Section Eight

Environmental Factors

Contents

List of Figures

List of Tables

List of Plates

8. Environmental Factors

8.1 Impact Assessment Methodology

Cameco and its consultants reviewed the Project design and discussed the aspects[6] of the Project against each of the environmental and social factors to determine data gaps and potential impacts of the Project. Cameco, in consultation with the regulators, then prepared a draft Environmental Scoping Document (ESD) for public review as outlined in Section 3.1. Specialist studies were commenced in accordance with the agreed scopes of works outlined in the ESD.

In order to ensure a complete assessment of the Project, Cameco undertook an environmental risk assessment for the Project following the principles outlined in the EPA's review of the environmental impact assessment process in Western Australia (EPA, 2009a). The purpose of the risk assessment was to ensure all potential impacts were identified, evaluate the risk associated with those potential impacts and determine appropriate management measures to remove or mitigate these impacts to an acceptable level of risk.

A separate Transport Risk Assessment was undertaken by the Australian Nuclear Science and Technology Organisation (ANSTO) Radiation Consultancy & Training Services to assess the risks of the various transportation routes considered, and conditions likely to be encountered during transport of uranium oxide concentrate (UOC) in WA and South Australia (SA) (Section 9.5.4).

8.1.1 Environmental Risk Assessment Methodology

The environmental risk assessment methodology followed the principles outlined in EPA (2009a) and AS/NZS 4360:2005 Risk Management standard. The process commenced with consultation with internal and external stakeholders as part of preparation of the ESD for the Project. Cameco then established the context for the risk assessment including Cameco's internal standards and business goals, expectations of key stakeholders (e.g. regulators, indigenous communities, non-government organisations) and applicable guidelines, standards and policies.

The key Project aspects or activities were identified and the relevant environmental factors listed for each aspect. Information from baseline and technical studies was used to identify the potential impacts for each aspect and factor, and assess the inherent risk rating. The risk ratings were based on a consequence versus likelihood risk matrix as shown in Figure 8-1. The consequence is defined by AS/NZS 4360:2004 as 'outcome or impact of an event' and likelihood is defined as 'a general description of probability or frequency'. The resulting risk rating is shown in the coloured squares in Figure 8-1.

The inherent risk ratings (i.e. with no controls or management measures) were evaluated to determine which risks needed treatment, or where further information was required to more accurately assess consequence and likelihood. These were reviewed internally and by Cameco's specialist consultants. Proposed controls or management measures were incorporated into the risk assessment and the risks re-evaluated to determine the residual risk (i.e. after application of controls or management measures). Proposed controls or management measures were refined until the residual risk was determined to be acceptable.

8.1.2 Risk Assessment Outcomes

The results of the Risk Assessment are presented in Appendix B. The risk assessment identified the following issue that had a Very High inherent risk rating:

- **Unplanned disturbance to Indigenous Heritage Sites:** This would be considered a Major consequence and almost certain to occur if appropriate management measures were not put in place. In order to mitigate this risk, Cameco has conducted a number of Aboriginal heritage surveys and drafted a Cultural Heritage Management Plan (CHMP) in negotiations with the Martu, as part of the Indigenous Land Use Agreement (ILUA). The Plan establishes agreed protection mechanisms and buffers to protect sites. Where necessary and subject to the Ground Disturbance Procedure (in place as part of the current Environmental Management

[6] Aspects are defined in ISO 14001:2004 standard for Environmental Management Systems as an 'element of an organisation's activities, products or services that can interact with the environment'.

Figure 8-1: Risk matrix table

			Likelihood				
			L1	L2	L3	L4	L5
			Rare	Unlikely	Possible	Likely	Almost Certain
Consequence		Environmental outcome	Extremely unlikely to occur during LOM.	Has occurred in different industries. Unlikely to occur during LOM.	Has occurred in similar projects. Possible during LOM.	Known hazard. Likely to occur within the LOM.	Likely to occur at least annually.
C5	Severe	Significant loss. Threatened closure of site.	Medium	High	High	Very High	Very High
C4	Major	Substantial loss. Regulator fine. Temporary closure of site.	Low	Medium	High	High	Very High
C3	Moderate	Moderate loss. Report to regulator or warning. Lost operation time.	Low	Low	Medium	High	High
C2	Minor	Minor loss. Minor disruption to operations.	Very Low	Low	Low	Medium	High
C1	Insignificant	Very minor loss. No disruption to operations.	Very Low	Very Low	Low	Low	Low

Plan) further inspections are completed prior to any ground disturbance activities to confirm site locations and boundaries. Should any of the elements of the Project likely impact on a registered site, it is a requirement under Cameco's CHMP to consult with representatives of the Martu (the Native Title holders over the Kintyre area) and obtain a Section 18 consent under the *Aboriginal Heritage Act 1972* prior to disturbance of any identified sites. These management measures and other measures outlined in Section 9.3.7. of this ERMP are expected to reduce the likelihood of unplanned disturbance to heritage sites to Rare (extremely unlikely) and result in a Low residual risk.

A number of issues had High or Medium inherent risk ratings, but all were considered to have a Low residual risk with the implementation of appropriate management measures with the exception of the following:

- **Loss of subterranean fauna from groundwater abstraction:** This would be considered a Moderate consequence and Likely to occur since some potentially significant species are located within the proposed pit area that will be dewatered and mined. Based on the likely ranges of the subterranean fauna species possibly threatened by the mine development and the management measures outlines in Section 8.7.5, the residual risk of loss of these species is reduced to Low. Cameco does not consider the impact on the species will be significant for the following reasons:
  - There are large areas of habitat for subterranean fauna outside of the pit area.
  - All but two of the species found within the areas of impact have also been found outside the areas of proposed impact.
  - Many species identified in the pit area were present in low numbers and there is uncertainty in the sampling of stygofauna with low abundances in multiple locations.

- **Deaths of significant fauna as a result of collision with vehicles on roads:** This was considered to be a Moderate consequence and Possible, resulting in an inherent risk rating of Medium. Cameco is proposing to implement management measures such as speed restrictions in certain areas and employee awareness as outlined in Section 8.6.5. However, even with these measures the residual risk is still expected to be Medium.
- **Impacts of the final pit void on groundwater and terrestrial environment from attraction of fauna to the water:** These were considered to be Moderate consequences and of Possible likelihood resulting in an inherent risk rating of Medium. Implementation of the proposed Mine Closure & Rehabilitation Plan which involves partial backfilling of the pit and the fact that the pit void will be saline is anticipated to reduce the likelihood of impacts from attraction of the fauna to water. The residual risk remains Medium.

Aspects of the Project with a Low inherent risk were generally not considered in detail in this ERMP.

8.2 Landform and Soils

8.2.1 Objective

The objective agreed to within the ESD with regards to landform and soils is to maintain the integrity, ecological function and environmental values of the soil and landform.

8.2.2 Relevant Legislation and Policy

In Western Australia the principal land degradation controls are under the *Soil and Land Conservation Act 1945* administered by the Commissioner of Soil and Land Conservation within the Department of Agriculture and Food (DAF). Under this Act the Commissioner is able to serve a Soil Conservation Notice where land is being degraded, or at risk of being degraded. A Soil Conservation Notice can direct a person to cease activities that may cause land degradation or take measures to reduce the risk of land degradation. Local governments are also able to issue erosion notices and place restrictions of vehicle use where there is a risk of soil or vegetation degradation.

The protection of native vegetation from land clearing is regulated under amendments made to the *Environmental Protection Act 1986* (EP Act) in 2004 and the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (Section 8.5.2).

8.2.3 Proponent Studies and Investigations

Cameco's Project design team has taken into consideration the natural landforms and topography of the Project area in designing the Project. For example the final outlines of the Waste Rock Landform (WRL) and Tailings Management Facility (TMF) have been designed with some curved outlines, moderately sloped embankments and flat tops in keeping with the mesas that occur in the area (Figure 8-2).

Engineering studies have also investigated soils and substrates to ensure adequate foundations can be constructed prior to the erection of structures, and sufficient resources are available for construction and rehabilitation purposes. Soil investigations particularly in regard to suitability for rehabilitation activities, will be ongoing prior to the commencement of construction. Proposed studies are outlined in more detail in the Mine Closure and Rehabilitation Plan (Appendix D17). Some historic information on soils is presented below.

8.2.4 Existing Environment

8.2.4.1 Landforms

The Project area lies in the Paterson Province between the Great Sandy Desert and the Little Sandy Desert in the Eastern Pilbara region of Western Australia. The Project area has been subject to millions of years of erosion from wind and rain. The area is an arid setting of exposed bedrock, low mesas, ephemeral watercourses and dunefields.

The topography of the Project area is made up of:

- flat floodplains of the Yandagooge Creek;
- flat Aeolian sand dune areas to the east of the Project area;
- isolated outcropping ridges within the floodplain areas; and
- hilly range areas with flat mesas that abut the edge of the Yandagooge Creek floodplain.

The Project lies within a broad valley bounded by rocky flat-topped hills comprising of Throssell Range to the west and Broadhurst Range to the east with the Watrara Range to the south. Remnants

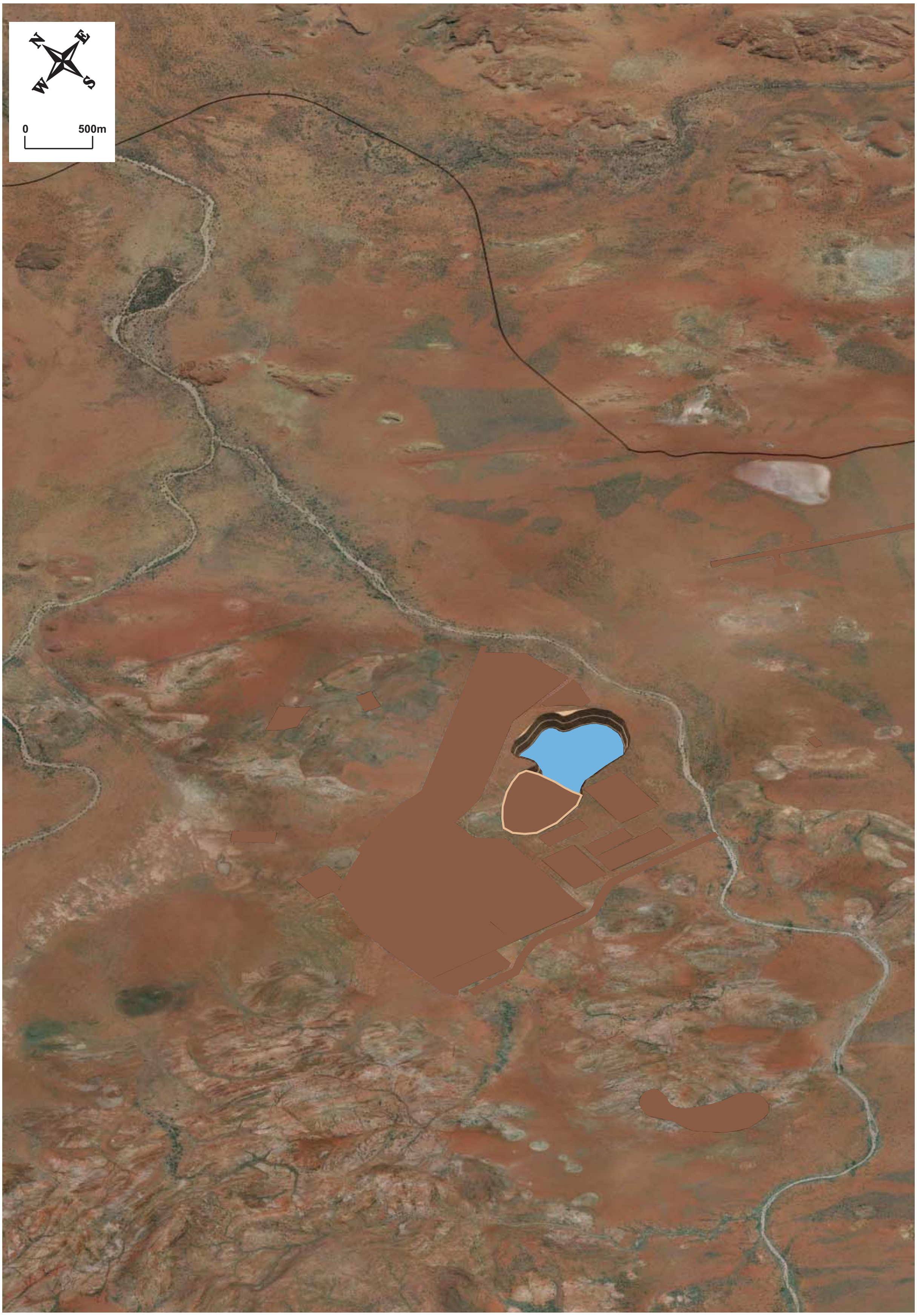


Figure 8-2: Isometric view of the closed and rehabilitated site.

of glacial action in the form of striated pavements and U-shaped valleys are present in places within and along the margins of the ranges. Isolated hills, surrounded by an apron of scree survive as erosional remnants within the main valley (Plates 8-1 to 8-4). Surface elevation ranges from about 375 m (AHD) in the main valley to about 500 m AHD in the ranges.

The majority of the access road is relatively flat or undulating where it crosses sand dunes that run north west to south east.

8.2.4.2 Soils

Some historic information on soils is available in Dames & Moore (1997) (Appendix H) and summarised in Table 8-1.

Soil units 1, 4, 5 and 6 are permeable sands which will allow rapid infiltration and have poor water holding characteristics. These soils have low cohesion soil structure and hence are susceptible to erosion by water or wind. All can be readily excavated by backhoe and are easy to handle.

Soil unit 2 consists of colluvial soils on steeper slopes. They generally have slow infiltration and fair water holding characteristics. This unit is subject to erosion due to its topographic position on steep slopes. It is difficult to excavate due to the high content of rock fragments within the unit.

Soil unit 3 is less permeable than units 1, 4, 5 and 6 and infiltration is therefore slow. Ponding at the surface is likely after heavy rains, leading to the formation of superficial clay pans. This unit is resistant to erosion unless broken up by vehicle traffic. Excavation of soil unit 3 would require more effort than for units 1, 4, 5 and 6 as it is more cohesive.

Soil unit 7 is essentially bare rock with poor infiltration and water holding characteristics. It is highly resistant to erosion and cannot be excavated without preliminary blasting.

In terms of rehabilitation suitability, soil units 1, 3, 4 and 5 would be suitable for use in rehabilitation even though they are of predominantly sandy texture. Soil units 2, 6 and 7 would be unsuitable for use in rehabilitation activities (Dames & Moore, 1997).

8.2.5 Potential Impacts and Management

The Project will disturb approximately 790 ha (Table 6-1) which will result in soils being disturbed or stripped. Soil that has been disturbed is susceptible to wind and water erosion and its structure may be damaged if handled or disturbed when wet. Disturbed areas that are no longer required for operations will be rehabilitated progressively throughout the life of mine in a manner which stabilises the soil surface and minimises the risk of erosion. Proposed rehabilitation methods for various Project domains are provided in more detail in the Mine Closure and Rehabilitation Plan (Appendix D17).

Table 8-1: Soil units in the Kintyre area

Unit	Title	Description	Pattern on Aerial Photograph
1	Flat sandy plains.	Red, deep sand (>2m thick).	Featureless with scattered trees.
2	Stony hills and scree slopes.	Rock fragments in sandy loam matrix, overlying weathered rock at 0.5 to 1m depth.	Light coloured vegetation concentrated in defined drainage lines.
3	Claypan areas and old drainage lines.	Red sandy loam and silty sand sometimes with superficial layer of sand.	Mottled with small light-coloured claypans and darker patches of vegetation.
4	Patches of aeolian sand and minor sand dunes.	Red sand.	Similar to Unit 1, but slightly paler, and vegetation more evenly scattered.
5	Levee banks and alluvium marginal to major drainage lines.	Red, loose sand.	Sinuous and linear zones, heavily vegetated, large trees.
6	Alluvium along active drainage lines.	Sand with gravel bars and lenses.	Light-coloured with lines and islands of large trees.
7	Rock outcrops.	Small scattered patches of Unit 2 soils.	Rock structure visible.

Plate 8-1: Flat Aeolian sand dunes to the east of the Project area.

Plate 8-2: Hilly range areas with flat mesas that abut the edge of the Yandagooge Creek floodplain.

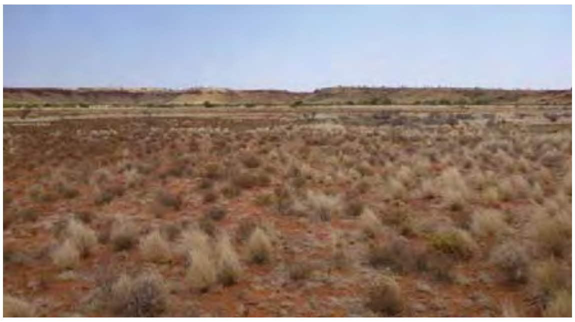


Plate 8-3: Open sand plain with hilly range areas in the background.

Plate 8-4: Flat floodplains of the Yandagooge Creek

All photos courtesy of Eleanor Bennett.

Where the pit, plant and Project infrastructure is proposed to be constructed, topsoil that is suitable for rehabilitation will be stripped and temporarily stockpiled until required. 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 WRL. Prior to commencement of construction, Cameco will have ascertained the availability and volumes of key materials required for rehabilitation such as competent waste rock, subsoil, topsoil and low-permeability clay (Refer to Appendix D17). 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.

On decommissioning and closure, there will be some permanent changes to the landscape. Closure will be based on the following concepts:

- With the exception of a portion which will be back filled to the pit, waste rock will be placed in permanent above-ground waste rock dumps. The permanent WRL will be designed to blend in with the landscape as far as practicable.
- The design of the final TMF will ensure long-term stability of the structure and ensure no exposure or release of material with elevated radiation levels.
- A lake will form in the open pit void. The pit lake will function as a terminal sink ensuring it is non-polluting to surrounding ground water and stable for the long-term.
- Groundwater production and monitoring bores will be closed and rehabilitated after they are no longer required and the Project closure completion criteria have been achieved (Refer to Appendix D17 for completion criteria). Relevant stakeholders will be consulted prior to the closure of the bores to ensure that they are not required for any other purpose.
- All plant and associated infrastructure (such as mine camp and airport) will be demolished and removed at the conclusion of operations, subject to negotiations with key stakeholders.

Closure monitoring and maintenance will be undertaken to monitor the progress of rehabilitation against completion criteria and undertake remedial work if required (Refer to Appendix D17).

Other issues relating to soil management are discussed elsewhere in this ERMP. Surface water management to minimise the risk of erosion is discussed in Section 8.3.5. Dust generation and hence wind erosion will be minimised through the dust management measures proposed in Section 8.10.5. The potential for contamination of land through inadequate storage and handling of hazardous and radioactive materials is addressed in Sections 6.9 and 8.11.5 respectively. The geochemical characteristics of the Project and potential impacts associated with these characteristics are addressed in Section 8.13.

8.2.6 Commitments

Cameco will complete all geophysical and chemical analysis of topsoil, subsoil and waste rock and ascertain the availability and volumes of key materials required for rehabilitation, prior to commencement of construction and present the results of this work in an updated Mine Closure and Rehabilitation Plan to be submitted prior to the commencement of construction.

Cameco will meet the completion criteria and values outlined in the Mine Closure and Rehabilitation Plan.

8.2.7 Outcome

It is expected that the potential impacts on landforms and soils will be manageable and will not result in land degradation in the short or long-term. Final landforms will blend in with the natural topography as far as is practicable notwithstanding the need to design to ensure the long-term erosional stability of the structures.

Cameco believes that the integrity, ecological functions and environmental values of the soil and landforms of the area will be protected.

8.3 Surface Water

8.3.1 Objectives

The objectives agreed to within the ESD with regards to surface water are:

- to maintain the integrity, ecological functions and environmental values of the watercourses; and
- to maintain the quantity and quality of surface water so that existing and potential environmental values, including ecosystem maintenance, are protected.

8.3.2 Relevant Legislation and Policy

Under the *WA Rights in Water* and *Irrigation Act 1914* (RIWI Act) disturbance to creek beds and banks cannot be undertaken without a Section 11/17/21A permit under the RIWI Act. Prior to any disturbance of Yandagooge Creek a 'Beds and Banks Permit' would be required before Cameco could commence construction of the access road across the creek.

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;
- aesthetics and recreation; and
- cultural and spiritual values.

Whilst surface waters within and around the Project areas are ephemeral and unlikely to be used for drinking water, water quality guidelines that apply to this environmental value may be used if considered appropriate for the protection of human health.

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

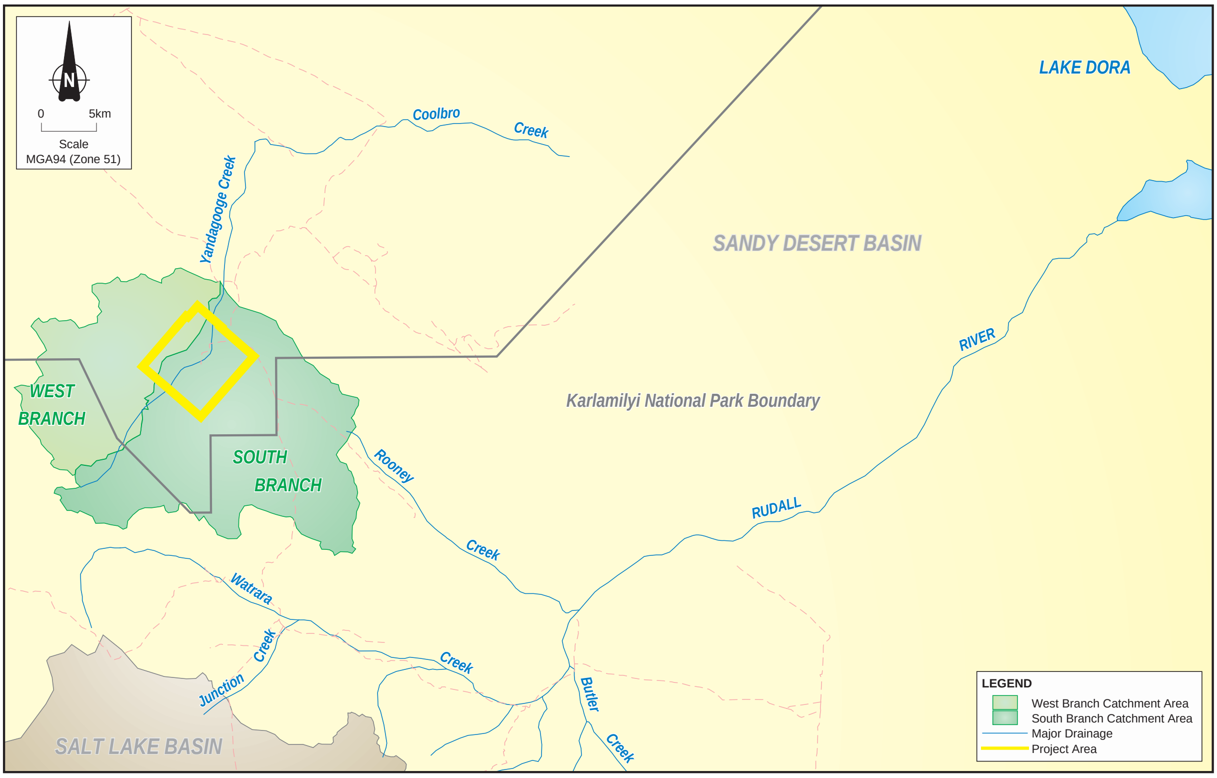


Figure 8-3: Surface water catchment areas within the Project area

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.

8.3.3 Proponent Studies and Investigations

In July 2009 MWH Australia Pty Ltd (MWH) completed an assessment of the existing surface water information, undertaking a gap analysis and provided recommendations on how surface water management should proceed for the Kintyre Project. This involved the review of documents detailing surface water monitoring conducted from 1988 to 1992 and a field visit by MWH in May 2009 to the Kintyre Project area.

Whilst some data are available for surface waters within and around the Project area, there is insufficient data to be able to develop site-specific water quality guidelines. This is due to the ephemeral nature of surface water flows in the creeks in the area and, inaccessibility to the area (due to flooding) following significant rainfall events. However, several water samples have been taken from the Yandagooge Creek and more will be taken as opportunities present.

