorded ethnographic places were entered on the Register of Aboriginal Sites and have the status of Registered Aboriginal Sites.

Wanmulla Peoples Social History Project, 1997

The Wanmulla Social History project was undertaken 'to record the social, cultural and historical affiliations of Wanmulla people to the land' between the towns of Wiluna and Leonora including the Yeelirrie Project Area as described by the Wanmulla Native Title Claim (WC95/82).

The project was conducted in 1997 (de Gand & Wohlan 1998). It involved visiting some parts of the claim area and taking oral history from a number of people. It discusses the various forces that impacted the relationships of Aboriginal people to other tribes and groups as well as to land. These forces included the movement of non-Indigenous people into the Northeastern Goldfields region and the establishment and formalisation of the pastoral industry.

Some of the most important cultural sites for the Wanmulla were also identified and visited during 1997. There are descriptions in the report to the sites recorded by Liberman and the WA Museum which are located in breakaways to the north of the Yeelirrie Project and include mythological and traditional sites as well as water sources. No sites were reported which are located on the low-lying land south of the breakaways or within the Project Development Envelope.

Stevens and Central Desert Native Title Service, 2009

Ahead of planned water exploration and geotechnical work, BHP Billiton commissioned ethnographic and archaeological surveys from the Central Desert Native Title Service. These were 'work area clearance' surveys which means that only the proposed impact areas were surveyed and no information about the nature of any reported sites was disclosed. (Stevens 2009a, 2009b, 2010).

No ethnographic sites were identified or reported; that is, no sites of mythological, ceremonial, ritual or historic significance were present in the areas surveyed, which were all within the Project Development Envelope. However, archaeological materials were recorded. These are discussed in the section below.

Gleason's Assessment, 2011

Ahead of proposed exploration drilling in an area 5 km northwest of the Project Area, BHP Billiton commissioned an ethnographic and archaeological review and assessment. This work was conducted by anthropologist J. Gleason and archaeologist M. McKenzie in October 2011. From a review of previous surveys in the district, a visit to the area and long experience in the Northeastern

Goldfields, Gleason concluded that ‘there are no examples of flat and featureless landscape such as occurs throughout [the study area] being recorded with ethnographic values’ (Gleason 2011).

9.11.3.2 Archaeological Surveys

WA Museum, 1976

An archaeological study and survey was conducted by the WA Museum in conjunction with the ethnographic study and survey by Liberman described above. The methodology applied a predictive model based on the environment and landscape of the Project Area, with inspections along existing tracks and in areas considered likely to contain archaeological places. The area of coverage was smaller than for the ethnographic survey, but larger than the Project Area.

In all, 26 places with only archaeological material were identified and recorded (WA Museum 1978). Some of these also included an ethnographic component, such as the engraving site, rockshelter with a painting, stone arrangements and very large campsites. As with many of the ethnographic sites and places recorded by Liberman, all of these archaeological sites or places are situated in the hills and breakaways approximately 8 km north of the Project Area, or are in hills and breakaways to the south. They are all outside of the Project Development Envelope and will not be disturbed by the Project.

Stevens and Central Desert Native Title Service, 2011

Archaeological surveys were carried out in 2009 and 2010 within the Project Development Envelope, in conjunction with the ethnographic ‘work area clearance’ surveys mentioned above.

In all, 35 ‘areas’ with archaeological material were identified; being either surface artefact scatters or culturally modified trees. Details of these areas are not provided in the report and it is not stated if Stevens considered these ‘areas’ to be archaeological sites or just places with archaeological material. Most of the ‘areas’ consisted of culturally modified trees (scarred trees) with the remainder being collections of stone artefacts.

Ironbark Heritage and Environment, 2011

A very comprehensive archaeological survey of the Yeelirrie Project Area was conducted by Ironbark Heritage & Environment Pty Ltd (IHE) for BHP Billiton. The IHE survey areas were similar to but smaller than the Project Development Envelope. (See Figure 9-59). Nonetheless, IHE’s results provide a very useful guide to the local archaeological landscape.

The survey methodology involved archaeologists conducting a comprehensive and systematic search by walking parallel transects spaced 25 m apart to cover all of the designated survey areas. A record was made of all archaeological material observed, including isolated artefacts, noting their form, size category and position. It included the re-recording of all heritage ‘areas’ initially recorded by Stevens (see above).

A total of 166 places with occurrences of archaeological materials were identified and recorded by IHE during their surveys (Table 9-77), and were called ‘archaeological sites’. Also, 2,933 isolated artefacts were recorded. All of the 35 heritage ‘areas’ recorded by Stevens in the Main Mining Area, and Steven’s two ‘not cleared’ points, were visited and either re-recorded or dismissed by IHE and are included in these totals. One of the archaeological sites (DAA #11526 “Yeelirrie 03”) recorded in 1976 by the WA Museum near the Northern Quarry was also re-recorded.

Only 63 of these 166 places, or so-called “archaeological sites”, were considered significant or important by IHE in 2011, and were considered possible Aboriginal sites under the AHA (IHE 2013: Appendix N). Not all of them are within the Project Development Envelope (see next section). In particular, the heritage places that contained rock shelters and quarries were all situated outside the Project Development Envelope, and are north and/or east of the Northern Quarry, close to the breakaways and granite outcrops where the WA Museum recorded numerous ethnographic, archaeological and ethno-archaeological sites.

The remaining 103 'archaeological sites' were assessed to not meet the AHA criteria and were thought likely to have the status of "Stored Data"[1] (IHE 2013: Appendix N). All of these likely Stored Data places were artefact scatters with less than 70 artefacts or artefactual pieces. The lower status was clearly based on the very small size of these 103 places, with most containing less than 20 pieces (Table 9-78).

Table 9-78: Size of artefact scatters and quarries in the IHE survey areas

		Assemblage Size (number of artefacts counted or estimated)						
		<20	20-50	51-100	101-250	251-500	501-5000	>5000
Possibly as site under AHA	Artefact scatter	-	3	10	11	3	5	2
	Artefact scatter &/or quarry	-	-	-	-	-	3	-
Likely Stored Data – not a site	Artefact scatter	68	30	3	-	-	-	-
	Artefact scatter & quarry	-	-	-	-	-	-	-

Source: IHE 2013: Appendix A & Appendix B

Waru Consulting, 2015

Cameco engaged Waru Consulting to undertake a review of the previous site surveys. The objectives were:

1. to determine whether Cameco's Project Development Envelope had been fully surveyed;
2. to confirm that the surveys previously carried out were of an appropriate standard and coverage; and
3. to assess the results of those surveys, with particular emphasis on the archaeological material and sites that were recorded by IHE in 2011.

A copy of the report prepared by Waru is attached as Appendix N.

It was found that the 1976 ethnographic survey by Liberman was thorough and no further ethnographic investigation was required. Also, no ethnographic sites or places were reported during the more recent surveys by Stevens.

It was also determined that the archaeological survey of IHE had been comprehensive and detailed, and had covered most but not all of the Project Development Envelope as shown in Figure 9-65.

The remaining areas will be searched for archaeological sites prior to commencement of ground disturbance activities. Nonetheless, the survey results provide a very reliable guide to the occurrence of archaeological sites in any unsurveyed land, and indicate there is generally a very low likelihood for such sites. The main exception is for culturally modified trees (CMTs) to occur in a small portion of unsurveyed land on the northwest margin of the Project Development Envelope, where the Yeelirrie palaeodrainage line enters it.

Another finding of the review was that previous archaeological work had not taken into account the geomorphology of the Yeelirrie landscapes where archaeological material was recorded. Consequently, the adverse effects of erosion and flooding on the archaeological material was not appreciated nor factored into the assessment of that material.

1. Stored Data: A place or feature that has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972* by the Aboriginal Cultural Material Committee. It is not a site and need not be protected.

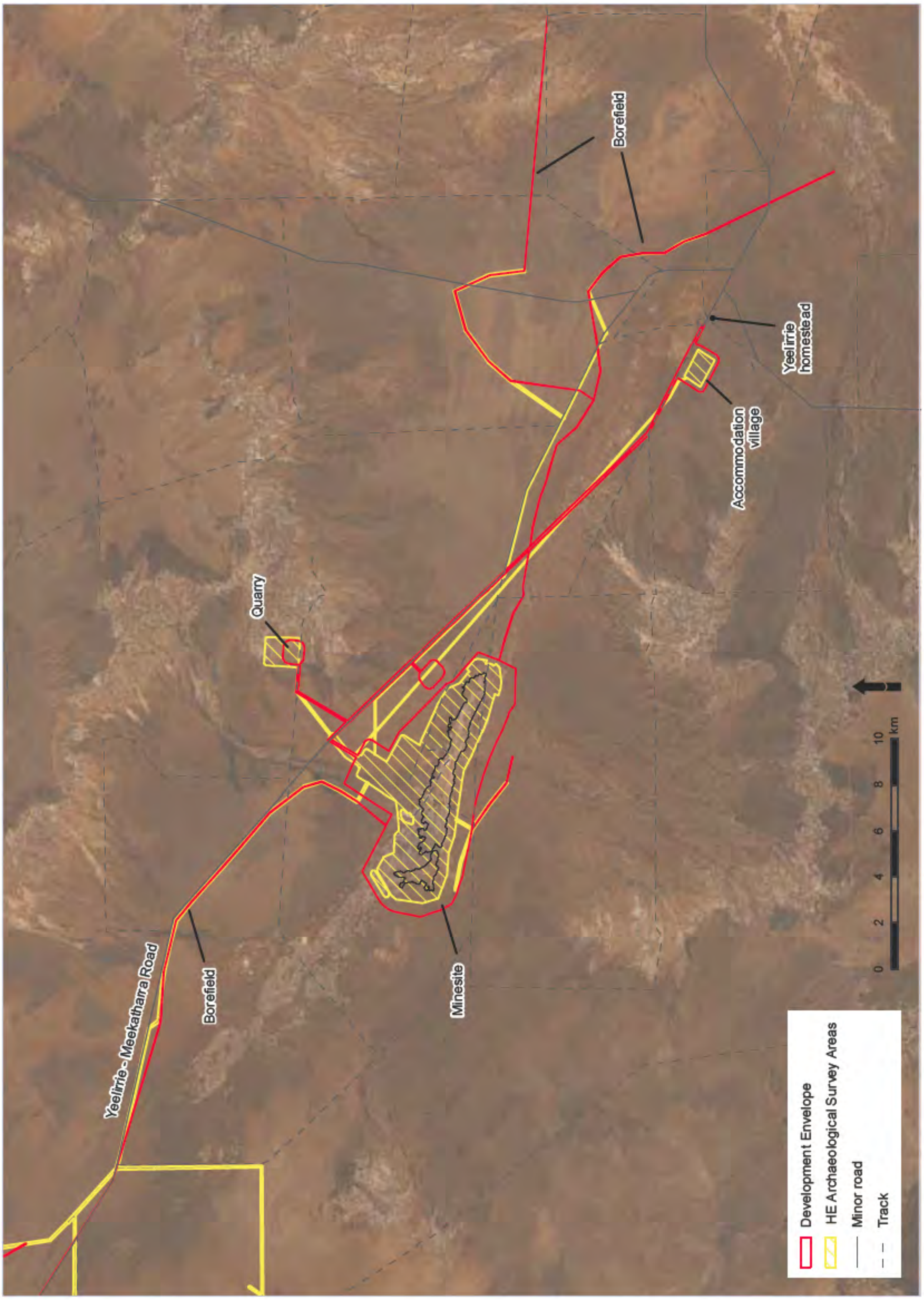


Figure 9-65: Extent of historical archaeological surveys in the Project Area

9.11.4 Existing Environment

9.11.4.1 Native Title

The Project Area occurs within one Native Title claim area. The Tjiwarl Native Title Claim was lodged in June 2011 and is currently being considered by the Federal Court. The claimants include Aboriginal people from the Leonora and Wiluna regions.

9.11.4.2 Aboriginal Heritage

The Heritage landscape of the Project Area and surrounds has been well documented (as noted above).

A number of significant ethno-archaeological sites are known to occur to the north of the Project Area. As stated above, these Registered Aboriginal Sites have mythological and/or cultural significance and some are said to be part of Dreaming stories. They have been identified and recorded consistently through each ethnographic survey conducted in the area.

These significant sites and the landscapes in which they occur will not be disturbed by the development of the Project which is located some distance to the south.

A large number of places with archaeological materials were recorded within or near the Project Development Envelope during the archaeological survey by IHE. These range from very small scatters of less than ten artefacts to larger artefact scatters with several thousand artefacts, and include culturally modified trees, rock shelters, a quarry for stone tools and artefact scatters with a quarry component. Not all of these and not all types of sites occur within the Project Development Envelope.

9.11.4.3 Heritage Places within the Development Envelope

A total of 43 heritage places were identified during IHE's archaeological survey within the Development Envelope which IHE considered likely would meet the criteria of the AHA and might be accorded the status of Registered Aboriginal Site (Table 9-79). These comprised 21 artefact scatters and 20 CMTs in the Main Mining Area, together with two artefact scatters in the Quarry area.

Table 9-79: Heritage places recorded by IHE within the Project development envelope

	Possibly a site meeting AHA criteria (in 2011)			Likely Stored Data – not a site			
	Mining Area	Quarry Area	Access Roads & Corridors	Mining Area	Quarry Area	Access Roads & Corridors	Totals
Artefact scatter	21	2	-	65	8	-	96
Artefact scatter & quarry	-	-	-	-	-	-	0
Quarry	-	-	-	-	-	-	0
Culturally modified tree (CMT)	20	-	-	-	-	-	20
Rock shelter	-	-	-	-	-	-	0
Sub-totals	41	2	0	65	8	0	
Totals	43			73			116

Source: IHE 2013: Appendix N

An assessment of the results of the IHE survey was conducted by Waru Consulting. In assessing the status of the "sites" considered by IHE likely to meet the criteria of the AHA, Waru has compared them with other recorded sites in the Northeastern Goldfields and with the sites recorded nearby by the WA Museum. Waru has also considered recent decisions of the Aboriginal Cultural Material Committee and the Registrar of Aboriginal Sites in determining whether "sites" of the size and nature of those recorded by IHE are likely to be considered significant and therefore be classified as a Registered Aboriginal Site under the AHA. The assessment included fieldwork to inspect many of the recorded places, as well as some sites recorded by the WA Museum.

Waru concluded that most of the places judged by IHE to be "sites" are unlikely to meet the criteria of section 5 of the Act (currently being applied by the Department of Aboriginal Affairs), and would not ultimately be classified as Registered Aboriginal Sites, for the following reasons:

- Erosion had adversely affected all of the artefact scatters inspected, with runoff, sheetwash and occasional flooding clearly shaping scatters and determining the distribution of artefacts within some scatters.
- Wind erosion also has likely deflated the low sand dunes and exposed artefacts at some places.
- Some of the smaller scatters likely were created by the movement and deposition of artefacts by water, not humans, while even the larger scatters are affected by the same erosional forces.
- IHE used an unusually low artefact density to define "sites", and so some scatters are very sparse and diffuse, and are better understood as a background scatter of isolated artefacts.
- Many similar scatters of artefacts and sites are very likely to exist in other portions of the valley floor, or palaeodrainage line, outside of the Project Area.

For these reasons, Waru concluded that of the 23 artefact scatter "sites" identified by IHE, only four could be considered to have the size, integrity and coherence required to meet the threshold of a registered heritage site. The other 19 scatters are likely Stored Data (not sites).

IHE also recorded numerous culturally modified trees across the Project Development Envelope. These trees made up 20 of the 43 recorded "sites". A culturally modified tree (CMT) or scarred tree is one from which Aboriginal people have cut out wood and bark to make containers or shields.

The occurrence of numerous scarred trees recorded as CMTs in the Project Development Envelope is noteworthy, as is the exclusive use of Kopi Gum (*Eucalyptus gypsophila*). It likely means there was some property of this tree species that made it preferable as a source of wood for containers or shields.

There is, however, little to be gleaned from the individual trees other than measurements and a photographic record of the scars. Waru suggests the individual CMTs are likely to have little archaeological significance, particularly since most of the scar trees within the Development Envelope are dead and many CMTs will occur in the Kopi Gum Woodland that extends widely over parts of the Yeelirrie palaeodrainage line beyond the proposed mining and infrastructure areas (Gleason 2011; Mattner 2015; *pers. obs.*). Similarly, the significance apparently attributed to these heritage places by Aboriginal participants in Stevens' surveys (Stevens 2009a: 3) will apply to any other examples, including those beyond the Project Development Envelope.

Previous consultants have discussed salvage of some of the [dead] CMTs for a small pilot study into dating them by dendrochronology (IHE 2013). However, that is not considered a practical avenue for this Project. These scars will only be relatively recent (i.e. within the last few hundred years) because of the rapid rate of destruction by termites of this species of tree. Dating will only confirm their recent age, without providing any indication of when this practice may have started, or if there were changes in the use of these trees over time.

It is considered likely that the 20 recorded CMTs will not meet a rigorous assessment under the criteria of the AHA and will not be considered to be Registered Aboriginal Sites. Instead, they likely will be assessed as Stored Data (not a site).

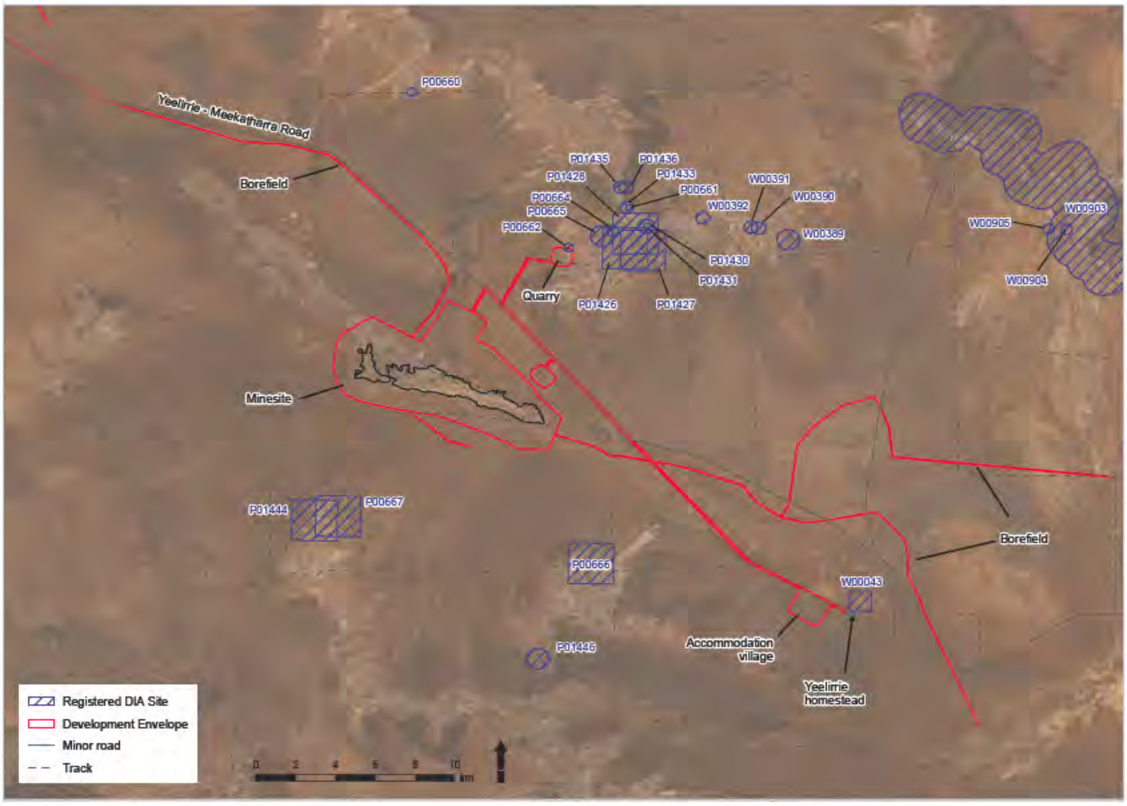


Figure 9-66: Location of registered Aboriginal sites in the Yeelirrie Project Area

9.11.5 Potential Impacts

The development of the Project will not have an impact on any Registered Aboriginal Sites (Figure 9-66).

The Project will impact a number of places where archaeological material and CMTs have been identified. Some of these places will not be able to be avoided in the development of the Project. When clearing the Project footprint, Cameco will plan and implement ground disturbing activities to avoid as many of the recorded places as possible.

9.11.6 Management

Proposed management measures are as follows:

General

- Cameco will consult with the Department of Aboriginal Affairs regarding the status and management of archaeological sites across the Development Envelope.
- Cameco will undertake consultation with members of the Tjiwarl Native Title claimants and with other Aboriginal groups with an interest in the area about the archaeological material and sites.
- Cameco will also consult with Tjiwarl elders and other Aboriginal community representatives about the proposal for a Management Area to protect ethnographic sites north and south of the Development Envelope.

Avoid and Minimise

- Investigations for archaeological sites will be carried out on land that has not previously been surveyed but which will be disturbed for the Project.

- Cameco will minimise ground disturbance and clearing activities in accordance with a Cultural Heritage Management Plan to be developed for the Project. This will include a pre-disturbance protocol to check for areas of significance.

9.11.7 Commitments

Cameco will:

- develop and implement a Cultural Aboriginal Heritage Management Plan.

9.11.8 Outcomes

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

9.12 Rehabilitation and Decommissioning

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

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

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

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

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

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

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

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

9.12.1 EPA Objective

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

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

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

9.12.2 Relevant Legislation and Policy

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

9.12.3 Studies and Investigations

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

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

9.12.3.1 Landform evolution modelling

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

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

1. Base case model: Soil erodibility values were kept constant throughout the entire 10,000 year modelling period. This is considered a "worst case" model scenario, as it assumed that no surface-stabilising vegetation or soil cover (e.g. cryptogam or plant material) will develop, and the soil will remain in a similar condition as it was in shortly after completion of the backfilling process.

2. Time-varying erodibility model: Soil erodibility values are constant for the first 100 years of the simulation, and decrease to 1/10th of the original values thereafter. This scenario estimated the effects of vegetation and surface cover development over time, and allowed for 100 years' worth of erosion before significant vegetation re-establishment occurred.

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

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

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

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

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

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

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

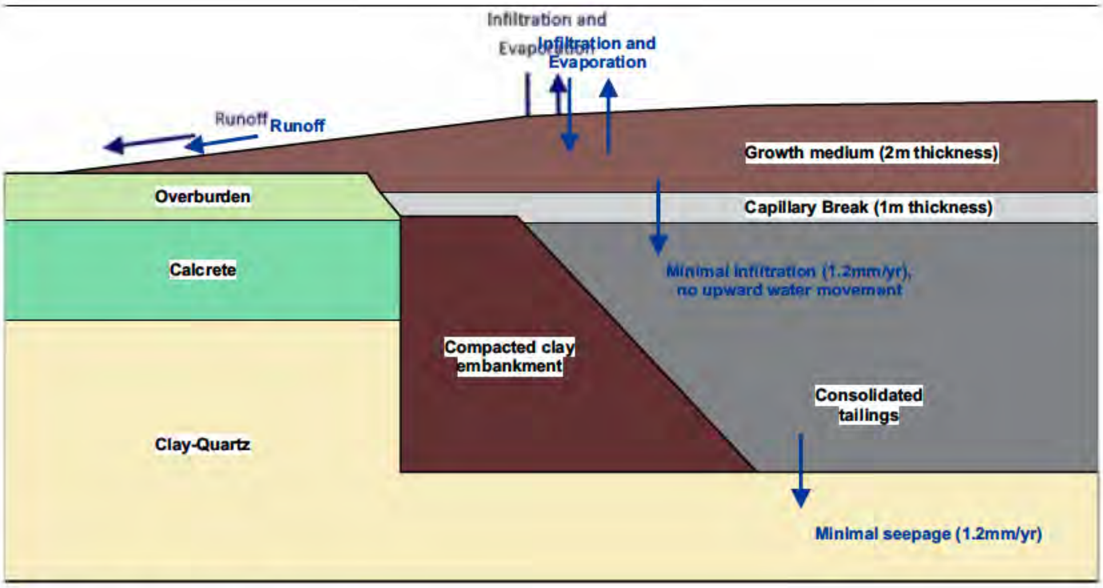


Figure 9-67: Proposed TSF cover design.

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

9.12.3.2 TSF cover system modelling

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

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

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

9.12.3.3 Post-closure groundwater modelling – groundwater levels

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

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

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

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

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

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

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

9.12.3.4 Post-closure groundwater modelling – groundwater quality

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

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

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

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

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

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

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

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

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

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

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

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

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

9.12.3.5 Post-closure surface water modelling

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

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

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

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

Figure 9-68: Conceptual mine closure landform

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

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

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

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

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

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

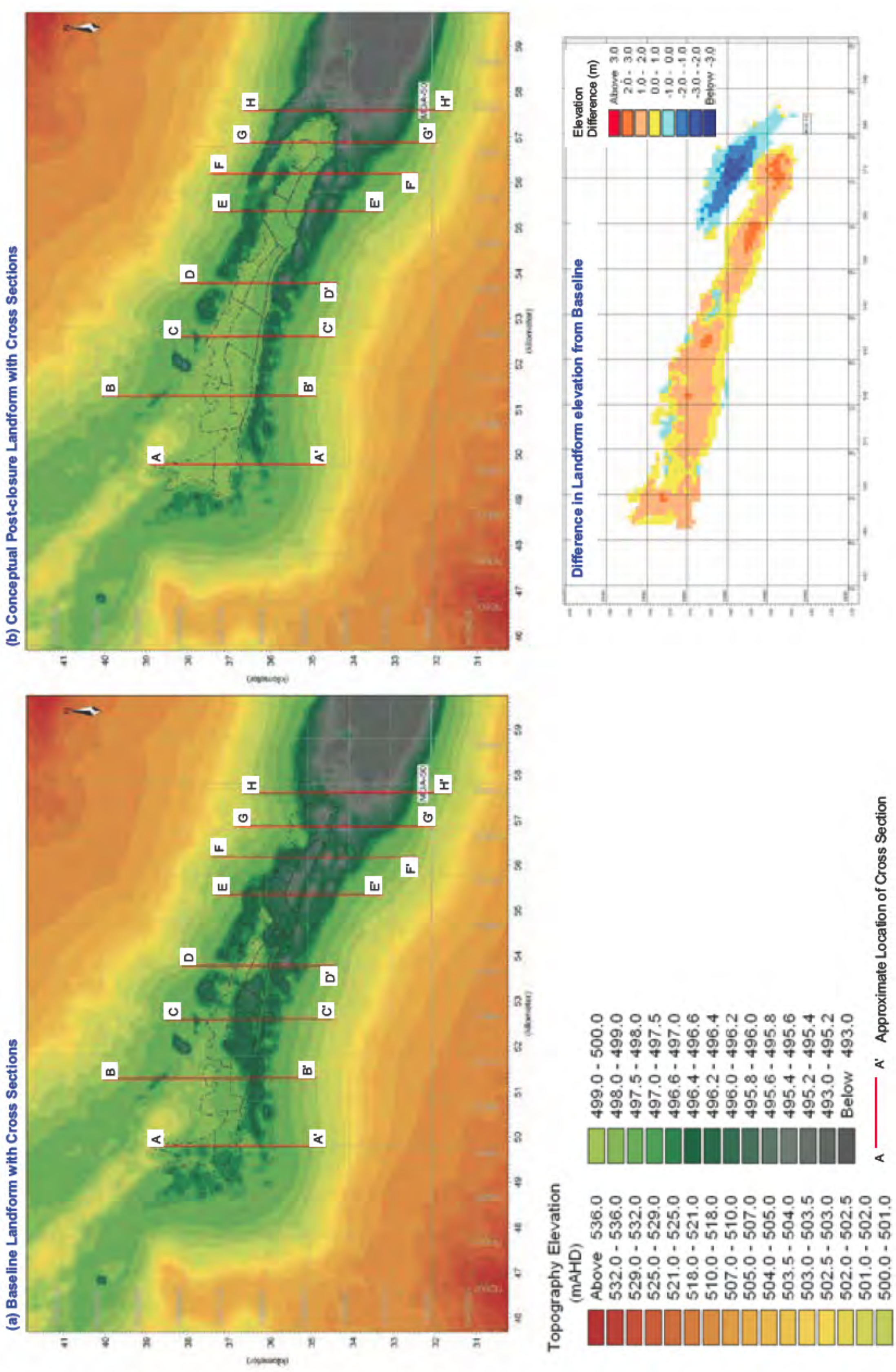


Figure 9-69: Cross section locations – baseline landforms and conceptual post closure landforms.

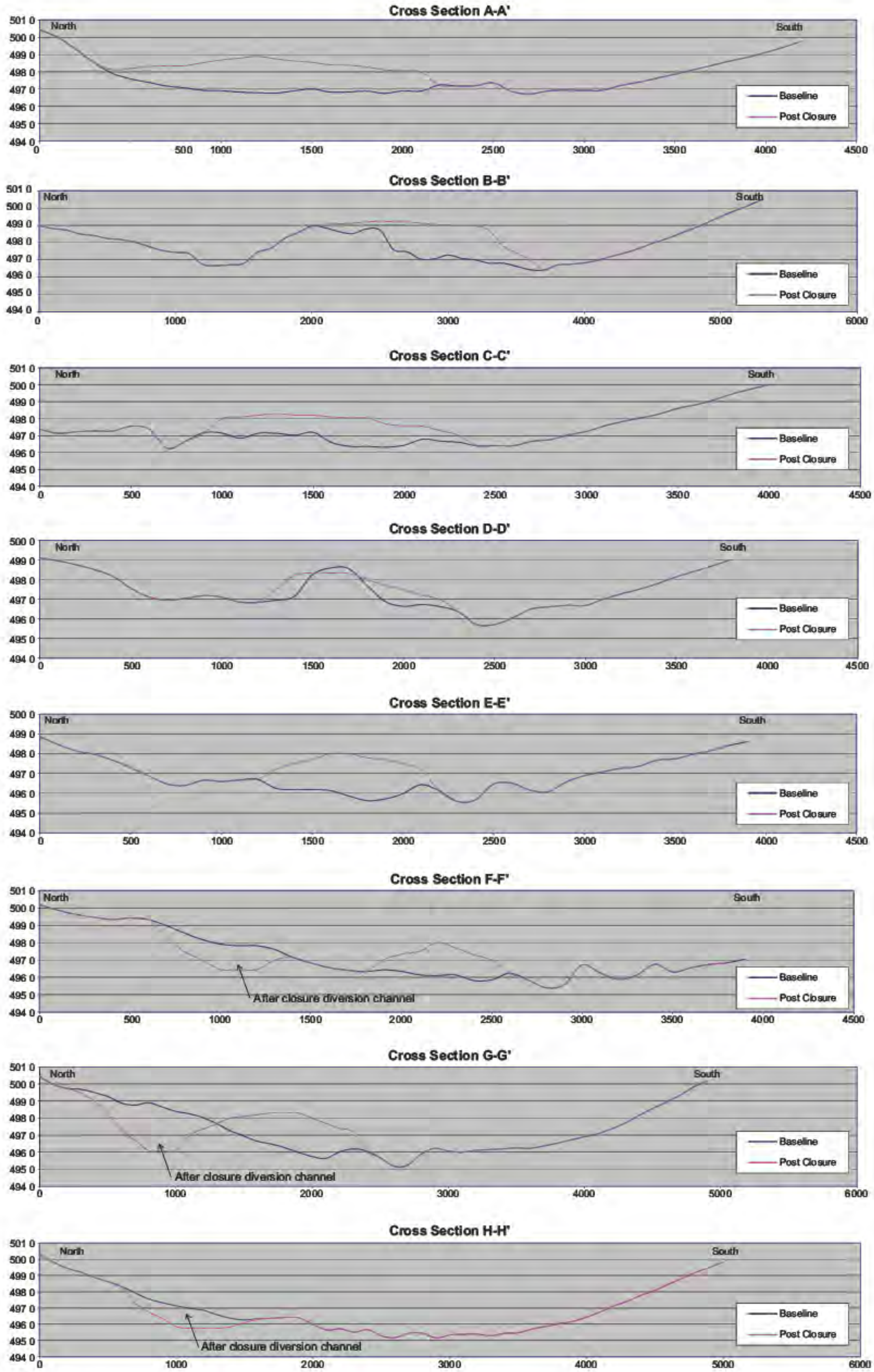


Figure 9-70: Comparison of basecase and conceptual landforms. Cross sections A, B, C, D, E, F, G and H.

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

9.12.3.6 Post-closure radiation assessment

Impact on non-human biota

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

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

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

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

Radon exhalation from the closed TSF

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

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

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

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

9.12.3.7 Waste Management

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

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

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

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

9.12.4 Management

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

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

Completion Criteria

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

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

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

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

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

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

Summary of Management Measures

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

9.12.5 Commitments

Cameco commits to;

- Reviewing and implementating the Mine Closure Plan.

9.12.6 Outcomes

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

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

Table 9-84: Identification of potential closure issues

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

Table 9-85: Management of potential closure issues

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

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

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

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

9.13 Regional and Cumulative Impacts

The Project is located approximately 660 km north east of Perth in the Murchison bioregion and in the Eastern Murchison (MUR1) subregion. Land use in the area surrounding the proposed site is typical to the Northern Goldfields area and consists predominantly of mining activities, pastoral stations and conservation reserves.

Other projects considered relevant to the assessment of regional and cumulative effects are those in the vicinity, with the potential to impact the same receptors, or use the same infrastructure as the proposed Project. There are no operating mining projects within a 50 km radius of Yeelirrie, while a number of operating mines (including Mt Keith, Leinster and Agnew) and a number of proposed projects (including the Wiluna Uranium Project) are within 150 km of Yeelirrie.

Potential regional and cumulative impacts to the key environmental factors have been assessed in consideration to the following key projects. The list is not intended to be exhaustive. Rather, it indicates the major projects that are most relevant to the Yeelirrie Project.

Mount Keith

The closest mining operation to the proposed Yeelirrie development is the Mount Keith nickel mine, operated by BHP Billiton Nickel West. Mount Keith is a large open-cut mine with a nickel concentrator about 65 km east of Yeelirrie.

Wiluna Uranium Project

Toro Energy Limited has been granted state and federal environmental approval to develop the Wiluna Uranium Project on the Lake Way playa, 15 km southeast of Wiluna, and 56 km northwest of the proposed Yeelirrie development.

Barrambie Vanadium Project

Neometals Limited proposes to develop the Barrambie Vanadium Project located 116 km south-east of Meekatharra, and 85 km west of the proposed Yeelirrie development.

Table 9-87 outlines the potential cumulative effects of these relevant projects with the Yeelirrie Project.

9.13.1 Land Systems

Land Systems mapped at a regional level by the Department of Agriculture, (Pringle *et al*.1994; Payne *et al*. 1998), provide an opportunity to compare impacts on vegetation types and fauna habitat. In addition to considering the cumulative impacts of the key aspects of the Project and the three relevant projects mentioned above, Cameco has also undertaken an assessment of Land Systems impact in the wider region. This assessment considered active, proposed and closed projects within the wider region and has been utilised to determine whether any particular land system is significantly affected by the cumulative disturbance in the region. While a Land Systems mapping approach might be considered too high level, it is the only regional level mapping available.

Sixteen land systems representing ten land types have been mapped at a scale of 1:500,000 over the Local Study Area at Yeelirrie. Table 9-2 (see Section 9-1) shows the sixteen land systems and the area and percentage of each land system that occurs within the Project Area. Four land systems of most interest are the Cosmos, Cunyu, Melaleuca and Mileura systems. These are amongst the four smallest by area within the region, however they are also those most represented across the Yeelirrie Project Area. They are associated with margins of salt lakes and occluded palaeodrainage channels, including calcrete drainage plains with mixed halophytic and non-halophytic shrublands. The systems are considered an uncommon and geographically isolated series of land systems and vegetation communities within the broader region (Western Botanical 2011).

Table 9-87: Relevant projects included in the assessment of cumulative effects

Project, Owner and Status	Land Systems	Flora and Vegetation	Subterranean fauna	Terrestrial fauna	Hydrological Processes and Inland Water Quality (Surface Water)	Hydrological Processes and Inland Water Quality (Groundwater)	Radiological Environment	Noise	Air quality and GHG Emissions	Heritage (Aboriginal)	Transport and logistics
Mount Keith (BHP Billiton Nickel West) Operational	Operation does not occur on similar land systems.	Operation impacts different vegetation types and is outside of the predicted area of impact of the Yeelirrie Project	Groundwater abstraction from Albion Downs wellfield may impact groundwater dependent ecosystems in the Lake Miranda catchment	Operation is outside of the predicted area of impact of the Yeelirrie Project and impacts different habitat	Operation is within the Lake Maitland catchment and outside of the predicted area of impact of the Yeelirrie Project.	Groundwater abstraction from Albion Downs wellfield and Yeelirrie may interact.	N/A	Existing operation covered in baseline assessment	Existing operation covered in baseline assessment	Heritage sites are highly unique in their individual cultural significance and therefore cumulative impacts are highly unlikely. There are no regional scale features of ethnographic importance impacted.	Existing operation covered in baseline assessment
Wiluna Uranium Project (Toro Energy Limited) Approved	Operation may impact on sensitive land systems common to the Yeelirrie Project and within the Murchison bioregion	Potential cumulative impacts to communities associated with calcrete and those likely to be groundwater dependent vegetation.	Operation is outside of the predicted area of impact of the Yeelirrie Project and share no common groundwater source	Operation is outside of the predicted area of impact of the Yeelirrie Project but may impact similar habitat. Regional impact is low.	Operation is within the Lake Way catchment and outside of the predicted area of impact of the Yeelirrie Project	Operation is outside of the predicted area of impact of the Yeelirrie Project and share no common groundwater source	Operation is outside of the predicted area of impact of the Yeelirrie Project, nevertheless, may contribute to public perception	Operation is outside of the predicted area of impact of the Yeelirrie Project	Operation is outside of the predicted area of impact of the Yeelirrie Project		Operation proposes to share transport infrastructure, including ports, with Yeelirrie Project
Barrambie Vanadium Project (Neometals Limited) Approved	Operation may impact on sensitive land systems common to the Yeelirrie Project within the Murchison bioregion	Cumulative impacts to conservation significant flora species are not expected. Potential for cumulative effects on communities associated with calcrete.	Operation is outside of the predicted area of impact of the Yeelirrie Project and share no common groundwater source	Operation is outside of the predicted area of impact of the Yeelirrie Project but may impact similar habitat. ,Regional impact is low.	Operation is within the Lake Mason catchment and outside of the predicted area of impact of the Yeelirrie Project	Operation is outside of the predicted area of impact of the Yeelirrie Project and share no common groundwater source	N/A	Operation is outside of the predicted area of impact of the Yeelirrie Project	Operation is outside of the predicted area of impact of the Yeelirrie Project		Operation proposes to share transport infrastructure, including ports, with Yeelirrie Project

Table 9-88 shows the area of the Cosmos, Cunyu, Melaleuca and Mileura land systems and the area and percentage to be cleared by development of the Project. As presented, the impact is low with less than 1% on any of the Land Systems to be disturbed by the Project.

Table 9-88: Impacted land systems

Land System	Total Area of Land System Mapped (ha)	Total Area of Land System within Local Study Area (ha)	Total Area to be Cleared (ha)	Percentage within Local Study Area to be Cleared (%)	Percentage of mapped Land System to be Cleared (%)
Cosmo	19100	1797	0	0	0
Cunyu	66800	2857	316.6	11.08	0.47
Melaleuca	39600	3008	98	3.26	0.25
Mileura	125000	3796	940.5	24.78	0.75

Figure 9-71 illustrates the extent of the land system assessment undertaken by Cameco and the active, proposed and closed projects that impact on the four land systems of most interest. The assessment area covers four Department of Agriculture surveys (Murchison River Survey, Wiluna-Meekatharra Survey, Sandstone Yalgoo Paynes Find Survey and the North Eastern Goldfields Survey) for a total area of 33,314,274 ha. In addition to the Yeelirrie Project and from the available data there are twelve active, proposed or closed (shut or on care and maintenance) projects in the wider region that will impact on the four land systems. (Figure 9-64).

The cumulative impact from these projects on the four land systems is presented in Table 9-89.

Table 9-89: Cumulative impact on land systems

Land System	Total Area of Land System Mapped (ha)	Total Area to be Cleared by the Yeelirrie Uranium Project (ha)	Total Cleared or proposed to be Cleared by other Projects (ha)	Percentage Cleared or proposed to be Cleared (%)
Cosmo	19100	0	228	1.19
Cunyu	66800	316.6	288	0.91
Melaleuca	39600	98	0	0.25
Mileura	125000	940.5	767	1.36

As evident by the figures presented in Table 9-89 the cumulative impact to the sensitive Land Systems would be minor.

9.13.2 Key Aspects

9.13.2.1 Flora and Vegetation

Cumulative impacts on Land Systems is expected to be minor and therefore potential cumulative impact to vegetation communities is also expected to be minor. There is expected to be no significant cumulative impact to conservation significant flora.

9.13.2.2 Subterranean Fauna

Stygofauna

The Project is located in the Yeelirrie Palaeodrainage System. The only other significant third party user in this system is BHP Billiton Nickel West groundwater production borefield known as the

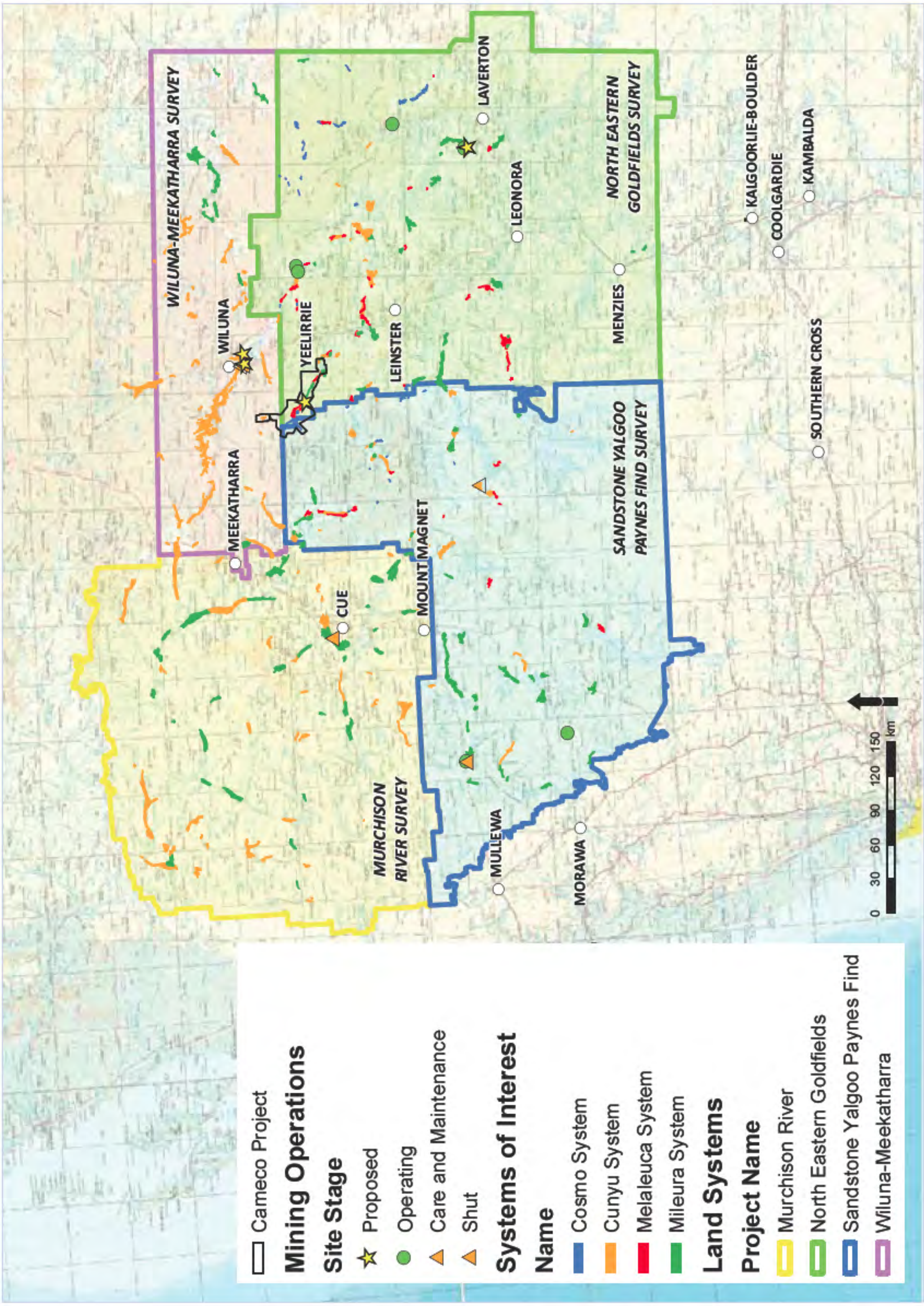


Figure 9-71: Land System Assessment

Albion Downs wellfield. The groundwater model developed and reported by Cameco (Section 9.5) was set up to simulate the combined impacts of the Project and Albion Downs wellfield. This simulation has been undertaken and reported using conservative assumptions relating to the connectivity of the two fields as well as to the future water abstraction from both fields.