In September 2011 MWH was appointed by Cameco to undertake a flood study to determine the nature and extent of the potential flooding that could occur at Kintyre (MWH, 2011; Appendix I). This included the conceptual design and assessment of a flood protection embankment. As part of this investigation the Hydrometeorological Advisory Service of the Bureau of Meteorology prepared Probable Maximum Precipitation (PMP) estimates for the Kintyre catchment.

Flood behaviour was defined using a computer based hydrological model of the catchments and a hydraulic model of the streams and flood plain. The hydrological model was a runoff routing model, which was initially tested against recorded rainfall and runoff data, and where observed data was not sufficient, regional design parameters were used. Design storms were then applied to the model to generate discharge hydrographs within the study area (MWH, 2011b).

A flood protection embankment has been proposed to provide additional flood protection to the Kintyre mine pit and important infrastructure. The conceptual embankment was incorporated into the hydraulic model and design flood scenarios were modelled to determine the embankment size required to prevent flooding of infrastructure and to assess downstream impacts (MWH, 2011b).

8.3.4 Existing Environment

The Project is located within the Sandy Desert River Basin (River Basin 025) which is an internally draining basin within the Western Plateau Drainage Division No. 12 (AWRC, 1975). The Sandy Desert River Basin is an internally draining basin. It is not gauged by the DoW and there are no published data listed in the Australian Water Resources Station Catalogue. A detailed description of the surface water environment is provided in MWH (2011b) (Appendix I) with a summary provided below.

Locally the Project lies within two tributaries of the Yandagooge Creek referred to as the South Branch and the West Branch (Figure 8-3). The drainage in the upper reaches of the creeks occurs within relatively incised channels which widen to include significant floodplain storage in the area surrounding the Project area. The South Branch and West Branch converge immediately downstream of the project site and flow north to the Coolbro Creek. Coolbro Creek then follows an easterly path into the Great Sandy Desert where the drainage eventually dissipates into sand dunes. The Yandagooge Creek channels surrounding the Project area are well defined, approximately one to two metres deep and have coarse sand and gravel beds, characteristic of rivers in the Pilbara.

The creeks in the region are generally dry and flow only in response to heavy rainfall, when they may flow for several days. Semi-permanent surface water pools exist to the north of the Project area in the northern, central and southern creeks of the Coolbro Hills (Dames and Moore, 1996). The most significant of these are Pinpi Pool upstream (south of the Project area) on the eastern branch of the Yandagooge Creek; Rock Pool north of the Project area on a minor tributary to Yandagooge Creek; and Coolbro Pool and Duck Pool north of the Project Area on Coolbro Creek, upstream of the confluence with Yandagooge Creek (Section 8.8).

Using topographical information, the catchment area of the South Branch has been estimated to be approximately 300 km^2 and the West Branch approximately 170 km^2. The major runoff generating areas are the sandstone and quartzite outcrops (MWH, 2011b). Previous hydrological investigation suggested that the more impermeable soil in the West Branch produces more runoff per unit area than the South Branch (Dames and Moore, 1996).

Rainfall data from the Telfer climate station shows a good annual correlation to the rainfall recorded at Kintyre, for the period of record available, indicating that the Telfer data are useful for looking at longer term regional rainfall trends. The largest rainfall event recorded at Telfer was in March 2004 as a result of Cyclone Fay where 372 mm of rainfall was recorded in three days which resulted in wide spread flooding. As a result, the road access to Telfer was cut for three months and a new causeway had to be constructed.

8.3.5 Potential Impacts and Management

Cameco's proposed mining and process plant are to be located between the two branches of the Yandagooge Creek. The Project has been designed to capture all process discharges and potentially contaminated surface water runoff from within Project area for use by the Project.

The footprint of the mining and processing operations is relatively small, covering approximately 1,500 ha which represents approximately 3% of the Yandagooge Creek catchment area. The proposed mining and process areas will be protected by a flood protection embankment in areas that may be subjected to inundation during major rainfall events (Figure 8-4).

The flood study undertaken by MWH (2011b) indicates that flood flows from the West Branch of Yandagooge Creek are unlikely to be a flood risk to the mine. The flood protection embankment will be required primarily to protect the mine from flood flows from the South Branch of Yandagooge Creek, following flood events larger than the 10 year annual recurrence interval (ARI) (Appendix I).

For the 1,000 year ARI event and probable maximum flood (PMF) event, the proposed flood protection embankment diverts significant flow away from the left bank area, out of the main channel and into a break-out overflow channel on the opposite bank (right bank). The proposed flood protection embankment reduces the floodplain width at the

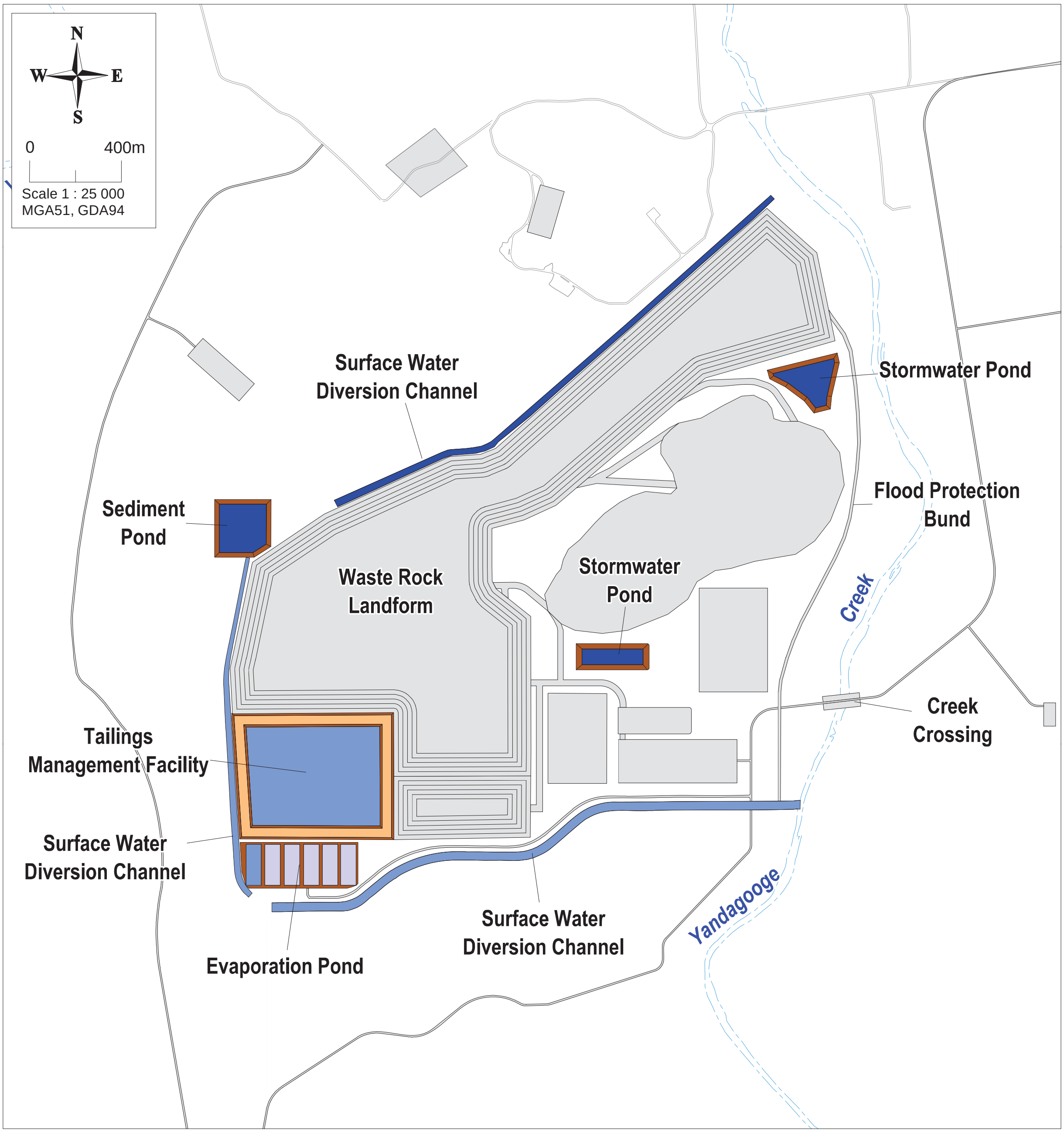


Figure 8-4: Surface water management infrastructure

closest point to the creek from 1.5 km to 0.8 km, and forces more flow onto the right bank overflow channels. Depths on the right bank floodplain are predicted to increase by approximately 0.5 m to 1.0 m for 2.5 km downstream. These effects are considered significant, however, they are associated with rare events (MWH, 2011b).

Increased flow velocities around the flood protection embankment may cause localised scour and increased sediment load. With the reduction of floodplain width the local velocities for events 20 year ARI and larger will be increased, leading to higher scour forces. This would be rare and could be partly offset if stable vegetation along the banks is retained during the mine operations. Potential scour over the mine footprint will be reduced due to the protection of the levee (MWH, 2011b).

Large areas of the Pilbara are predisposed to soil erosion because of their susceptible, often fine textured soils, land degradation (removal of vegetation that exposes the fragile soil structure) and the highly intense rainfall that is experienced. During a large rainfall event, the background mobilisation of natural sediments within the

Yandagooge catchment is expected to be high (MWH, 2011b). The impact of the proposed flood protection embankment is expected to have a minimal impact in comparison to the high sediment loading from the natural surrounding environment in large rainfall events (MWH, 2011b).

Generally the mining operations will not significantly impact on the natural flow regime of the Yandagooge Creek with respect to the timing and volume of natural flow in the creek system. The proposed flood embankment would minimally impact the natural timing and magnitude of flows in the South Branch but not impact on the total volume of downstream flow.

The overall size of the footprint area that is to be isolated from the existing catchment area, compared to the size of the catchment is so small that the loss of catchment runoff to the drainage system is from the mine site is considered negligible.

Other disturbances to the natural surface water drainage systems are likely to be associated with the construction of access roads to the sites. Any structure such as a concrete flood way built across the drainage systems would be designed to have minimal disturbance to the natural flow system, allowing the surface water flows to continue on its normal flow path unimpeded.

Water quality of the stream water has been monitored on a number of occasions including recent flood events. The water quality of the flood waters is generally fresh, however slightly elevated natural radionuclide values have been observed during these flood events from naturally occurring material.

The development of the minesite between the two branches of the creek is not expected to have a significant impact on the stream flow characteristics of the system. Similarly Cameco does not expect the Project to have any impact on the water quality of the system.

Groundwater discharge zones are not common in the Project area, with the exception of some larger rock pools in the Coolbro Sandstone, which are sustained over dry periods by groundwater discharge along shear zones. As such, Cameco does not anticipate the Project will have an impact on creek hydrology due to groundwater abstraction (Section 8.4).

8.3.5.1 Design Philosophy

The basis for the design of surface water management features at Kintyre is, firstly, to keep cross country runoff and flood water from Yandagooge Creek off the Project Area, and, secondly to have the capacity to store rainwater captured on site within site facilities including the TMF, evaporation ponds and stormwater ponds and as a last resort, the open pit.

The flood protection bund and the diversion channels have been designed to divert the runoff around the Project Area to minimise site flooding during extreme rainfall events.

The proposed flood protection bund will be constructed between the pit and Yandagooge Creek for a probable maximum flood (PMF) +1-metre event. Cameco has designed this based on a minimum 200 m offset from the Yandagooge Creek and a minimum of 30 m offset from the pit (for geotechnical reasons). The width of this bund is up to 50 m wide at its base and the height is up to 6 m. The levee joins natural features to the north and south of the proposed Project site as shown in Figure 8-4.

Surface water diversion channels would be constructed on the western and northern sides of the Project Area.

These have been have been designed to 1 in 100-year ARI to capture cross country runoff.

Cameco's flood model used for the design is considered conservative. This uncertainty will be updated prior to mining using additional information obtained on an ongoing basis through collection of surface water data, recalibration of the flood model and implementation of the Surface Water Management Plan, and the latest guidance from the Bureau of Meteorology.

Facilities within the site including the TMF and the Evaporation Pond will be designed to capture surface water runoff in an extreme rainfall event. Specifically the design basis for these facilities will be to retain 400 mm rainfall in 72 hours, plus 1.0 m freeboard for the TMF and 400 mm in 72 hours, plus 0.5 m for the Evaporation Pond.

In the event the capacity of the TMF were exceeded, excess water from the TMF will be pumped to evaporation ponds.

Table 8-2: Kintyre surface water management basis for design

Surface Infrastructure	Design Basis	Duration (hr)	Rainfall (mm)
Surface Water Management (ponds and channels)	1:100 ARI + 0.5m freeboard	72	266
Tailings Management Facility Design	Extreme Event (400mm) + 1.0 m freeboard	72	400
Evaporation Ponds Design	Extreme Event (400mm) + 0.5 m freeboard	72	400
Pit Bund Conceptual Design	PMF + 1 m freeboard	6	680

In the event of a more extreme event, additional capacity will be obtained by discharging captured rainfall from these facilities into the open pit.

The design basis for the infrastructure is summarised in Table 8-2.

Runoff from areas such as that from the process area and stockpiles which may be potentially contaminated (with elevated levels of radionuclides) will be captured for use in the processing plant or otherwise directed to the Evaporation Pond and stormwater ponds.

Stormwater management at the TMF will be managed via a perforated riser system designed to redirect stormwater that collects on the TMF surface, and the construction of two diversion channels to redirect TMF runoff flows for evaporation. The top of the TMF will be graded to direct flows to the risers. Flows will then be combined into an overdrain pipe which will direct the captured stormwater to the Evaporation Pond.

Runoff from the TMF slopes will be captured in one of two diversion channels, which will direct the runoff to the Evaporation Pond.

The Evaporation Pond will also store surface water collected within the boundaries of the metallurgical plant. The potential for leaks and spills from pipelines and process water circuits will be managed through the installation of leak detection equipment. Pipelines will be bunded where necessary.

A Surface Water Management Plan has been developed for the Project (Appendix D6), including a water balance for the Project and surface water quality monitoring.

8.3.6 Commitments

Cameco will design and construct the Kintyre Project surface water management features as outlined in Table 8-2.

Cameco will implement the Surface Water Management Plan.

8.3.7 Outcome

Cameco does not anticipate that the Project will affect the quantity or quality of surface water of the surrounding areas. With the proposed management measures outline above, Cameco believes the Project can be constructed, operated and closed in a way which maintains the integrity, ecological functions and environmental values of the watercourses in the area.

8.4 Groundwater

8.4.1 Objectives

The objective agreed to within the ESD with regards to groundwater management is to maintain the quantity and quality of groundwater so that existing and potential environmental values, including ecosystem maintenance, are protected.

8.4.2 Relevant Legislation and Policy

The Department of Water (DoW) has recently released its draft guideline on the management of water in mining in Western Australian (DoW, 2012). This document 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 Western Australia, 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 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 objective of these guidelines is to provide a national framework for the protection of water bodies from contamination as part of Australia's National Quality Management Strategy (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.

As part of the NWQMS, the 2011 Australian Drinking Water Guidelines (ADWG) have been developed in collaboration with the Natural Resource Management Ministerial Council (NRMMC). The ADWG are designed to address both the health and aesthetic quality aspects of supplying good quality drinking water.

8.4.3 Proponent Studies and Investigations

Comprehensive groundwater investigations were commissioned by Cameco. This included drilling and testing programmes undertaken in 2009-10 and 2011-12. The information collected in the new investigations was interpreted and analysed along with information obtained in previous investigations completed in the 1980s and 1990s by Rio Tinto/CRA, to produce a robust hydrogeological model, which was used to assess the sustainability and impacts of dewatering and abstraction.

8.4.4 Existing Environment

The Kintyre deposit lies within rocks on the Rudall Complex, a sequence of deformed Proterozoic age metamorphic rocks. These rocks were carved by glaciers during the Permian Period, which formed large valleys that were infilled by sand silt and gravel as the glaciers receded. The Permian glacial valleys remain as active drainages, forming the catchment to the Yandagooge and Coolbro Creeks, as well as the Rudall River. The Permian-age sediments laid down in the valleys, the Paterson Formation, form the most important local aquifer.

8.4.4.1 Groundwater Occurrence

The main aquifer units in the Kintyre area are located in Permian sand, gravel and conglomerate deposits of the Paterson Formation, and fractured and weathered sandstone of the Coolbro Sandstone. Smaller local aquifers are present in Cenozoic deposits where saturated, and in secondary permeability features within basement rocks of the Rudall Metamorphic Complex. Regional and local aquifer qualities are summarised in Table 8-3.

Cenozoic Aquifer

Cenozoic deposits are generally unsaturated over most of the Project area, although thicker, deeper deposits are coincident with branches of the Yandagooge Creek. Isolated lens-like aquifers form where sands are present below the watertable. Cenozoic deposits do not form a significant aquifer.

Upper Paterson Aquifer

The upper unit of the Paterson Formation has significant storage potential, and generally forms an extensive clayey sand aquifer with a lower aquitard associated with the fine-grained glacio-lacustrine facies. Analysis of pumping tests suggests that the aquitard is leaky and there is a weak connection to the aquifer beneath.

Lower Paterson Aquifer

Tillite and fluvioglacial sand and gravel form aquifers of varying spatial extent in the lower portion of the Paterson Formation. Sequences of interbedded sand with loose running basal sand and gravel are the highest yielding for groundwater, although the lateral extent of these lenses is as yet, unknown.

The unit is thickest in the deepest parts of the palaeovalley, reaching a maximum of 105 m, and increases northward forming a laterally continuous

Table 8-3: Summary of aquifer types in the Kintyre area

Aquifer	Geological unit	Average thickness (m)	Bore yield (kL/day)	Aquifer potential	Lithology
Cenozoic	Alluvium	15	Minor	Minor	Unconsolidated localised sedimentary aquifers
Upper Paterson	Paterson Formation (upper unit)	50	100 to 1,500	Minor to Major	Glacio-lacustrine clay, siltstone and sand
Lower Paterson	Paterson Formation (lower unit)	100	100 to 1,700	Minor to Major	Fluvioglacial sand, gravel and basal conglomerate
Coolbro	Coolbro Sandstone	>1,000	200 to 800	Major where sheared	Sandstone
Rudall fractured rock	Rudall Metamorphic Complex	>1,000	<50 to 250	Minor	Schists, carbonates, quartzite

aquifer or series of aquifers along the length of the palaeovalley.

Coolbro Sandstone Aquifer

Although the Coolbro Sandstone is a recrystallised sandstone and siltstone with close to zero primary porosity, there are some weathered and highly fractured areas that yield water. Several bores drilled into the Coolbro Sandstone aquifer have targeted potentially high permeability areas within the Kintyre Shear Zone, though all suffered from boundary effects during pump testing.

Rudall Fractured Rock Aquifer

Proterozoic rocks in the Rudall area have little or no inter-granular permeability, but secondary permeability exists within the rocks as fault and shear structures. Rocks of the Rudall Metamorphic Complex are generally less productive and contain poorer quality groundwater than the Coolbro Sandstone.

8.4.4.2 Groundwater Dynamics

Groundwater Recharge

Groundwater is recharged directly by rainfall over the Cenozoic deposits, unconfined portion of the Paterson aquifer and outcropping fractured rock units (Coolbro Sandstone and Rudall Complex) by the downward infiltration from infrequent and often heavy rainfall events. Groundwater flow is typically away from the Kintyre prospect, with very little groundwater inflow as the area lies near the top of local catchments.

Recharge Areas

Groundwater recharge areas can be identified by their low salinity. The lowest groundwater salinity in the Project area was noted in the Coolbro Sandstone adjacent to plateau outcrop areas, indicating higher rates of recharge. Modest groundwater recharge occurs over the valley areas, which contain Cenozoic silt and sand over sub-cropping Paterson Formation. Initial infiltration of rainfall into the valley sediments may be significant, but subsequent losses via evapotranspiration will account for most of this water, reducing the net rate of groundwater recharge.

Elevated groundwater salinity is associated with the Rudall Complex outcrop, including the Kintyre pit area. This high groundwater salinity reflects very low rates of groundwater recharge.

Recharge Rates

Recharge rates in semi-arid to arid climates mostly range from 0.1% to 5% of long-term average annual precipitation (Scanlon, *et al*., 2006). Using the chloride mass balance method, the recharge rate of the Coolbro Sandstone at Kintyre varies between 1.2% and 5% of rainfall (Table 8-4). A recharge value of around 1% rainfall is most likely, which would be equivalent to an annual recharge rate of about 3.5 mm.

Long-term monitoring of water levels shows that there has been a significant rise between 1988 and 2010, which corresponds to a period of higher than average annual rainfall. Recharge rates in the area have been significantly higher than the long-term average, with the increase in groundwater recharge much larger than the 50% increase in rainfall.

Table 8-4: Recharge rates calculated using Chloride Mass Balance (CMB) method

Bore	Interval (mbgl)	Salinity (mg/L)	Chloride (mg/L)	Date	Recharge (% annual rainfall)
Coolbro Sandstone					
2PS	37.5-43.5	103 [a]	14	Nov 2010	5%
OB16	40.75-64.75	252 [a]	60	Sept 2010	1.2%
Paterson Formation					
1PS	23.6-29.6	646 [a]	120	Oct 2011	0.6%
9PS	32.8-38.8	4,640 [a]	1,600	Nov 2010	0.04%
CWB3s	12-30	884 [a]	88	Oct 2011	0.8%
WEX3	28-124	2,750 [a]	1,100	Oct 2011	0.06%
WEX4	28.5-118.5	608 [a]	140	Oct 2011	0.5%
Kintyre Pit Area					
13PS	32.6-38.6	2,298 [b]	747	Jan 1988	0.09%
KWP1	23.9-119.9	6,440 [a]	2,300	Oct 2011	0.03%
KWX4	24-96	5,527 [a]	1,800	1997	0.04%
KWX11	39-75	1,050 [c]	320	March 2010	0.2%

Notes:
a = sum of ions
b = TDS by calculation
c = field salinity 3,680 mg/L in May 1997

Table 8-5: Carbon-14 isotope age dates from the Paterson aquifer near Kintyre (after Lewis, 2011)

Bore	Age (years)	Percentage Modern Carbon	Interval (mbtoc)	Geological Unit
WEX2	1,880 +/- 15	78.56 +/- 0.16	44-128	Lower Paterson Formation
CWB8D	15,915 +/- 40	13.69 +/- 0.07	103-139	Lower Paterson Formation
WEX5S	4,496 +/- 20	56.72 +/- 0.13	20-38	Upper Paterson Formation
WEX5D	8,328 +/- 20	35.21 +/- 0.1	93.5-129.5	Lower Paterson Formation

8.4.4.3 Groundwater Levels and Flow

The watertable is typically 10 m to 20 m below ground level and reflects the topography, with an average north-northeast gradient of 1:300 (Figure 8-5).

Groundwater age is a good method for determining the rate of groundwater flow. Groundwater is typically younger in upgradient and shallower portions of the aquifer. The youngest groundwater age of 1,880 years was found from WEX2 located at the lowest point of the western palaeochannel branch (Table 8-5), and a groundwater flow rate of about 1 m per year was determined for this area.

8.4.4.4 Groundwater Discharge

Groundwater in the Project area flows to the northeast and out into aquifers in the Canning Basin. Groundwater can also be discharged through evapotranspiration where the watertable is sufficiently shallow. The watertable is too deep for direct evaporation in the Project area.

8.4.4.5 Groundwater Quality

Groundwater salinity in the Project area is variable, but is generally fresh to moderately saline. The best quality water (TDS <1,000 mg/L) is found in Coolbro Sandstone and in the Paterson aquifers. Salinity variations within the Project area are complex and the typical vertical stratification of aquifer salinity is not maintained.

Groundwater in the region varies from sodium bicarbonate, to sodium chloride, to calcium sulphate type. Figure 8-6 shows that sulphate, bicarbonate and chloride concentrations are elevated in bores surrounding the Rudall Complex

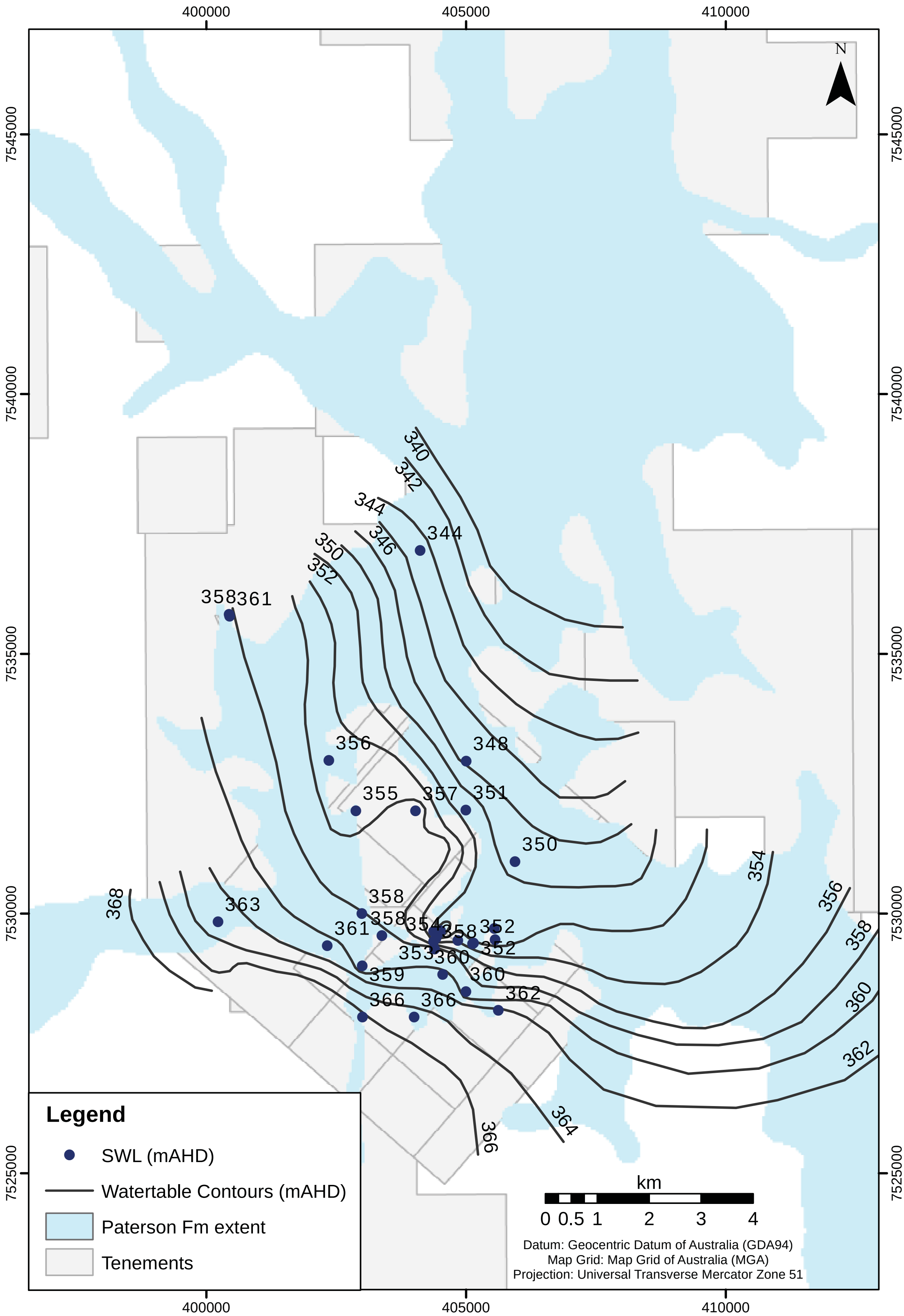


Figure 8-5: Interpretive watertable contours for the Yandagooge Creek Valley

at Kintyre. This suggests there is some interaction between the groundwater and aquifer materials.

The Kintyre groundwater chemistry dataset indicates that in some bores highly alkaline, naturally occurring groundwater may occur. The pH in these bores is greater than 12.

An evaluation of the water analysis was conducted for ion balance, hardness and TDS/EC ratios. Apart from a small number of charge balance values that are high, which is a common analytical problem with highly saline samples, the remainder of the results do not indicate obvious analytical error. Compounded with the difference in sampling periods, this would indicate that this pH is not an artefact of sampling or analytical errors.

Considering that the Kintyre site has no proximity to any other industrial or mining activities, groundwater contamination is unlikely. There is a small risk that the construction of the bores may be introducing some contamination, but this is unlikely as newly sampled bores have been installed by different drilling companies to the historical bores.

In addition, there appears to be a correlation of high pH with geology, as bores 1PD, 4PD, 11PI and 14PS are installed into the Proterozoic rock. Bores with a lower pH of 9-10, appear to be only partially screened in the Proterozoic formations, suggesting that some mixing of waters may be decreasing the pH.

These considerations suggest that this high pH is natural and that the mineralogy in the Proterozoic formations is causing the unusually high alkalinity. Prior to mining this phenomenon will be investigated.

8.4.5 Potential Impacts and Management

8.4.5.1 Project Groundwater Demand

The estimated maximum demand of the Project for water is estimated to be 3.1 MLpd (Table 6-1). Project water will be supplied by pit dewatering and opportunistic storm water capture, with a water supply borefield to make up any shortfall.

The demand figure is made up of an estimated 1.4 MLpd for dust suppression, 1.5 MLpd in the process plant and 0.2 MLpd potable water for the accommodation village and safety systems.

Dewatering

Advance dewatering of the pit area will start during the construction phase and continue for the life of the mine. Dewatering will use several methods to maximise effectiveness, including; out of pit dewatering bores, in pit dewatering bores, horizontal seep wells and in pit sumps.

Production Borefield

A borefield will be developed adjacent to the north branch of the Yandagooge Creek to access water from the upper and lower Paterson Aquifers. With the design peak demand of 3.1 MLpd and based on an average bore yield of 0.5 MLpd, sustainable over a period of 12 years, the borefield will comprise a minimum of seven duty bores, plus three standby bores. Each bore will be located nominally 1.5 km apart (+/- 500 m) to minimise borefield drawdown interference.

8.4.5.2 Pit Dewatering

The cumulative impact of dewatering the Kintyre pit was simulated using the calibrated regional model in conjunction with the water supply simulation. Abstraction from out-of-pit dewatering bores was simulated using the MODFLOW-SURFACT fracture well package, while dewatering from in-pit sumps was simulated using drain nodes.

The results of the cumulative dewatering simulations suggest that pit influx would stabilise at about 1.1 MLpd after the first 1.5 years. The cone of water table depressurisation will be a maximum of 220 m in the centre of the pit, decreasing away from the pit, with the limits of discernible drawdown impacts (nominally the 1 m drawdown contour) at the end of mining predicted to extend about 5 km from the pit (Tetra Tech, 2012b) (Figure 8-7).

At the cessation of mining activities, the dewatering system will be turned off and the groundwater will be allowed to rebound to static conditions. It is anticipated that a pit lake will form in the mined out pit.

8.4.5.3 Pit Lake

The lakes that form in open pit voids upon completion of mining can have a significant impact on the environment and are often the most challenging aspects of mine closure.

This section details the results of modelling conducted by Cameco, of the lake that is expected to develop in the Kintyre open pit, and discusses the physical and chemical properties of the pit lake, and potential impacts on groundwater and fauna.

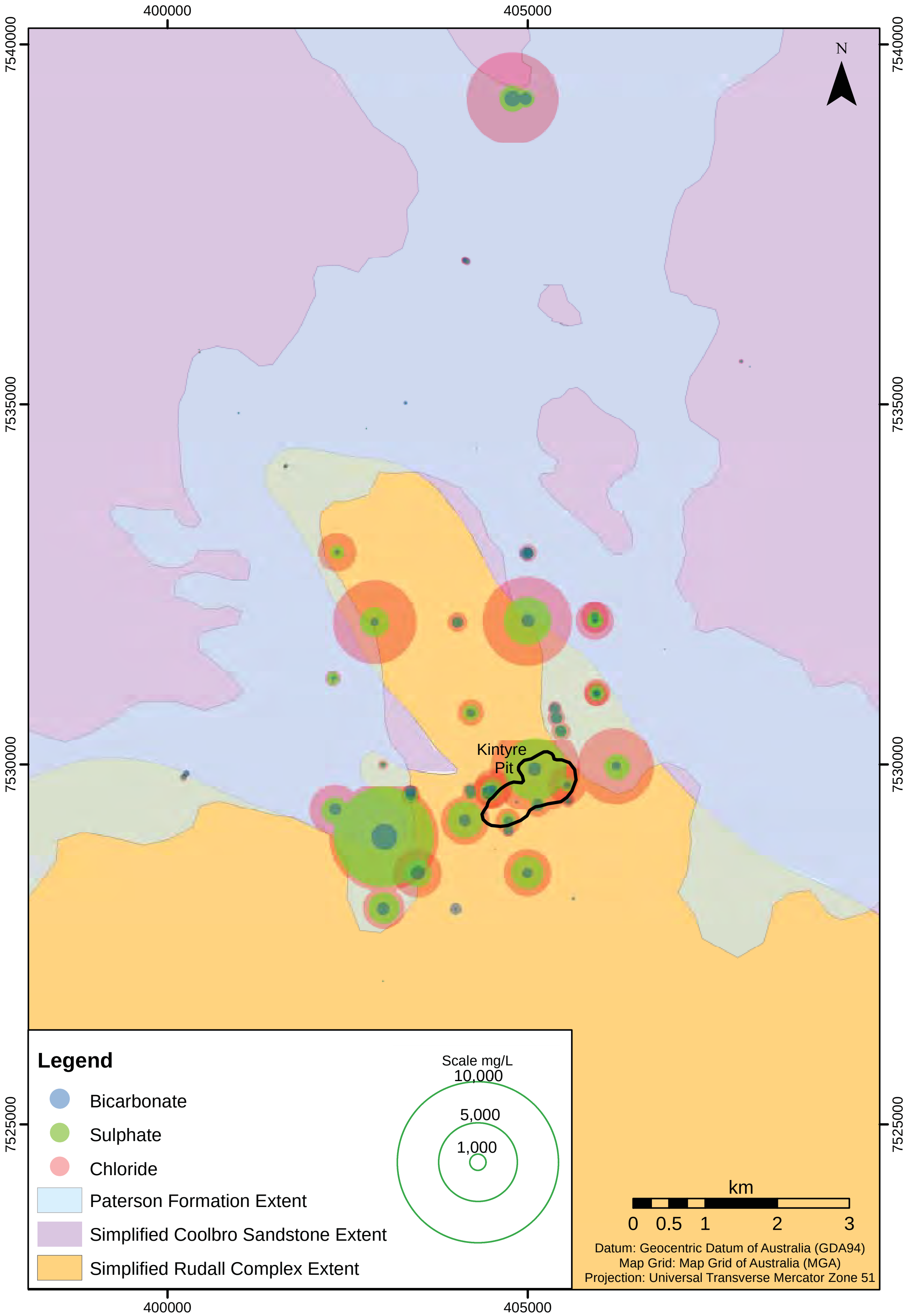


Figure 8-6: Chloride, sulphate, and bicarbonate ion concentration in groundwater

Hydrogeological Water Balance

Prior to the commencement of mining, boreholes are installed in and around the pit to remove the in-flowing groundwater. This action acts to depress the groundwater level over the dewatering area such that the pit becomes a low point towards which everything within the cone of depression flows. When dewatering ceases once mining is complete in most systems the groundwater rebounds to pre-mining levels.

At Kintyre, groundwater flow simulation results suggests that pit lake water elevations will rise rapidly after cessation of mining and approach a steady state of around 270 mAHD after about 100 years. Water balance results indicate that groundwater inflow accounts for between about 57% to 70% of the total inflow to the pit lake, with rainfall making up the difference.

Kintyre is located in a low rainfall/ high evaporation area. Once mining ceases and groundwater is allowed to rebound, the evaporation from the newly exposed pit lake surface has a significant impact on the rise of groundwater levels, effectively acting in the same manner as a dewatering well to depress the area around the pit, permanently creating a depression towards which groundwater flows.

At Kintyre, the water table is not expected to rebound to pre-mining levels after dewatering has ceased, as precipitation and recharge is low. Therefore, the pit lake is predicted to form a terminal sink.

Terminal Sink

Under a terminal sink the pathway for the contamination of groundwater from a source such as a pit lake is eliminated with no outflows of pit water into the receiving environment. This is illustrated by Figure 8-8 which shows the interaction of groundwater and water seeping from an open pit under different groundwater flow scenarios. The terminal sink is a highly advantageous situation from a risk of contamination point of view.

Interaction with Groundwater

Under terminal sink conditions there is no flow from the pit into the groundwater, rather the flow is from groundwater to the pit. This establishes a minor cone of depression around the pit but has no impact at a regional level.

Fate and Transport Modelling

Fate and transport modelling was completed utilising particle tracking to determine the path of the water flow from monitoring bores that have uranium concentrations above 0.1 mg/L based on water quality data collected by Cameco and its predecessors from 1987 to 2012. Particle tracking was simulated during life of mine and 10,000 years post closure.

Results confirm that the groundwater depression created by the open pit acts as a terminal sink. All particles migrate toward and are captured by the pit lake. There will therefore be no flow into the aquifer out of the pit, and therefore no potential for the pit lake to contaminate the aquifer. Similarly, any seepage to groundwater beneath the waste rock dump or the tailings management facility is expected to migrate towards the open pit rather than the regional aquifer.

Baseline Groundwater Quality

The chemistry of the groundwater is dominated by sodium and chloride with significant concentrations of sulphate, alkalinity and hardness. Concentrations of major ions generally fluctuate only slightly in response to rainfall, suggesting recharge areas are some distance from the site. General groundwater quality for different geological units is given in the following Table 8-6 (Dames & Moore, 1993; MWH, 2010). These data are an indication of the existing groundwater quality and do not represent the full data set.

Radionuclide activity and concentrations show high fluctuation between lithologies and is strongly affected by the presence of the uranium mineralisation. Gross alpha activity ranges from below the minimum detection limit to 21,000 mBq/L and gross beta activity ranges from 390 mBq/L to 200,000 mBq/L. The most common radionuclides in ground water are from the U-238 and the Th-232 decay series. Radionuclides in the decay series of these two elements and all isotopes of the U-235 decay series are highly immobile or have short half-lives and are not expected to be present in significant amounts in groundwater. The highest activities in the previous table are present in the groundwater sampled from a bore installed in the ore body.

Pit Lake Model

A post-closure model was developed to predict the water chemistry during a simulation period of 600

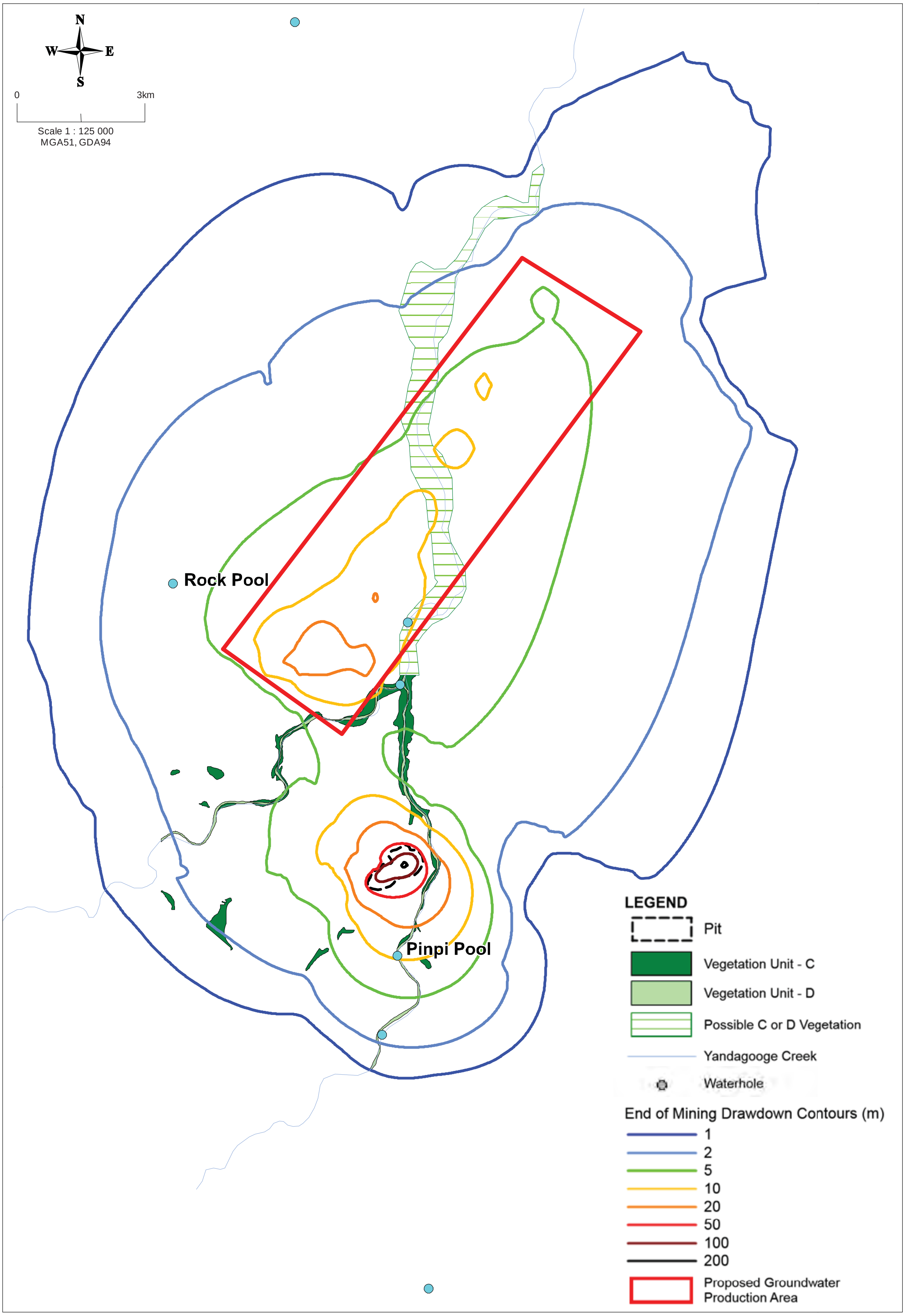


Figure 8-7: Modelled water table drawdown at end of mining

years. From the hydrogeological water balance it is expected that evaporation will far exceed precipitation and any other inflows such that the water quality is predicted to become saline and alkaline with elevated concentrations of boron, chlorine, manganese, molybdenum, sodium, and uranium in the pit lakes.

Saturation indices are indicators of whether a mineral is likely to precipitate or dissolve in a fluid such as ground water. A value <0 indicates that the ground water is undersaturated with respect to the mineral and dissolution of the mineral from solid phase should occur. If the value = 0, the ground water is at equilibrium with respect to the mineral. When the value is >0, the ground water is supersaturated with respect to the mineral, and precipitation is likely to occur. Table 8-7 indicates minerals that are expected to be supersaturated in the pit lake and precipitate, removing metals from solution (Tetra Tech, 2012f).

Sufficient water quality data has been collected over the various investigation periods to establish a statistically robust set of baseline water quality data. These baseline data will be used to determine whether the mining activities are having a negative impact on the groundwater regime.

The pit lake model predicts that the pH will decrease slightly from around 8 and stabilise at approximately 7.5. Kinetic results indicate a higher pH of approximately 9.5 in the initial weeks of testing which steadily decreases, until approximately 6 months of leaching where an increase to approximately 9.5 is seen again, coinciding with higher concentrations of lead, copper, manganese and zinc and possibly indicating the dissolution of minor carbonate minerals. Subsequently, the pH decreases again to approximately 7.5. It is unlikely the pH of the pit lake will be greater than predicted by the model. A system in equilibrium with the atmosphere cannot increase greater than 8.3 if there is sufficient calcium present. This is the pH at which the mineral calcite forms and acts as a buffer.

The pit lake model predicts uranium concentrations to be 4-5 mg/L. In oxidising conditions uranium occurs as U(VI) as the highly soluble uranyl ion (UO_2^{2+}). The solubility of this ion is enhanced by the presence of sulfate, carbonate, hydroxide, fluoride, chloride, nitrate, phosphate or organic ligands such as humic or fulvic acids. Under acidic conditions the uranyl-sulfate complex will dominate, while under alkaline conditions the uranyl-carbonate complex will dominate. The concentration of uranium in water under optimal conditions can reach into thousands of mg/L and travel great distances.

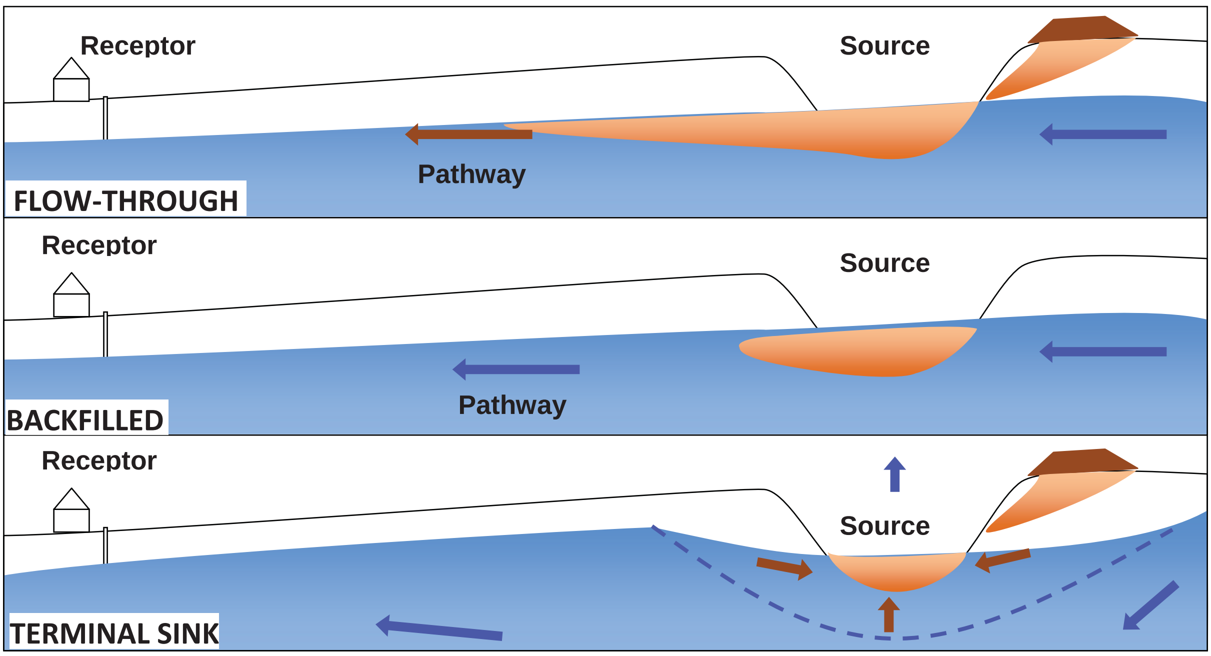


Figure 8-8: Interaction of groundwater and water seeping from an open pit under different groundwater flow scenarios