Cameco considers that drawdown of 0.5 m more than the natural fluctuations as the threshold that will have an impact on stygofauna. Section 9.5.5.2 shows maximum drawdown with separation of the two cones of drawdown at the 0.3 m contour, and therefore no cumulative impact to stygofauna is expected. In addition to this, the incremental impacts of the Project on the area between the two fields, is highly manageable. Adjustments to the abstraction rates from the closer Yeelirrie bores can be used to further reduce the slight additional drawdown if ongoing monitoring shows that this is necessary.

Troglofauna

There are no other excavation activities planned or approved within the Yeelirrie Palaeodrainage System and therefore no cumulative impact to Troglofauna is expected.

9.13.2.3 Terrestrial Fauna

Table 9-90 lists the Conservation significant species recorded within the Study Area and their land system associations. There are no conservation significant fauna restricted to any of the four Land Systems discussed. Due to the isolated location of the Project there would be no cumulative effects to local populations of conservation significant fauna, or their preferred habitats.

Table 9-90: Conservation significant species

Species	Status in area	Habitat	Associated Land System
Leipoa ocellata Malleefowl Vul (EPBC) S1 (WCA)	Resident/ Recorded	Dense Acacia shrublands	Yanganoo, Sherwood and part Bullimore
Petrogale lateralis Black-flanked Rock-Wallaby Vul (EPBC) S1 (WCA)	Resident/ Old records (BCE 2011a; 2015a)	Rocky outcrops with caves and rock piles associated with the Barr Smith Range.	Sherwood
Merops ornatus Rainbow Bee-eater Mig (EPBC) S3 (WCA)	Regular migrant/ Recorded (BCE 2011a; 2015a)	Sandy- loam soils.	Bullimore, Desdemona
Apus pacificus Fork-tailed Swift Mig (EPBC) S3 (WCA)	Irregular visitor/ Recorded (BCE 2015a)	Not applicable: aerial species	All
Migratory waterbirds	Vagrants to irregular visitors, usually in very small numbers	Seasonal waterbodies	Cunyu, Mileura
Ardeotis australis Australian BustardP4 (DPaW)	Resident/ Recorded (BCE 2011a; 2015a).	Spinifex sand plains.	Bullimore
Amytornis striatus Striated Grasswren P4 (DPaW)	Resident/ Not recorded.	Spinifex sandplains with an overstorey of shrubs, usually mallee eucalypts.	Bullimore

Species	Status in area	Habitat	Associated Land System
Dasycercus blythi Brush-tailed Mulgara P4 (DPaW)	Resident/ Recorded (BCE, 2011a; 2015a)	Spinifex sand plains, mulga shrubland and open woodland.	Bullimore, Yanganoo
Sminthopsis longicaudata Long-tailed Dunnart P4 (DPaW)	Resident/ Not recorded.	Rocky ridges, stony slopes with Spinifex.	Sherwood
Nyctophilus major Inland Long- eared Bat P4 (DPaW)	Resident/ Recorded (BCE, 2011a)	Spinifex sand plains. May roost in tree hollows in E. gypsophila woodland.	Cunyu, Melaleuca
Burhinus grallarius Bush Stone-curlew	Resident/ Recorded (BCE 2011a; 2015a)	E. gypsophila woodland, dense Acacia shrublands, gnamma holes and Casuarina woodland.	All
Lophoictinia isura Square-tailed Kite	Resident/ Recorded (BCE 2011a)	E. gypsophila woodland and Mulga shrubland.	All
Antichinomys laniger Kultarr	Resident/ Not recorded.	Open plains.	Bullimore

9.13.2.4 Surface Water

There are no recently approved or proposed projects located within the Lake Miranda palaeochannel; therefore no cumulative effects to flow regime or water quality from the proposed development in conjunction with other activities are expected.

9.13.2.5 Groundwater

The Project is located in the Yeelirrie Palaeodrainage System. The only other third party user in this system is BHP Billiton Nickel West Albion Downs wellfield.

The groundwater model developed and reported by Cameco (Section 9.5) was set up to simulate the combined impacts of the Project and Albion Downs wellfield. This simulation has been undertaken and reported using conservative assumptions relating to the connectivity of the two fields as well as to the future water abstraction from both fields. The simulations demonstrate very limited overlap between the drawdown cones of the two fields and the DoW has advised in writing (email dated 29th April 2015) that the work presented by Cameco to assess groundwater impacts meets the requirements of a H3 level of assessment as outlined in DoW Operational Policy No. 5.12 (DoW, 2009).

Figures in Section 9.5.5.2 show maximum drawdown with separation of the two cones of drawdown at the 0.3 m contour. The impact on the area between the two developments arises primarily from Albion Downs abstraction, due to much lower intensity of abstraction associated with the Project (Yeelirrie abstraction is about one third of Albion Downs rates when expressed as total project volume or rate per kilometre of palaeochannel). Key areas of model conservatism are as follows:

- The model simulates a continuous hydraulic gradient through the major salina located between the two borefields, however static water level data (such as it is known from pre-Albion Downs records) suggests that net discharge at the salina means it acts as a hydraulic barrier effectively isolating the two parts of the groundwater flow system.
- Monitoring results have shown drawdown impact from Albion Downs is less than the model prediction in shallow aquifer between the two projects.
- Model simulation assumes continuing Albion Downs operation for full duration of Yeelirrie Project (until Year 2035) whereas current planned closure date for Mount Keith is 2021.

The incremental impacts of the Project on the area between the two fields, is highly manageable. Adjustments to the abstraction rates from the closer Yeelirrie bores can be used to further reduce the slight additional drawdown if ongoing monitoring shows that this is necessary. Further detail on the impacts of the Project on groundwater is provided in Section 9-5.

9.13.2.6 Radiological Environment

As discussed in Section 9.6.5.2 and Appendix J1 the extent of the Project's radiological impact on sensitive receptors is extremely low. The proposed Wiluna Uranium Project is located approximately 56 km from Yeelirrie and the project has no similar sensitive receptors with Yeelirrie. Areas of radiological impact associated with this proposed development would not likely extend further than 20 km from the project sites. The areas of radiological impact associated with this proposed project would not overlap with the Yeelirrie Project and therefore cumulative radiological effects are not expected.

Predicted effects to non-human biota would not extend a significant distance from the Project footprint. As discussed above, the distance between the proposed Yeelirrie development and other proposed uranium projects mean cumulative effects to non-human biota will not occur.

9.13.2.7 Noise

Sensitive receptors identified for the proposed development are not common to any recently approved or proposed projects. Therefore, cumulative impacts to noise for sensitive receptors from reasonably foreseeable projects are not expected.

9.13.2.8 Air Quality

Sensitive receptors identified for the proposed development are not common to any recently approved or proposed projects. Therefore, cumulative impacts to air quality for sensitive receptors from reasonably foreseeable projects are not expected.

9.13.2.9 Greenhouse Gas Emissions

The data presented in Section 9.9 and Appendix L2 show that, as a proportion of state, national and global emissions, the contribution of the Project to atmospheric greenhouse gas emission levels is very low. The exact quantity of additional greenhouse gas emissions likely to be released by reasonably foreseeable projects and activities cannot be known with certainty due to the variability in the publicly available information, however cumulatively their emissions are unlikely to result in a significant contribution to Western Australia's greenhouse emissions.

9.13.2.10 Terrestrial Environmental Quality

No cumulative impacts to terrestrial environmental quality from the Project in conjunction with other activities are expected due to the remoteness of the Project.

9.13.2.11 Heritage (Aboriginal)

Heritage sites are highly unique in their individual cultural significance. The Yeelirrie Project does not have a significant impact on cultural heritage sites, and as there are no regional scale places of ethnographic significance, that intersect Yeelirrie and any other Project, so no cumulative effects are expected.

9.13.2.12 Other

Transport

There are numerous projects proposed for development in the Mid-West region which, individually, are unlikely to impact traffic flows, but may present some cumulative impact.

Traffic volumes for the Goldfields Highway were assessed by Arup (2011) for BHP Billiton. The daily two-way traffic volume for the Goldfields Highway near Mount Keith was assessed to be 482 vehicles. Arup also estimated the increase from the Yeelirrie Project during the operational phase to be approximately 18.8 vehicles per day representing an increase of approximately 4 percent in the traffic flows for this route. This should be able to be absorbed within the available capacity along this route.

Extrapolating from the Yeelirrie estimates and allowing for two more projects to come into operation with no net loss from other operating projects that use the Goldfields Highway, the overall increase would be approximately 12 percent above the current flow.

It is unlikely that this increase would be of a magnitude that would lead to significant changes to the current levels of service for road users.

Transport of UOC

Each of the proposed Western Australian uranium projects is planning to utilise either Port Adelaide and/or the Port of Darwin to export UOC. To assess a worst-case scenario for cumulative impacts to transport, port infrastructure and capacities, it was assumed that all containers from all projects would be exported from the Port of Adelaide. If all four projects (Mulga Rocks (Vimy), Wiluna (Toro), Kintyre and Yeelirrie (Cameco) currently under consideration were to get into production they may produce up to 10,000 tonnes of UOC per year.

If this volume was to be trucked to the Port of Adelaide in shipping containers on two trailer road trains it would take approximately 260 vehicle movements, or 5 trucks each week.

The product from these projects would constitute a 0.2% increase in the number of container movements through Port Adelaide compared to 2010 movements. This increase is within the capacity of the port, and is therefore unlikely to result in a significant impact.

In summary, the cumulative transport movements relating to the development of new projects and the movement of UOC is unlikely to lead to significant changes to the current levels of service for road users.

Community Perception

The development of multiple uranium projects in Western Australia may affect community perceptions, in particular in relation to transport and emergency response and Cameco will work with local communities and other companies in the industry to ensure a high level of industry planning and co-operation and community education and engagement.

9.13.3 Summary of the assessment of regional and cumulative effects with other projects

Table 9-91 summarises the outcomes of the assessment of cumulative effects for the Yeelirrie Uranium Project with consideration to other Projects that may be developed within a similar timeframe.

Table 9-91: Summary of potential cumulative effects of the proposed development

Aspect	Cumulative effect
Terrestrial Fauna Surface Water Radiological Environment Noise Air Quality Greenhouse Gas Emissions Terrestrial Environmental Quality Heritage (Aboriginal)	Due to the isolated location of the Project and the absence of other developments in the vicinity, there would be no expected cumulative effects.
Vegetation and flora	Cumulative impacts on Land Systems are expected to be minor and therefore potential cumulative impact to vegetation communities is also expected to be minor. There is expected to be no cumulative impact to conservation significant flora.
Subterranean fauna	Cumulative impact to stygofauna is manageable and therefore no additional impact is expected.
Groundwater	Minor cumulative impact with the Albion Downs Wellfield is expected. The incremental impacts of the Project on the area between the two fields, is considered to be readily manageable.
Transport	Minor traffic increase in the mid-west region is expected, however it is unlikely that this increase would be of a magnitude that would lead to significant changes to the current levels of service for road users. Minor cumulative effect on the Port of Adelaide is expected, however the increases are within its capacities, and are therefore unlikely to result in a significant impact to existing users or the public..

Section 10

Matters of National Environmental Significance

10. Matters of National Environmental Significance

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) facilitates national environmental assessment and approvals regarding Matters of National Environmental Significance (MNES). The objectives of the EPBC Act are:

- to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance;
- to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- to promote the conservation of biodiversity;
- to provide for the protection and conservation of heritage;
- to promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and Indigenous peoples;
- to assist in the co-operative implementation of Australia's international environmental responsibilities;
- to recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and
- to promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

There are nine currently MNES listed under the EPBC Act. Actions that are likely to have a significant impact on any MNES, are subject to an environmental assessment and require approval from the Australian Federal Minister for the Environment.

In June 2009 the Federal Environment Minister determined that the original Project was a 'controlled action' and required approval under the EPBC Act. Cameco advised the DoE of the change of proponent and proposed variation to the Project in November 2014. In December 2014 the DoE accepted the proposed variation to the Project under section 156B of the EPBC Act. The controlling MNES relevant to Cameco's Yeelirriie Uranium Project are:

- Nationally threatened species;
- Migratory species; and
- Nuclear actions.

The impacts of the Project on these matters are discussed in the following sections.

10.1 Listed Threatened Species, Migratory Species and Ecological Communities

This section provides an assessment of the potential impacts of the Project on threatened and migratory fauna species protected by the EPBC Act. The assessment was supported by database searches, desktop assessments, literature reviews and local and regional surveys.

10.1.1 Relevant Legislation and Policy

Fauna species of national conservation significance under the EPBC Act may be classified as:

- Critically Endangered - A taxon is Critically Endangered when it is considered to be facing an extremely high risk of extinction in the wild in the immdiate future.
- Endangered - A taxon is Endangered when it is considered to be facing a very high risk of extinction in the wild in the near future.

- Vulnerable - A taxon is Vulnerable when it is considered to be (not critically endangered or endangered) facing a high risk of extinction in the wild in the medium term future.
- Conservation Dependent - A taxon is Conservation Dependent if the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.

Migratory species listed under international agreements are also protected under the EPBC Act. The national list of migratory species consists of those species listed under the following international agreements:

Japan-Australia Migratory Bird Agreement (JAMBA)

The agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Japan and Australia. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.

Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)

The agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between South Korea and Australia. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.

China-Australia Migratory Bird Agreement (CAMBA) 1986

The agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between China and Australia. Protection is afforded by limiting the circumstances under which migratory birds are taken or traded, protecting and conserving important habitats, exchanging information and building cooperative relationships.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)

The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.

Under the EPBC Act, a proposal which is likely to have a significant impact on threatened species, populations or ecological communities or migratory species must be referred to the DoE. A significant impact is determined through application of Significant Impact Criteria (DoE, 2013) (Table 10-4).

In assessing the potential impact of a proposal on MNES under the EPBC Act, the Commonwealth Environment Minister must consider the following national and international requirements. These have been addressed by Cameco as follows:

Table 10-1: Considerations of Matters of National Environmental Significance

Requirement	Applicability to Project
Take into account the principles of ecologically sustainable development and the precautionary principle (refer to Section 12.5);	Cameco has undertaken detailed assessments of the fauna species and habitats within the Project area, and investigated potential impacts of the Project on MNES. Cameco has considered the long-term and intergenerational impacts of the Project on groundwater (Sections 9.5.5.2 and 9.5.5.3) and landforms (Section 9.12.3) that will affect fauna habitat. Where there is lack of full scientific certainty, Cameco has used conservative assumptions in assessing potential impacts of the Project. Cameco has designed the Project to avoid impacts on matters of NES where practicable, and minimise and manage impacts that cannot be avoided through implementation of the following plans that will be developed for the Project: • Flora and Vegetation Management Plan; • Conservation Species Management Plan (Appendix E3); • Fauna Management Plan; and • Mine Closure and Rehabilitation Plan (Appendix O1).
Not act inconsistently with Australia's obligations under the Biodiversity Convention, the Apia Convention or CITES;	Cameco believes the proposed Project and management actions, will not be inconsistent with Australia's obligations under these instruments.
Not act inconsistently with CAMBA, JAMBA or any other international agreement relating to migratory species;	Cameco has identified migratory species that have been recorded as present in the Project area, or could potentially occur based on the presence of suitable habitat. Management of process water within the Project area (that may attract migratory species) is discussed in detail in Section 9.5.5, and summarised below. Deterrents will be used to discourage waterbirds from using artificial waterbodies within the Project area.
Not act inconsistently with a species recovery plan or threat abatement plan;	The Project is not expected to have a significant impact on any fauna species that is the subject of a Species Recovery Plan or Threat Of Abatement Plan.
Have regard to any approved conservation advice (e.g. species listing advice); and	Cameco has referred to conservation advice (e.g. species listing advice) in the identification of fauna present within the Project area.

10.1.2 Studies and Investigations

A search of the EPBC Protected Matters Search tool was conducted in January 2015 over an area that included a 40 km buffer around the Study Area (DoE 2015). Numerous terrestrial vertebrate and invertebrate fauna investigations have been conducted within the Study Area (e.g. BCE 2011a, 2011b, 2015a, 2015b; Ecologia 2011a, 2011b).

Targeted searches for significant fauna were conducted during all site surveys, within the Study Area and suitable adjacent habitat. Surveys focussed on Malleefowl, Mulgara, Slender-billed Thornbill, Black-flanked Rock-Wallaby and the Shield-backed Trapdoor Spider. Survey methods and effort are outlined in BCE (2011a) and Section 9.3.3.

Regional information was available from Cowan (2001, 2008), Thompson and Thompson (2006), Benshemesh *et al.* (2008), Dell *et al.* (1998), BCE (2014), KLA (2012) and Outback Ecology (2011). In addition to the database searches and regional studies, there is information on fauna of Wanjarri Nature Reserve, 50 km east of Yeelirrie (DPaW 2015).

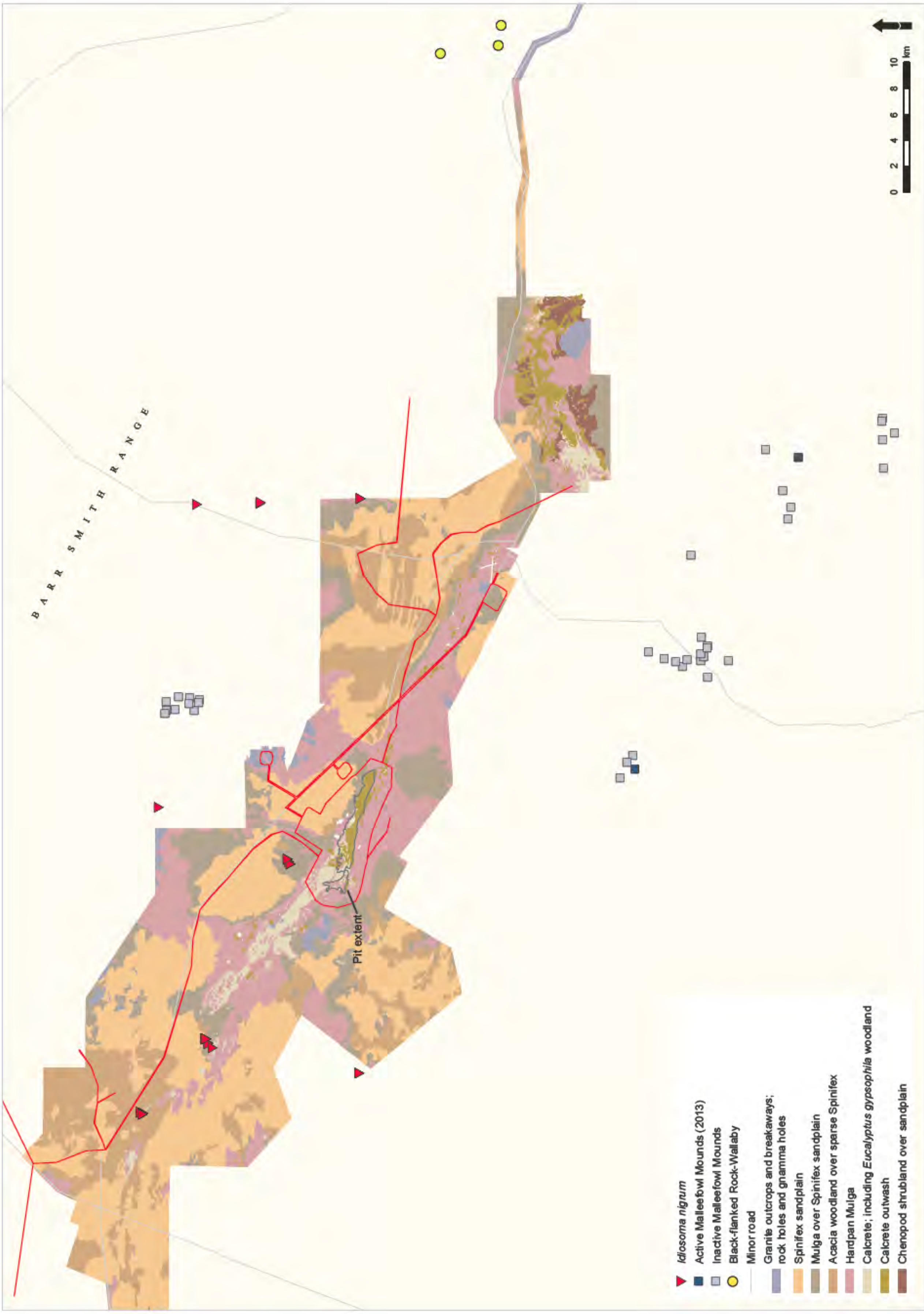


Figure 10-1: Locations of conservation significant fauna records across the Yeelirrie Project

10.1.3 Existing Environment

10.1.3.1 Fauna habitats

Background biophysical data of the region and Study Area can be found in Sections 9.1.4 (Vegetation and Flora), 9.9.4 (Soil Characteristics) and BCE (2011a).