Table 8-6: General groundwater quality

Parameter	Upper Paterson Fm	Basal Paterson Fm	Coolbro Sst and Deposit (50 – 100 m)	Deposit, schists & carbonates (100 – 150 m)
pH	6.9 – 8.5	7 – 8.5	6 – 12.1	6.4 –12.5
Conductivity (µS/cm)	850 –18 710	920 – 8 200	215 – 18 000	160 – 21 000
Colour (Hazen units)	<2.5 – 7.5	<2.5 – 35	<2.5 – 30	-
Turbidity (NTU)	2 – 26	1 – 50	0.2 – 15	-
Total dissolved solids (TDS)	550 – 12 270	570 – 5 170	120 – 11 900	930 – 14 260
Suspended Solids (TSS)	4 – 830	<1 – 245	<1 – 108	30 – 290
Total organic carbon (TOC)	1 – 3	1 – 2	1.3 – 2	-
Sodium (Na^+) (mg/L)	160 – 8 360	210 – 1 510	12 – 3 635	8 – 3 750
Potassium (K^+) (mg/L)	16 – 350	7 – 98	4 – 1 071	4 – 320
Calcium (Ca^{2+}) (mg/L)	19 – 200	18 – 578	10 – 510	4 – 530
Magnesium (Mg^{2+}) (mg/L)	14 – 410	16 – 136	0.1 – 370	<0.1 – 560
Ammonium (NH^{4+}) (mg/L)	<0.01 – 0.24	<0.01 – 0.5	<0.01 – 1.5	<0.01 – 2.2
Chloride (Cl^-) (mg/L)	102 – 5 370	141 – 1 832	16 – 5 695	12 – 5 245
Sulfate (SO_4^{2-}) (mg/L)	46 – 2 250	77 – 1 050	7 – 1 965	3 – 3 440
Nitrate (NO_3^-) (mg/L)	<0.1 – 24	<0.1 – 22	<0.1 – 43	0 – 9
Phosphate (PO_4^{2-}) (mg/L)	<0.01 – 4	<0.01 – 6.1	<0.01 – 1	<0.01 – 0.97
Fluoride (F^-) (mg/L)	<0.01 – 12	<0.1 – 4.5	<0.1 – 15	<0.3 – 18
Silica (SiO_2^{2-}) (mg/L)	5 – 59	6 – 50	2 – 80	0.6 – 40
Bicarbonate (HCO_3^-) (mg/L)	77 – 877	44 – 758	1.2 – 661	62 – 792
Total hardness ($CaCO_3$) (mg/L)	108 – 2 086	123 – 1 171	45 – 2 795	39 – 3 152
Carb hardness ($CaCO_3$) (mg/L)	70 – 1 890	40 – 572	45 – 1 300	39 – 1 325
Non-carb hardness (mg/L)	0 – 1 315	0 – 1 131	0 – 2 552	1 – 2 878
Total alkalinity (mg/L)	70 – 798	40 – 670	67 – 1 386	57 – 2 085
Silver (Ag) (mg/L)	<0.1 – 0.06	0.01 – 0.08	<0.01	<0.01 – 0.05
Aluminium (Al) (mg/L)	<0.05 – 28	0.5 – 4.5	<0.005 – 4.7	0.1 – 4.4
Arsenic (As) (mg/L)	<0.05 – 0.025	<0.002 – 0.11	<0.005 – 0.9	<0.005 – 0.015
Boron (B) (mg/L)	<0.2 – 5.3	<0.1 – 1.7	<0.01 – 0.99	<0.01 – 2
Barium (Ba) (mg/L)	<0.02 – 0.04	<0.02 – 0.13	<0.02 – 0.58	<0.02 – 0.16
Cadmium (Cd) (mg/L)	<0.01 – 0.1	<0.01 – 0.01	<0.01 – 0.01	<0.01 – 0.02
Cobalt (Co) (mg/L)	<0.01 – 0.8	<0.01 – 0.02	<0.01 – 0.02	<0.01 – 0.02
Chromium (Cr) (mg/L)	<0.01 – 0.1	<0.01 – 0.03	<0.01 – 0.71	<0.01 – 0.45
Copper (Cu) (mg/L)	<0.02 – 0.8	<0.01 – 0.44	<0.02 – 0.8	<0.02 – 0.53
Iron (Fe) (mg/L)	<0.03 – 54	<0.03 – 0.13	<0.03 – 8	<0.03 – 4.3
Mercury (Hg) (mg/L)	<0.0001 – 0.0003	<0.0001	<0.0001	<0.001 – 0.09
Manganese (Mn) (mg/L)	<0.01 – 14	<0.01 – 1.2	<0.01 – 4.8	<0.01 – 96
Molybdenum (Mo) (mg/L)	<0.01 – 0.02	<0.01 – 0.05	<0.01 – 0.06	<0.01 – 0.02
Nickel (Ni) (mg/L)	<0.02 – 0.2	<0.02 – 0.05	<0.02 – 0.04	<0.02
Lead (Pb) (mg/L)	<0.02 – 0.32	<0.02 – 0.04	<0.02 – 0.15	<0.02 – 0.44
Selenium (Se) (mg/L)	<0.005 – 0.008	<0.002 – 0.006	<0.002 – 0.01	<0.005 – 0.01
Vanadium (V) (mg/L)	<0.01 – 0.15	<0.01 – 0.04	<0.01	<0.01 – 0.49
Zinc (Zn) (mg/L)	<0.02 – 6.7	<0.02 – 4.8	<0.02 – 0.15	<0.02 – 0.33

Parameter	Upper Paterson Fm	Basal Paterson Fm	Coolbro Sst and Deposit (50 – 100 m)	Deposit, schists & carbonates (100 – 150 m)
U (µg/L)	<1 – 130	<1 – 120	<1 – 320	<1 – 170
Th (µg/L)	<1 – 9	<1 – 4	<1 – 3	<1 – 3
Gross Alpha (mBq/L)	<70 – 21 000	<70 – 4 000	<70 – 21 000	<70 – 8 800
Gross Beta (mBq/L)	690 – 9 900	590 – 4 600	390 – 200 000	470 – 9 400
$Radium^{226}$ (Ra -mBq/L)	6 – 610	11 – 1 200	18 – 180 000	16 – 760
$Polonium^{210}$ (Po -mBq/L)	<7 – 110	<7 – 280	<7 – 17 000	<20 – 100
$Lead^{210}$ (Pb -mBq/L)	<15 – 70	<15 – 110	<15 – 3 800	<70 – 970
$Thorium^{230}$ (Th -mBq/L)	<7 – 1 400	<7 – 470	<7 – 170	<7 – 98

Table 8-7: Minerals predicted to precipitate in the pit lake and remove metals from the water

Mineral Name	Formula	Mineral Name	Formula
Silver Selinide	Ag_2Se	Dolomite	$CaMg(CO_3)_2$
Aluminum Hydroxide	$Al(OH)_{3(am)}$	Ferrihydrite	$Fe(OH)_3(am)$
Alunite	$KAl_3(SO_4)_2(OH)_6$	Ferrihydroxichloride	$Fe(OH)_{2\cdot7}Cl_{0\cdot3}$
Aragonite	$CaCO_3$	Fluorite	CaF_2
Bariumarsenate	$Ba_3(AsO_4)_2$	Gibbsite	$Al(OH)_3$
Barite	$BaSO_4$	Goethite	FeO(OH)
Boehmite	AlO(OH)	Gypsum	CaSO4 $2H_2O$
Calcite	$CaCO_3$	Halite	NaCl
Cerrusite	$PbCO_3$	Na-Jarosite	$NaFe^{3+}{}_3(OH)_6(SO_4)_2$
Chalcedony	SiO_2	Natron	$Na_2CO_{3\cdot10}H_2O$
Carbon Dioxide	$CO_{2(g)}$	Pyromorphite	$Pb_5(PO_4)_3Cl$
Cuprousferrite	$CuFeO_2$		

The concentration of uranyl complexes is reduced in solution by:

- Coprecipitation: particularly with carbonate and iron-aluminium-oxy-hydroxides;
- Adsorption: onto negatively charged surfaces of sulfides, clays and organic matter as well as iron, manganese and aluminium oxyhydroxides; and
- Decreasing Eh: uranium becomes highly insoluble under reducing conditions and in contact with hydrogen sulfide (H_2S).

The maximum groundwater concentration of uranium for the entire dataset (n=295) is 0.49 mg/L. This indicates that potential high concentrations are controlled by one or all of the above factors.

In the pit lake, soluble uranium present in the top, oxidised layer will most likely be reduced with the precipitation of calcite and other carbonate minerals.

Since this is a mining pit and therefore has an unnaturally deep shape, the lake is expected to be highly stratified as convection and wind movement only mixes the top layer of water. Below this top layer the pit lake water quickly becomes depleted in oxygen and reducing conditions form. Soluble uranium in solution in the oxygenated layer will precipitate quickly on contact with these reducing conditions, and may also be removed on contact with hydrogen sulfide gas that may reach the surface. Uranium concentrations will therefore occur at concentrations below detection limits in the lower portion of the lake, and may in fact result in the average lake concentrations being significantly below the predicted 4-5 mg/L.

Salinity

The final pit lake water will become hypersaline over time driven by the high levels of evaporation. For comparison the salt content of average sea water is approximately 3.5%, while the Dead Sea is approximately 30%. The maximum salinity of the pit lake is expected to reach approximately 10%.

Impact on Wildlife

Salinity is likely to be the defining characteristic when considering the impacts on wildlife from any potential consumption of pit water. As a result of this high salinity it is expected that birds will avoid this body of water in favour of other nearby fresher sources.

Regardless of the potential limitations in predicting metals concentration in the pit water and the potential impact on wildlife, the hyper-saline conditions that will develop through evaporation will render the pit lake unsuitable for fauna usage. Therefore while it may be desirable to have a high level of certainty around pit water metal concentrations and potential impact on wildlife, it is not a critical factor in predicting impact or toxicity as it is over-ridden by the salinity of the water and the resulting benefitial use of the pit water.

Cameco commits to undertaking a an ecological risk assessment with a focus on avian fauna, of the final pit lake, using an updated pit void closure model, prior to the conclusion of mining.

Implications of Partial Backfilling of the Open Pit

Cameco is intending to partially backfill the western pit with waste rock. While this scenario has not been modelled as part of the above work, extensive column testing of the waste rock material has been completed which indicates that leaching from waste rock would not significantly impact pit lake water quality. Cameco will undertake modelling of this option and report the results in the Mine Closure and Rehabilitation Plan to be provided to DMP for review prior to the commencement of construction.

Backfilling Versus not Backfilling the Open Pit

In some circumstances in open pit mining it is considered desirable to back fill an open pit. However there are often site specific reasons why this can't occur. At Kintyre there are a number of reasons why it is considered preferable not to backfill the Pit. These are,

- Groundwater protection – the current groundwater and open pit void modelling suggests that by not backfilling the Pit it will remain a terminal sink, therefore removing the groundwater contamination pathway, that is, the movement of potentially contaminated Pit water into the groundwater.
- Backfilling the entire Pit would sterilise the underground resource potential. Cameco proposes to partially backfill the western end of the Pit but retain access to the floor of the Pit in the Eastern Zone which would allow portal access to an underground resource if desirable in the future.
- The cost of backfilling the pit would render the project uneconomic. The partial backfilling of the western zone can be conducted as part of waste stripping in the eastern zone and as such does not incur additional cost. While partial backfilling is not expected to have sufficient impact on evaporation of Pit water to change the pit function to change from a terminal sink to a flow through pit (as shown in Figure 8-8) this scenario has not been modelled and further modelling, including this option will be conducted during the next phase of project development.

Cameco accepts that the modelling of groundwater and interaction is not an exact science and at best may predict trends rather than accurate concentration levels. Cameco commits to reviewing the groundwater model to confirm pit water quality, and interaction with groundwater during the next phase of development.

Cameco commits to gathering data on the volume and quality of groundwater pit water inflows during mining operations to revise the final pit void closure models both during and at the ceasation of mining and reporting on the revised model via the revised mine closure plan.

8.4.5.4 Groundwater Abstraction from the Borefields

The maximum design Project demand is 3.1 MLpd which will be supplied by pit dewatering, storm water capture and the water supply borefield. The proposed borefield will comprise ten production bores (seven active water supply bores, plus three standby bores), pumping at an approximate average rate of 0.5 MLpd over the mine life.

As a contingency measure, the borefield abstraction has been simulated at 5 MLpd, 1.9 MLpd more than required. The results of model simulations of the water supply area demonstrate that there is more than sufficient borefield capacity and contingency to sustain an overall abstraction of 3.1 MLpd from sediments of the Paterson Formation and Coolbro Sandstone over the mine life without causing significant drawdown or loss of bore productivity.

There are no other users of the groundwater within 50 km of the Project area, and discernible drawdown impacts of the borefield and pit dewatering (based on the 1 m drawdown contour) are not expected to extend further than about 10 km from the abstraction bores (Figure 8-7). Therefore, there are not expected to be any impacts on other water users, including water supplies at local Aboriginal communities and places of cultural value such as Lake Dora and water holes associated with Rudall River.

The potential impact on groundwater-dependent vegetation is discussed in Section 8.5.4.2. The vegetation condition monitoring programme will include monitoring control sites and potential impact sites in susceptible vegetation communities within the predicted groundwater drawdown zone. Should a decline in vegetation health be observed within the predicted drawdown zone and correlated with changes in groundwater levels, then contingency measures will be implemented. These could include re-injection of groundwater or irrigation of affected areas. In the water supply borefield, other management measures would include rotating of bores to minimise drawdown.

The hydrology of the Yandagooge Creek and its catchment is dominated by seasonal rainfall and is unlikely to be affected by groundwater drawdowns (Section 8.3). Several ephemeral rockholes are present in the Yandagooge Creek system including Pinpi Rockhole, about 2 km south of Kintyre. Analysis of the hydrology (Appendix J) of these features showed that:

- the water table is separated from the riverbed in the pools by an intervening unsaturated zone some 4-20 m thick depending on the pool;
- there is no relationship between river levels and water levels in shallow monitor bores nearby to the creek; and
- water quality is orders of magnitude different between the pools and the aquifer.

Consequently it is accepted that the rockholes are surface water features hydraulically disconnected from the aquifer, that are filled following significant streamflow events, then gradually drain through seepage and evaporation over the subsequent months. There should be no impact on these pools as a result of groundwater drawdowns.

A Groundwater Management Plan has been prepared detailing a monitoring programme including abstraction volumes, groundwater levels, river water levels, and groundwater quality. Trigger levels have been set based on the groundwater monitoring and baseline testing, and contingencies developed should any triggers be breached. Contingencies include reconfiguring the timing or location of abstraction, developing new bores in other parts of the aquifer or other aquifers or reducing the draw from production bores near the affected feature.

8.4.5.5 Seepage from Mine Infrastructure to Groundwater

There is the potential for seepage from spills within the process plant area, or leaks from site infrastructure (such as tailings pipelines, fuel tanks etc.) to cause groundwater contamination. Cameco has considered the risk potential for contamination during the preliminary design phases and has designed the infrastructure to minimise the risk.

Engineered pads will be constructed to manage rainfall and run off seepage from the stockpiles of mineralised overburden and contaminated waste. Modelling has been undertaken to predict water quality of run off and seepage water emanating from the stockpile of mineralised overburden and the contaminated waste stockpile. Drainage from these areas will be directed to the evaporation pond.

Cameco will implement the Chemical and Fuel Storage Management Plan which includes control measures in case of a spill from process or infrastructure areas.

8.4.5.6 Seepage from Mineralised Stockpiles

Cameco has stated that the mineralised overburden stockpile may be temporary. The material may be processed during (for blending purposes), or after, mining operations have been completed, depending on the economics at the time.

Cameco has undertaken modelling of the stockpile to determine the potential for rainfall to either run-off the stockpile or to seep through the stockpile and leach metals and or radionuclides into the soil.

Given the high evaporation present at the site, infiltration into the stockpile is low. Water that does infiltrate either leaves the system as evaporation or ultimately becomes seepage into the foundation soil. Seepage is only expected to occur after large storm events. The height of the stockpile also has a significant impact on seepage with a taller stockpile contributing to less groundwater seepage.

Modelling has concluded that peak seepage corresponds to the largest simulated precipitation event of 119.2 mm on day 1,106. The resultant seepage flux into the foundation soil is low and the average flux for the 1.5 Mt (10m height) and 6.0 Mt (20m height) scenarios are 8.2e-5 m^3/day/m and 4.4e-5 m^3/day/m, respectively. The average seepage rate decreases with a taller mineralised overburden stockpile due to the volume of material water must migrate through to reach the base of the stockpile. Seepage in general occurs only after large storm events (Tetra Tech, 2012d).

Cameco will investigate the base soil to determine porosity and if necessary an engineered clay pad will be constructed to limit seepage to soil and groundwater.

8.4.5.7 Tailings Management Facility and Water Storage and Evaporation Ponds

The Integrated Waste Landform - Tailings Management Facility (IWL-TMF) would have a nominal free standing final height of around 20 m, and would be designed to store approximately 7 Mt of tailings material over the life of the operation. The tailings consist of the neutralised filter cake, post acid leaching. The slurry would be deposited in the TMF at a rate of approximately 600,000 tpa. The TMF would consist of an integrated system with a total footprint of approximately 38 ha (Section 8-12).

The TMF would have a minimum 1 m of freeboard for the management of stormwater at the conclusion of tailings deposition. Supernatant water will be drained from the facility through the central reclaim tower and recycled through storage and evaporation ponds or back to the plant when suitable.

A liner system has been designed to limit seepage from the impoundment to the adjacent sub-surface soil and groundwater. The limits of the tailings cell will be lined with a double membrane liner system fitted with a leachate collection system above the liners and a leak detection system between the liners.

The TMF and evaporation pond liner systems were designed based on best available technology practice and previous experience. The proposed Kintyre TMF and evaporation pond liner systems consist of a 60 mil (1.5 mm) High Density Polyethylene (HDPE) secondary (bottom) liner and a 60 mil (1.5 mm) HDPE primary (top) liner with a Leak Collection and Removal System (LCRS) installed between the liners. The LCRS design ensures sufficient flow capacity to allow evacuation of fluids between the liners. Any leaks through the primary liner would flow to the leak collection sump through the drain liner and geo-net drainage layers.

The Kintyre liner system design utilises a Geo-synthetic Clay Liner (GCL) which will be used in lieu of a 150 mm thick layer of Low Permeable Soil (LPS) material due to the unknown availability of onsite LPS borrow materials. The GCL soil liner provides an equivalent 300 mm minimum thickness of $1x10^{-6}$ cm/sec or lower permeability soil layer. Subgrade preparation for the GCL placement will involve compaction to 95% of the maximum dry density based on standard ASTM D 698 for testing compaction. Rocks larger than 38 mm in diameter will first be removed from the upper 150 mm of the subgrade prior to compaction.

In summary, the proposed TMF and Evaporation Pond liner systems will consist of the following components, from bottom to top:

- minimum 150 mm-thick layer of properly compacted Liner Bedding Fill (prepared subgrade);
- needle-punched reinforced GCL which is equivalent to having a 300 mm-thick layer of compacted soil having a permeability no greater than 10^{-6} cm/s;
- 60 mil (1.5mm) HDPE secondary (bottom) liner (drain liner on side slopes);
- HDPE geo-net drainage layer (pond floor); and
- 60 mil (1.5mm) HDPE primary (top) liner.

Any leakage through the primary liner will flow to the leak collection sump through the geo-net or drain liner. The sump will be equipped with an automatic, fluid-level activated pump. The pump has been sized to remove fluids such that the hydraulic head (pressure) on the secondary liner is minimised.

Additionally, the TMF liner system will include the following liner over-drain system layers above the top liner:

- 10-oz non-woven geotextile cushioning layer;
- 450 mm-thick drainage gravel layer;
- network of corrugated, perforated polyethylene leachate collection pipes; and
- 150 mm-thick sand filter layer to separate the tailings from the drainage layer.

The TMF design has been prepared in accordance with generally accepted engineering practices and Best Available Technology industry practice to provide a high level of groundwater protection and Cameco considers that any residual risk to groundwater is very low and acceptable. As a contingency, Cameco will establish monitoring bores adjacent to the facility to monitor water quality around and beneath the facility to confirm the performance of the liner system.

8.4.6 Commitments

To develop further certainty about the Project groundwater regime, Cameco commits to:

- implementing the Groundwater Management Plan;
- modelling the impact of backfilling the western zone of the open pit with waste rock and reporting the outcome in a revision of the Mine Closure and Rehabilitation Plan to be submitted to DMP for review prior to the commencement of construction;
- address the risks associated with the pit lake in the Mine Closure Plan;
- prepare a post-closure monitoring plan in order to confirm predicted effects;
- establish a robust set of baseline water quality data based on statistically defensible concentrations for individual parameters to inform water quality objectives;
- preparing and submitting a detailed Groundwater Operating Strategy as part of the application of a 5C groundwater licence; and
- designing, constructing and operating the IWL-TMF using current Best Available Technology and practices.

Cameco also commits to ongoing development of the pit lake model, including an ecological risk assessment on impacts to avian fauna from water chemistry.

8.4.7 Outcome

In summary, the abstraction of 3.1 MLpd of groundwater from the Paterson Formation Sedimentary Aquifer is not expected to result in any unacceptable environmental impacts. Based on the drilling, testwork and modelling completed and the proposed IWL-TMF and pond management measures, Cameco believes the Project can be implemented in a manner which meets the EPA objective.

8.5 Flora and Vegetation

8.5.1 Objective

The objective agreed to within the ESD with regards to flora and vegetation is to maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

8.5.2 Relevant Legislation and Policy

8.5.2.1 *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 is given special protection under this Act and the following conservation categories may be applied to certain species:

- T: Threatened Flora (Declared Rare Flora [DRF] – Extant) under Schedule 1 of the WC Act. Taxa that 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 (DRF – Extinct) under Schedule 2 of the WC Act. Taxa which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such.

Taking of Threatened Flora cannot occur without special permission from the WA Minister for the Environment.

The Department of Parks and Wildlife (DPaW) also produces a list of Priority species and ecological communities under the WC Act. Priority flora categories are as follows:

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

2: 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.

3: 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.

4: 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) Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

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

Proponents who intend to disturb Priority flora should first consult with DPaW regarding the impact of the proposal on the species' conservation status.

DPaW has been identifying and informally listing threatened ecological communities (TECs) since 1994. As of April 2012, 102 TECs have been endorsed by the Environment Minister, only two of which occur in the Pilbara (www.dec.wa.gov.au/management-and-protection/threatened-species.html).

Ecological communities with insufficient information available to be considered a TEC, or which are rare but not currently threatened, are placed on the Priority list and referred to as priority ecological communities (PECs). To April 2012 there were 298 PECs listed by DPaW including 30 communities present in the Pilbara. Proponents who intend to disturb a PEC should first consult with DPaW regarding the impact of the proposal on the ecosystem's conservation status.

8.5.2.2 Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides protection for nationally or internationally threatened native plants and ecological communities. The EPBC Act provides for the identification and listing of threatened species, development of conservation advice and recovery plans, development of a register of critical habitats, recognition of key threatening processes and where appropriate reducing the impacts of these processes through threat abatement plans.

Under the EPBC Act listed threatened species are given one of the following classifications:

- Critically Endangered - A taxon is Critically Endangered when it is considered to be facing an extremely high risk of extinction in the wild.
- Endangered - A taxon is Endangered when it is considered to be facing a very high risk of extinction in the wild.
- Vulnerable - A taxon is Vulnerable when it is considered to be facing a high risk of extinction in the wild.
- Conservation Dependent - A taxon is Conservation Dependent if the species is the focus of a specific conservation programme the cessation of which would result in the species becoming vulnerable.

Also under the EPBC Act, the Minister for the Environment is able to provide special protection to ecological communities of national importance that are subject to process that threaten to destroy or significantly modify these communities. The Commonwealth list of TECs under the EPBC Act can differ from the State TEC list. No TECs listed in the Pilbara by the DPaW are listed under the EPBC Act. Any proposal that is likely to result in impacts to an EPBC Act listed TEC must be referred to the Commonwealth Environment Minister to determine if assessment under the EPBC Act is required.

8.5.2.3 WA Clearing Regulations

The WA Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (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. The Project area occurs within an area that is classified as an ESA as a result of historically being within the old boundary of the Rudall River National Park (Section 8.9.4). Any clearing undertaken as part of Cameco's exploration programme for Kintyre has been done in accordance with clearing permits issued by Department of Mines and Petroleum (DMP) on behalf of the Department of Environment and Regulation (DER).

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.

8.5.2.4 EPA Policies

The EPA has produced Position Statement No. 2 for the environmental protection of native vegetation in WA specific to the clearing of native vegetation (EPA, 2000a). 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. These elements have been considered in Section 8.5.5 of this ERMP.

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. Based on the guidance provided in Position Statement No. 3 Cameco has undertaken Level 2 biological surveys for assessment of the impacts of the Kintyre Uranium Project. This has included desktop studies, a reconnaissance survey and comprehensive flora survey of the Project area to assess the conservation values of the site in a local and regional context. Further detail on the requirements for flora and vegetation surveys is provided in EPA Guidance Statement No. 51 (EPA, 2004b). The remnant vegetation in the Project area was surveyed using the methods set out in accordance with this guidance statement (Section 8.4.3).

The EPA also provides guidance on the rehabilitation of terrestrial ecosystems (EPA, 2006). The Mine Closure and Rehabilitation Plan has been prepared in accordance with this guidance (Appendix D17).

8.5.3 Proponent Studies and Investigations

The Project area has been extensively surveyed as summarised in Table 8-8. A summary of the flora and vegetation of the Project area is presented in Bennett Environmental Consulting (2011a) and (2011b) (Appendix L).

Following a meeting between Cameco, its botanical consultants and representatives of the DPaW, the 2010 survey was designed to cover the entire Kintyre Project leases and to meet the requirements of a Level 2 survey under the EPA Guidance No. 51 (EPA, 2004b) for terrestrial flora and vegetation surveys. Dr van Leeuwen of the DPaW confirmed that permanent 50 m by 50 m quadrats were to be used, or strip quadrats where vegetation communities were narrow (e.g. along creeklines).

In 2011 the access road to Kintyre was surveyed. Where the proposed route deviated from the existing track the corridor was surveyed with access by vehicle, helicopter and on foot. Approximately 6 km was inaccessible during this survey and was only viewed from the air. This section of the proposed access road was surveyed in 2012 using four-wheel

Table 8-8: Flora and vegetation surveys of the Project area

Author	Date of Survey(s)	Type of Survey
Hart, Simpson & Associates Pty Ltd (1994b and 1997)	Between 1986 and 1992 over a number of seasons and varied annual conditions.	Detailed flora and vegetation surveys including vegetation mapping of the Kintyre lease
Bennett Environmental Consulting (2007)	25 June – 4 July 2007	Flora and vegetation survey of proposed drilling area, village and associated infrastructure. Confirmed vegetation units mapped by Hart Simpson & Associates.
Bennett Environmental Consulting (2010)	27 April – 4 May 2010	Flora and vegetation survey of whole lease. Confirmed vegetation units mapped by Hart Simpson & Associates.
Bennett Environmental Consulting (2011b)	16 - 19 May 2011	Resurvey of selected quadrats following good rainfall
Bennett Environmental Consulting (2011a)	16 – 22 August 2011	Survey and vegetation mapping of access road between Kintyre and Telfer-Marble Bar Road following good rainfall
Bennett Environmental Consulting (2013)	12 – 19 October 2012	Targeted searches for Threatened and Priority flora. Resurvey of selected quadrats not surveyed in May 2011. Survey and vegetation mapping of an additional 6 km of access road (not previously accessible). Weed survey along Rudall River Road.

drive and quad bikes. Surveys of the access road were undertaken using relevés. Where a change in vegetation was observed, a site was recorded. Each relevé recorded all flora within 50 m of a central point. Taxa outside of this area, but in the same vegetation type were also opportunistically surveyed. The use of relevés was agreed to with Dr van Leeuwen of the DPaW.

Where species were unknown in the field they were collected, pressed and identified with the collection at the Western Australian Herbarium or the available botanical description.

8.5.4 Existing Environment

The Project area is located in the Little Sandy Desert (LSD1 – Rudall Subregion) as classified by the Interim Biogeographical Regionalisation for Australia (IBRA) (Thackway and Cresswell, 1995). The LSD1 sub region comprises sparse shrub-steppe over *Triodia basedowii* (hard spinifex) on stony hills, with River Gum communities and bunch grasslands on alluvial deposits in and associated with ranges (Kendrick, 2001).

A total of 34 vegetation units were recorded within and around the Project area during the 2007 and 2010 surveys. These units are grouped according to the following landforms: hillsides; base of hills; sand dunes; flat red sandy soils; lower slopes above creek; creek lines; and claypans (Table 8-9).

Bennett Environmental Consulting (2011b) noted that the vegetation within the site varied with the rocks and associated soils. The hillslopes in the northern section of the lease had scattered shrubs of *Acacia robeorum*, *Grevillea wickhamii* and *Senna glutinosa* as the dominant shrubs. *Acacia retivenea* was observed only in the southern area of the lease where the rocks were more schistose than in the northern area. *Eucalyptus leucophloia* was only recorded on a few hillslopes and was not a common taxon.

The sandy soils typically supported *Triodia basedowii* and *Triodia schinzii* associated with *Acacia ligulata* and *Stylobasium spathulatum*. The latter taxon was more common on the raised dunes rather than on the flatter sandy soils. *Dicrastylis georgei* and *Lachnostachys roseoazurea* were typically associated with the sandy soils across the lease.

The drainage lines varied with the taxa located on the hill slopes or flat areas. As an example Acacia retivenea was common in the drainage lines in the south of the lease but less common in the north of the lease. *Grevillea wickhamii* occurred across all vegetation units and did not appear to be restricted to a specific soil.

A comparison was made between the vegetation units recorded by Bennett Environmental Consulting and those described in Hart Simpson & Associates (1994b, 1997). Bennett Environmental

Table 8-9: Vegetation units and landforms of the Project area (after Hart Simpson & Associates, 1997)

Code	Vegetation Unit	Landform
WOODLANDS		
C	Drainage line Woodland of *Corymbia opaca*	Minor drainage lines
D	Woodland of *Eucalyptus camaldulensis*	Larger river channels
SHRUBLANDS[1]		
I	*Acacia dictyophleba* Shrubland over *Triodia basedowii* and *Triodia pungens*	Drainage lines on flat ground where there is outwash from hills
R	Mulga Shrubland	Wash away on edge of river
STEPPES		
A	Hummock Grass Steppe[2] dominated by *Triodia wiseana*	Stony hills
F1	*Acacia ancistrocarpa* and *Acacia ligulata* over *Triodia basedowii*	Flat plains
F2	*Acacia retivenea* Shrub Steppe1 over *Triodia wiseana*	Stony hills
F3	*Acacia inaequilatera* Shrub Steppe over *Triodia basedowii* and *Triodia pungens*	Low lying areas with slightly clayey soil
F4	Mixed Low Shrub Steppe over *Triodia basedowii*	Flat plains
F8	*Grevillea/Acacia* Shrub Steppe over mixed *Triodia* species on sand	Flat areas of sandy soils
F9	*Acacia dictyophleba* Shrub Steppe over *Triodia basedowii*	Flat plains
F10	*Acacia wanyu* Shrub Steppe over *Triodia wiseana*	Scree slopes, lower slopes of stony hills
G	Open Shrub Steppe over *Triodia basedowii*	Flat plains
MALLEE STEPPE		
O	Mallees of *Eucalyptus odontocarpa* over *Triodia basedowii*	Flat area of sandy soil
TREE STEPPE		
B	Trees of *Eucalyptus leucophloia* over *Triodia wiseana*	Stony hills
GRASSLAND		
L	Grassland[3]	Small areas below scree slopes
SHRUB SAVANNA[4]		
H	Sennas over grass	Low lying areas
SCRUBS		
E	Chenopod Dwarf Scrub	Low lying areas adjacent to claypans
COMPLEXES		
J	Sand dunes	Sand dunes
K	Claypans with little or no vegetation	Claypans with impeded or internal drainage
M	Sparse shrubs on clay soils	Low lying areas of impeded drainage
N	Drainage lines of *Acacia* and other scrubs over *Triodia pungens*	Drainage lines in stony hills or as outwash channels
P	Bare Stony Slope	Scree slope below stony hill
Q	White quartzite scree slopes	Apron around stony hills

Notes:

1. Shrubland – Shrubs 1.5-4m tall with a cover of 20-40%
2. Grass steppe – Varies from almost pure Triodia species to Shrub steppe
3. Grassland – Dominated by non-Triodia species
4. Shrub savannah – Shrubs and grasses present but dominated by non- Triodia species

Plate 8-5: Hummock grassland of *Triodia epactia* and *Triodia wiseana*

Photo courtesy of Bennett Environmental Consulting.

Plate 8-6: *Acacia ancistrocarpa* shrubland over closed hummock grassland of *Triodia basedowii* and *Triodia schinzii*

Photo courtesy of Bennett Environmental Consulting.

Consulting (2007, 2010) noted that fire had changed the make-up of the units between the surveys although when the sampling sites (quadrats and opportunistic sites) were overlain on the original vegetation map there was a reasonable correlation between them.

The key vegetation units mapped within the Project area by Hart Simpson & Associates 1997) are shown in Figure 8-9.

A total of 49 vascular plant families, 155 genera and 348 taxa (species, subspecies and varieties) were recorded during the surveys the most dominant of which were the Poaceae (grass family) and Fabaceae (pea family) and Malvaceae families (Appendix L).

Vegetation condition was rated during the 2010 survey in accordance with Keighery (1994). Prior to the 2007 survey, there had been good rainfall, but in 2009 a fire had burnt through a large portion of the area and 2010 was a very dry season. Above average rainfall was recorded in the first part of 2011 which resulted in a flush of growth and a number of annuals being recorded during the 2011 surveys that had not previously been observed. Vegetation condition across the Project area was typically excellent to very good.

Examples of vegetation communities within the Project area are presented in Plates 8-5 and 8-6.

A total of 28 vegetation units were recorded along the proposed access road during the 2011 and 2012 surveys. The majority of vegetation was grassland, predominantly *Triodia basedowii* and/or *Triodia schinzii* with emergent shrubs or trees. These units occurred across sand dunes, rivers, claypans and some rock outcrops where the vegetation changed slightly.

The key vegetation units mapped along the access road are shown in Figure 8-9. For detailed maps and a legend refer to Appendix L.

Vegetation condition along the proposed route was in very good to excellent condition, except where it was close to the existing Telfer – Marble Bar Road. The vegetation along the current Telfer Road varied considerably from excellent to degraded depending on the presence and density of *Cenchrus ciliaris* and *Aerva javanica* (Bennett Environmental Consulting, 2011a).

Seven introduced taxa were recorded in the Kintyre area and along the access road (Bennett Environmental Consulting 2011a and 2011b), none of which are Declared Weeds (Department of Agriculture and Food, 2010a) or listed as Weeds of National Significance:

- Buffel Grass (*Cenchrus ciliaris*), which is a perennial tussock grass was recorded throughout the Project area and is abundant along the verge of the access road and creek banks (Plate 8-7). This grass was deliberately and widely disseminated as a pasture plant, and is now common throughout the Pilbara and desert areas.
- The small shrub known as Kapok Bush (*Aerva javanica*), was found on Kintyre Hill which had been ripped after the original exploration phase. This was found to have spread to some additional locations in 2011. It was also recorded along the existing Telfer to Kintyre road.

- Beggars Ticks (*Bidens bipinnata*) was recorded on the bank of the southern arm of the creek. Several of the locations were sampled. This weed is regionally widespread.
- The melon (*Cucumis melo* subsp. *agrestis*) was also recorded from several locations. It occurs as scattered plants and was not observed as a dense mass.
- *Citrullus lanatus* was recorded in damp soil close to creeks and along the existing access road verge. Typically, it formed dense areas over the ground with several round fruits up to 150 mm wide.
- *Chloris virgata* was recorded from one claypan quadrat and only a few plants were recorded.
- *Malvastrum americanum* was recorded opportunistically from one quadrat associated with Corymbia opaca.

In addition a survey of the distribution of *Cenchrus ciliaris* along the Rudall River Road (from the Kintyre Project area to the Karlamilyi National Park) was undertaken in October 2012 which recorded dense stands of this weed along drainage lines and in creeks (Bennett Environmental Consulting, 2013).

8.5.4.1 Significant Flora

Significant flora that have been recorded in the Project area and along the access road are outlined in Table 8-10 and shown on Figure 8-10.

Based on a search of the DPaW Flora Database, several other Priority flora that could potentially occur within the Project area, were not found during surveys. These are listed in Bennett Environmental Consulting (2011a and 2011b) (Appendix L).

8.5.4.2 Groundwater Dependent Vegetation

The Project is bounded by two creek lines (Section 8.3.4) along which the species *Eucalyptus camaldulensis* (River Red Gum) and *Corymbia opaca* (Desert Bloodwood) grow just above the creek line. *E. camaldulensis* is known to use both groundwater and water held in the unsaturated vadose zone (above the watertable) depending on soil water availability (DoW, 2010). *C. opaca* may also be groundwater dependent (O'Grady *et al*., 2010), although there is no literature to indicate this is the case in Western Australia.

The DoW has undertaken a study in the Pilbara to determine the water depth ranges of dominant riparian plant species. It used the distribution of species across an ecological gradient and measured depth to groundwater or depth of inundation across that range.

The study determined water level ranges for 16 species across 23 sites located west and northwest of the Project area including on the Robe, Yule and De Grey Rivers and the Fortescue River at Millstream. Only one of the species, *Eucalyptus camaldulensis*, was recorded in the Project area in Community D (River channels with Woodland of *E. camaldulensis*) (Table 8-9).

The water level range of *E. camaldulensis* was calculated from the data collected and the results are summarised in Table 8-12. In this table a negative number indicates depth to groundwater and a positive number indicates depth of inundation.

There was little difference in water level ranges calculated across the four time periods. From data collected over 20 years, the mean minimum depth to water for *E. camaldulensis* was -1.16 m (from the minimum elevation of the species to the 20 year mean maximum water level) and the mean maximum depth was -3.86 m (from the maximum elevation of the species to the 20 year mean minimum water level). Therefore the mean depth to water for *E. camaldulensis* over a 20 year period at all of the Pilbara sites was -1.16 m to -3.86 m. Over a five year period the depth to water was -1.68 m to -4.86 m (DoW, 2010).

Water level ranges can be used to determine the susceptibility of riparian species to altered water regimes. Comparison of a species' regional (e.g. Pilbara) mean range with the range of that species within the Project area will show whether it occurs towards the 'wet' or 'dry' end of its mean water level range. However, although this approach is a useful tool in predicting susceptibility, DoW caution that the method should only be used as a 'rule of thumb' in the absence of site specific understanding of physiological responses to changes in water (DoW, 2010).

Within the Project area, the groundwater levels in the vicinity of Community D are in the order of 12 m – 20 m below ground level (mbgl) (Figure 8-11). This is greater than the absolute maximums recorded for *E. camaldulensis* as a riparian species elsewhere in the Pilbara (Table 8-12). This species is commonly associated with both shallow groundwater

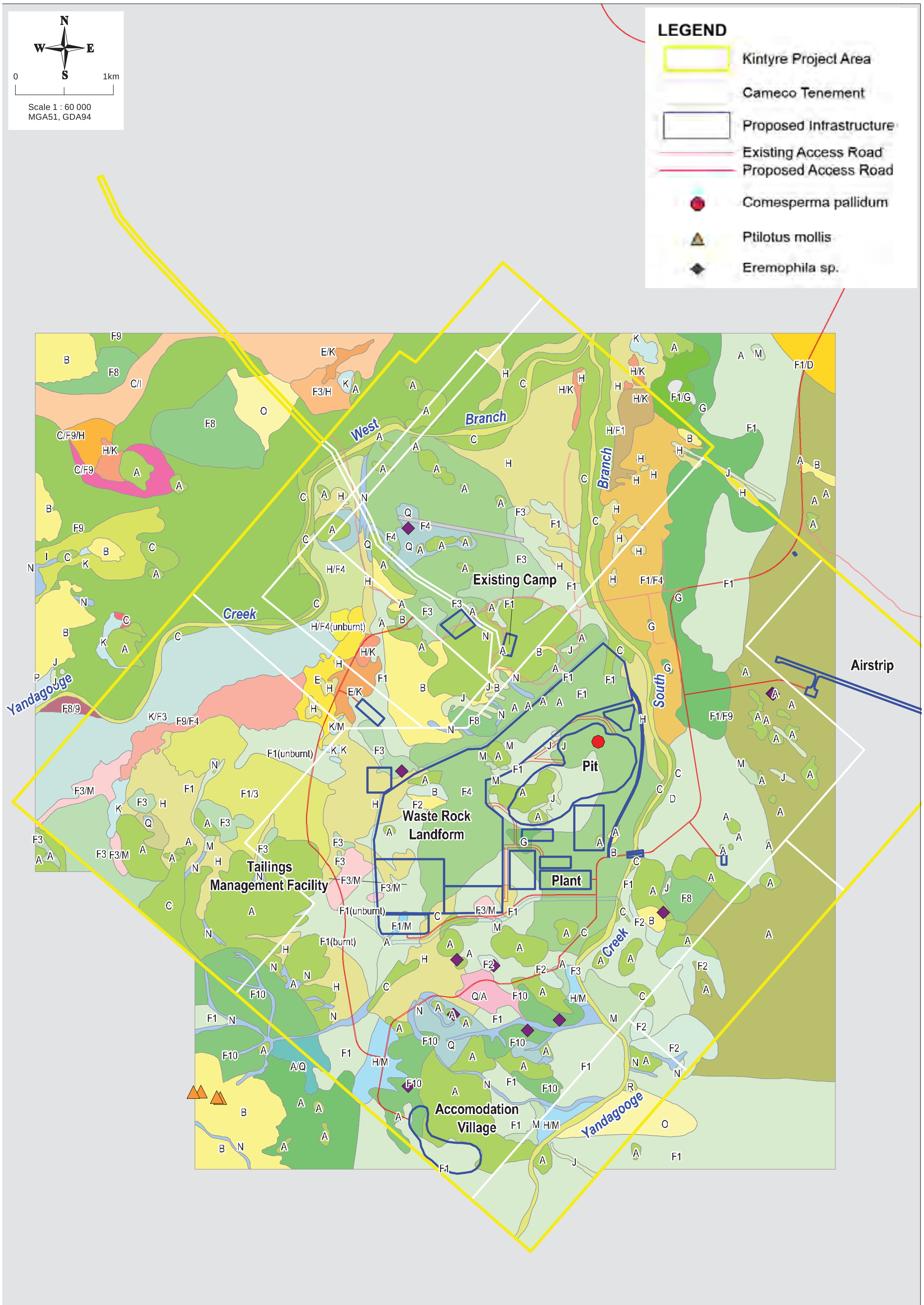


Figure 8-9: Vegetation communities of the Project area

	VEG TYPE	DESCRIPTION 1	DESCRIPTION 2
	C	Woodlands	Woodland of *Corymbia opaca*
	D	Woodlands	Woodland of *Eucalyptus camaldulensis* in river channels
	I	Shrublands	*Acacia dictyophleba* over the hard spinifex *Triodia basedowii* and the soft spinifex *Triodia pungens*
	R	Shrublands	Mulga shrubland
	A	Hummock Grass Steppe	Hard spinifex *Triodia wiseana*
	F1	Shrub Steppes	*Acacia ancistrocarpa* and *A. ligulata* over the hard spinifex *Triodia basedowii*
	F2	Shrub Steppes	*Acacia retivenia* over the hard spinifex *Triodia wiseana*
	F3	Shrub Steppes	*Acacia inaequilatera* over the hard spinifex *Triodia basedowii* and the soft spinifex *Triodia pungens*
	F4	Shrub Steppes	Mixed low shrubs over the hard spinifex *Triodia basedowii*
	F8	Shrub Steppes	Grevillea and Acacia shrubs over mixed spinifex on sand
	F9	Shrub Steppes	*Acacia dictyophleba* over the hard spinifex *Triodia basedowii*
	F10	Shrub Steppes	*Acacia wanyu* over the hard spinifex *Triodia wiseana*
	G	Shrub Steppes	Sparse shrubs over the hard spinifex *Triodia basedowii*
	O	Mallee Steppe	Mallees of *Eucalyptus odontocarpa* over the hard spinifex *Triodia basedowii*
	B	Tree Steppe	Trees of *Eucalyptus leucophloia* over the hard spinifex *Triodia wiseana*
	L	Grasslands	*Xerochloa laniflora* grassland
	E	Scrubs	Chenopod dwarf scrub
	H	Shrub Savanna	Senna over grass
	J	Complexes	Sand dunes
	K	Complexes	Claypans with little or no vegetation
	M	Complexes	Sparse shrubs on clay soils
	N	Complexes	Drainage lines of Acacia and other shrubs over the soft spinifex *Triodia pungens*
	P	Complexes	Bare stony slopes
	Q	Complexes	White quartzite scree slopes
		Airfield	Tracy Airfield

Table 8-10: Vegetation units and landforms of the access road (Bennett Environmental Consulting, 2011a)

Code	Vegetation Unit
TREES – HILLSLOPES / ROCKY GROUND	
El	Open Woodland of *Eucalyptus leucophloia* over Tall Grass of *Triodia basedowii* or *Triodia schinzii.*
Ca	Open Low Woodland A of *Corymbia aspersa* over Low Heath C of mixed shrub species over Tall Grass dominated by *Amphipogon caricinus* and *Eriachne mucronata*
TREES – FLAT GROUND / SANDY SOIL	
CE	Open Woodland to Woodland of *Corymbia opaca* and/or *Eucalyptus victrix* over Mid-Dense to Dense Hummock Grass of *Triodia basedowii* or *Triodia schinzii*
Ap	Open Low Woodland A of *Acacia pachycarpa* over Tall Grass of *Chrysopogon pallidus* and **Cenchrus ciliaris*
MALLEES	
Eb	Open Shrub Mallee of *Eucalyptus kingsmillii* and/or *Eucalyptus gamophylla* over Mid-Dense Hummock Grass of *Triodia basedowii*
Es	Open Shrub Mallee of *Eucalyptus kingsmillii* and/or *Eucalyptus gamophylla* over Mid-Dense Hummock Grass of *Triodia schinzii*
EA	Shrub Mallee of *Eucalyptus gamophylla* over Open Low Scrub A of *Acacia melleodora* over Mid-Dense Hummock Grass of *Triodia schinzii*
SHRUBS >3 m	
AB	Open Scrub of *Acacia coriacea* subsp. *pendens* over Low Heath C of mixed shrubs including *Scaevola parvifolia* subsp. *pilbare* and *Bonamia rosea* over Open Hummock Grass of *Triodia basedowii* and *Triodia schinzii*
Hl	Scrub of *Hakea lorea* over Mid-Dense to Dense Hummock Grass of *Triodia basedowii*
Ae	Scrub of *Acacia eriopoda* over Dwarf Scrub C of mixed taxa over Dense Hummock Grass of *Triodia basedowii*
SHRUBS 1 – 3 m	
Ac	Scrub of *Acacia ancistrocarpa* over Dense Hummock Grass of *Triodia basedowii* occasionally *Triodia schinzii*
Al	Scrub of *Acacia ligulata* over Dense Hummock Grass of *Triodia basedowii*
Gs	Thicket of *Grevillea stenostachya* or *Grevillea wickhamii* over Low Scrub A of *Acacia dictyophleba* over Dense Hummock Grass of *Triodia basedowii*
Am	Scrub of *Acacia melleodora* over Mid-Dense Hummock Grass of *Triodia basedowii*
Sa	Open Scrub of *Acacia synchronicia* over Dwarf Scrub C of *Senna artemisioides* subsp. *helmsii* and *Eremophila forrestii* subsp. *forrestii* over Dense Hummock Grass of *Triodia basedowii*
Aw	Scrub of *Acacia wanyu* over Dwarf Scrub C of *Senna artemisioides* subsp. *oligophylla* over Dense Hummock Grass of *Triodia basedowii*
Ss	Low Scrub B of *Sida* sp. Sand Dunes over Open Dwarf Scrub of *Corchorus sidoides* subsp. *sidoides* over Hummock Grass of *Triodia basedowii* and Open Tall Grass of *Eragrostis eriopoda*
SHRUBS <1 m	
As	Low Heath C of *Acacia stellaticeps* over Dense Hummock Grass of *Triodia basedowii*
Cc	Dwarf Scrub C of *Senna artemisioides* subsp. *helmsii* and *Senna artemisioides* subsp. *oligophylla* over herbs and grasses including **Cenchrus ciliaris*
Dd	Dwarf Scrub C dominated by *Dicrastylis dorrienii* and *Dampiera cinerea* over Hummock Grass of *Triodia schinzii* and Open Tall Grass of *Aristida holathera* and *Eriachne aristida*
GRASSLAND	
Tp	Mid-Dense Hummock Grass of *Triodia pungens* and *Triodia basedowii* with scattered low shrubs
CLAYPANS	
SF	Dwarf Scrub C of *Sclerolaena*, *Maireana* and *Frankenia* species over Dense Hummock Grass of *Triodia basedowii* in the clay pans
SM	Scrub of *Acacia wanyu* over Open Dwarf Scrub C of *Senna artemisioides* subsp. *helmsii* and *Senna artemisioides* subsp. *oligophylla* over Low Heath D dominated by *Sclerolaena* and *Maireana* species
CREEKS / DRAINAGE LINES	
Co	Open Low Woodland B of *Corymbia opaca* over Dense Hummock Grass of *Triodia basedowii* or **Cenchrus ciliaris*
At	Thicket of *Acacia tumida*, *Grevillea wickhamii* and *Grevillea eriostachya* over Low Heath C dominated by *Jacksonia aculeata*

Code	Vegetation Unit
Ev	Low Woodland A of *Eucalyptus victrix* over Dense Tall Grass of *Sorghum plumosum* and **Cenchrus ciliaris*
Ec	Open Low Woodland A of *Eucalyptus camaldulensis* over Dense Tall Grass of **Cenchrus ciliaris*
ES	Low Woodland A of *Eucalyptus camaldulensis* over Low Scrub A of *Acacia marramaba* over Very Open Tall Grass of *Sorghum plumosum*

Table 8-11: Significant flora recorded in the Project area and along the access road

Conservation Category	Species	Location	Impact
P2	*Acacia auripila*	Recorded historically in the Kintyre region by Hart Simpson & Associates (1994b, 1997). Not recorded in recent surveys.	NA
P2	*Eremophila* sp. Rudall River (formerly small-leaved form of *Eremophila tietkensii*)	Recorded from scree slopes at several locations within the Kintyre leases in 2012	Populations recorded at 7 locations. One population may be disturbed by the construction of a sediment pond.
P2	*Goodenia hartiana*	Recorded historically in the Kintyre region by Hart Simpson & Associates. Not recorded in recent surveys.	NA
P2	*Thysanotus* sp. Desert East of Newman (RP Hart 964)	Recorded from four sites along the access road in 2011 and historically in the Kintyre region by Hart Simpson & Associates	Populations recorded at four locations. Populations may be able to be avoided pending detailed road alignment design.
P3	*Comesperma pallidum*	Recorded from the Project area within the proposed pit (1 plant) in 2007 and not recorded since, possibly due to fire	The location of the recorded plant occurs within the area that would be disturbed by the construction of the open pit.
P3	*Indigofera ammobia*	Recorded from one site along the access road.	Plant recorded from one site. The population may be able to be avoided pending detailed road design.
P4	*Ptilotus mollis*	Recorded at 10 locations across the Project area in 2012 and historically by Hart Simpson & Associates.	Populations recorded at 10 locations. None of these populations would be disturbed by the Proposal.