Eight major Vegetation and Substrate Associations (VSAs) (distinct environments that provide habitat for fauna) have been identified across the Study Area (BCE 2011a):

- Granite Outcrops and Breakaways. Supporting mixed shrubland on gravelly/sand. Some areas of chenopod shrubland on heavier soil also present;
- Hardpan Mulga. Mulga woodland with poorly-developed understorey on hard loam soils;
- Calcrete. Low calcrete rises with Eucalypt open woodland (variable) over a sparse shrubland;
- Calcrete Outwash. Clayey-loam and clay flats, subject to occasional inundation with some open claypans. Vegetation includes Acacia open shrubland, sometimes with thickets of *Melaleuca xerophila*, and chenopod shrub-heaths;
- Chenopod Shrubland over Sandplain. These shrublands occur in sandy soils on the margins of playas in the southeast of the Study Area;
- Spinifex Sandplain. Sandplains dominated by Triodia hummock grasslands and scattered shrubs with areas of open Acacia/Eucalypt woodland;
- Mulga over Spinifex Sandplain. Mulga woodland over Spinifex on sandy-loam soils; and
- Acacia woodland over sparse Spinifex. Areas of dense Acacia woodland with or without a Spinifex understorey of variable density.

10.1.3.2 Listed Threatened Species

The database search identified seven species that are listed under the EPBC Act and include the threatened species: Malleefowl, Princess Parrot, Northern Marsupial Mole, Great Desert Skink and Eastern Great Egret. A further five species (also listed under the EPBC Act) are known from the region and include: Black-flanked Rock-Wallaby, Slender-billed Thornbill, Night Parrot, Greater Bilby and Shield-backed Trapdoor Spider (Table 10-2).

Three of these (Malleefowl, Black-flanked Rock-Wallaby and Shield-backed Trapdoor Spider) were confirmed during surveys (Table 10-2 and Figure 10-1).

It should be noted that the Northern Marsupial Mole (*Notoryctes caurinus*) is listed as Endangered under the EPBC Act, but no suitable habitat for this species (i.e. sand dunes) is present in the Study Area or close to the Study Area. Searches of other databases found the species more than 400 km away (DPaW 2015). Therefore, this species has been omitted from the expected species list.

Species lists generated from database searches are generous as they include records drawn from a large region and possibly from environments not represented in the survey area. Even records made in the Study Area may not be representative of the status of the species in the area, as fauna are highly mobile. Therefore, interpretation of lists of significant species generated through the desktop review and site surveys include assigning an expected status within the Study Area to species of conservation significance. This gives an indication of the likely importance of the area to the species and this has been done in Table 10-2.

Table 10-2: Threatened species listed under the EPBC Act.

Common Name	Latin Name	EPBC Act status	Expected status in Study Area	Local records	Recorded in the Study Area	
					BCE (2011a)	BCE (2015a)
Malleefowl	*Leipoa ocellata*	Vul	Resident	Yeelirrie	X	
Princess Parrot	*Polytelis alexandrae*	Vul	Irregular visitor	Wanjarri		
Great Desert Skink	*Liopholis kintorei*	Vul	Unknown	Wanjarri		
Black-flanked Rock-Wallaby	*Petrogale lateralis*	Vul	Resident	Albion Downs	X	X
Slender-billed Thornbill	*Acanthiza iredalei*	Vul	Irregular visitor	Lake Way		
Night Parrot	*Pezoporus occidentalis*	CrE	Vagrant	None recent		
Greater Bilby	*Macrotis lagotis*	Vul	Vagrant	Wiluna		
Shield-backed Trapdoor Spider	*Idiosoma nigrum*	Vul	Resident	Yeelirrie		X

EPBC Act listed species: Vul = Vulnerable, End = Endangered, CrE = Critically Endangered.

See Section 10.1.1 for descriptions of EPBC Act conservation status levels.

A description of these species is provided in Section 9.3.4.

10.1.3.3 Listed Migratory Species

The database search identified three species that are listed as Migratory under the EPBC Act that could occur within the Study Area: the Rainbow Bee-eater, Eastern Great Egret and Oriental Plover. The Oriental Plover (*Charadrius veredus*) is a wetland species but is unlikely to occur in the Study Area, except possibly as a vagrant. A further nine migratory species listed under the EPBC Act are known from the region. Of these, the Rainbow Bee-eater and Fork-tailed Swift were recorded during recent surveys (Table 10-3).

Most of the migratory species are waterbirds expected only as vagrants or irregular visitors in small numbers. These species were not even recorded in March 2015 when wetlands were present in the Study Area and when migratory species are present in Australia. The two migratory species that were recorded, are abundant species that are not habitat-restricted.

Table 10-3: Migratory species listed under the EPBC Act.

Common Name	Latin Name	EPBC Act status	Expected status in Study Area	Local records	BCE (2011a)	BCE (2015a)
Rainbow Bee-eater	*Merops ornatus*	Mig	Regular migrant	Yeelirrie	X	X
Eastern Great Egret	*Ardea modesta*	Mig	Irregular visitor	Yeelirrie		
Oriental Plover	*Charadrius veredus*	Mig	Vagrant	None but returned from EPBC search tool		

Common Name	Latin Name	EPBC Act status	Expected status in Study Area	Local records	BCE (2011a)	BCE (2015a)
Fork-tailed Swift	*Apus pacificus*	Mig	Irregular visitor	Yeelirrie		X
Common Sandpiper	*Acitis hypoleucos*	Mig	Irregular visitor	Meekatharra		
Common Greenshank	*Tringa nebularia*	Mig	Irregular visitor	Cue		
Marsh Sandpiper	*Tringa stagnatalis*	Mig	Irregular visitor	Cue		
Wood Sandpiper	*Tringa glareola*	Mig	Irregular visitor	Cue		
Red-necked Stint	*Calidris ruficollis*	Mig	Irregular visitor	Cue		
Sharp-tailed Sandpiper	*Calidris acuminata*	Mig	Irregular visitor	Yeelirrie		
Curlew Sandpiper	*Calidris ferruginea*	Mig, Crit Endg.	Irregular visitor	Lake Austin		
Black-tailed Godwit	*Limosa limosa*	Mig	Irregular visitor	Yeelirrie		

10.1.3.4 Threatened Ecological Communities

No Threatened Ecological Communities, World Heritage Properties or Wetlands of international importance (listed under the EPBC Act) were found in the search area.

10.1.4 Potential Impacts and Management

The following section summarises the status of each EPBC listed species. Possible impacts to these species are based upon the threatening processes outlined in BEC (2015a) and include: habitat loss (leading to population decline and fragmentation), habitat degradation (due to weed invasion), ongoing mortality (leading to population decline) and species interactions (feral or overabundant native species). Other potential impacts include: changes to hydroecology, altered fire regimes, disturbance from operations and bioaccumulation.

Further discussion of impacts upon listed fauna and locations of recorded species is given in Section 9.3.5. Proposed management measures to minimise impacts are also provided below.

Impact categories used include:

- Negligible: Effectively no population decline or other change in the immediate area;
- Minor: Population decline of <1% in the immediate area;
- Moderate: Permanent population decline 1-10% in the immediate area;
- Major: Permanent population decline >10% in the immediate area; and
- Critical: Taxon extinction in the immediate area.

10.1.4.1 Listed Threatened Species

Malleefowl

Suitable Malleefowl habitat is present, and one Malleefowl mound was recorded, within the Study Area by BCE during the field surveys (BCE 2011a). A recently used mound was recorded amongst closed Acacia shrubland on the northern sandplain, approximately 2 km north of the resource area.

Annual monitoring of Malleefowl mounds in the Yeelirrie area by the Malleefowl Preservation Group indicates a resident population is present. Most known Malleefowl mounds are situated away from the orebody, within stands of dense Mulga woodland. Clusters of monitored mounds are located close to the Study Area, including approximately 10 km north of the orebody and 20 km south of the orebody (Figure 10-1).

Impacts and Management

The local Malleefowl population occurs mainly outside the Study Area. Potential impacts include roadkill, loss of habitat, increase in feral predators and a change in fire regime. Impacts from the Project on this species are expected to be minor. Mitigation measures include management plans for fire and feral animals, and restrictions on speed for Project-related vehicles. Large areas of suitable habitat for this species occur outside of the Development Envelope.

Princess Parrot

The Princess Parrot is considered an irregular visitor to the Yeelirrie area and movements are largely unknown (Higgins, 1999). The species has been recorded at Wanjarri Nature Reserve (DPaW, 2015), however few other records exists for the region.

Impacts and Management

Potential impacts include loss of habitat, removal of hollow-bearing trees, changes in fire regime, dust, light, noise and vibration. However, impacts of the Project on this species are expected to be negligible. Proposed management measures are similar to those for the Malleefowl.

Great Desert Skink

The status of the Great Desert Skink is listed as Unknown, as no evidence of the species was recorded by BCE, however there is potential for the species to occur at Yeelirrie due to the extensive availability of suitable habitat and nearby records. The species typically has a clumped distribution which is influenced by fire regimes (McAlpin, 1997).

Impacts and Management

Potential impacts include increased mortality, loss of habitat, increase in feral predators and changes in fire regime. However, impacts of the Project on this species are expected to be minor. Management measures include management plans for fire and feral animals (including stray stock).

Black-flanked Rock-Wallaby

The Black-flanked Rock-Wallaby was known to occur in the region and genetic analysis of old scats collected from a cave in the Barr Smith Range during the 2015 assessment confirmed the species identification as the Black-flanked Rock-Wallaby (*Petrogale lateralis*). The assumed status of the species in the area is Resident.

While much of the rocky habitat along the Barr Smith Range appears marginal, the presence of scattered waterholes in association with caves and rock crevices may allow the species to persist. While not expected to occur within habitats associated with the orebody, the species may persist in the extensive rocky habitats to the north and south (BCE, 2015a).

Impacts and Management

The Project will result in the clearing of approximately 15 ha of suitable habitat for the proposed quarry. The Project could also result in an increase in feral predators that may affect what is an isolated and relict population. Implementation of a feral animal management plan would reduce this impact. A small population may also be particularly vulnerable to roadkill as the Yeelirrie–Meekatharra Road is situated alongside suitable habitat and as such restrictions on speed for project-related vehicles would be imposed. Overall, impacts from the Project on this species are expected to be minor.

Slender-billed Thornbill

The Slender-billed Thornbill has not been recorded at Yeelirrie despite a number of bird surveys conducted in the area by BCE (2011a, 2015a) and historical surveys conducted by previous land managers. As a result a resident population appears unlikely but if a population persist nearby, individuals might disperse though the area. While habitat potentially suitable for the species occurs at Yeelirrie (dense tall chenopod shrubland), such habitat appears marginal and lacks the samphire elements of chenopod shrublands known to support the species in the region (e.g. Lake Way and Lake Annean). A site, a salt lake near Sir Samuel, where the species was recorded in 1978 was visited in March 2015 and was found to support a quite different chenopod shrubland from that found at Yeelirrie. This site had extensive low, dense samphire shrubland with occasional taller patches, whereas the chenopod shrubland at Yeelirrie was very patchy with tall clumps but extensive open areas (BCE, 2015a).

Impacts and Management

If present in the fauna Study Area, the species could be sensitive to habitat loss and fragmentation. Therefore, as a precaution, impacts on chenopod shrublands will be minimised where practical. However, impacts of the Project on this species are expected to be negligible.

Night Parrot

The Night Parrot is included as potentially occurring due to the presence of suitable habitat and historical records. However an extant population has not been confirmed for the region.

Impacts and Management

If the species is present, there may be some loss of habitat and the possibility of increased mortality on roadsides. Proposed management measures are similar to those for the Malleefowl.

Greater Bilby

There are anecdotal records of the Greater Bilby further north of the Study Area (BCE, 2014), and the species is thriving at the DPaW managed Lorna Glen approximately 180 km north-west of the fauna Study Area. While no sign of Bilbies were recorded by BCE during field surveys, suitable habitat (spinifex sandplains) is extensive at Yeelirrie and it is feasible that individuals may move through the area currently, or in the future.

Impacts and Management

Extensive habitat is available in the Study Area and thus it is feasible for individuals to move through the area. Potential impacts, if the species is present, would include increased mortality, loss of habitat, increase in feral predators and changes in fire regime. However, impacts are expected to be minor. Management measures include management plans for fire and feral animals and restrictions on speed for project-related vehicles.

Shield-backed Trapdoor Spider

The Shield-backed Trapdoor Spider was recorded from 17 locations at Yeelirrie by BCE (2015b) and favours Acacia shrublands with a sandy substrate to a depth of at least 30 cm. It appears to be absent from the grey loamy-clay soils around some calcrete areas and in the Development Envelope. Spiders also appear absent from shallow, rocky soils of the Barr-Smith Range.

The Shield-backed Trapdoor Spider occurs at Yeelirrie in apparently much lower densities than those observed elsewhere, with typically only one or two spiders recorded across a number of hectares. At Yeelirrie, the spider does not appear to form matriarchal clusters, which is perhaps an artefact of low recruitment rates (BCE, 2015b).

Impacts and Management

Potential impacts to this species relate to dust generation from nearby activities. Standard management practices, such as watering access roads to control dust, would be sufficient to avoid impacts. It is noted however that this species appears to exist in very low numbers, and therefore Cameco will focus on minimising impacts on areas where they are known to occur.

10.1.4.2 Listed Migratory Species

Rainbow Bee-eater and Fork-tailed Swift

The Rainbow Bee-eater was recorded throughout the fauna Study Area in 2009, 2010 and 2015 (BCE 2011a, 2015a). While of high conservation significance because of its listing as a migratory species, it is widespread across Australia and frequently uses disturbed environments. The Fork-tailed Swift is likely to be an irregular visitor to the Study Area and was recorded at Yeelirrie during the 2015 survey, with two sightings of several (and possibly the same) birds (BCE 2015a). It is a highly aerial species and largely independent of terrestrial environments.

Impacts and Management

The Rainbow Bee-eater is a widespread species and versatile in natural and altered habitats. Potential impacts include increased mortality and loss of habitat. Mitigation measures include management plans for fire and feral animals, and protecting nest sites during earthworks and road maintenance. The Fork-tailed Swift is largely independent of terrestrial environments. Impacts to these two migratory species are expected to be negligible.

Migratory waterbirds

Ten waterbirds listed as migratory may periodically utilise the Study Area during migration (Table 10-3). Of these, the Eastern Great Egret, Sharp-tailed Sandpiper and Black-tailed Godwit have been recorded in the Yeelirrie area, although the Black-tailed Godwit is largely a species of marine coastal environments and therefore the record was probably of a vagrant bird or birds. All of the migratory waterbirds are expected only as occasional visitors in small numbers. Some seasonal wetlands were identified in March 2015, as a result of recent rains, but no migratory waterbird species were observed (BCE 2015a).

Impacts and Management

Potential impacts to migratory waterbirds include loss of habitat, changes to hydroecology and the introduction of new water bodies (e.g. an evaporation pond). These impacts are discussed in detail in Section 9.3.5.

An assessment of the potential impacts from the 50 ha evaporation pond on waterbird species was conducted by BCE (2015a). The evaporation pond has the potential to attract wildlife although the water quality of the pond (alkaline with salinity similar to or greater than seawater) is expected to make the water unpalatable. However, there may be occasions where stratification of the pond may occur, or following heavy rainfall where a fresh water lens may form, where the water in the evaporation pond may be more palatable.

The Uranium concentration of the evaporation pond water is expected to be less than 60 mg/L. The Uranium No Observable Adverse Impact Level (NOAEL) benchmark for drinking water for birds is 68.8 mg/L (Sample *et al*. 1996). Therefore for migratory birds, uranium concentrations are expected to be below NOAEL benchmarks at least initially, although how concentrations change will require to be monitored.

The presence of a water body in an arid landscape will attract passing waterbirds at least occasionally, even if the water is unpalatable. This includes weak birds that would be unlikely to survive under normal circumstances. It is possible therefore that dead birds may be recorded in and around the evaporation pond, and that these have not died as a direct result of contact with the evaporation pond.

Several deterrents will be used to discourage waterbirds from using artificial waterbodies and these will be outlined in a Fauna Management Plan to be developed for the Project. Bird deterrents are used at the Olympic Dam mine site, South Australia, where acidic liquid is stored. A rotating beacon with an intermittent beam directed at a shallow angle across the water surface (in combination with gas guns) effectively discourages most waterbirds (Read 1999).

Further mitigation measures to protect migratory birds may include:

- conducting an ecological risk assessment of the evaporation ponds;
- implementing a water quality monitoring program and adapting fauna management strategies (e.g. bird deterrents) based on the outcomes of the ecological risk assessment; and
- monitoring bird visitation of the evaporation ponds and reporting fauna deaths.

The impacts on migratory water birds from the evaporation pond are expected to be minor due to the implementation of mitigation measures.

10.1.4.3 Significant Impact Guidelines

The EPBC Act Policy Statement 1.1, 'Significant Impact Guidelines Matters of National Environmental Significance' (DotE, 2013) is used to assess project impacts on MNES. Given the studies and investigations undertaken for the Project (Section 10.1.2), potential impacting processes and the mitigation measures proposed (Section 10.1.4), an assessment of the listed species of MNES against the EPBC significant impact criteria was conducted (Table 10-4).

It is not expected that any EPBC significance criteria will be exceeded for the majority of species occurring within the Development Envelope. However, individual species of concern include the Shield-back Trapdoor Spider and Malleefowl (Table 10-4).

The proportional impact upon habitat is generally low due to the extent of habitat outside of the development envelope and proposed mitigation strategies outlined above. After mitigation, residual impacts include a loss of up to 2,421 ha of habitat.

Table 10-4: Assessment against EPBC significant impact guidelines

EPBC Criteria (DoE 2013)	Likelihood and rationale
Listed Threatened Species	
Lead to a long term decrease in the size of a population[1] (or an important population[2])	**Unlikely to occur.** Species of MNES that may occur within the Development Envelope largely rely on environments that are regionally widespread with only small proportional direct impacts from the project. Rehabilitation of cleared habitat will reduce effects of habitat loss. Some threats related to processes such as fire and feral species, but these are existing and amendable to management. Migratory waterbirds occur only as vagrants and irregular visitors in small numbers so any change in wetland availability would have a negligible impact. **Species of concern:** The Shield-backed Trapdoor Spider occurs in very low numbers on the spinifex sandplain VSA across the Study Area. Less than 2% (821 ha) of this VSA within the Study Area will be impacted, and it is extensive outside the development envelope. Malleefowl are sensitive to ongoing mortality and increased predation from feral species but can be managed with onsite management procedures.
Reduce the area of occupancy of the species (or an important population).	**Unlikely to occur.** It is unlikely that the Project will reduce the area of occupancy of listed species, as species of MNES that may occur within the Project Area largely rely on environments that are regionally widespread with only small proportional direct impacts from the project. There are also rehabilitation commitments to further minimise impacts. **Species of concern:** There will be an approximately 2% loss of occupied habitat of the Shield-backed Trapdoor Spider within the Study Area, but there is extensive suitable habitat outside this area.
Fragment an existing population (or important population) into two or more populations.	**Unlikely to occur.** No barrier to movement of listed species is expected. Retention of chenopod shrublands around impact areas will enable Slender-billed Thornbills to move though the area if this species persist anywhere in the region.
Adversely affect habitat critical to the survival of a species[3].	**Unlikely to occur.** Habitat loss for species of MNES that may occur within the Project Area is low on a local scale. Extensive habitat is available adjacent to and outside the development envelope.
Disrupt the breeding cycle of a population (or important population).	**Unlikely to occur.** Not likely to disrupt breeding cycle of listed species. Species of concern: Loss of one Malleefowl mound recorded in the development envelope; this mound has not been used for at least several years. 40 mounds are currently being monitored on an annual basis outside of the Project Area (MPG, 2014). Some minor disturbance during the operational phase is expected. If management measures are implemented then unlikely to be significant in the long term.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	**Unlikely to occur.** Although up to 2,421 ha of vegetation will be impacted as a result of the Project, the proportional loss of vegetation types upon which species on MNES that may occur within the Project Area are reliant is low. Rehabilitation of the site and the provision of offsets will minimise long term impacts associated with vegetation clearing.
Result in invasive species that are harmful to a threatened species becoming established in the threatened species' habitat.	**Unlikely to occur.** Feral and native competitors are present in the region, but can be effectively controlled with onsite management procedures.

EPBC Criteria (DoE 2013)	Likelihood and rationale
Introduce disease that may cause the species to decline.	**Unlikely to occur.** Hygiene management measures will be implemented.
Interfere or substantially interfere with the recovery of the species.	**Unlikely to occur.** Highly localised impacts. Broad-scale threatening processes are of greatest concern for these species (e.g. fire and feral species impacting upon the Greater Bilby). No active, direct recovery measures are currently undertaken in the Study Area although de-stocking of the station has probably been of some benefit. At a regional scale, the removal of 2,421 ha of habitat is unlikely to interfere with regional recovery programs. There are several opportunities to contribute to conservation efforts in the area (e.g. Black-flanked Rock-Wallaby).
Listed Migratory Species	
Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat[4] for a migratory species.	**Unlikely to occur.** Some minor loss of seasonal wetlands in the mining area, but this environment is extensive in the region. The Rainbow Bee-eater is a habitat generalist so not threatened by habitat loss, while the Fork-tailed Swift is largely aerial in Australia.
Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species.	**Unlikely to occur.** Feral and native competitors are present in the region but can be effectively controlled with onsite management measures. Furthermore, the risk they pose to migratory species is low. Even the ground-nesting Rainbow Bee-eater breeds successfully in locations where feral predators such as foxes and cats are present.
Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion[5] of the population of a migratory species[6].	**Unlikely to occur.** Not likely to disrupt the lifecycle of listed migratory species. Of these species, only the Rainbow Bee-eater is likely to breed in the Study Area and measures to reduce impacts on breeding birds are proposed. These may include identifying and avoiding roadside nest sites.

1 A 'population of a species' is defined under the EPBC Act as an occurrence of the species in a particular area (includes a geographically distinct regional population, or collection of local populations, or a population, or collection of local populations, that occurs within a particular bioregion). Pertains to critically endangered, endangered and vulnerable species.

2 An 'important population' is a population that is necessary for a species long term survival and recovery (includes populations identified as such in recovery plans, and/or key source populations either for breeding or dispersal, populations that are necessary for maintaining genetic diversity, and/or populations that are near the limit of the species range). Pertains to vulnerable species.

3 'Habitat critical to the survival of a species' refers to areas that are necessary: for activities such as foraging,breeding, roosting, or dispersal; for the long term maintenance of the species (including the maintenance of species essential to the survival of the species); to maintain genetic diversity and long term evolutionary development; or for the reintroduction of populations or recovery of the species. Pertains to critically endangered, endangered and vulnerable species

4 An area of 'important habitat' for a migratory species is:

a. habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or

b. habitat that is of critical importance to the species at particular life-cycle stages, and/or

c. habitat utilised by a migratory species which is at the limit of the species range, and/or

d. habitat within an area where the species is declining.

5 Listed migratory species cover a broad range of species with different life cycles and population sizes. Therefore, what is an 'ecologically significant proportion' of the population varies with the species (each circumstance will need to be evaluated). Some factors that should be considered include the species' population status, genetic distinctiveness and species specific behavioural patterns (for example, site fidelity and dispersal rates).

6 'Population', in relation to migratory species, means the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries including Australia.

Summary of Management Measures

Cameco will implement the following management measures to minimise impacts on species listed under the EPBC Act:

- The evaporation pond will be inspected daily for fauna and bird access. Should fauna visitations to the facilities be considered significant, measures will be taken to deter fauna.
- Training on the identification and reporting of conservation-significant fauna species will be included in the Cameco site induction.
- The ground disturbance protocol will ensure that areas to be cleared are first inspected by qualified environmental personnel to determine if there are any significant habitats or signs of significant fauna activity. Training on vegetation clearing procedures will be included in the environmental induction.
- Dust suppression will be undertaken in accordance with the Dust Management Plan.
- Work with DPaW and local indigenous groups to assist in the implementation of a landscape scale fire management program.

10.1.5 Commitments

Cameco will implement a Fauna Management Plan.

10.1.6 Outcomes

Development of the Yeelirrie Project will not have a significant impact to listed Threatened or Migratory Fauna.

10.2 Nuclear Actions

The EPBC Act recognises the protection of the environment from nuclear actions as a matter of national environmental significance. Nuclear actions include mining or milling of uranium ores, and decommissioning or rehabilitating a facility or area where this has occurred. The Yeelirrie Uranium Project is therefore a nuclear action.

For projects that are considered to be a nuclear action, the proponent must describe the nature and extent of likely impacts (both direct and indirect) on the whole environment. This PER document (specifically Sections 7 – 11) describes the:

- environmental context of the Project;
- potential impacts of the Project on the whole environment; and
- proposed impact avoidance, mitigation and management measures.

10.2.1 Studies and Investigations

The following specific investigations in relation to radiation have been undertaken by Cameco (Table 10-5). These are presented in Appendix J.

Table 10-5: Radiological studies undertaken for the Project by Cameco

Study	Section of PER
Radiation assessment (ERICA modelling) for non-human biota	9.1.5.5 (Flora and vegetation) 9.3.5.4 (Fauna)
Radiological baseline assessment including radon concentration monitoring	9.6
Modelling of radiation exposure pathways, exposure estimates for workforce and critical groups	9.6
Assessment of risks to human health from bush tucker consumption	9.6
Investigate radon emanation potential and design project to minimise resultant impacts on surface water, groundwater and bushtucker.	9.6
Input into the engineering design of the TSF, waste rock dumps and open pits to minimise human radiation exposure to ALARA	6 9.6

10.2.2 Potential Impacts and Management of the Project

The assessment of impacts of a nuclear action should refer to the Significant Impact Guidelines 1.2 (Commonwealth of Australia, 2013). The impacts and proposed management of the Project on all environmental factors are discussed in Sections 9 – 11.

Radiological impacts are discussed in Section 9.6 and a summary provided in Table 10-6.

Table 10-6: Summary of radiological impacts

Aspect	Estimated Dose	Guideline Dose Limit
Radiation exposure of mine workers	Estimated maximum average annual dose of 10.5 mSv/year.	20 mSv/year
Radiation exposure of process plant workers	Estimated maximum average annual dose of 6.4 mSv/year concentrator ore handling workers	20 mSv/year
Radiation exposure of administration workers	Estimated average annual dose < 1 mSv/year	20 mSv/year

Aspect	Estimated Dose	Guideline Dose Limit
Radiation exposure of camp workers	Estimated average annual dose 1 mSv/year	20 mSv/year
Radiation exposure of construction workers	Negligible	20 mSv/year
Radiation exposure of transport workers	Estimated average annual dose 0.5 mSv/year	20 mSv/year
Radiation exposure to public (inhalation of radionuclides in dust and radon decay products)	Estimated average annual dose 0.2 mSv/year (at Yeelirrie Pool)	Background plus 1 mSv/year
Radiation exposure to public (ingestion of bush tucker)	Estimated average annual dose 0.04 mSv/year (at Yeelirrie Pool)	Background plus 1 mSv/year
Radiation exposure of non-human biota	<10 µGy/hr	Trigger value of 10 µGy/hr

Note. The dose estimates have been calculated from first principles and the assumptions used in the modelling are very conservative for the reasons outlined in Section 9.6 and Sections 9.1.5.5 and 9.3.5.4. Therefore the impacts outlined in this table represent worst-case predictions, and in some cases are more than double the actual doses measured at operating mines and expected for this project.

Radiation management measures are discussed in Section 9.6.6. As part of the approval and authorisation process, a draft Radiation Management Plan (RMP) will be developed for the Project and provided to the Radiological Council for approval prior to construction. The RMP would include details of radiation protection and radioactive waste management specific to the plant and would address the requirements of the Western Australian NORM Guidelines (DMP 2010) and the ARPANSA Mining Code (ARPANSA 2005).

A Transport Radiation Management Plan (TRMP) which includes an Emergency Response Assistance Plan (ERAP) will also be prepared for approval prior to the commencement of mining. The transport carrier will be required to develop a plan consistent with Cameco's ERAP.

Section 9.6 of this PER outlines the principles that will be applied in managing radiation exposure and radioactive waste, and outlines the way these principles will be applied to the Project, including an outline of the radiation control methods and an overview of the proposed monitoring.

10.2.3 Commitments

Cameco will:

- Develop and Implement a Radiation Management Plan
- Develop and implement a Transport Radiation Management Plan.

10.2.4 Outcomes

No significant radiological impacts on human health or the environment.

Section 11

Other Factors

11. Other Factors

During assessment of proposals other factors or matters are often identified as relevant to a proposal, but not of significance to warrant further assessment by the EPA, or can be regulated by other statutory processes, to meet the EPA's objectives. The ESD has identified one other factor of Amenity, in relation to noise and access to roads.

11.1 Amenity

Amenity can generally be described as "the pleasant or normally satisfactory aspects of a location which contribute to its overall character and the enjoyment of residents or visitors."[1]

Section 9.7, Amenity (Noise), discusses the expected noise impact of the Project. Section 6, The Project, identifies the requirement for transport of goods and materials during the construction and operational phases of the proposed development.

This section discusses the expected impact of noise and transport activities on local amenity and regional amenity, for residents and visitors. It also discusses the expected positive impacts on amenity arising from the Project.

11.1.1 Local Amenity

The Yeelirrie Uranium Project is sited within the Cameco-owned Yeelirrie Pastoral Lease. The surrounding pastoral leases of Yakabindie, Mount Keith and Albion Downs are owned by BHP Billiton, while the Ululla Pastoral Lease (immediately north of Yeelirrie) is currently abandoned.

The nearest occupied homesteads to the proposed Yeelirrie accommodation village by road are (Figure 11-1):

- Yeelirrie Homestead on the Yeelirrie pastoral station –1.5 km east-south-east and home to three permanent residents;
- Albion Downs Homestead on Yeelirrie pastoral station – 35 km west-south-west and home to two permanent residents;
- Ululla Homestead on the Ululla pastoral station – about 75 km north; and
- Youno Downs Homestead on the Youno Downs pastoral station – 95 km west-north-west and home to two permanent residents.

11.1.1.1 Access and Disturbance

Local unsealed roads in the vicinity of Yeelirrie, which are under the care and control of the local shires, include (see Figure 11-1):

- Albion Downs–Yeelirrie Road, which connects Yeelirrie to the Goldfields Highway (44 km length);
- Yeelirrie–Wiluna Road, which runs north of Yeelirrie and connects with the Goldfields Highway (49.3 km length);
- Yeelirrie–Meekatharra Road, which connects Yeelirrie to Yuono Downs Homestead and continues to Meekatharra (87 km length); and
- Altona–Yeelirrie Road, which connects Yeelirrie to Altona Homestead in the south (36.5 km length).

The traffic flow most affected by the increased traffic generated from the proposed Yeelirrie development would be that on the Albion Downs–Yeelirrie Road and at the intersection of the Albion Downs–Yeelirrie Road and the Goldfields Highway.

[1] http://theplanningacademy.com.au/planning-language; accessed 26/05/2015

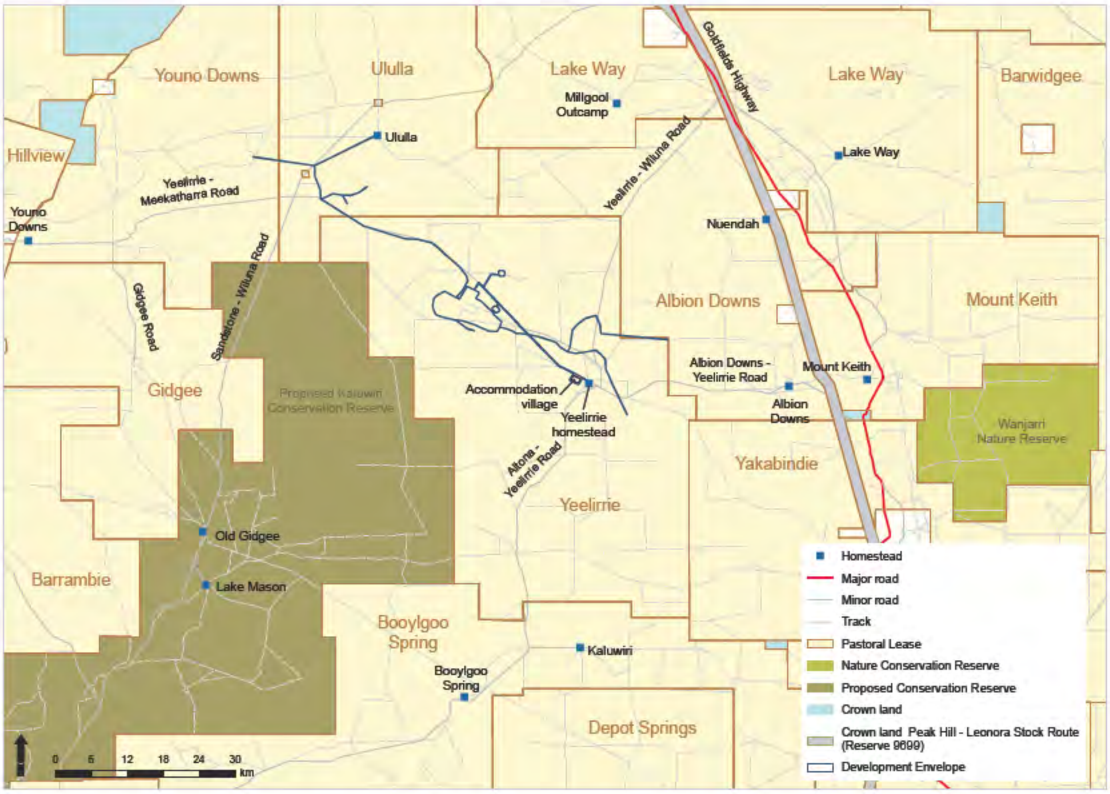


Figure 11-1: Nearest occupied homesteads to the proposed Yeelirrie Uranium Project

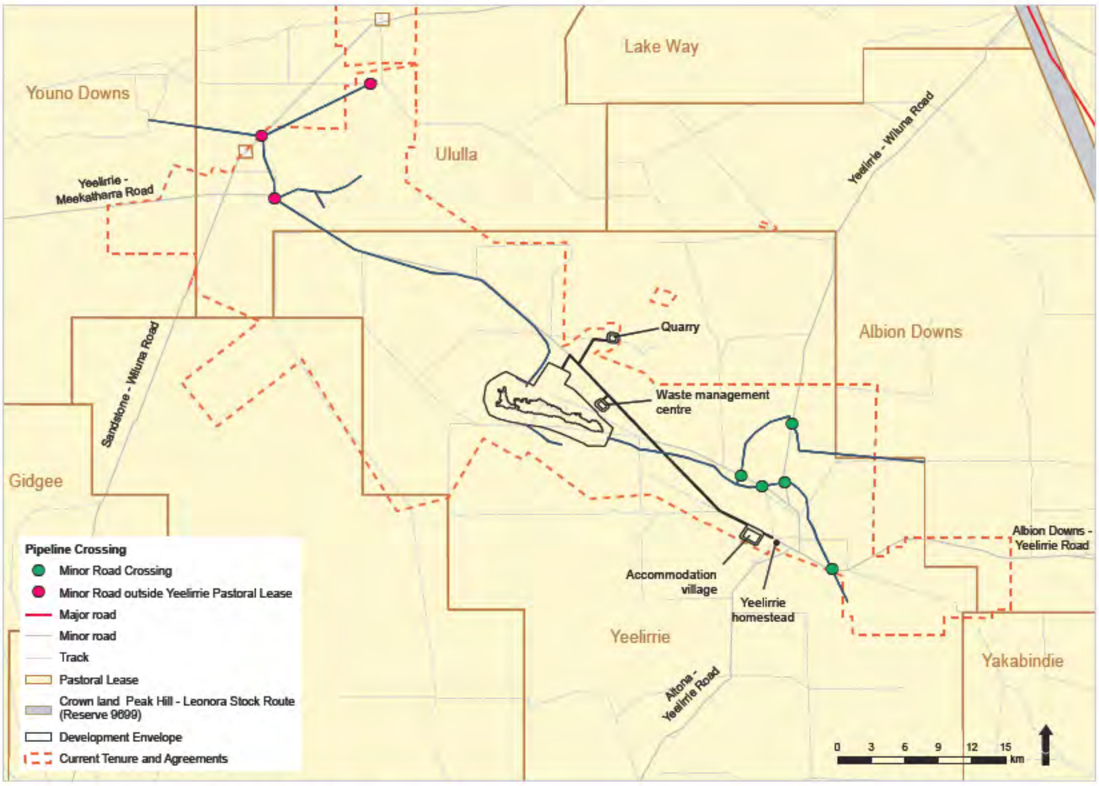


Figure 11-2: Proposed water infrastructure crossings

Effect of Road Works on Public Access

As outlined in Section 6, some road works would be required to upgrade the existing road infrastructure for use by heavy vehicles and to construct the proposed borefield water supply pipeline.

The roads listed above would remain as unsealed roads, but would require some upgrade and regular maintenance to cope with the expected daily mine traffic load, which includes increased frequency of heavy vehicles. It is likely that the following works would be required:

- improving the unpaved road surface to minimise dust generation;
- widening the road in certain areas and adjusting the alignment;
- realigning and redesigning cattle grids to improve road safety by widening them and retaining an 'at grade' approach with the road surface;
- redesigning and strengthening crossings at surface water drainage points by including concrete pavements where pipes are laid below the road surface; and
- increasing road signage.

This work would be undertaken in consultation with relevant local government authorities and landholders and in a manner that minimised disruption to traffic movements. It is anticipated that such works would be undertaken over a 6 month period prior to the commencement of the construction of the processing plant. The result of such work would be improved access for road users.

The installation of the borefield water supply pipeline would involve some minor road works where it passed underneath local roads, which might result in temporary diversions or partial lane closures on regional roads. After construction, the road surface would be re-established so the use of the regional road by existing traffic would remain unchanged. Construction is expected to take 3 to 6 months.

Three new access roads would be constructed from the Yeelirrie–Meekatharra Road to the proposed metallurgical plant, quarry and waste management centre (see Figure 11-2). These roads would be private, internal roads for the Project and would be located entirely in the Yeelirrie and Albion Downs pastoral stations. There is not expected to be any impact on BHP Billiton's operations on Albion Downs, or any other third-party landholder.

The intersection of the Albion Downs–Yeelirrie Road and the Goldfields Highway would be upgraded to provide appropriate traffic measures, such as slip lanes and turning lanes, for vehicles entering or leaving the Goldfields Highway at this intersection. The effects of this upgrade are discussed in Section 11.1.2.1 below.

Effect of Increased Road Traffic

Daily mine traffic associated with the construction and operation of the Project will result in greater usage of local roads than currently. Cameco expects that traffic will increase two to threefold on movement recorded by BHP Billiton and is discussed below.

Traffic counts along the Albion Downs–Yeelirrie Road were obtained by the previous project proponent, BHP Billiton, from the Shire of Leonora for the period 18 July to 6 August 2009. During this period there were 409 vehicle movements. Light vehicles accounted for 274 movements (a daily average of 14) and heavy vehicles for 135 movements (a daily average of seven), approximately 33% of the traffic volumes. At the time of the traffic counts, BHP Billiton was undertaking exploratory drilling and traffic flows were higher than normal.

Anecdotal information suggests that other regional roads also experience very low traffic volumes and the Albion Downs–Yeelirrie Road counts are considered to be indicative of volumes on these roads.

As limited current traffic flow data exists for the Albion Downs-Yeelirrie Road to Yeelirrie, the percentage increase in traffic flow expected to result from the construction and operation of the Project cannot be accurately determined. However, given Cameco's projected daily traffic count, Project-related traffic volume will increase traffic flows on this regional road considerably. Necessary road works, as outlined above, would be undertaken to ensure appropriate road safety for workers, residents and visitors to the area, reflecting the higher traffic volumes.

Increased daily traffic would also have the effect of decreasing the 'remoteness' of Yeelirrie and its surrounds, thereby resulting in some loss of amenity to the travelling public visiting the area because of its remote location. The presence of an operating mine would be typical of the region however, and therefore not unexpected for visitors to the area.

11.1.1.2 Noise

The closest noise sensitive premises to the development would be the Yeelirrie homestead, located approximately 17 km south east of the proposed mine.

As presented in Section 9.7, Amenity (Noise), assessable noise levels at noise sensitive premises were modelled for the original project and shown to easily comply with the Environmental Protection (Noise) Regulations 1997. Cameco expects similar noise emissions from the revised Project and therefore predicts no noise impacts on the closest noise sensitive premises.

Cameco will minimise noise emissions from the Project by operating and maintaining equipment and machinery in accordance with manufacturers' requirements.

The expected impact of noise on local amenity is anticipated to be low.

11.1.1.3 Dust

Dust emissions from the Project were estimated as part of the air quality assessment and atmospheric dispersion modelling was conducted as outlined in Section 9.8. Total suspended particulates (TSP) is normally associated with nuisance impacts such as dust fallout and impacts on amenity. The New South Wales Office of Environment and Heritage provides a dust deposition guideline of 4 g/m^2/month maximum total deposited dust, and 2 g/m^2/month maximum increase in deposited dust levels.

The results of the dispersion modelling indicate that fugitive dust emissions from the Project are not likely to result in unacceptable air quality impacts at the nearest sensitive receptors. The maximum predicted 24-hour and annual average TSP ground level concentrations and the monthly incremental dust depositions rates will comply with the relevant air quality criteria at each of the sensitive receptors.

Dust will be required to be managed as part of radiation management for the Project (Section 9.6.6). The Project has been designed with a strong focus on minimising dust emissions and Cameco will prepare and implement a Dust Management Plan for the Project. The Dust Management Plan will outline the ambient air quality monitoring program, management targets and measures to minimise dust emissions (Section 9.8.6).

It is expected that the impact of dust on local amenity is expected to be low.

11.1.1.4 Air Access

The predominantly fly-in/fly-out workforce required during the construction and operational phases of the Project would utilise charter air services in and out of Mount Keith (approximately 55 km from the Yeelirrie accommodation village). Bus services would operate from Mount Keith airport to the accommodation village and from the village to the mine site.

Should the use of Mount Keith airport not be viable, Cameco would consider options to establish an airstrip at Yeelirrie to accommodate a fly-in/fly-out workforce. This may have an impact on surrounding landholders as they would experience a greater number of flights in closer proximity to their homes than currently. Given the distances to nearby occupied homesteads and the number of anticipated daily flights, the impact on amenity is expected to be low. Operating a fly-in/fly-out workforce directly from Yeelirrie may improve local amenity through improved access to air services for nearby landholders, if the charter service were accessible to the public.

11.1.2 Regional Amenity

The Project is located in a sparsely populated area; the nearest towns by road from the proposed Yeelirrie Project accommodation village are Wiluna (approximately 90 km north, residential population 200), Leinster (115 km south east, residential population 700) and Sandstone (135 km south west, residential population 130). The nearest regional cities are Kalgoorlie-Boulder (500 km south by road) and Geraldton (635 km west by road); both have urban populations of around 33,000.

11.1.2.1 Access and Disturbance

Major roads near the proposed Yeelirrie Project are:

- Goldfields Highway;
- Great Northern Highway;
- Geraldton-Mount Magnet Road; and
- Mount Magnet-Leinster Road.

The proposed Project site is approximately 45 km west of the Goldfields Highway along the Albion Downs-Yeelirrie Road.

Effect of Road Works on Public Access

Upgrading the intersection of the Albion Downs–Yeelirrie Road and the Goldfields Highway is likely to be the main cause of access disruption and disturbance for users of major roads in the vicinity of the Project. The installation of slip lanes and turning lanes, required to handle the increased vehicle traffic associated with the Project, may create some minor delays and interruptions for road users. It is anticipated these road works will take up to three months and an appropriate traffic management plan would be developed to minimise impact on road users.

Effect of Increased Road Traffic

The increased traffic volumes associated with the proposed Yeelirrie development, and particularly the movement of over-dimensional loads on public roads, would impact traffic conditions and involve periodic delays and disruptions to road users during the 18 months of the construction phase of the Project.

Cameco would implement a detailed traffic management plan to reduce the potential annoyance to the travelling public and other road users during the construction phase.

During the operational phase, the impact to the travelling public would be expected to be minimal compared to existing road traffic volumes. Given the anticipated number of vehicle movements, it is expected that overall traffic movements on the Goldfields Highway could increase by around 9%.

The Project is not expected to result in significant adverse traffic effects for road users during either the construction or operational phase.