(Strategen, 2006; Loomes & Bainbridge, 2010) and deeper groundwater up to 21 mbgl (Landman, 2001). The lateral and tap roots of the tree enable it to use both groundwater and water held in the unsaturated vadose zone (above the watertable) depending on soil water availability (DoW, 2010). In the case of *E camaldulensis* in Community D in the Kintyre area, it is likely that the species primarily uses moisture in the vadose zone following significant rainfall and flow in the drainage lines. *E. camaldulensis* is capable of sinking new tap roots in response to groundwater drawdown. However, drawdown of greater than 10 m over a prolonged period may cause irreversible stress (Woodward-Clyde, 1997).

There is the possibility that *Corymbia opaca* (in Community C: Minor drainage line with Woodland of *C. opaca*) which occurs just above the creek in the flat flood zone, is also groundwater dependent. O'Grady *et al*. (2010) indicate that this could be the case in central Australia (Northern Territory). However, there is no literature to indicate this is the case in Western Australia. Cameco has taken a conservative approach and assumed this community is groundwater dependent.

The National Atlas of Groundwater Dependent Ecosystems (GDE Atlas; BoM, 2012) presents the current knowledge of GDEs across Australia. A

Plate 8-7: *Eucalyptus camaldulensis* in the creek and tussock grassland of **Cenchrus ciliaris* on the bank

Photo courtesy of Bennett Environmental Consulting.

review of the Atlas was undertaken to determine the likelihood of ecosystems that may interact with the subsurface presence of groundwater or the surface expression of groundwater occurring within a 40 km radius of the Project area. The GDE Atlas showed that ecosystems within the Project area have a low potential for subsurface groundwater interaction or have not been analysed. An area approximately 20 km to the south and south east of the study area, corresponding to the location of the Rudall River, was identified as having a high potential for ecosystems interacting with both subsurface groundwater and surface expressions of groundwater. The presence of ecosystems with a low potential for subsurface groundwater interaction within the Project area on the GDE Atlas provides some assurance that the consideration of vegetation communities C and D as groundwater dependent is a conservative approach.

The locations of Communities C and D and the current static water levels are shown on Figure 8-11. The potential impacts on these communities from groundwater abstraction are discussed in Section 8.4.5.

8.5.4.3 Threatened and Priority Ecological Communities

Flora and vegetation surveys of the Project area and surrounding areas considered the locations of Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs) listed by the DPaW.

Two TECs are listed for the Pilbara Region but neither of these communities occur in the vicinity of the Project. Thirty PECs are listed by the DPaW for the Pilbara of which one, "Riparian vegetation including phreatophytic species associated with creek lines and watercourses of Rudall River" occurs nearby. This is considered a Priority 3 PEC and is represented by semi-permanent pools along courses of the Rudall River. The Project occurs within the Coolbro Creek catchment and Yandagooge Creek sub-catchment (Section 7.1.5; Figure 7-1) and is not expected to have an impact on this PEC (Section 8.4.5). No semi-permanent pools occur along the creeklines within the Project area.

Three of the ten Beard (1975) communities listed by Kendrick (2001) as reservation status for the region were recorded during the surveys (Bennett Environmental Consulting 2007, 2010) (Appendix L). These are:

- Shrubland, mulga scrub (Beard [1975] Vegetation Code 39). This unit was recorded along the proposed deviation from the existing access road, and in the south eastern portion of the Project area on a sandy slope above a creek in vegetation unit R (Figure 8-9) and in one site in vegetation unit Aw along the access road. These areas will be avoided by the Project.
- *Triodia wiseana* Grass Steppe on stony hills (Beard [1975] Vegetation Code 157). This community was recorded at one quadrat

Table 8-12: Water level ranges of *Eucalyptus camaldulensis* at four Pilbara study sites over varying time periods (DoW, 2010)

Time period for calculating mean water levels	Mean minimum depth to water (m)	Absolute minimum depth to water (m)	Mean maximum depth to water (m)	Absolute maximum depth to water (m)
20 years	-1.16	1.99	-3.86	-8.88
10 years	-1.14	1.99	-4.12	-9.21
5 years	-1.68	1.56	-4.86	-9.21
Current	-1.87	1.56	-4.88	-8.54

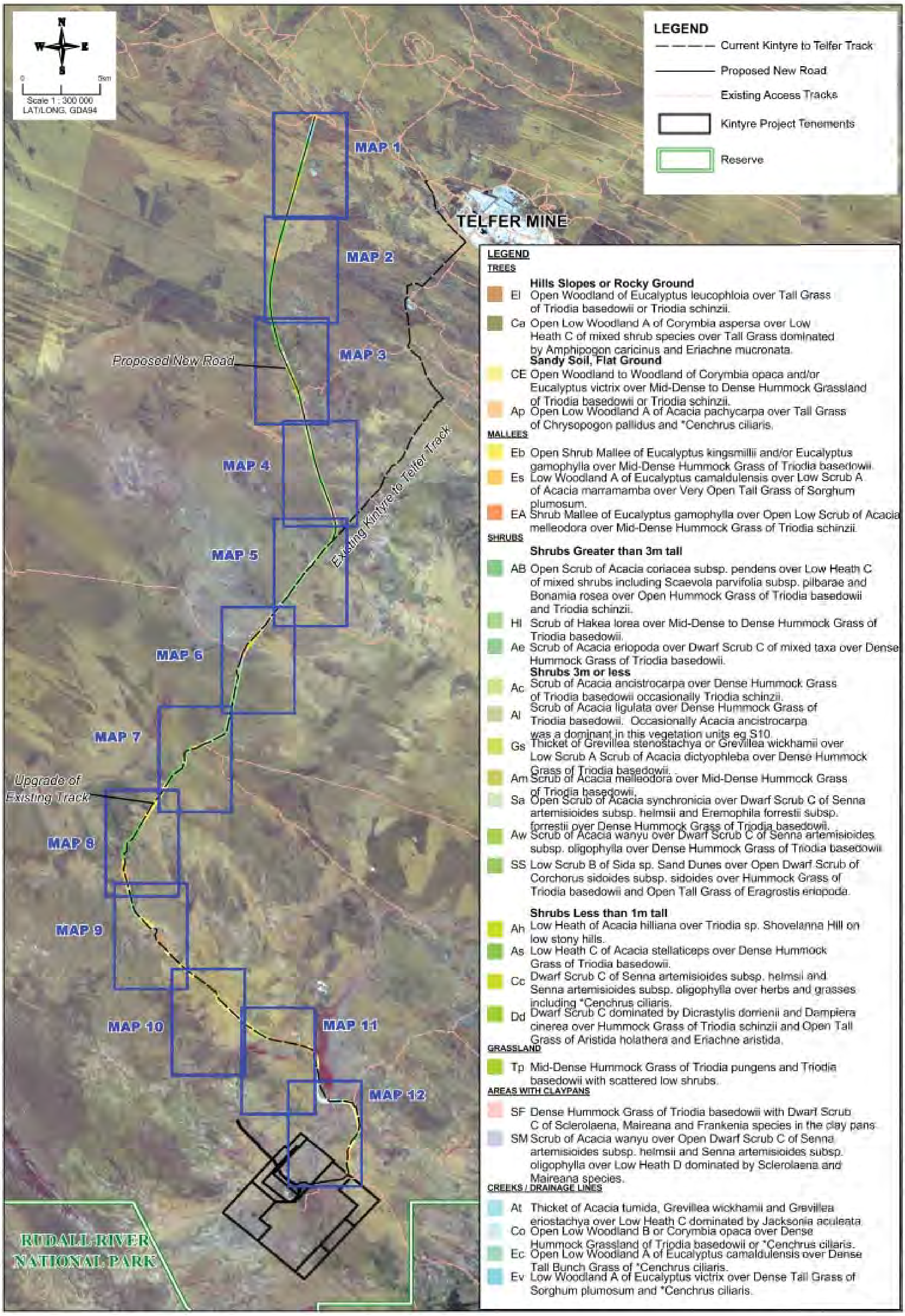


Figure 8-10: Vegetation communities along the access road


MAP 1


MAP 2

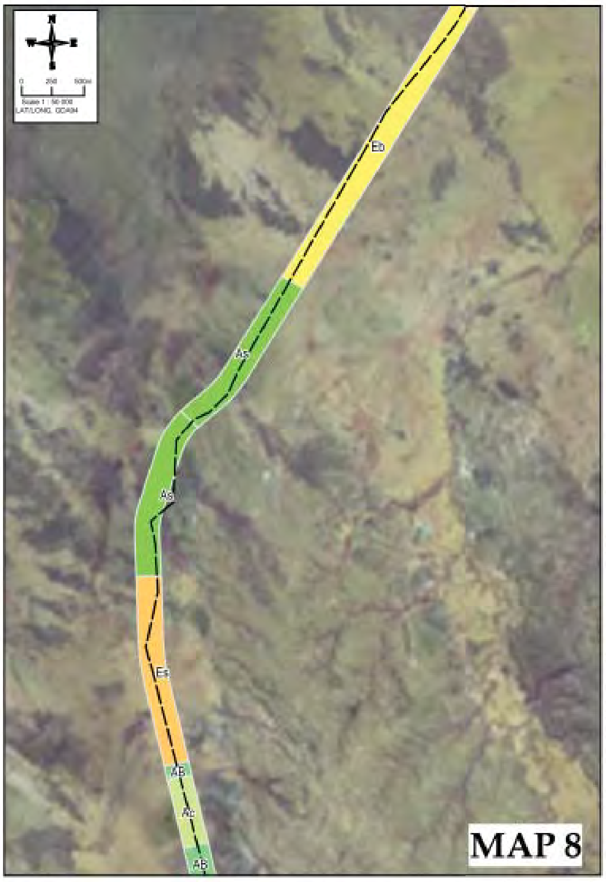

MAP 3

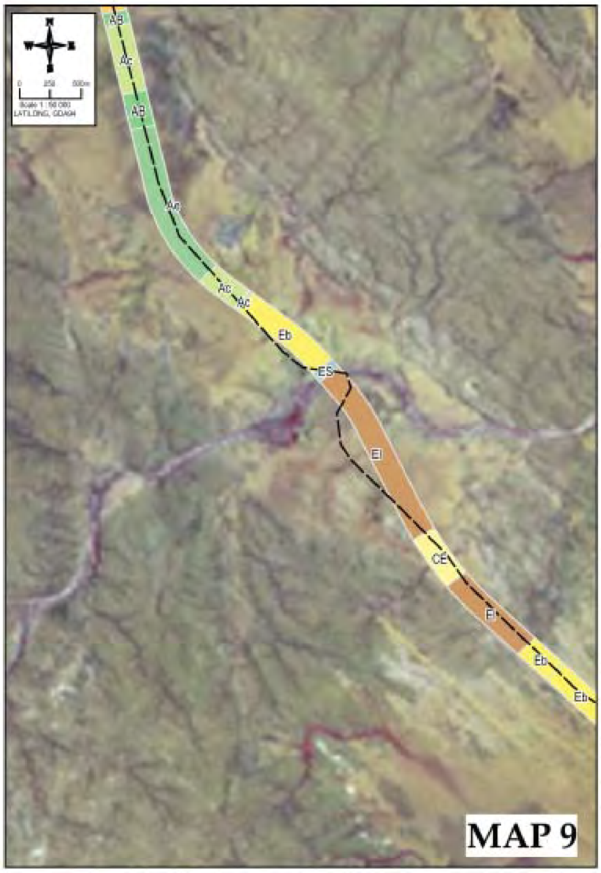

MAP 4


Ac
Aw
Aw
Sa
Sa
Ac
Al
Hl
Hl
Hl
Ac
Hl
As
SM
MAP 5


SM
Ap
Aj
Ap
Cc
Cc
Ap
SM
Hl
CE
Hl
Eb
Hl
MAP 6

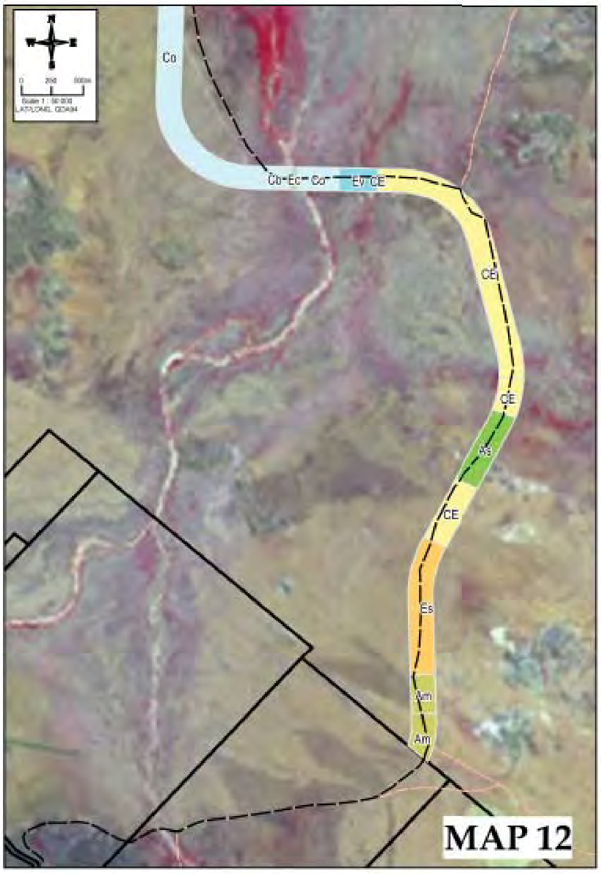

Hl
CE
Eb
Ae
As
Es
As
Ae
Ac
An
As
CE
MAP 7


Eb
As
As
Es
AB
Ac
AB
MAP 8


MAP 9


MAP 10


MAP 11


MAP 12

within vegetation unit A near the existing exploration camp, and possibly another quadrat in vegetation unit F3 adjacent to the proposed Waste Rock Landform (WRL). The proposed area of disturbance of these vegetation communities is outlined in the following section. It appears that the *Triodia wiseana* community, as described by Beard (1975), has been mapped by Hart Simpson & Associates (1997) (Table 8-9) as a subset of vegetation unit A and possible vegetation unit F3. Cameco will be disturbing one of the stony hills associated with these two communities.

- Mixed Shrub Steppe between sandhills with *Triodia schinzii* (Beard [1975] Vegetation Code 136). This unit was recorded along the access road between several of the large sand dunes (Bennett Environmental Consulting, 2013). As the road corridor will be <15 m in width, the percentage of this unit that will potentially be disturbed is minimal. Within the Project area, although there were several areas where *Triodia schinzii* was found to be the dominant grass, there was only one quadrat in vegetation unit J (Table 8-9) where it occurred between sand hills, east of the Yandagooge Creek South Branch. This area will not be disturbed by the Project (Bennett Environmental Consulting, 2010).

8.5.5 Potential Impacts and Management

8.5.5.1 Potential Impacts from Clearing

The Project will involve the clearing of approximately 510 ha of native vegetation over the Project area (Figure 6-5). The key vegetation units which will be impacted by clearing are presented in Table 8-13.

The Project will not have any impacts on PECs or TECs listed by the DPaW or TECs listed under the EPBC Act. Cameco will clear less than 20% of each of the mapped areas of vegetation communities within the Project area with the exception of Community F4 (Mixed Low Shrub Steppe over *Triodia basedowii*) where up to 41% is proposed to be cleared. However, this community also forms mosaics with Community F1, of which 0.1% of the F1/F4 community will be cleared. Sparse shrub-steppe over *Triodia basedowii* is characteristic of the Little Sandy Desert sub-region (LSD1) (Kendrick, 2001) and community F4 is considered likely to occur outside of the area mapped by Cameco.

The Priority 3 species *Comesperma pallidum* was recorded in the proposed pit area during the 2007 survey (Figure 8-9). Subsequent searches of this area and similar habitats across the Project area have not relocated this species, possibly due to the effects of fire. Should this species reoccur in the pit area, disturbance will be unavoidable. *Ptilotus mollis* (Priority 4) and *Eremophila* sp. Rudall River (formerly small-leaved form of *Eremophila tietkensii*) (Priority 2) have also been recorded within or near the Project area, however, no known populations of these species will be disturbed by the Project layout (Figure 8-9).

An additional 200 ha of vegetation will be disturbed by the construction of the road and borrow pits. Along the proposed access road *Thysanotus* sp. Desert East of Newman (RP Hart 964) (Priority 2) was recorded at four locations along the route. *Eremophila* sp. Rudall River (Priority 2), *Indigofera ammobia* (Priority 3) and *Ptilotus mollis* (Priority 4) were each recorded at one location along the proposed access road. Significant flora will be avoided during construction of the access road where practical. Where this is impractical or disturbance is unavoidable Cameco will first consult with DPaW to ascertain the impact of proposed clearing on the conservation status of the species.

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 area on vehicles and machinery brought into the area, or in soil moved within the Project area.

8.5.5.2 Potential Impacts from Groundwater Drawdown

Groundwater drawdown from pit dewatering or borefield operation could also reduce water available to groundwater-dependent vegetation if there is a connection between the aquifer being targeted by pumping operations and the near-surface water table being used by the vegetation.

Groundwater consultants have developed a numerical groundwater model to assist Cameco in designing the groundwater dewatering programme to dewater the open pit to facilitate mining. The model predicts that at the end of mine life the effects of pit dewatering and groundwater production (i.e. 1 m drawdown contour) may extend 20 km from the pit. Drawdowns of 10 m or more

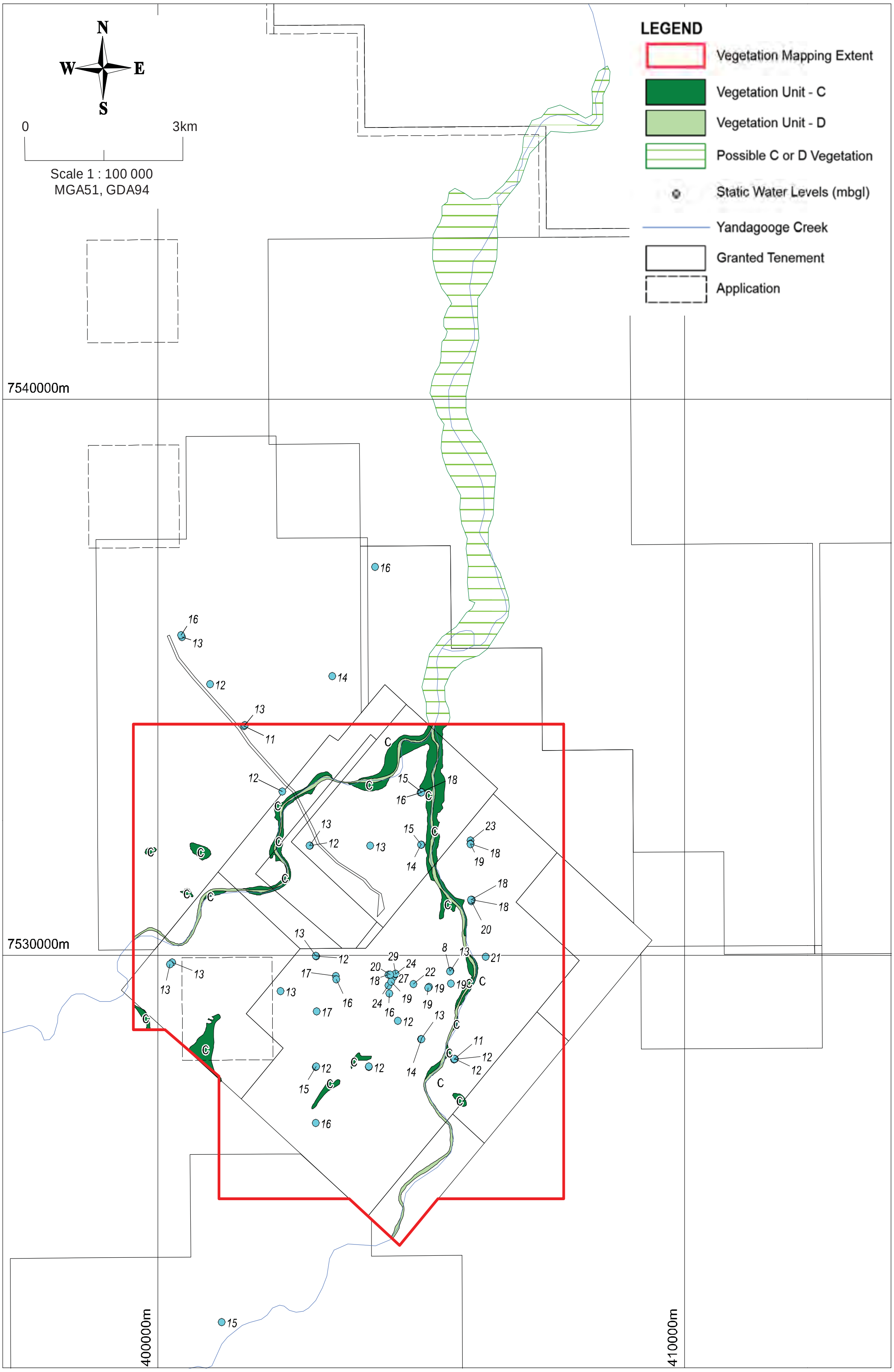


Figure 8-11: Predicted groundwater drawdown within potentially groundwater-dependent vegetation communities

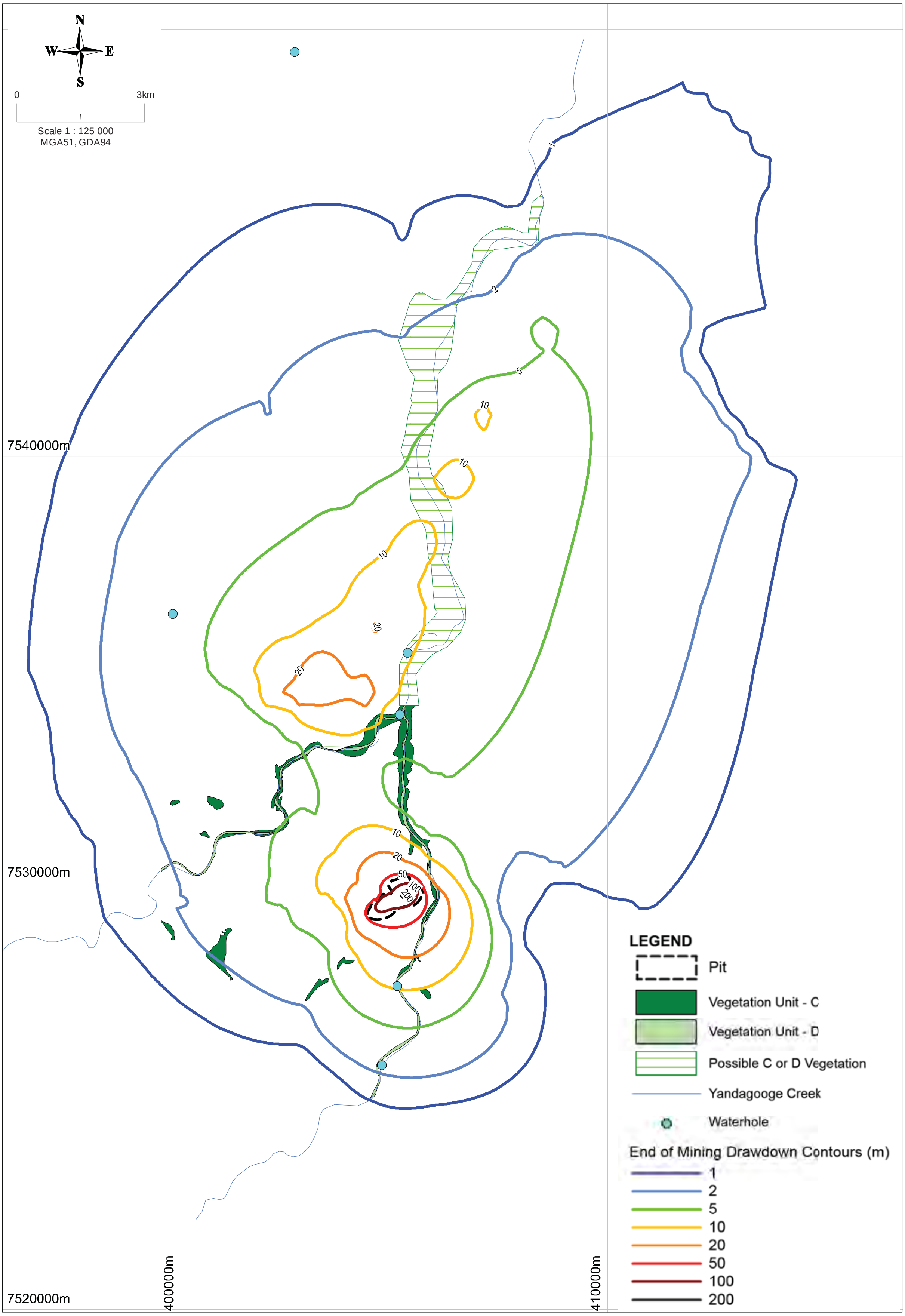


Figure 8-12: Predicted groundwater drawdown (end of mine life) within potentially groundwater-dependent vegetation communities