Effects on Landholders near Transport Corridors

The townships of Menzies and Leonora and the suburbs west of Kalgoorlie-Boulder near Anzac Parade and the Goldfields Highway may experience some noise, disturbance and inconvenience as a result of increased movements of trucks and over-dimensional and indivisible loads. However, as presented in Section 9.7, noise impacts from increased traffic on the Goldfields Highway are predicted to be negligible at residences located along transport routes and would be imperceptible above normal background to residents.

Similarly, residents along the proposed routes for indivisible loads originating in Geraldton, Port Hedland, Kalgoorlie-Boulder and Perth may experience some noise, traffic congestion and delays during the 18 month construction phase of the proposed development. In practice however, the planned transport routes for Yeelirrie are presently used for heavy vehicle movements and, as such, landholders are already exposed to some noise and disturbance from road traffic.

When operations began, the impact to landholders would be expected to be minimal, with traffic from the development representing only a small increase above existing volumes (around 9%).

11.1.3 Positive Impact on Amenity

As outlined in Section 2, Project Background, Cameco has identified a number of objectives for the Yeelirrie Project, including:

- maintain an employment source in the northeastern Goldfields of Western Australia; and
- enhance the current opportunities, lifestyle and amenities of local and regional communities.

Cameco is committed to earn the trust and support of local communities and stakeholders wherever it operates. In addition to maintaining safe, clean operations, Cameco pursues initiatives to ensure that local communities benefit from its activities. These initiatives are developed around five pillars:

- business development;
- community engagement;
- community investment;
- environmental stewardship; and
- workforce development.

In Canada, where Cameco has operating mines, these initiatives have established the Company as the nation's largest industrial employer of Aboriginal peoples. In Australia, Cameco will adapt this successful model and implement location-specific programs and initiatives based on ongoing engagement with local communities.

Currently, Cameco supports Indigenous communities in the Wiluna and Leonora regions through participation in the Murlpirrmarra Connection. The Murlpirrmarra Connection assists and supports young Wiluna and Murchison-based Aboriginal men and women, improving opportunities in the areas of education, educational options, sporting pathways, health, rehabilitation, discipline, self-confidence and employment prospects.

Through its 5 pillars program, Cameco intends to positively contribute to the amenity of the region by enhancing employment and business opportunities and supporting community projects. Section 4, Stakeholder Consultation, outlines how Cameco is engaging with local stakeholders about the Project.

Section 12

Management Framework

12. Management Framework

12.1 Introduction

As one of the world's largest uranium producers, Cameco's mission is to bring the multiple benefits of nuclear energy to the world. Cameco's goal is to be recognised globally as a leader in corporate social responsibility by proactively addressing the social, environmental and financial aspects of the business.

Sustainable development is viewed as integral to the way Cameco does business. The company aims to integrate sustainable development principles and practices into every level of the company – from overall corporate strategy to every aspect of day to day operations. To track this, Cameco uses four measures of success:

- a safe, healthy and rewarding workplace;
- a clean environment;
- supportive communities; and
- outstanding financial performance.

These measures are supported by Cameco's values and effective governance to guide planning, decision-making and evaluation processes (Cameco's 2014 Sustainable Development Report; www.cameco.com/sustainable_development/2014).

12.2 Safety, Health, Environment and Quality (SHEQ) Policy

Cameco has a Safety, Health, Environment and Quality (SHEQ) Policy that is applicable to all of Cameco's employees, representatives, subsidiaries and joint venture projects. This policy recognises the safety and health of Cameco's workers and the public, protection of the environment, and quality of Cameco's processes as the highest corporate priorities during all stages of activities, including exploration, development, operations, decommissioning and rehabilitation. Cameco strives to be a leading performer through a strong safety culture, environmental leadership, operational excellence and commitment to the following principles:

- keeping risks at levels as low as reasonably achievable;
- prevention of pollution;
- complying with and moving beyond legal and other requirements;
- ensuring quality of processes, products and services; and
- continually improving overall performance.

Cameco's management system for implementation of its SHEQ Policy for the Yeelirrie Uranium Project will comprise the following programs:

- Quality Management Programme;
- Safety and Health Management Programme;
- Radiation Protection Programme;
- Environment Management Programme;
- Emergency Preparedness and Response Programme;
- Contractor Safety Programme; and
- Management System Audit Programme.

Cameco has also created an environmental management system (EMS) which commits each Cameco operating site to the development and implementation of a formal system which addresses the short and long term impacts of its activities on the environment. The system includes written materials such as programs, plans and procedures, as well as the allocation of resources, the assignment of responsibilities and the training of employees.

12.3 Management Plans

In the PER, Cameco has outlined a range of management measures for each aspect and has made commitments to implementing these. A series of management plans, within the overarching Environment Management Programme, building on the measures outlined, will be developed for approval prior to the commencement of development of the Yeelirrie Project. These will include as a minimum:

- **Flora and Vegetation Management Plan** including ground disturbance procedures, weed management practices and a monitoring program to monitor the health of potentially groundwater-dependent vegetation, and vegetation potentially affected by surface water diversion and management structures.
- **Conservation Species Management Plan** for the management of known populations of *Atriplex* sp. Yeelirrie Station and priority flora present within the Development Envelope. A draft of the Conservation Species Management Plan, which includes an outline of the proposed Research Plan, is provided as Appendix E3. Prior to disturbance of *Atriplex* sp. Yeelirrie Station, Cameco will work with the Department of Parks and Wildlife (DPaW) to develop an Interim Recovery Plan which is likely to include proposed translocation, followed by a full Recovery Plan.
- **Fauna Management Plan** including specific measures for managing conservation significant species (State-listed and Commonwealth-listed).
- **Subterranean Fauna Management Plan** to be developed in conjunction with the Groundwater Operating Strategy and Groundwater Management Plan. The Plan will include measures to minimise impacts on subterranean fauna, including managing groundwater abstraction from the various borefields to limit drawdown in sensitive areas, requirements for the bunding of storage facilities for process chemicals and hydrocarbons to avoid any groundwater pollution.
- **Surface Water Management Plan** outlining how the site will be managed as a 'no-release' site to prevent the release of contaminants to the environment.
- **Groundwater Management Plan** to be developed as part of the Groundwater Operating Strategy. The Groundwater Management Plan will include measures to minimise impacts on subterranean fauna, groundwater-dependent vegetation and any interaction with surface water.
- **Dust Management Plan** outlining measures to keep dust levels as low as reasonably achievable (ALARA), the ambient air quality monitoring program (for PM_{10} and dust deposition), development of air quality management targets, and contingency measures to ensure compliance with the Air NEPM standard.
- **Mine Closure and Rehabilitation Plan** in accordance with the Department of Mines and Petroleum (DMP) and Environmental Protection Authority (EPA) guidelines for preparing mine closure plans (DMP & EPA 2015). This includes closure obligations and commitments, collection and analysis of closure data, identification and management of issues, stakeholder consultation strategy, post-mining land use and closure objectives, completion criteria, closure implementation, monitoring and maintenance, financial provisioning and management of information and data. A conceptual Mine Closure and Rehabilitation Plan is presented as Appendix O1.
- **Greenhouse Gas and Energy Management Plan** outlining measures to minimise greenhouse gas emissions through the application of best practices.
- **Cultural Heritage Management Plan** outlining the processes for the protection of cultural heritage during development, mining and closure. This will reference ground disturbance procedures to ensure no unplanned disturbance to areas of heritage significance.
- **Fire Prevention and Management Plan**.

Radiation management will be undertaken as part of the Radiation Protection Programme which will include:

- a **Radiation Management Plan** incorporating radiation protection principles and controls, general radiation management measures, radiation dose monitoring, radioactive waste management measures including management of mineralised materials and radiation management during closure and rehabilitation. This management plan will require approval by DMP prior to commencement of the Project;
- a **Transport Radiation Management Plan** for the safe transport of uranium oxide concentrate in accordance with Australian and international requirements. This will include an **Emergency Response Assistance Plan** (ERAP) to outline emergency planning and preparedness for responding to a transport incident involving uranium oxide concentrate (UOC). The Transport Radiation Management Plan will also refer to the general **Traffic Management Plan** which will be implemented to minimise the impact of Project-related vehicle movements on other road users.

12.4 Offsets

Environmental offsets are actions that provide environmental benefits which counterbalance the significant residual environmental impacts or risks of a project or activity. Unlike mitigation actions which occur on-site as part of the project and reduce the direct impact of that project, offsets are undertaken outside of the project area and counterbalance significant residual impacts.

12.4.1 Regulatory Framework

State

The WA EPA has published the WA Environmental Offsets Policy (EPA, 2011) and WA Environmental Offsets Guideline (2104) relevant to the use of environmental offsets in such approvals. This document provides a position on environmental offsets and establishes an approach for the use of environmental offsets in the context of environmental impact assessments in Western Australia.

The EPA defines environmental offsets as “environmentally beneficial activities” undertaken to “an offsite action or actions to address significant residual environmental impacts of a development or activity” to achieve a “net environmental benefit”.

Offsets can be direct offsets or indirect offsets. The policy states that environmental offsets should only be considered after all avoidance and mitigation options have been considered.

Commonwealth

The Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) can also require the consideration of environmental offsets as part of approvals and have also prepared a number of guidance documents relevant to the use of offsets under the EPBC Act.

The Australian Government defines environmental offsets as “measures that compensate for the residual adverse impacts of an action on the environment” (SEWPaC 2012).

12.4.2 Proposed Offsets

In the PER, Cameco has outlined the mitigation and management measures designed to avoid and minimise the impact of the development of the Project on the environment. In applying the environmental impact assessment significance framework outlined in Environmental Assessment Guideline EAG9 (EPA 2015b) and EPCB Act Policy Statement 1.1, there are two environmental factors that are likely to have residual impacts:

- clearing of Threatened species *Atriplex* sp. Yeelirrie Station (Section 9.1.5); and
- excavation and groundwater drawdown impacts on restricted stygofauna species (Section 9.2.5).

Proposed offsets for these two factors are discussed below. In addition, Cameco proposes a overall land use management plan for the Yeelirrie Pastoral Lease.

Atriplex sp. Yeelirrie Station

Cameco proposes an offset to address the residual impacts of the Yeelirrie Project on the genetic diversity of *Atriplex* sp. Yeelirrie Station as follows.

- Permanent protection of the Eastern population of *Atriplex* sp. Yeelirrie Station:
  - In the medium term, this would involve erecting a boundary fence and conducting ongoing maintenance;
  - In the long term, establishing appropriate vesting of land, for example with DPaW, or provide permanent long term protection for the area within the existing Pastoral Lease.
- Commitment to work with the DPaW and the EPA to develop and implement a Recovery Plan to translocate *Atriplex* sp. Yeelirrie Station (Western population) to the satisfaction of the EPA.

Subterranean fauna

Cameco proposes indirect offsets to address the residual impacts of the Project on Subterranean fauna.

- Cameco commits to develop and implement a plan, with input from DPaW and the EPA to define the values of the Yeelirrie PEC.
- Cameco commits to develop a research program to further understand the key variables required to support subterranean fauna habitat. Cameco would work with DPaW and the EPA to develop a research program and fund the program.

The Offsets Table is shown as Table 12-1.

12.5 Principles of Environmental Protection

The object and principles of the *Environmental Protection Act 1986* (EP Act) are outlined in Section 4A of the Act. The object of the Act is to protect the environment of the State having regarding to the principles outlined in Table 12-2. These Principles of Environmental Protection are also reflected in the EPBC Act under Section 3A (Principles of ecologically sustainable development) and Section 391 (Precautionary Principle). Cameco has considered these principles in the design and proposed management of the Project.

Table 12-1: Offsets Table

Project Name: YEELIRRIE URANIUM PROJECT									
Existing environment/ Impact	Mitigation			Significant Residual Impact	Offset Calculation Methodology				
	Avoid and Minimise	Rehabilitation Type	Likely Rehab Success		Type	Risk	Likely Offset Success	Time Log	Offset Quantification
Clearing of a population of *Atriplex* sp. Yeelirrie Station (Western genotype). An estimated 84,500 plants exist over an area of approximately 76 hectares which occurs above some of the highest grade ore within the Open Pit.	Avoidance of the impact is not possible if the Project is to proceed. A second population of the species (Eastern genotype) will be avoided and protected from grazing and longer term tenure options will be considered for permanent protection.	Pre-impact offsets are planned and presented in the Project PER. Plantations of equivalent area containing similar number of plants to be established over a number of sites to replace lost population. May not be able to restore full ecosystem function. Research and planting will occur prior to the commencement of mining.	**Can the environmental values be rehabilitated/Evidence?** Cameco considers that it has established reasonable (albeit preliminary) multiple lines of evidence to suggest successful revegetation to replace the population removed through mining is achievable. Work completed so far includes, • seed collection, storage and germination testing demonstrating that the plants seed well and that seed can be stored and will retain viability for several (at least) 5 years. • identification of suitable relocation sites. Soil and hydrology surveys of habitat and potential relocation sites to demonstrate similar sites can be located. • Plant demographic studies have been completed, including assessment of a small population on a rehabilitation site to understand and record population demographics.(see Section 9.1.5.3 of the PER for a full discussion of the work completed). A plan for ongoing work and revegetation has been proposed. The plan includes annual seed collection, preparation of Management and Relocation Plans and the commencement of seeding of new populations. The plans continue until 2018 when it would be reviewed based on the success of the work and approvals and plans to commence mining at Yeelirrie. **Operator experience in undertaking rehabilitation?** Cameco has not undertaken rehabilitation of *Atriplex* sp. before. Cameco have engaged companies with extensive experience in seed collection, handling and storage and in seed treatment and seeding, who will continue to support the project. In the PER Cameco has committed to the revegetation work prior to approval and commencement of ground disturbing activities, which provide a long lead time to establish techniques for successful revegetation. **What is the type of vegetation being rehabilitated?** Cameco will be re-establishing populations of *Atriplex* sp. Yeelirrie, a saltbush plant belonging to the subfamily Chenopodiaceae. **Time lag?** Research and planning has commenced. Establishment of new populations is planned for 2017, which is at least 4 to 5 years before the natural population would be cleared. **Credibility of the rehabilitation proposed (evidence of demonstrated success)** Cameco has not demonstrated success in re-establishing the plants. However, there are examples where the plant has grown within rehabilitated areas and Cameco has done considerable work at this stage to provide multiple lines of evidence to support the hypothesis that the plant can be successfully re-established.	**Extent** Low. Cameco proposes to establish new areas of similar area and numbers of plants. This work will commence a number of years before the natural population is cleared. **Quality Conservation Significance** The conservation significance of the plants impacted is considered to be medium to high. The population to be taken represents approximately 30% of the species and 100% of the genotype. **Land Tenure** The replacement population would be established on land owned and managed by DPAW or by Cameco where full protection can be achieved. **Time Scale** The impact to the natural population is permanent. However, some of the replacement populations would be established before the natural populations are disturbed. According to the agreed significance framework, residual impact is considered to be of low to moderate significance because of the time available to establish new populations before disturbance of the natural population.	Research Program - As detailed in the PER (Section 9.1.5.3 and in Appendix E3)	**Low** The work completed to date, while preliminary, provides reasonable evidence to support a proposition that a population of *Atriplex* sp. Yeelirrie Station could be established to replace the Western population that would be lost as a result of proceeding with the Project.	**Can the values be defined and measured?** Yes. Value of the preservation of the genetic diversity of the species can be measured. **Operator experience/Evidence?** The science of revegetation using *Atriplex* species is well developed. Cameco will work with experienced consultants and DPaW to achieve success. **What is the type of vegetation being revegetated?** Cameco will be re-establishing populations of *Atriplex* sp. Yeelirrie Station, a saltbush plant belonging to the subfamily Chenopodiaceae. **Is there evidence the environmental values can be re-created (evidence of demonstrated success)?** Yes, there is a small rehab population in an area that was rehabilitated in 2004. These plants have persisted on sub-optimal soil types compared to the natural habitat and provide some confidence that the species can be established in new locations where soil types similar to the natural habitat have been identified.	Cameco has committed to continuing the research plan commenced in 2014 (see Table 9-22 and Appendix E3). Cameco plans to undertake the first round of seeding to re-establish the plant in 2017. This is at least 4 years before the natural population would be cleared.	Cameco is committed to funding and implementing the research program as outlined.

Project Name: YEELIRRIE URANIUM PROJECT									
Existing environment/ Impact	Mitigation			Significant Residual Impact	Offset Calculation Methodology				
	Avoid and Minimise	Rehabilitation Type	Likely Rehab Success		Type	Risk	Likely Offset Success	Time Log	Offset Quantification
Loss of subterranean fauna habitat due to excavation and dewatering. Potential loss to Troglofauna and Stygofauna species that are restricted to the pit and drawdown zone.	The management options to further reduce the impact of the operation on stygofauna species are limited. However, Cameco has utilised the hierarchy of control to manage the impact of the Project on stygofauna. This includes: • **Avoid**: No abstraction wells have been located within the palaeochannel to the northwest of the proposed mine pit. While this area is potentially an excellent source of groundwater, it also supports many stygofauna species. • **Minimise**: Abstraction wells will be relocated throughout the supply area to reduce the groundwater impact where possible. Cameco believes that there are number of opportunities to continue to minimise this impact and these opportunities will be explored during a DFS.	N/A	**Can the environmental values be rehabilitated/Evidence?** No, however there is potential for species to recolonise from adjacent habitats as groundwater recovers and areas are backfilled. **Operator experience in undertaking rehabilitation?** N/A **What is the type of vegetation being rehabilitated?** N/A **Time lag?** Groundwater levels are expected to significantly recover in 50 years following cessation of the Project. **Credibility of the rehabilitation proposed (evidence of demonstrated success)** Successful rehabilitation of Subterranean Fauna has yet to be proved or attempted.	**Extent** Drawdown of >0.5 m will occur in the eastern part of the Yeelirrie calcrete, impacting on approximately 37% and 60% of the areas of inferred calcrete and playa, respectively. **Quality** There will be changes to groundwater quality which may affect the ability for species to recolonise impacted areas. **Conservation Significance** The Yeelirrie Priority 1 PEC represents a conservation significant community None of the 115 subterranean fauna species from Yeelirrie is currently listed for special protection under the State WC Act or Commonwealth EPBC Act. **Land Tenure** Pastoral Lease **Time Scale** Groundwater levels are expected to significantly recover in 50 years following cessation of the Project.	Offsets are proposed. At this stage of the approval process Cameco has not proposed the specific offset for Subterranean Fauna. Cameco will have further discussions with DPaW and the OEPA to determine a suitable and practical offset.	Currently unknown	**Can the values be defined and measured?** To be determined once offset is developed **Operator experience/Evidence?** To be determined once offset is developed **What is the type of vegetation being revegetated?** N/A **Is there evidence the environmental values can be re-created (evidence of demonstrated success)?** To be determined once offset is developed	To be determined once offset is developed	To be determined once offset is developed

Table 12-2: Principles of environmental protection

Principle	Cameco's Response
1. The precautionary principle Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of this precautionary principle, decisions should be guided by: (a) Careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and (b) An assessment of the risk – weighted consequences of various options.	The environmental impact assessment has enabled Cameco to gain a better understanding of the potential impacts of the Project and develop appropriate measures to mitigate and manage these potential impacts. Part of the environmental impact assessment has included a risk analysis (Section 8.3) to investigate the likelihood and consequence of certain events occurring, and identify high risks areas that may require further mitigation and management. Where there is uncertainty, Cameco has used conservative assumptions in assessing the potential impact of the Project and developing suitable management measures.
2. The principle of intergenerational equity The present generation should ensure that the health, diversity and productivity of the environment is maintained and enhanced for the benefit of future generations.	Cameco will ensure that the development of the Project does not affect the ability of future generations to benefit from a healthy, diverse and productive environment. One of the key issues is management of radioactive materials during all stages of the Project and beyond closure. The Conceptual Mine Closure Plan (Appendix O1) outlines the framework and measures Cameco proposes to ensure long term protection of the environment.
3. The principle of the conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration.	Cameco will ensure the disturbance of flora and fauna is kept to the minimum required for safe operation of the Project. Cleared areas no longer required, will be rehabilitated with native species throughout the life of the mine, and monitored for a period of time following closure to ensure the establishment of a self-supporting ecosystem. All aspects of the Project from design, construction, operation and closure will take into consideration the biological diversity of the area to ensure the ecological integrity of the broader area is protected. Where there are potential residual impacts on threatened flora and subterranean fauna, Cameco is proposing offsets as outlined in Section 12.4.2. A detailed Offset Package will be developed in consultation with DPaW and EPA.
4. Principles relating to improved valuation, pricing and incentive mechanisms (1) Environmental factors should be included in the valuation of assets and services. (2) The polluter pays principles – those who generate pollution and waste should bear the cost of containment, avoidance and abatement.	Cameco will: (1) Consider environmental factors in the valuation of the Project's assets; (2) Minimise the risk of pollution and generation of waste and ensure that any pollution that may occur is cleaned up; (3) Consider the full life cycle of materials used and generated by the Project and ensure waste is reused or recycled where practical; and (4) Pursue environmental goals in a cost effective manner whilst not compromising the environmental outcomes.

Principle	Cameco's Response
(4) Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solution and responses to environmental problems.	
5. The principle of waste minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	Cameco will implement the waste hierarchy of: • Avoid; • Reduce; • Reuse; • Recycle; • Recover; • Treat; and • Dispose.

Section 13

References

13. References

ALA (2015). Atlas of Living Australia Database. www.ala.org.au (accessed January 2015).

Anon. (1978). Unpubl. Species list for Yeelirrie Project area from 1978 ERMP.

Australian Atomic Energy Commission (AAEC) (1978). Three baseline studies in the environment of the uranium deposit at Yeelirrie, Western Australia, Brownscombe, A. J *et al*, Australian Atomic Energy Commission, 1978.

AAEC (1985). Australian Atomic Energy Commission Research Establishment Lucas Heights Research Laboratories, Options for clean-up of the Maralinga test site, Environmental Science Division, June 1985.

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (2005). Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005), Australian Radiation Safety and Nuclear Safety Agency.

Australian Radiation Protection and Nuclear Safety Agency, Australian National Radiation Dose Register Fact Sheet. 2013.

ARPANSA (2011) http://www.arpansa.gov.au/radiationprotection/Basics/understand.cfm

ARPANSA (2012). 'Understanding Radiation', Radiation Protection, (http://www.arpansa.gov.au/radiationprotection/basics/understand.cfm) accessed: 14 May 15.

ARPANSA (2014). A review of existing Australian radionuclide activity concentration data in non-human biota inhabiting uranium mining environments, Technical Report 167 May 2014.

Arup Pty Ltd (2011) Transport Impact Assessment-Proposed Yeelirrie Development.

Australian Bureau of Statistics (ABS) (2012a), 2011 Census QuickStats for Shire of Wiluna (LGA59250), ABS, Canberra (http://www.abs.gov.au/websitedbs/censushome.nsf/home/quickstats) viewed 28 January 2015.

Australian Bureau of Statistics (ABS) (2012b), 2011 Census QuickStats for Western Australia (5RWAU), ABS, Canberra (http://www.abs.gov.au/websitedbs/censushome.nsf/home/quickstats) viewed 28 January 2015.

Australian Early Development Census (AEDC) (2012). (https://www.aedc.gov.au) viewed 31 March 2015.

Bamford Consulting Ecologists (BCE) (2011a). Vertebrate Fauna Assessment: Yeelirrie Project Baseline Report. Unpubl. report to URS Australia Pty Ltd, by Bamford Consulting Ecologists, Kingsley.

BCE (2011b). Fauna Assessment of the Yeelirrie Fauna Study Area Impact Assessment Report. Unpubl. report to URS Australia Pty Ltd, by Bamford Consulting Ecologists, Kingsley.

BCE (2011c). Hinge Project Area Fauna Assessment. Unpubl. report to Karara Mining Pty Ltd, by Bamford Consulting Ecologists, Kingsley.

BCE (2014). Rosslyn Hill Project Proposed Priority Expansion Areas Fauna Assessment October 2014. Unpubl. report to Strategen, by Bamford Consulting Ecologists, Kingsley.

BCE (2015a). Yeelirrie Terrestrial Vertebrate Fauna Review Report. Unpubl. report to Cameco Pty Ltd, by Bamford Consulting Ecologists, Kingsley.

BCE (2015b). Yeelirrie Terrestrial Invertebrate Fauna Review Report. Unpubl. report to Cameco Pty Ltd, by Bamford Consulting Ecologists, Kingsley.

Banta, R.M., Newsom, R.K., Lundquist, J.K., Pichugina, Y.L., Coulder, R.L and Mahrt, L.D. (2002). Nocturnal Low-level Jet Characteristics over Kansas during CASES-99. Boundary-Layer Meteorology, 105, pp.221–252.

Barrett, R. (2014). Genetic difference and the definition of taxonomic rank: Implications for the classification of Atriplex sp. Yeelirrie Station. Draft report prepared by Russell Barrett, B.Sc., Ph.D. for Western Botanical and Cameco Australia.

Barranco, P., and Harvey, M.S. (2008) The first indigenous palpigrade from Australia: a new species of Eukoenenia (Palpigradi: Eukoeneniidae). Invertebrate Systematics 22, 227-233.

Baehr, B.C., Harvey, M.S., Burger, M., and Thoma, M. (2012) The new Australasian Goblin Spider genus Prethopalpus (Araneae, Oonopidae). Bulletin of the American Museum of Natural History, 369, 1-113.

Beard, J.S. (1976). Vegetation survey of Western Australia. Murchison 1:1 000 000 Vegetation series. Explanatory Notes to and Map Sheet 6. University of Western Australia Press, Perth.

Beard, J.S. (1979). A New Phytogeographic Map of Western Australia. Western Australian Herbarium Research Notes. No 3, pp 37-58.

Beard J.S. (1998). Position and developmental history of the central watershed of the Western Shield, Western Australia. Journal of the Royal Society of Western Australia 81, 157-164.

Bennelongia (2007). Report on subterranean fauna of the Duketon Gold Project area, north of Laverton. Report 2007/014. Bennelongia Pty Ltd, Jolimont, 23 pp.

Bennelongia (2008a) Troglofauna survey at Koolyanobbing. Report 2008/49. Bennelongia Pty Ltd, Jolimont 19 pp.

Bennelongia (2008b) Troglofauna survey at Mount Jackson. Report 2008/50. Bennelongia Pty Ltd, Jolimont, 11 pp.

Bennelongia (2009) Jimblebar Iron Ore Project troglofauna assessment. Report 2009/61, Bennelongia Pty Ltd, Jolimont, 55 pp.

Bennelongia (2011) Yilgarn Iron Ore Project: troglofauna surveys. Report 2011/119, Bennelongia Pty Ltd, Jolimont, 27 pp.

Bennelongia (2012) Mummaloo Project: Subterranean fauna. Report 2012/173, Bennelongia Pty Ltd, Jolimont, 24 pp.

Bennelongia (2015) Yeelirrie Stygofauna Assessment. Unpublished letter report to Cameco Australia. Jolimont, WA, 11 pp.

Benshemesh, J., S. Dennings, C. Danzi, and A. Sanders. (2008). Malleefowl searches at Yeelirrie station in arid Western Australia: a valuable collaboration between industry and volunteers. In: Davies S.J.J.F. (ed) Katanning National Malleefowl Forum 2007. School of Environmental Biology Bulletin No.28, Curtin University of Technology, Perth WA.

BHP Billiton (2009). Olympic Dam Expansion Draft Environmental Impact Statement (DEIS) 2009, Supplementary Environmental Impact Statement (SEIS) 2011.

Birdlife Australia (2015). Birdata Database. www.birdata.com.au (accessed January 2015).

Blandford (D.C.) & Associates Pty Ltd (2011). Soils and Soil Landscapes of the Study Area. Prepared for Landcare Holdings Pty Ltd on behalf of BHP Billiton Yeelirrie Development Company Pty Ltd, January 2011.

Bradford, T., Adams, M., Humphreys, W.F., Austin, A.D., and Cooper, S.J.B. (2010) DNA barcoding of stygofauna uncovers cryptic amphipod diversity in a calcrete aquifer in Western Australia's arid zone. Molecular Ecology Resources 10, 41-50.

Bradshaw, S. D., Morris, K. D., and Bradshaw, F. J. (2001). Water and electrolyte homeostasis and kidney function of desert-dwelling marsupial wallabies in Western Australia. Journal of Comparative Physiology B, 171(1), 23-32.

Brown, J.E., Alfonso, B., Avila, R., Beresford, N.A., Copplestone, D., Prohl, G., Ulanovsky, A. (2008). The ERICA Tool. Journal of Environmental Radioactivity, 99pp 1371 – 1383.

Burbidge, A.A. and McKenzie, N.L. (1989). 'Patterns in the modern decline of Western Australia's vertebrate fauna: causes & conservation implications.' Biological Conservation, vol. 50, pp. 143-98.

Byrne, M., Steane, D.A., Joseph, L., Yeates, D.K., Jordan, G.J., Crayn, D., Aplin, K., Cantrill, D.J., Cook, L.G., Crisp, M.D., Keogh, J.S., Melville, J., Moritz, C., Porch, N., Sniderman, J.M.K., Sunnucks, P., and Weston, P.H. (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. Journal of Biogeography 38, 1635-1656.

Byrne, M., Yeates, D.K., Joseph, L., Kearney, M., Bowler, J., Williams, M.A.J., Cooper, S.J.B., Donnellan, S.C., Keogh, J.S., Leys, R., Melville, J., Murphy, D.J., Porch, N., and Wyrwoll, K.H. (2008) Birth of a biome: insights into the assembly and maintenance of the Australian arid zone biota. Molecular Ecology 17, 4398-4417.

Cameco (2013). Kintyre Uranium Project Environmental Review and Management Programme, Cameco Australia 2013.

Cameco (2015a). Conceptual Mine Closure Plan for the Yeelirrie Uranium Project. Mineral Field number 53, Document ID YRE-MCP-001, Version: C.1, June 2015.

Cameco (2015b). Conservation Species Management Plan, May 2015.

Cameco (2015c). Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine, January 16, 2015 (Geo-environmental Engineering, SHEQ, Environmental Affairs).

Cameco (2015d). Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit, January 2015 (Geo-environmental Engineering, SHEQ, Environmental Affairs).

Cameco (2015e). Yeelirrie Tailings Storage Facility Design and Management, January 16, 2015 (Geo-environmental Engineering, SHEQ, Environmental Affairs).

Cember (2009). Introduction to Health Physics (4th Edition) Herman Cember & Thomas E Johnson.

Chambers (2009). Radon Emissions From Tailings Ponds, Presented at National Mining Association (NMA) /Nuclear Regulatory Commission (NRC) Uranium Recovery Workshop Denver – July 2, 2009, Dr. Douglas B. Chambers, SENES Consultants Limited

Clarke, L.J., Jardine, D.I., Byrne, M., Shepherd, K. & Lowe, A.J. (2012). Significant population genetic structure detected for a new and highly restricted species of Atriplex (Chenopodiaceae) from Western Australia, and implications for conservation management. Australian Journal of Botany 60(1): 32-41.

Cooper, S.J.B., Hinze, S., Leys, R., Watts, C.H.S., and Humphreys, W.F. (2002) Islands under the desert: molecular systematics and evolutionary origins of stygobitic water beetles (Coleoptera: Dytiscidae) from central Western Australia. Invertebrate Systematics 16, 589-598.

Cooper, S.J.B., Saint, K.M., Taiti, S., Austin, A.D., and Humphreys, W.F. (2008) Subterranean archipelago: mitochondrial DNA phylogeography of stygobitic isopods (Oniscidea: Haloniscus) from the Yilgarn region of Western Australia. Invertebrate Systematics 22, 195-203.

Copplestone, D., Hingston, J. & Real, A. (2008). The development and purpose of the FREDERICA radiation effects database. In. Journal of Environmental Radioactivity, 2008, 99pp, 1456 – 1463.

Cowan, M. (2001). Murchison 1 (MUR1 – East Murchison subregion). In: Department of Conservation and Land Management (CALM) (2002). A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002.

Cowan, M. (2008). Australian biodiversity assessment. Annex 2.3, examples of trends in significant species and communities: small mammals and reptiles of Lorna Glen ex-pastoral station. Department of Environment and Conservation, Kensington, WA.

Creely, KS, Van Tongeren, M, While, D, Souter, AJ, Tickner, J, Agostini, M, De Vocht, F, Kronhout, H, Graham, M, Bolton, A, Cowie, H and Cherrie JW, (2006). Trends in Inhalation Exposure – mid 1980s till present, HSE Research Report 460, HSE Books, Sudbury, UK.

CSIRO, Australian Bureau of Meteorology (2007). Climate change in Australia: technical report 2007. CSIRO. 148 pp

de Broekert, P., Sandiford, M., (2005). Buried inset-valleys in the eastern Yilgarn Craton, Western Australia: geomorphology, age and allogenic control, Journal of Geology, 113, 471-493.

de Gand, D. & Wohlan, C., (1998). The Wanmulla Peoples social history project. Prepared for the Wanmulla People Native Title Claimants.

Department of the Environment (DoE) (2013). Matters of National Environmental Significance. Significant impact guidelines 1.1. Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment. Canberra, Australia.

DOE (2014a). National Greenhouse Accounts (NGA) Factors, published by the Department of Climate Change and Energy Efficiency, Commonwealth of Australia, Canberra, July 2014, pp. 1-74.

DOE (2014b). Technical Guidelines for the Estimation of Greenhouse Gas Emissions by Facilities in Australia: National Greenhouse and Energy Reporting (Measurement) Determination 2008.

DoE (2015). EPBC Protected Matters Search Tool. (accessed January 2015). Department of the Environment. Canberra, Australia.

Department of Environment and Conservation (DEC), Government of Western Australia, 2004, Ambient Air Quality Guidelines, http://www.dec.wa.gov.au/

DEC, Traditional Owners Millstream Park Council & Conservation Commission Western Australia (2011). Millstream Chichester National Park and Mungaroona Range Nature Reserve Management Plan No. 69, 2011.

Department of Environment Regulation (DER), 2006, Air Quality Modelling Guidance Notes.

Department of Mines and Petroleum (DMP) (2010). Managing naturally occurring radioactive material (NORM) in mining and mineral processing: Guideline. NORM 1. Applying the System of Radiation Protection to Mining Operations: Resources Safety, Department of Mines and Petroleum, Western Australia, 34pp.

DMP (2013). Guide to Uranium in Western Australia. Department of Mines and Petroleum, May 2013.

DMP (2014). Mineral and Petroleum Industry 2013-14 Review. (http://www.dmp.wa.gov.au/1525.aspx) viewed 27 January 2015.

DMP and Environmental Protection Authority (2015). Guidelines for Preparing Mine Closure Plans, May 2015 (Revision of the Guidelines for Preparing Mine Closure Plans, June 2011).

Department of Industry Tourism and Resources (DITR) (2006a). Leading Practice Sustainable Development Program for the Mining Industry: Mine Closure and Completion. October, 2006.

DITR (2006b). Leading Practice Sustainable Development Program for the Mining Industry: Mine Rehabilitation. October, 2006.

Department of Parks and Wildlife (DPAW) (2015). NatureMap Database. http://naturemap.dpaw.wa.gov.au/default.aspx (accessed January 2015).

Department of Sustainability Environment Water Population and Communities (SEWPaC) (2012). Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy, October 2012

Dell. J., How, R.A., Milewski, A.V. and Keighery, G.J. (1998). The biological survey of the eastern Goldfields of Western Australia. Part 7. Edjudina-Menzies Study Area. Records of the Western Australian Museum, Supplement No. 31:1-137. Perth, WA.

Dickman CR, Glen AS & Letnic M (2009). Reintroducing the dingo: Can Australia's conservation wastelands be restored? In: MW Hayward & MJ Somers (eds).Reintroduction of top order predators. pp. 238-269. Wiley-Blackwell, London

Doughty, P. and Ellis, R. (2014a). Checklist of the Amphibians of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Doughty, P. and Ellis, R. (2014b). Checklist of the Reptiles of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Ecologia Environment. (2011a). Proposed Yeelirrie development Short range endemic invertebrate baseline Survey. Report prepared for URS Australia.

Ecologia Environment. (2011b). Yeelirrie Short-Range Endemic Invertebrate Impact Assessment. Report prepared for URS Australia.

Edward, K.L., and Harvey, M.S. (2008) Short-range endemism in hypogean environments: the pseudoscorpion genera Tyrannochthonius and Lagynochthonius (Pseudoscorpiones: Chthoniidae) in the semiarid zone of Western Australia. Invertebrate Systematics 22, 259-293.

Environmental Protection Authority (EPA) (1979). Yeelirrie Uranium Proposal by Western Mining Corporation. Report and Recommendations by the Environmental Protection Authority. January 1979, Department of Conservation and Environment, Western Australia. Bulletin No. 53.

EPA (2000). Environmental Portection of Native Vegetation in Western Australia. Position Statement No. 2.December 2000.

EPA (2002a). Guidance for the Assessment of Environmental Factors: Guidance Statement for Minimising Greenhouse Gas Emissions. Guidance statement No. 12, October 2002.

EPA (2002b). Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3. March 2002.

EPA (2004a). Guidance for the assessment of environmental factors: Terrestrial fauna surveys for environmental impact assessment in Western Australia. No. 56. Environmental Protection Authority, Perth, Western Australia.

EPA (2004b). Guidance for the assessment of environmental factors: Terrestrial flora and vegetation surveys for environmental impact assessment in Western Australia. No. 51. Environmental Protection Authority, Perth, Western Australia.

EPA (2006). Guidance for the assessment of environmental factors: Rehabilitation of Terrestrial Ecosystems. No. 6. Environmental Protection Authority, Perth, Western Australia.

EPA (2007) Guidance for the Assessment of Environmental Factors: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia Draft Guidance Statement No. 54A, Environmental Protection Authority, Perth, 37 pp.

EPA (2009). Guidance for the Assessment of Environmental Factors, Statement No 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia.

EPA (2013) Environmental Assessment Guildline No. 12 - Consideration of Subterranean Fauna in Environmental Impact Assessment in WA. Environmental Protection Authority Western Australia, Perth, 24 pp.

EPA (2014). Environmental Assessment Guideline for Consideration of environmental impacts from noise. Environmental Assessment Guideline No. 13. September 2014.

EPA (2015a). Environmental Assessment Guideline for Environmental factors and objectives. Environmental Assessment Guideline No. 8. January 2015.

EPA (2015b). Environmental Assessment Guideline for application of a significance framework in the environmental impact assessment process: Focusing on the key environmental factors. Environmental Assessment Guideline No. 9. January 2015.

EPA and DEC (2010). Technical Guide - Terrestrial Vertebrate Fauna surveys for Environmental Impact Assessment (eds B.M. Hyder, J. Dell and M.A Cowan). Perth, Western Australia.

Emery, C., Tai, E. & Yarwood, G., (2001). Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes, The Texas Natural Resource Conservation Commission, Austin, Texas 78753.

ERA (2014). Ranger 3 Deeps Draft Environmental Impact Statement (accessed from http://www.energyres.com.au/whatwedo/3108_draft_eis.asp November 2014).

Galassi, D.M.P., Huys, R., and Reid, J.W. (2009) Diversity, ecology and evolution of groundwater copepods. Freshwater Biology 54, 691-708.

Gardner, C.A. (1942) The Vegetation of Western Australia with special reference to climate and soils. J. Proc. R. Soc. West. Aust. 28:11-87.

Garnett, S. and Crowley, G. (2000). The Action Plan for Australian Birds. Environment Australia and the Royal Australasian Ornithologists Union.

Garnett, S., Szabo, J. and Dutson, G. (2011). The Action Plan for Australian Birds 2010.CSIRO Publishing.

Garnier-Laplace, J., Copplestone, D., Gilbin, R., Alonzo, F., Ciffroy, P., Gilek, M., Ag ero, A., Bj rk, M., Oughton, D.H., Jaworska, A., Larsson, C.M., & Hingston, J.L. (2008). Issues and practices in the use of effects data from FREDERICA in the ERICA Integrated Approach. Journal of Environmental Radioactivity 99pp. 1474-1483.

Gaull B.A., Michael-Leiba M.O., and Rynn J.M.W., (1990). Probabilistic earthquake risk maps of Australia. Australian Journal of Earth Sciences,37, 169-187.

Geoscience Australia (2015). Earthquakes Map (http://www.ga.gov.au/earthquakes/) viewed 22 January 2015.

GHD (2010a) Stygofauna baseline survey: Murray drainage and water management plan and associated studes. Perth, 18 pp.

GHD (2010b) Report for Jack HIlls expansion project troglofauna phase 5 and 6 results and habitat assessment. GHD, Perth, 22 pp.

Gibert, J., and Deharveng, L. (2002) Subterranean ecosystems: a truncated functional biodiversity. Bioscience 52, 473-481.

Giribet, G., McIntyre, E., Christian, E., Espinasa, L., Ferreira, R.L., Francke, O.F., Harvey, M.S., Isaia, M., Kovác, L., McCutchen, L., Souza, M.F.V.R., and Zagmajster, M. (2014) The first phylogenetic analysis of Palpigradi (Arachnida) - the most enigmatic arthropod order. Invertebrate Systematics 28, 350-360.

Gleason, J., (2011). Report of Indigenous heritage assessment for BHP Billiton: mineral exploration program at Yeelirrie – western zone, southwest of Wiluna, WA. Unpublished report prepared for BHPB-YDC.

Golder (1982). Report to K.S.R. Joint Venture on Tailings Disposal for Yeelirrie Uranium Mining Project, Yeelirrie, WA. Golder Associates, April 1982.

Golder (2010). Yeelirrie In-pit Benchmarking Study, Golder Associates, 2010.

Government of Western Australia (2000). Bush Forever 2000, Vol. 2

Government of Western Australia (2004). Western Australian Greenhouse Strategy. Prepared by the Western Australian Greenhouse Task Force. September 2004.

Government of Western Australia (2007). Making Decisions for the Future: Climate Change Statement. The Premier's Climate Change Action Statement, May 2007.

Grant, C.D. & Blackmore, A.V. (1991). Self-mulching behaviour in clay soils: Its definition and measurement. Australian Journal of Soil Research, vol. 29, 155-173.

Guzik , M.T., Cooper, S.J.B., Humphreys, W.F., Ong, S., Kawakami, T., and Austin, A.D. (2011) Evidence for population fragmentation within a subterranean aquatic habitat in the Western Australian desert. Heredity 107, 215-230.

Guzik, M.T., Austin, A.D., Cooper, S.J.B., Harvey, M.S., Humphreys, W.F., Bradford, T., Eberhard, S.M., King, R.A., Leys, R., Muirhead, K.A., and Tomlinson, M. (2011) Is the Australian subterranean fauna uniquely diverse? Invertebrate Systematics 24, 407-418.

Halse, S.A., and Pearson, G.B. (2014) Troglofauna in the vadose zone: comparison of scraping and trapping results and sampling adequacy. Journal of Subterranean Biology 13, 17-34.

Harrington, R. (2002). The effects of artificial watering points on the distribution and abundance of avifauna in an arid and semi-arid mallee environment. PhD thesis, Department of Zoology, The University of Melbourne.

Harrison, S.E., Guzik, M.T., Harvey, M.S., and Austin, A.D. (2014) Molecular phylogenetic analysis of Western Australian troglobitic chthoniid pseudoscorpions (Pseudoscorpiones: Chthoniidae) points to multiple independent subterranean clades. Invertebrate Systematics 28, 386-400.

Harvey, M. (2002). Short-range Endemism amongst the Australian fauna: examples from non-marine environments. Invertebrate Systematics, 16: 555-570

Harvey, M.S., and Edward, K.L. (2007) A review of the pseudoscorpion genus Ideoblothrus (Pseudoscorpiones, Syarinidae) from western and northern Australia. Journal of Natural History 41, 445-472.

Harvey, M.S., and Leng, M.C. (2008) Further observations on Ideoblothrus (Pseudoscorpiones: Syarinidae) from subterranean environments in Australia. Records of the Western Australian Museum 24, 381–386.

Herring Storer Acoustics (2011a). BHP Billiton Limited Environmental Noise Assessment Yeelirrie Project, February 2011 Ref: 11840-3-09060.