Table 8-13: Disturbance to vegetation units mapped within Project area

Code	Vegetation Unit	Area of Disturbance (ha)	Total Area of Unit within Mapped Area (Figure 8-9)
A	Hummock Grass Steppe dominated by *Triodia wiseana*	34.1	613.2
B	Trees of *Eucalyptus leucophloia* (*E. brevifolia* in Hart Simpson and Assoc., 1997) over *Triodia wiseana*	5.4	249.5
D	Woodland of *Eucalyptus camaldulensis* along drainage channels	0.3	82.9
C	Drainage line Woodland of *Corymbia opaca*	9.1	209.8
E	Chenopod Dwarf Scrub	1.5	28.3
F1	*Acacia ancistrocarpa* and *Acacia ligulata* over *Triodia basedowii*	158.1	1,167.2
F2	*Acacia retivenea* Shrub Steppe over *Triodia wiseana*	5.9	65.3
F3	*Acacia inaequilatera* Shrub Steppe over *Triodia basedowii* and *Triodia pungens*	13.5	133.5
F4	Mixed Low Shrub Steppe over *Triodia basedowii*	222.9	531.3
F10	*Acacia wanyu* Shrub Steppe over *Triodia wiseana*	3.6	161.1
G	Open Shrub Steppe over *Triodia basedowii*	4.7	246.1
H	Sennas over grass	106.5	434.5
J	Sand dunes	4.5	26.7
K	Claypans with little or no vegetation	1.5	23.2
M	Sparse shrubs on clay soils	0.4	34.9
N	Drainage lines of *Acacia* and other scrubs over *Triodia pungens*	0.7	66.0
Q	White quartzite scree slopes	0.1	60.6
	Mosaic vegetation units	26.0	1258.9

are not expected to extend more than 2 km from the pit (Figure 8-12).

Given that the natural depth to groundwater recorded in the area that these species occur is greater than that recorded in groundwater-dependent communities of *E. camaldulensis* in other areas of the Pilbara, Cameco considers that it is unlikely that the trees are groundwater dependant in the Kintyre area. They are more likely to rely on seasonal flooding and moisture held in the unsaturated vadose zone along the creekline. Therefore, the health of the trees is more likely to be influenced by drought than drawdown. However, if there are some *E. camaldulensis* trees that are accessing groundwater via deep tap roots, then there may be localised impacts within Community D near the pit and North Bore where drawdown exceeds the rate of 1 m per year (i.e. 10 m drawdown contour at end of mine life of ~10 yrs). There are approximately 21.8 ha (10% of the mapped area) of Community C, 15.2 ha (18% if the mapped area) of Community D and 41.32 ha (5% of mapped area) of inferred Community C or D along Yandagooge Creek that occur within the 10 m drawdown contours at the end of mine life, as shown on Figure 8-11. Cameco accepts there is a level of uncertainty and a programme would be implemented to monitor the condition of Communities C and D.

Vegetation condition also may be affected as a result of changes to surface water flows, poor erosion control, dust deposition or saline overspray from dust suppression activities.

8.5.5.3 Proposed Management

In regards to the protection of flora and vegetation, Cameco is proposing to address the principles outlined in the EPA Position Statement No. 2 (EPA, 2000a) as summarised in Table 8-14.

Table 8-14: Proposed management of flora and vegetation in accordance with EPA Position Statement No. 2 (EPA, 2000a)

EPA Principle	Cameco's Response
1. A comparison of development scenarios, or options, to evaluate protection of biodiversity at the species and ecosystem levels, and demonstration that all reasonable steps have been taken to avoid disturbing native vegetation.	In designing the Project Cameco has kept the area of proposed disturbance to the minimum required for safe and efficient operations. Protection of biodiversity has been considered in the layout of the Project. Further detail on the alternatives considered is provided in Section 5.2 of this ERMP.
2. No known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable.	Cameco is not proposing to disturb any DRF. The pit is located in an area where a Priority 3 plant species was recorded in 2007, but not in 2010. Cameco will undertake further survey work to determine the status of the species within and outside of the Project area. Cameco will consult with DPaW regarding the potential impact of clearing on the conservation status of the species.
3. No association or community of indigenous plants ceases to exist as a result of the project.	No Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) occur within or near the Project area.
4. 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.	The proposed disturbance will not take any vegetation type below the threshold level of 30% of the pre-clearing extent of the vegetation type.[1]
5. Where a proposal would result in a reduction below the 30% level, the EPA would expect alternative mechanisms to be put forward to address the protection of biodiversity.	N/A
6. There is comprehensive, adequate and secure representation of scarce or endangered habitats within the Project area and/or in areas which are biologically comparable to the Project area, protected in secure reserves.	There will be some disturbance of vegetation units A and F3 within which the *Triodia wiseana* Grass Steppe community (Vegetation Code 157, Beard [1975]) is thought to occur. However, it is not expected the Project will have a significant impact on this community on a regional scale.
7. If the Project area is large the Project area itself should include a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity is secure and protected.	The Project area is not considered large and is not expected to fragment vegetation communities.
8. The on-site and off-site impacts of the project are identified and the proponent demonstrates that these impacts can be managed.	Impacts are expected to be localised within the Project area and within the immediate groundwater drawdown zone (as shown on Figure 8-12: Predicted groundwater drawdown within potentially groundwater-dependent vegetation communities).

[1] More than 30% of the mapped area of Community F4 (Mixed Low Shrub Steppe over *Triodia basedowii*) is within the Project footprint (Table 8-13). However, this community also forms mosaics with Communities F1 and F9. When the mosaics of Community F4 are also taken into consideration, the proposed disturbance within the mapped area is less than 30%. The community is also likely to occur outside of the mapped area

Cameco has developed a Flora and Vegetation and Management Plan (Appendix D9) to minimise and manage potential impacts of the Project on the flora and vegetation communities of the area. As part of this management plan Cameco will implement a ground disturbance procedure that will apply to all clearing activities.

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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 rain to reduce the risk of erosion and damage to soil structure.

Should any other significant flora species be recorded during pre-disturbance checks these would not be disturbed without approval of the Minister (in the case of Threatened Flora) or consultation with DPaW (in the case of Priority Flora) to ensure the species conservation status is not adversely affected.

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. Topsoil 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.

Areas no longer required during operations will be progressively rehabilitated in accordance with current best practices. This will include areas such as the outer embankments of the TMF and tracks that are no longer required. Further detail on proposed rehabilitation measures is provided in Section 10.4 and Appendix D17.

The proposed borefield operations and pit dewatering will be conducted in accordance with the measures outlined in Section 8.4.5. A vegetation condition monitoring programme will be implemented. The programme would include monitoring control sites and potential impact sites in Communities C and D within the predicted groundwater drawdown zone (Appendix D8). Should a decline in vegetation health be observed within the predicted drawdown zone and correlated with changes in groundwater levels, then contingency measures will be developed. These could include re-injection or irrigation, or rotating of bores to minimise drawdown in the water supply borefield.

As part of monitoring of the integrity of surface water diversion and management structures, Cameco will also monitor nearby vegetation health to determine if water ponding, water starvation or erosion is occurring that could affect vegetation condition as outlined in the Surface Water Management Plan (Appendix D7).

Dust management and suppression measures will be undertaken as outlined in Section 8.10.5. Water used for dust suppression may be brackish (up to 5,000 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.

8.5.6 Commitments

Cameco will implement the Flora and Vegetation Management Plan. This will include ongoing monitoring of potentially ground-water dependent vegetation within the vicinity of the pit and North Bore.

Should Priority flora occur within areas proposed to be cleared, Cameco will consult with the DPaW prior to clearing.

Cameco will undertake progressive rehabilitation of the Project area in accordance with the Mine Closure and Rehabilitation Plan.

8.5.7 Outcome

Cameco does not anticipate that the Project will affect the conservation status of any plant species or particular ecosystem. With the proposed management measures outlined above, Cameco believes the Project can be constructed, operated and closed in a way which maintains the abundance, diversity, geographic distribution and productivity of native plant species in the area.

8.6 Terrestrial Fauna

8.6.1 Objectives

The objective agreed to within the ESD with regards to terrestrial fauna is to maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

8.6.2 Relevant Legislation and Policy

All native fauna in WA are protected under the WA *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 (Special Protected Fauna) Notice classifies rare and endangered fauna using four conservation codes or 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 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.

In addition to the above schedules, 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 recognised by the DPaW:

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

2. 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.

3. 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.

4. 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) Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

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

Fauna species of national conservation significance are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and 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.
- Endangered - A taxon is Endangered when it is considered to be facing a very high risk of extinction in the wild.
- Vulnerable - A taxon is Vulnerable when it is considered to be facing a high risk of extinction in the wild.
- Conservation Dependent - A taxon is Conservation Dependent if the species is the focus of a specific conservation programme the cessation of which would result in the species becoming vulnerable.

Table 8-15: Fauna surveys of the Kintyre Project area

Author	Date of Survey(s)	Type of Survey
Hart Simpson and Associates (1994a)	Between 1986 and 1992 over a number of seasons and varied annual conditions.	Detailed surveys. Opportunistic observations.
Bamford Consulting Ecologists (2007)	October 2007	Reconnaissance survey to support review of earlier reports from Hart, Simpson and Assoc. Opportunistic observations. Included short-range endemic species.
Browne-Cooper and Bamford (2010)	July-August 2010	Targeted fauna survey for conservation significant fauna with Martu Traditional Owners. Further short range endemic work.
Bamford Consulting Ecologists (2011)	June 2011	Targeted fauna survey along access road.
Bamford Consulting Ecologists (Bamford *et al.*,2012)	June 2012	Annual inspection of recorded locations of significant species.

Migratory wader species are also protected under the EPBC Act. The national list of migratory species consists of those species listed under the following International Conventions:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA); and
- Convention on the Conservation of Migratory Species of Wild Animals - (Bonn Convention).

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 Commonweath DoE for a decision by the Commonwealth Minister for the Environment as to whether the action is a 'controlled action'. A significant impact is determined through application of Significant Impact Criteria (Department of Environment, Heritage and the Arts, 2009).

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. Based on the guidance provided in Position Statement No. 3, Cameco has undertaken Level 2 biological surveys for assessment of the impacts of the Project. This has included desktop studies, a reconnaissance survey and comprehensive fauna survey of the Project area to assess the conservation values of the site in a local and regional context. Further detail on the requirements for fauna surveys is provided in EPA Guidance Statement No. 56 (EPA, 2004c) and Technical Guide on Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC, 2010).

Previous fauna survey work within the Project area (mine tenement) was undertaken in the 1980s and early 1990s (Hart, Simpson and Associates, 1994a). This involved a survey equivalent to a level 2 survey that used a methodology that is in accordance with EPA Guidance Statement 56 (EPA 2004c).

The EPA also provides guidance on the rehabilitation of terrestrial ecosystems (EPA, 2006). This is discussed in more detail in Section 10.4.

8.6.3 Proponent Studies and Investigations

The Project area has been extensively surveyed as summarised in Table 8-15. A summary of the results of these surveys is provided in Bamford *et al.* (2012) (Appendix M).

Historic surveys were undertaken by Hart Simpson and Associates between April 1986 and November 1988 over a number of seasons and varied annual conditions covering all of the habitats present in the Kintyre Project area. These surveys involved detailed assessment of 39 sites and were considered equivalent to a level 2 intensity survey as described in EPA Guidance Statement No. 56 (EPA, 2004c). In addition, an opportunistic survey was conducted in

June 1989 that involved searching the environment for signs of fauna, particularly those not likely to be caught in pit traps. Bird observations in the area were made systematically and opportunistically (Browne-Cooper and Bamford, 2010).

Bamford Consulting Ecologists was commissioned to carry out a review of the existing information on the 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. As part of this review, an extended site inspection was undertaken in October 2007 with particular emphasis on searching for signs of significant species within the Project area (Bamford Consulting Ecologists, 2007).

Cameco commissioned a targeted fauna survey in August 2010 (Browne-Cooper and Bamford, 2010). Following discussions between Bamford Consulting Ecologists, DPaW and Cameco in March 2010, a targeted species approach was accepted as an appropriate means to provide additional information and supplement the above-mentioned surveys for the Kintyre Project. Subsequently a field survey was conducted in August 2010 by Bamford Consulting Ecologists with the assistance of Martu trackers. The purpose of this survey was to search for significant fauna in and around the Kintyre area.

In June 2011 Cameco commissioned Bamford Consulting Ecologists to undertake a targeted significant fauna survey along a proposed access road between the Kintyre Project area and Telfer. The total length of corridor surveyed was approximately 90 km, which included approximately 60 km of the existing access track and a 30 km deviation west of Telfer to meet the existing Telfer-Marble Bar road (Bamford Consulting Ecologists, 2011). Locations where significant fauna were observed in 2010 in the Project area were also inspected.

8.6.4 Existing Environment

Three broad habitats were identified during the 2007 survey within the Project area. These are:

- Sandy Loam plains supporting Acacia shrublands and spinifex hummock grasslands (*Triodia* spp.). The proposed pit areas and associated development lie within this association.
- Low Rocky hills supporting spinifex grasslands and sparse shrubs. This association lies adjacent to the Project area. The rocky hills are small outliers of the Throssell Range and have many small caves and overhangs, sufficient for owl roosts and some bat species.
- Eucalypt Woodland with a grassy understorey along drainage lines and flats. The Yandagooge Creek lies to the east of the Project area. Watercourses are seasonal but occasionally flow very strongly, with gravel beds approximately 50 m wide.

Based on the desktop reviews and field investigations, the vertebrate fauna assemblage of the Project area and surrounds is expected to be composed of 282 species including eight frogs, 96 reptile, 132 bird, 39 native mammal and eight introduced mammal species. An additional eight mammal species have been recorded in the Kintyre area from owl pellets (Hart Simpson and Associates, 1994a), however, these species are now considered extinct in the region. A total of 204 species have been recorded at Kintyre either by Hart Simpson and Associates (1994a) or Bamford Consulting Ecologists. This includes 16 of the 29 conservation significant species expected in the area (Bamford *et al*., 2012) (Table 8-16).

The fauna assemblage of the Project area is considered diverse and reflects the transition zone from the Pilbara region to the arid deserts, containing species typical of both areas. Consequently some fauna species expected to occur in the Project area occur near the extreme edge of their range, particularly those species typically found in the Pilbara (Bamford *et al*., 2012).

8.6.4.1 Fauna of Conservation Significance

Of the 29 conservation significant species which could occur within the Kintyre Project area, 16 have been recorded as shown in Table 8-16.

Significant fauna species most relevant to the Project are the Greater Bilby and Crest-tailed Mulgara (Figure 8-13). These have been recorded in spinifex sandplain with open Acacia shrubland (Bamford *et al*., 2012).

The Greater Bilby is listed as ‘Vulnerable’ under the EPBC Act and ‘Schedule 1’ under the WC Act. This species was formerly found in a wide range of habitat types across the continent. Current populations are now restricted to a variety of “tall shrublands, open woodlands, hummock grasslands and sparse forblands” (Maxwell *et al*., 1996).

Table 8-16: Fauna of conservation significance expected in the Project area (Bamford *et al*, 2012)

Species	Reason For Significance			Comments		
	EPBC Act	WA Wildlife Conservation Act	DPaW Priority	Recorded at Kintyre Project	Expected Status in study area	Local records
CONSERVATION SIGNIFICANCE 1 (CS1)						
Liopholis kintorei Great Desert Skink	Vulnerable	Schedule 1			Possibly Resident	Karlamilyi National Park (NP)
Polytelis alexandrae Princess Parrot	Vulnerable		P4		Irregular Visitor	Lake Disappointment
Pezoporus occidentalis Night Parrot	Critically Endangered	Schedule 1			status uncertain in region	Unknown
Falco peregrinus Peregrine Falcon		Schedule 4			Resident	Karlamilyi NP
Ardea modesta Eastern Great Egret	Migratory				Irregular Visitor	Karlamilyi NP
Apus pacificus Fork-tailed Swift	Migratory				Regular Visitor	Telfer
Merops ornatus Rainbow Bee-eater	Migratory			Recorded	Regular Visitor	Kintyre
Dasyurus hallucatus Northern Quoll	Endangered	Schedule 1		Unconfirmed, (scats only)	Possibly Resident	Kintyre
Macrotis lagotis Bilby	Vulnerable	Schedule 1		Recorded	Resident	Kintyre
Rhinonicteris aurantius Orange Leaf-nosed Bat	Vulnerable	Schedule 1		* From owl pellets only	Locally extinct?	Kintyre
Notoryctes caurinus Northern Marsupial Mole	Endangered	Schedule 1			Resident	c. 70km north-west of Kintyre
Dasycercus cristicauda [1] Crest-tailed Mulgara	Vulnerable	Schedule 1		From active burrows only	Resident	Karlamilyi NP
CONSERVATION SIGNIFICANCE 2 (CS2)						
Sminthopsis longicaudata Long-tailed Dunnart			P4	*From owl pellets only	Resident	Kintyre
Macroderma gigas Ghost Bat			P4	*	Possibly Resident	Kintyre
Lagorchestes conspicillatus Spectacled Hare-Wallaby			P3		Possibly Resident	none
Leggadina lakedownensis Lakeland Downs Mouse			P4		Possibly resident	Karlamilyi NP
Pseudomys chapmani Western Pebble-mound Mouse			P4	*From inactive mounds only	Locally extinct?	Kintyre
Lerista macropisthopus remota skink			P2		Possibly resident	70 km south Karlamilyi NP
Falco hypoleucos Grey Falcon			P4	Recorded	Resident	Kintyre

Species	Reason For Significance			Comments		
	EPBC Act	WA Wildlife Conservation Act	DPaW Priority	Recorded at Kintyre Project	Expected Status in study area	Local records
Ardeotis australis Australian Bustard			P4	Recorded	Regular Visitor	Kintyre
Burhinus grallarius Bush Stone-curlew			P4	Recorded	Resident	Karlamilyi NP
Amytornis striatus Striated Grasswren			P4		Resident	Lake Disappointment
CONSERVATION SIGNIFICANCE 3 (CS3) (Local significance)						
Ninox connivens Barking Owl					Possibly Resident	Woodie Woodie
Stipiturus ruficeps Rufous-crowned Emu-wren					Resident	Karlamilyi NP
Trichosurus vulpecular Northern Brushtail Possum				*From owl pellets only	Possibly Resident	Great Sandy Desert
Antechinomys laniger Kultarr				*From owl pellets only	Possibly Resident	Kintyre
Pseudomys nanus Western Chestnut Mouse					Locally Extinct	Kintyre
Rattus tunneyi Pale Field Rat					Locally Extinct	Kintyre
Petrogale sp.[2] Rock-Wallaby				From unconfirmed sightings, tracks and scats	Resident	Kintyre

* Historic Records (Hart Simpson & Associates, 1994)

1 Mulgara recorded during surveys of the Project area are likely to be *D. blythi*. However, in this table they are listed as *D. cristicauda* as *D. blythi* is not recognised as a separate species by DoE.

2 This species was recorded from recent tracks and is most likely Rothchild's Rock-Wallaby (*Petrogale rothschildi*). However, it is possible that it is the Black-Flanked Rock-Wallaby (*P. lateralis*) which is listed as 'Vulnerable' under the EPBC Act and 'Schedule 1' under the WC Act.

The species appears to remain widespread but patchily distributed across the Great Sandy Desert and is often associated with Acacia shrublands along palaeodrainage lines in sandy loams (M. Bamford *pers. obs.*). There are scattered populations across the northern Pilbara including near Port Hedland (Bamford *et al.*, 2012).

The Greater Bilby has been recorded from old bone material found in an owl roost (Hart Simpson and Associates, 1994a) and from the Kintyre site in 1998 (C. Gupanis *pers. comm.*). Bamford Consulting Ecologists recorded a single bilby via a motion-sensor video camera (Plate 8-8) and observed scats, tracks and active burrows within the Project area during the 2010 and 2011 surveys.

In 2010 this specimen was recorded 3.6 km north west of the mine camp near the North Bore Road on the northern side of Yandagooge Creek West Branch (Figure 8-13) (Browne-Cooper and Bamford, 2010). In 2011, further bilby sightings were made in the same general location (possibly the same animal). Evidence of mulgara and bilby activity was also sighted along the proposed access road (BamfordConsulting Ecologists, 2011) (Figure 8-14).

In the Project area Greater Bilbies were recorded in spinifex sandplain with open Acacia shrubland and sparse low Eucalypt woodland on red sandy loam including drainage lines. This environment is widespread in the Kintyre area, however, it appears that bilbies are sparse and patchily distributed. This species is potentially widespread in the greater Kintyre and Rudall River region but is probably scarce due to impacts from extensive recent fires and predation by feral species (Bamford *et al*., 2012).

Plate 8-8: Bilby recorded during the 2010 survey

Photo courtesy of Bamford Consulting Ecologists.

There are two recognised species of mulgara in Western Australia; the Crest-tailed Mulgara (*Dasycercus cristicauda*) and the Brush-tailed Mulgara (D. *blythi*). For nearly 30 years only one species - D. *cristicauda* - has been recognised. A recent review reclassified Mulgara as two separate species (Woolley, 2005, 2006). Due to the historic taxonomic confusion, there is some uncertainty of the distribution of the two mulgara species. The Brush-tailed Mulgara is listed as Priority 4 by the DPaW in WA, but is not recognised under EPBC legislation. It is known to occur in spinifex (*Triodia* spp.) grasslands, and burrows in flats between sand dunes (Woolley, 2008). The Crest-tailed Mulgara is listed as Vulnerable under the EPBC Act and Schedule 1 under the WC Act and is found primarily in Sandhill Canegrass (*Zygochloa paradoxa*) dominated dunes, Nitre Bush (*Nitraria billardierei*) grasslands, and Sandhill Canegrass flats near salt lakes (Woolley, 2008). It is also possible that both species occur in close proximity to each other (Bamford *et al*., 2012). A recent study in the Northern Territory found the two species to be sympathetic, with the Crest-tailed Mulgara occurring along dune supporting spinifex, and the Brush-tailed Mulgara occurring on spinifex flats between dunes (Pavey *et al*., 2011). The Crest-tailed Mulgara has been recorded 100 km east of Newman (Phoenix Environmental, 2011).

Within the Project area, Bamford Consulting Ecologists identified active and recently active mulgara burrows along the proposed access road in red sandy plains with or without mixed Acacia shrubs and spinifex (Bamford Consulting Ecologists, 2011). One active burrow and several inactive burrows were also located approximately 15 km southeast of the Exploration Camp (Browne-Cooper and Bamford, 2010) (Figure 8-13). The available data indicate that mulgara is low in numbers and patchily distributed within suitable habitat across the Project area, although the species was not observed. However, as the EPBC Act does not currently recognise *D. blythi* as a separate species, DoE would consider any mulgara within the Project area to be *D. cristicauda* (Bamford *et al*., 2012).