Herring Storer Acoustics (2011b) BHP Billiton Limited Vehicle Movement Noise Assessment Yeelirrie Project, February 2011, Ref: 11838-3-09060.

Higgins, P. J. (Ed.) (1999). Handbook of Australian, New Zealand and Antarctic Birds. Volume 4: Parrots to Dollarbird. Oxford University Press, Melbourne, Australia.

Hondros, J. (2015) Yeelirrie Development – Radiation Technical Report. Report for Cameco, June 2015

How, R. A., Cooper, N. K. and Bannister, J. L. (2013). Checklist of the Mammals of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Humphreys, W.F. (2001) Groundwater calcrete aquifers in the Australian arid zone: the context to an unfolding plethora of stygal biodiversity. Records of the Western Australian Museum Supplement 64, 63-83.

Humphreys, W.F. (2008) Rising from Down Under: developments in subterranean biodiversity in Australia from a groundwater fauna perspective. Invertebrate Systematics 22, 85-101.

International Atomic Energy Agency (IAEA) (1992). Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards. In: Technical reports Series, 1992, IAEA, Vienna.

IAEA (1996). International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources. Vienna.

International Commission on Radiological Protection (ICRP) (1977). Publication 26, Recommendations of the International Commission on Radiological Protection, Annals of the ICRP 1, 3 (1977).

ICRP (1994). Dose Coefficients for Intakes of Radionuclides by Workers, ICRP Publication 68. Ann. ICRP 24 (4), 1994.

ICRP (2003). ICRP, 'A Framework for Assessing the Impact of Ionising Radiation on Non-Human Species', International Commission on Radiological Protection Publication 91, Annals of the ICRP, 2003, 33 (3): pp. 201–270.

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. (http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains1.html) viewed 28 January 2015.

Ironbark Heritage & Environment Pty Ltd (IHE) (2013). Archaeological Assessment: Yeelirrie, Northern Goldfields Region Western Australia. Yeelirrie Project Areas and Infrastructure Corridors Survey. A report to BHP Billiton – YDC. May 2013.

Johansen, M.P. & Twining, J.R. (2010). Radionuclide concentrations in Australian terrestrial wildlife and livestock: data compilation and analysis. Radiation and Environmental Biophysics, 49pp, 603-611.

Johnson, S. L., Commander, D. P. & O'Boy, C. A. (1999). Groundwater resources of the Northern Goldfields, Western Australia: Water and Rivers Commission, Hydrogeological Record Series, Report HG 2, 57p.

Johnstone, R. E. (2013). Checklist of the Birds of Western Australia. Department of Terrestrial Zoology, Western Australian Museum, Welshpool, Western Australia.

Johnstone, R. E., Storr, G. M. (1998). Handbook of Western Australian birds, volume I: non-passerines (emu to dollarbird). Western Australian Museum, Perth, Western Australia.

Judd, S., and Horwitz, P. (2003). Diversity and biogeography of terrestrial isopods (Isopoda, Oniscidea) from southwestern Australia: organic matter and microhabitat utilization in seasonally dry landscapes. Crustaceana Monographs 2, 191-215.

Karanovic, T. (2004) Subterranean copepods (Crustacea: Copepoda) from arid Western Australia. Crustaceana Supplement 3, 1-366.

Karanovic, T., and Cooper, S.J.B. (2011a) Molecular and morphological evidence for short range endemism in the Kinnecaris solitaria complex (Copepoda: Parastenocarididae), with descriptions of seven new species. Zootaxa 3026, 1-64.

Karanovic, T., and Cooper, S.J.B. (2011b). Third genus of parastenocarid copepods from Australia supported by molecular evidence (copepoda, Harpacticoida). In: Defaye, D.E., Suárez-Morales, J.C., Vaupel Klein (eds.) Crustacean Monographis, studies on Freshwater Coipepoda: a volume in honour of Hernard Dussart. Brill, 574pp.

Karanovic, T., and Cooper, S.J.B. (2012) Explosive radiation of the genus Schizopera on a small subterranean island in Western Australia (Copepoda : Harpacticoida): unravelling the cases of cryptic speciation, size differentiation and multiple invasions. Invertebrate Systematics 26, 115-192.

Karanovic, T., Eberhard, S., Cooper, S.J.B., and Guzik, M.T. (2014) Morphological and molecular study of the genus Nitokra (Crustacea, Copepoda, Harpacticoida) in a small palaeochannel in Western Australia. Organisms, Diversity & Evolution 15, 1-35.

Kaste, J.M., Heimsath, A.M. & Bostick, B.C. (2007). Short-term soil mixing quantified with fallout radionuclides. Geology, 35pp, 243-246.

Katestone (2014a). Air Quality Assessment of the Yeelirrie Uranium Project. Prepared for Cameco Australia Pty Ltd, December 2014

Katestone (2014b). Radon Assessment of the Yeelirrie Uranium Project. Prepared for Cameco Australia Pty Ltd, December 2014.

Keighery, B. J. (1994). Bushland Plant Survey. A Guide to Plant Community Survey for the Community. Wildflower Society of WA (Inc.), Western Australia.

King, J. M., and Bradshaw, S.D. (2008). Comparative water metabolism of Barrow Island macropod marsupials: Hormonal versus behavioural-dependent mechanisms of body water conservation. General and Comparative Endocrinology, 155, 378-385.

KLA (2012). Spring Fauna Assessment - C3, C4 and Bowerbird, Wiluna West Project. Unpublished report. Keith Lindbeck and Associates, Perth.

Landcare Services (2011). Atriplex sp. Yeelirrie Station (L. Trotter & A. Douglas LCH25025) Seed Collection Program Report, February 2011. Consultants report prepared for URS Australia Pty Ltd and BHP Billiton Yeelirrie Development Company Pty Ltd. Report ref LCS693.

Landgate (2010). Firewatch. (http://firewatch.landgate.wa.gov.au/landgate_firewatch_public.asp) viewed 22 January 2015.

Lamoureux, J. (2004) Stygobites are more wide-ranging than troglobites. Journal of Cave and Karst Studies 66, 18-19.

Larsson, C.M. (2008). An overview of the ERICA Integrated Approach to the assessment and management of environmental risks from ionising contaminants. Journal of Environmental Radioactivity, 2008, pp 1364 -1370.

Latz, P. (1995). Fire in the desert. Increasing biodiversity in the short term, decreasing it in the long term. In: D. Bird Rose (ed.). Country in Flames. Proceedings of the 1994 Symposium on Biodiversity and Fire in North Australia. Biodiversity Unit, Department of the Environment, Sport and Territories and North Australia Research Unit, The Australian National University, Canberra and Darwin.

Lenzen, M. (2008). Life cycle energy and greenhouse gas emissions of nuclear energy: A review. Energy Conversion and Management, Vol. 49, pp. 2178-2199.

Leys, R., and Watts, C.H.S. (2008). Systematics and evolution of the Australian subterranean hydroporine diving beetles (Dytiscidae), with notes on Carabhydrus. Invertebrate Systematics 22, 217-225.

Liberman, K. (1977a). A survey for Aboriginal sites - Yeelirrie Uranium Project - Supplementary Report – Nov. 1977. Unpublished report prepared for Aboriginal Sites Department, WA Museum, on behalf of Western Mining Corporation.

Liberman, K. (1977b). Eastern Goldfields Aboriginal People and the proposed Yeelirrie Uranium Development - a supplement to the report, "Tjankultjanu". Unpublished report prepared as part of a submission to the Registrar of Aboriginal Sites, WA Museum.

Lyons, T.J., Steedman, R.K. & Steedman, R.K., (1981). Stagnation and Nocturnal Temperature Jumps in a Desert Region of Low Relief. B, 21, pp.369–387.

Mabbutt, J.A. (1963) General report on the lands of the Wiluna-Meekatharra area, Western Australia 1958. Land Research Series 7. CSIRO, Melbourne.

Magee, J.W. (2007). Australian lake-level studies. In: Elias, S.A. (ed.). Encyclopaedia of Quaternary Science. Elsevier, B.V. 1359-1365.

Malleefowl Preservation Group. (2014). Annual monitoring of Malleefowl mounds at Yeelirrie, Western Australia. Malleefowl Preservation Group.

Mann, A.W.H., .C (1979) Groundwater calcrete deposits in Australia some observations from Western Australia. Australian Journal of Earth Sciences 26, 293 - 303.

Mann, A.W., and Horwitz, R.C. (1979) Groundwater calcrete deposits in Australia: some observations from Western Australia. Journal of the Geological Society of Australia 26, 293-303.

Mason, C., Elliot, T. & Hong Gan, T. (1982). A study of radon emanation in waste rock at Northern Territory uranium mines, Melbourne: Australian Radiation Laboratory.

Mattner, J. (2015). Review & verification of Aboriginal heritage landscape Yeelirrie Project, Northeastern Goldfields, June 2015. Prepared for Cameco Australia, Waru Consulting Pty Ltd.

McAlpin, S. (1997). Conservation of the Great Desert Skink, Egernia kintorei, at Uluru - Kata Tjuta National Park, N.T. Page(s) 1-63. Canberra: ANCA.

McTainsh, G. and Tews, K. (2007) Soil erosion by wind - Dust Storm Index (DSI): National Monitoring and Evaluation Framework, prepared for the National Land & Water Resources Audit, Canberra

Meissner, R. (2011). Flora and vegetation of calcrete palaeodrainage channels in the north eastern Goldfields (Draft). Department of Environment and Conservation, Western Australia.

Mid West Development Commission (2014). Mid West Regional Blueprint: A 2050 growth and development strategy for an intergenerational, global, innovative and dynamic Mid West region that attracts and retains talent and investment. Draft for public comment, 23 September 2014 (http://www.mwdc.wa.gov.au/Assets/Mid_West_Regional_Blueprint_-_draft_for_Public_Comment.pdf) viewed 28 January 2015.

Morgan, K.H. (1993) Development, sedimentation and economic potential of palaeoriver systems of the Yilgarn Craton of Western Australia. Sedimentary Geology 85, 637-656.

National Energy Research and Demonstration Council (NERDC) (1988). "Air Pollution from Surface Coal Mining: Volume 2 Emission Factors and Model Refinement". Project 921.

Needham, S. (2009). Yeelirrie uranium deposit in Western Australia. Parliament of Australia, Parliamentary Library Background Note, Science Technology Environment and Resources Section. 24 November 2009, 2009-10, (http://www.aph.gov.au/binaries/library/pubs/bn/sci/uraniumwa.pdf) viewed 22 January 2015.

Outback Ecology (2011). Toro Energy Limited Wiluna Uranium Project: Terrestrial Fauna Assessment 2010. Unpublished report, 2011. Outback Ecology Services, Jolimont, WA.

Outback Ecology (2011) Wiluna Uranium Project subterranean fauna assessment (Toro Energy Pty Ltd). Outback Ecology, Jolimont.

Payne, A.L., Van Vreeswyk, A.E., Pringle, H.J.R., Leighton, K.A., and Hennig, P. (1998). An inventory and condition survey of the Sandstone – Yalgoo - Paynes Find area, Western Australia. Technical Bulletin #90, Department of Agriculture, South Perth, WA. Text and associated 1:250,000 maps.

Pearson, D. J. (2012). Recovery Plan for five species of rock-wallabies: black-flanked rock-wallaby (Petrogale lateralis), Rothschild's rock-wallaby (Petrogale rothschildi), short-eared rock-wallaby (Petrogale brachyotis), monjon (Petrogale burbidgei) and nabarlek (Petrogale concinna). Department of Environment and Conservation, Perth.

Phoenix Environmental (2015). Identification and assessment of short-range endemism of invertebrates from Yeelirrie, Western Australia. Taxonomic Report. Prepared for Bamford Consulting, March 2015.

Pinder, A.M. (2008) Phreodrilidae (Clitellata: Annelida) in north-western Australia with descriptions of two new species. Records of the Western Australian Museum 24, 307-313.

Platnick, N.I. (2008) A new subterranean ground spider genus from Western Australia (Araneae : Trochanteriidae). Invertebrate Systematics 22, 295-299.

Pringle, H.J.R., Van Vreeswyk A.M.E. and Gilligan, S.A. (1994). An inventory and condition survey of rangelands in the North-eastern Goldfields, Western Australia. Western Botanical 240 Technical Bulletin No. 87, Department of Agriculture, South Perth, WA. Text and associated 1:250,000 maps.

Read, J.L. (1999). A strategy for minimizing waterfowl deaths on toxic waterbodies. Journal of Applied Ecology, 36, 345–350.

Rodríguez, J.P., Rodríguez-Clark, K.M., Baillie, J.E.M., et al. (2011) Establishing IUCN Red List Criteria for Threatened Ecosystems. Conservation Biology 25, 21-29.

Sanders, C.C. (1974) Calcrete in Western Australia. Western Australian Geological Survey, Annual Report for 1973. Pp. 12-14.

Sample, B. E., D.M. Opresko, and G.W. Suter, (1996). Toxicological Benchmarks for Wildlife: 1996 Revision, ES/ER/TM-86/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Scheller, U. (2010) Pauropods (Myriapoda: Pauropoda) from Western Australia, with descriptions of a new family, a new genus and three new species. Records of the Western Australian Museum 26, 1-10.

Scheller, U. (2013) Pauropoda (Myriapoda) in Australia, with descriptions of new species from Western Australia. Records of the Australian Museum 82, 140.

Schoknecht N (2002). Soil Groups of Western Australia - a guide to the main soils of Western Australia, Edition 3. Resource Management Technical Report 246. Department of Agriculture, Western Australia.

Scoble, J. (2012). No place to go and nowhere to be?: Characterising demography of the southern scrub-robin (Drymodes brunneopygia) using molecular and modelling tools for conservation. Thesis (Ph.D.), University of Adelaide, School of Earth and Environmental Sciences, 2012.

Shepherd, K.A., Sampson, J, Thiele, K and Byrne, M. (Science Division, Department of Environment and Conservation) (no date). Taxonomic resolution of Atriplex sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025) utilising morphological and molecular methods. Report commissioned by BHP Billiton Yeelirrie Uranium Project.

Soilwater Consultants (SWC) (2015a). Memorandum to Cameco Australia: Yeelirrie Uranium Project MCP, Landform Evolution Modelling, 14 May 2015. Project & Document No: CAM-003-1-13, 002.

SWC (2015b). Atriplex sp. Yeelirrie Station Investigation. Report for Cameco Australia Pty Ltd, 23 June 2015. CAM-0002-1-2.

Southgate, R., R. Paltridge, P. Masters & S. Carthew (2007). Bilby distribution and fire: A test of alternative models of habitat suitability in the Tanami Desert, Australia. Ecography. 30:759-776.

Sovacool, B. K. (2008). Valuing the greenhouse gas emissions from nuclear power: A critical survey, Energy Policy, Vol. 36, 2008, pp. 2940-2953.

Specht, R.L. (1970) Vegetation. In. The Australian Environment. 4th edition, ed. Leeper, G.W. pp. 44–67, CSIRO-Melbourne Univ. Press, Melbourne.

SRK (2011). Proposed Yeelirrie Development Assessment of Tailings and Mine Waste Source Terms, SRK, March 2011.

Standards Australia (1993) AS 1170.4-1993: Minimum design loads on structures – Part 4: Earthquake Loads, Standards Australia, Homebush, Sydney.

Stevens, R., (2009a). Report of a work area clearance heritage survey of the Yeelirrie Uranium Project exploration drilling program in the Western Australian Goldfields region. Unpublished report prepared for CDNTS on behalf of BHPB-YDC.

Stevens, R., (2009b). Report of a work program clearance heritage survey of Yeelirrie Uranium Project hydrological bore placement program, Western Australian Goldfields. Unpublished report prepared for CDNTS on behalf of BHPB-YDC.

Stevens, R., (2010)/ Heritage survey report work program clearance - BHP Billiton – Yeelirrie Uranium Project hydrological bore sump program, Western Australian Goldfields. Unpublished report prepared for CDNTS on behalf of BHPB-YDC.

Subterranean Ecology, S. (2011) Yeelirrie Subterranean Fauna Survey. Proposed Yeelirrie Development. Report prepared for BHP Billiton Yeelirrie Development Company Pty Ltd. Subterranean Ecology Pty Ltd, Stirling, Western Australia, 87 pp.

Taiti, S. (2014) New subterranean Armadillidae (Crustacea, Isopoda, Oniscidea) from Western Australia. Tropical Zoology, 27, 1-13.

Taiti, S., and Humphreys, W.F. (2001) New aquatic Oniscidea (Crustacea: Isopoda) from groundwater calcretes of Western Australia. Records of the Western Australian Museum 64, 133-151.

Thompson, R.S. (1994). Residence time of contaminants released at surface coal mines – a wind-tunnel study. Proceedings of 8th Air Pollution and Meteorology Conference, Americal Meteorological Society.

Thompson, S.A. and Thompson, G.G. (2006). Reptiles of the Western Australian Goldfields. Kalgoorlie, WA: Goldfields Environmental Management Group.

Thompson, J. E. and Wilson, O.J. (1980). Calculation of Gamma Ray Exposure Rates from Uranium Ore Bodies, 1980 Australian Radiation Laboratory.

Tille, P. (2006). Resource Management Technical Report 313 – Soil landscapes of Western Australia's Rangelands and Arid Interior. Department of Agriculture and Food, Government of Western Australia.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (1996). Report to the General Assembly, Scientific Annexe: Effects of radiation on the environment, New York.

United States Department of Energy (2002). A graded approach for evaluating radiation doses to aquatic and terrestrial biota. In: Department of Energy Standard, 2002, Washington.

URS (2011a). Geochemical Assessment of Tailings and Mine Waste – Proposed Yeelirrie Development, URS, March 2011.

URS (2011b) Groundwater Study, Yeelirrie Uranium Project. Draft Report prepared for BHP Billiton Yeelirrie Development Company Pty Ltd. East Perth, Western Austrlaia, 195 pp.

URS (2015a). Greenhouse Gas (GHG) Forecast for the Proposed Yeelirrie Development, January 2015 Ref: 42908765/01/02.

URS (2015b). Surface Water Study Proposed Yeelirrie Development, 1 June 2015. Ref: 42908794/BW-Wat-0129/0.

URS (2015c). Yeelirrie Water Balance Study. 11 June 2015. Ref: 42908794/BW-Wat-0175/B

Van Dyck, S. and Strahan, R. (Eds.) (2008). Mammals of Australia.3rd Edition. Australian Museum, Sydney.

Western Australian Museum (WAM) (1976). A survey for Aboriginal sites – 1976 - Yeelirrie Uranium Project. Unpublished report prepared for Aboriginal Sites Department, WA Museum, on behalf of Western Mining Corporation.

WAM (2009). Species List from Western Australian Museum Arachnid Database. Latitude: 026°30`"S to 027°030`"S, Longitude: 119°"E to 121°"E.

Western Mining Corporation Limited (1978). Vegetation and flora survey for the draft EIS and ERMP.

Western Mining Corporation Limited (1979). Draft Environmental Impact Statement and Environmental Review and Management Programme Yeelirrie Uranium Project, WA.

Western Botanical (2007). Flora and Vegetation Assessment of Clearing Permit Application Area at Leinster Nickel Operation. Report WB468 to BHP Billiton, Nickel West, Leinster Operations, WA.

Western Botanical (2008a). Assessment of Flora and Vegetation for a Native Vegetation Clearing Permit Application. Report WB561 to BHP Billiton, Nickel West, Mount Keith Operations, WA.

Western Botanical (2008b). Flora, Vegetation and Conservation Values of the northwestern corner of the Wanjarri Nature Reserve. Report WB491 to BHP Billiton, Nickel West, Mount Keith Operations, WA.

Western Botanical (2008c) Flora and Vegetation of the Proposed Clearing within the Koonoonooka Sand Quarry. Report WB507 to BHP Billiton, Nickel West, Leinster Operations, Leinster, WA.

Western Botanical (2009) Flora and Vegetation Interim Baseline Report, October 2009. Report WB611 to BHPB Yeelirrie Uranium Project.

Western Botanical (2011). Yeelirrie Project, Flora and Vegetation Survey Baseline Report, February 2011, for BHP Billiton Yeelirrie Development Company Pty Ltd, Report WB653, 28 February 2011.

Western Botanical (2014). Demographic Study of Atriplex sp. Yeelirrie Station, August 2014. Report WB 836 to Cameco Australia.

Western Botanical (2015a). Addendum to Report WB653: Yeelirrie Project Flora and Vegetation Survey (February 2011), March 2015, Report WB839 to Cameco Australia,.

Western Botanical (2015b) (In Prep). Demography assessment Phase 1, Atriplex sp. Yeelirrie Station eastern, western and rehabilitation populations. March 2015. Report WB844 to Cameco Australia.

Western Botanical (2015c) (In Prep). Draft Initial Review of Lake Mason for Potential Translocation Sites of Atriplex sp. Yeelirrie Station, June 2015. Report WB848 to Cameco Australia.

Western Botanical (2015d) (In Prep). Germination Trial of Atriplex sp. Yeelirrie Station, May 2015, Report WB849 to Cameco Australia.

White, N. (2015). DNA identification of sample WF15-01-1 (Yeelirrie). Australian Wildlife Forensic Services, Curtin University, Bentley.

Wisz, M.S., Hijmans, R.J., Li, J., Petersen, A.T., Graham, C.H. and Guisan, A. (2008). Effects of sample size on the performance of species distribution models. Diversity and Distributions 14, 763-77.

World Nuclear Association (2014). Uranium Markets (updated April 2014) (http://www.world-nuclear.org/info/nuclear-fuel-cycle/uranium-resources/uranium-markets/) viewed 27 January 2015.

World Nuclear Association (2015). World Nuclear Power Reactors & Uranium Requirements (updated 1 January 2015) (http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/) viewed 27 January 2015.

Yankovich, T.L., Beresford, N.A., Wood, M., Aono, T., Andersson, P., Barnett, C.L., Bennett, P., Brown, J.E., Fesenko, S., Fesenko, J., Hosseini, A., Howard, B.J., Johansen, M.P., Phaneuf, M., Tagami, K., Takata, H., Twining, J.R., Uchida, S., (2010). Whole-body to tissue concentration ratios for use in biota dose assessments for animals. Radiation and Environmental Biophysics 49pp, 549-565.