8.6.4.2 Short Range Endemic Species

Short Range Endemic (SRE) invertebrates had not been sampled in the Kintyre area prior to 2007. Cameco followed the advice produced in EPA's Guidance Statement No. 20 for sampling SREs to conduct an initial risk assessment based upon the nature of the landscape and the potential threat

Table 8-17: List of invertebrates found within the Project area

SRE Group	Family	Genus / species	Notes
Pseudoscorpion	Atemnidae	*Oratemnus* sp.	Leaf-litter sample from drainage line near North Bore (404 050E, 7 531 200N) WA Museum ref. 107426
Mygalomorph spider	Nemesiidae	*Aname armigera* group	Two specimens extracted from burrows in loam close to creekline, under a *Corymbia* and in sparse spinifex (around 400 600E, 7 532 500N). WA Museum ref. 107370, 107373
Scorpion	Urodachidae	*Urodacus "yashenkoi"*	Several specimens collected; very common in spinifex plains on sandy loam soil in region. Locations include: 402 476E, 7 532 642N and 405 526E, 7 532 263N.
Scorpion	Urodachidae	*Urodacus "yashenkoi"*	Two specimens collected in spinifex plains on sandy loam soil south-west of Kintyre around 413350E, 7 525 800N. Both were juveniles.

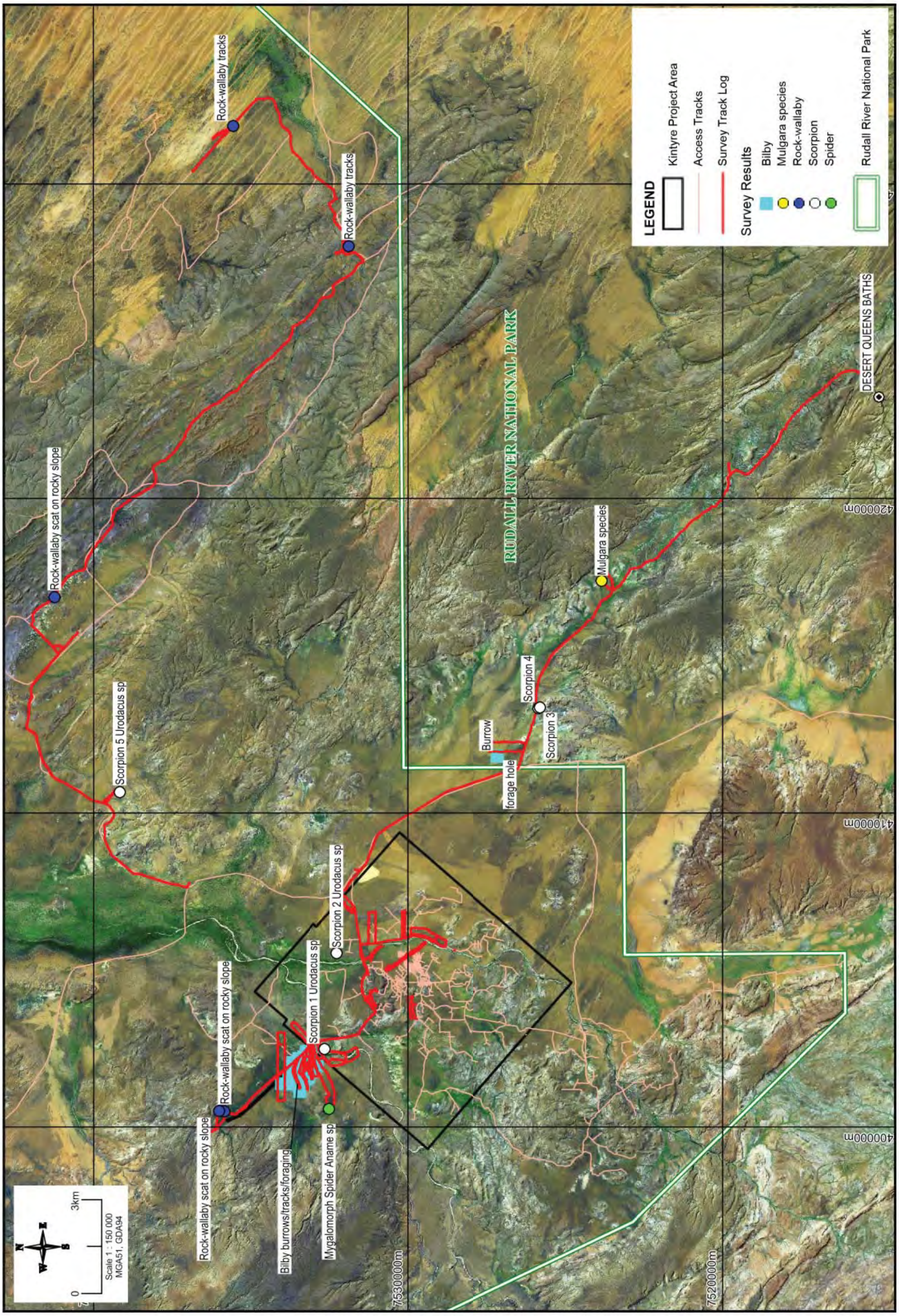


Figure 8-13: Recorded locations of significant fauna within the Project area

to any SREs that may be present, from the project. Although the initial risk assessment concluded that the likely presence of SRE invertebrates was low, some searching for, and collection of invertebrates was conducted (Browne-Cooper & Bamford, 2010).

Bamford Consulting Ecologists (2007) undertook an opportunistic search of the Project area for potential SRE invertebrates such as millipedes, land snails and scorpions, and no specimens were found. The conditions during the survey were probably too dry to find active millipedes and snails and it is likely that land snails were absent from the Project area due to lack of suitable habitat. Scorpions are undoubtedly present and inactive burrows were found, but no specimens were collected. In general, the Project area lacked the sort of mesic refugia, such as deep gorges or persistent waterholes that can be expected to support populations of short range endemic invertebrates (Bamford Consulting Ecologists, 2007).

Further investigations into short range endemic species were undertaken as part of the 2010 investigations. Four potential SRE specimens were collected during the survey as shown in Table 8-17.

The scorpions were dug from burrows at a depth of almost 1 m. Several specimens of the spider were dug from burrows amongst leaf-litter in spinifex on sandy loam with scattered acacia and eucalypt. The pseudoscorpion was found in a leaf-litter sample.

No land snails were found despite recent heavy rainfall that resulted in there being some pools of water present and in moist soil near the surface (Browne-Cooper and Bamford, 2010).

Of the species listed in Table 8-17 the scorpion is not considered an SRE as the specimens were collected from extensive environments that are well-represented in the wider region. The mygalomorph spider (Plate 8-9) is widespread in the Pilbara, although may be a species complex, so the distribution of the species recorded at Kintyre is uncertain. The distribution of the pseudoscorpion is unknown. The genus is widespread, but the undescribed species at Kintyre may be a SRE. Little can be concluded from a single specimen, but as a group pseudoscorpions are often associated with mesic (relatively moist) microhabitats. Therefore, it is likely that *Oratemnus* sp. is restricted to creeklines and other moist habitats such as at the base of rocky hills (Browne-Cooper and Bamford, 2010).

8.6.4.3 Introduced Fauna

Eight introduced fauna have either been recorded or are expected to occur in the Project area. These are the house mouse, rabbit, camel, feral cattle, donkey, goat, fox and cat. The dingo is also present and, while introduced, it pre-dates the other species by over 3,000 years and has a long ecological association with the environment. In terms of impacts and management, it needs to be considered separately from other introduced species.

Predation by feral species is a major factor in the decline of Australian mammals (Burbidge and McKenzie, 1989). Feral cats have been known to coexist with Bilbies in the Great Sandy Desert (M. Bamford *pers. obs*.) and rock-wallabies in the Pilbara (Browne-Cooper and Bamford, 2010), but have been implicated in the failure of attempts to reintroduce the Bilby (Miller *et al*., 2010). Introduced herbivores can significantly alter the vegetation composition and thus fire regimes, in turn affecting native fauna that rely on these habitats. The camel is the only introduced herbivore that is regularly seen in the Kintyre area.

There was evidence of a fox in the Kintyre region but the species appeared uncommon. Dingoes can suppress the numbers of foxes and feral cats, but the dingo is also an efficient predator (Browne-Cooper and Bamford, 2010).

8.6.5 Bilby, Mulgara and Rock Wallaby

Of the species that are listed in Table 8-16, a number are listed as a result of historical records (pre 1994) and some of these were from analysis of

Plate 8-9: Mygalomorph spider recorded during the 2010 survey

Photo courtesy of Bamford Consulting Ecologists.

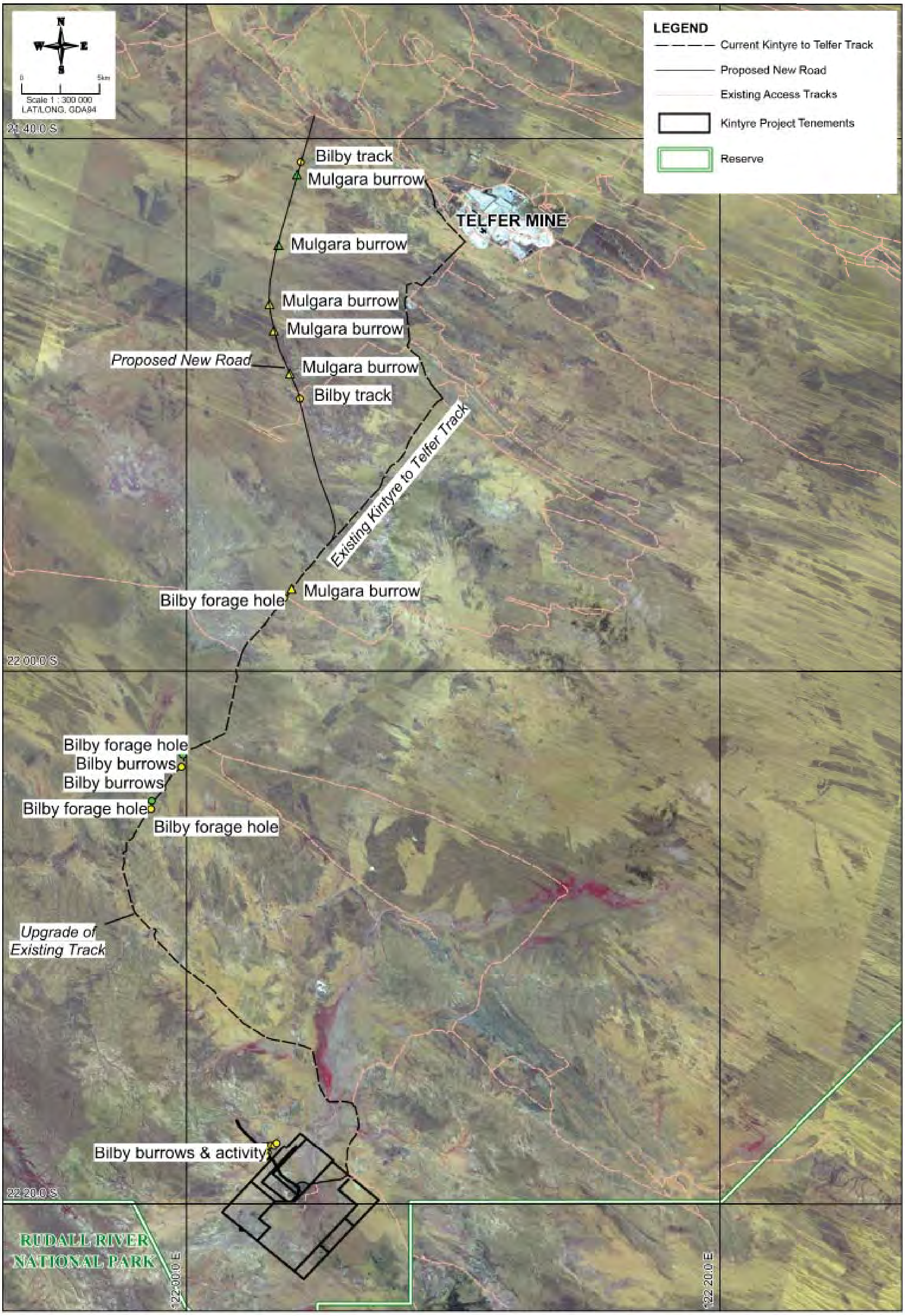


Figure 8-14: Recorded locations of significant fauna along the access road

owl pellets. Evidence of only three of these species (the bilby, mulgara and rock wallaby) have been recorded since 2007 and therefore the discussion of impacts on significant fauna focusses on these three species.

8.6.5.1 Potential Impacts

The presence of the bilby, mulgara and rock-wallaby are of greatest interest because of their conservation status and limited recordings in the region. The bilby is listed under both the EPBC Act and WA WC Act. The mulgara (probably the Brush-tailed Mulgara) is listed as Priority 4 by DPaW. Under current recognition DoE would consider it to be the Crest-tailed Mulgara which is listed as 'Vulnerable' under the EPBC Act. The rock-wallaby is probably Rothschild's Rock-Wallaby which is of local conservation interest but is not formally listed under the EPBC Act or WC Act.

The bilby and mulgara have similar habitat requirements, occurring on sandy-loam soils that support spinifex and acacia shrublands. They are thus potentially widespread in the Kintyre region but are probably scarce because of impacts from extensive recent fires and predation by feral species. The rock-wallaby occurs on rocky hills and breakaways and appears to be widespread but in low abundance through the region. It is sensitive to predation by feral species and may also be affected by fire.

Cameco has mapped habitat types in the vicinity of the Kintyre area (Figure 8-15) and calculated the area of disturbance of the Project on each habitat type within a 15 km radius. Habitat loss due to the Project on the Sandy Loam Plains is estimated to be 5.6% and in Low Rocky Hills 1.2% of the area mapped within a 15 km radius. Both of these habitats are widespread across the broader East Pilbara region.

There are a number of key threatening processes that allow impacts upon these three species from the proposed Kintyre project to be assessed. The assessment of a threatening process as a key threatening process is the first step to addressing the impact of a particular threat. These processes are:

- habitat loss (leading to population decline);
- ongoing mortality leading to population decline;
- habitat (population) fragmentation;
- disturbance;
- changed fire regimes; and
- interactions with other species (feral or over-abundant native species).

The impact of these processes on the three species can be assessed as outlined below.

Habitat Loss

The Project will involve clearing of approximately 790 ha of native vegetation. The direct impact from clearing is likely to be minor for the bilby, mulgara and rock-wallaby, as their habitats are extensive and the Project area is small in the regional context. Regionally significant areas noted by Kendrick (2001) will not be affected by the Project, including:

- The upper Rudall River which, drains into Lake Dora: This is one of two arid zone rivers, with near permanent wetlands along its course that flow from uplands across the desert and into a major salt lake within the Little Sandy Desert bioregion.
- Small permanent rock-hole wetlands associated with ranges and uplands: These are locally significant water sources with high biological significance.
- Karlamilyi National Park: Part of the park is contained in the Little Sandy Desert bioregion. Karlamilyi National Park itself may provide a seasonal refuge to wildlife.

Indirect impacts of clearing, including dust, can be managed through appropriate control measures. Field inspections conducted in advance of clearing will also ensure that any resident animals are avoided or relocated.

Disturbance to fauna habitat will be minimised and areas known to contain conservation significant species or significant fauna habitat shall be excluded from the Project footprint where practicable. The DPaW will be consulted prior to any disturbance, should populations of significant species be identified within the Project boundary and disturbance of the area cannot be avoided. All sightings of significant species will be reported to the appropriate environmental personnel and be recorded on the site significant species register.

Ongoing mortality leading to population decline can occur as a result of road kill. Individuals of both the bilby and rock-wallaby are wide-ranging which makes them vulnerable to road kill. With small local populations, even small numbers of deaths from road kill can have a major impact. A number of procedures can be implemented to reduce the interaction between species and aspects of the operation. These are discussed in the Fauna Management Plan.

Habitat Fragmentation

The potential impact through habitat fragmentation is likely to be minor for the bilby, mulgara and rock-wallaby, as impact areas associated with the mine are concentrated and habitats are extensive. Roads are unlikely to present barriers to the movement of these species but large pipelines placed on the ground could disrupt movement of the mulgara. The potential impact through the establishment of linear infrastructure, such as pipelines, is considered to be minimal as the pipes are only small diameter. The management of impacts from this threat will be addressed in the Fauna Management Plan.

Disturbance

Impacts of disturbance (light, noise and vibration) are expected to be minor. The bilby found during the 2010 survey had been foraging within 20 m of the North Bore track which is used several times a day by the water truck and light vehicles. Evidence of bilby activity was also found at four locations along the existing Telfer to Kintyre road. Mulgara have also been recorded living within 20 m of active haul roads and public roads (M. Bamford *pers. obs.*). Significant fauna recorded within the Project area were located away from the proposed mining area.

Fire Regimes

Fire is a major contributor to the decline of a large proportion of Australian mammals (Burbidge and McKenzie, 1989). The main issue is the replacement of mosaic burning of small areas with very extensive but infrequent fires. The bilby and mulgara, in particular, are known to be sensitive to changed fire regimes. The most recent fires in the Kintyre region occurred during summer 2007/2008 and were extensive. During the surveys one bilby was found associated with one of the largest patches of hummock grassland that escaped that fire.

Fire regimes are unlikely to change as a direct result of the Project, assuming standard operating procedures are implemented, such as a system of hot work permits. However, the Project may provide indirect benefits including the establishment of linear infrastructure which will act as local fire breaks, the construction of physical and patch burnt fire breaks around the Project area for asset protection, and the availability of fire fighting equipment which may all assist in the reduction of frequency and extent of wildfires in the vicinity of the Project. There is also the potential for Cameco to work in conjunction with the DPaW and traditional owners to implement a landscape scale fire management programme, to create a mosaic of fire ages that would favour rare mammal species.

Species Interactions

Predation by feral species is the second major factor in the decline of Australian mammals, including bilby and rock-wallabies (Burbidge and McKenzie, 1989). The fox is of greatest concern. Bilbies coexist with feral cats in the Great Sandy Desert (M. Bamford *pers. obs.*). A feral cat was recorded close to the single bilby at Kintyre. However, feral cats have been implicated in the failure of attempts to reintroduce the bilby (Miller *et al.*, 2010). Rock-wallabies are thought to coexist with cats in the Pilbara.

There was evidence of a fox in the Kintyre region but the species appeared uncommon. Any fire management programme to improve the condition of the environment in the region for rare mammals would need to include a feral predator control strategy. Management of dingoes would need to be considered in this plan, as the presence of dingoes can suppress the numbers of foxes and feral cats, but it is also an efficient predator of native species.

Introduced fauna populations can increase if waste management and disposal sites are not properly maintained, as these can become a readily available food source. Waste disposal sites can also impact on native fauna through entrapment in waste disposal areas, ingestion of waste materials leading to death or the contamination of surface waters.

Within the Project area, there is the potential for fauna to be attracted to process water ponds, the IWL-TMF, landfill or accommodation village which may result in native fauna injury or mortality.

The key proposal from these fauna investigations is that the Project provides the opportunity for a landscape scale conservation programme that manages fire and feral species in order to conserve populations of the bilby, mulgara and rock-wallaby.

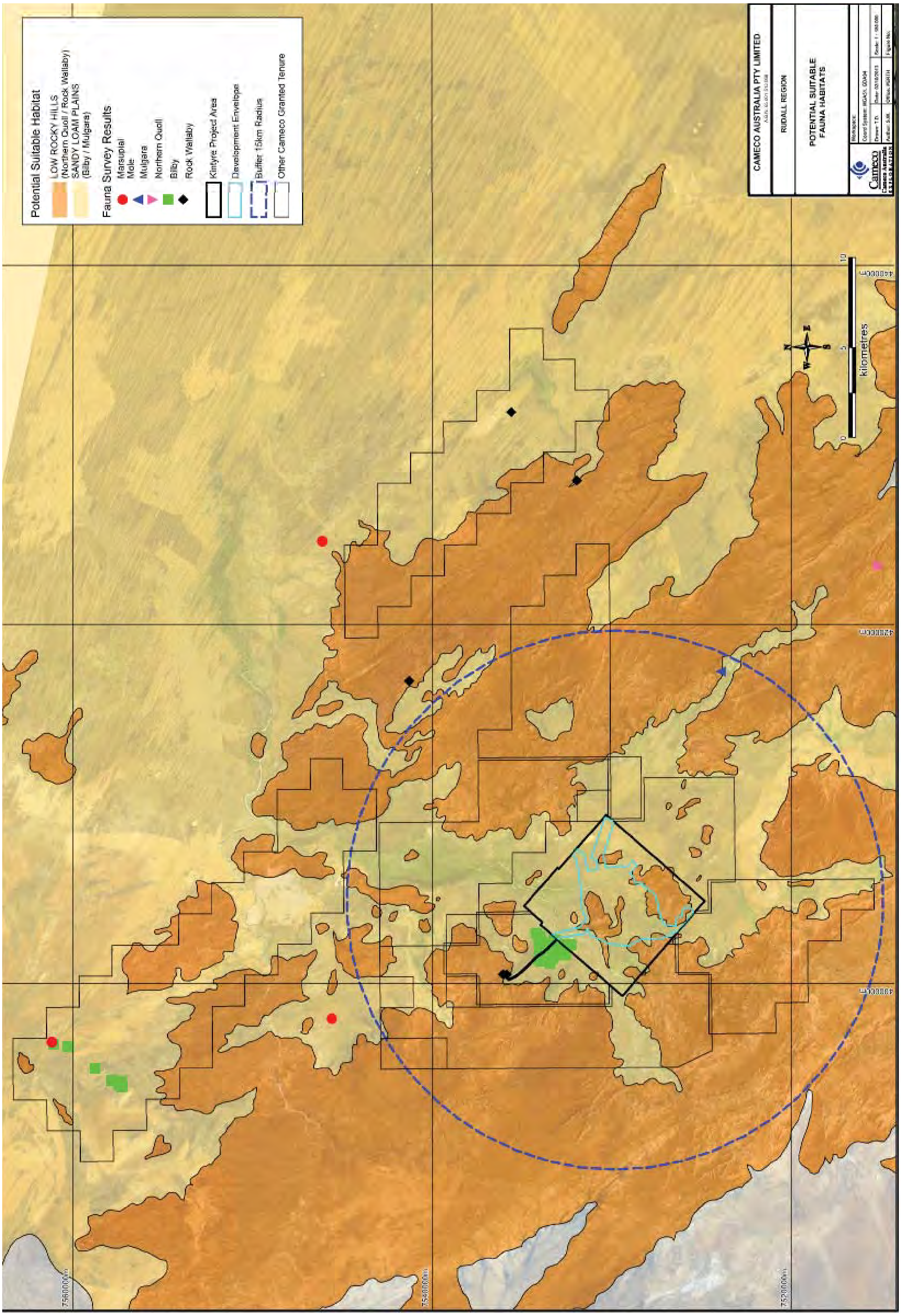


Figure 8-15: Habitat types in the vicinity of the Kintyre Project area

8.6.5.2 Short Range Endemic Species

Development of the Project is unlikely to present a threat to SREs. The two scorpions recorded during invertebrate sampling are almost certainly not SREs, as they were found in extensive environments that are well-represented in the broader region. The mygalomorph spider is widespread in the Pilbara although the specimens may be a species complex, so the distribution of the species recorded at Kintyre is uncertain. However, both the specimens found were found close to creeklines which will not be disturbed by the Project. The distribution of the pseudoscorpion is unknown but while the undescribed species at Kintyre may be an SRE, pseudoscorpions as a group are often associated with mesic microhabitats (i.e. locations where conditions are relatively moist within a local context), and it is likely that *Oratemnus* sp. is restricted to creeklines and other locations where moisture concentrates, such as the base of rocky hills. The creekline habitat will not be disturbed by the mine and associated facilities and rocky hills are a common feature in the region.

8.6.5.3 Proposed Management

Cameco has developed a Fauna Management Plan (Appendix D10) to minimise and manage potential impacts from the Project on native fauna. All ground disturbance and clearing activities will be undertaken in accordance with the Flora and Vegetation Management Plan (Appendix D9). 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.

There will be no unauthorised driving off tracks, night driving will be limited and vehicle speeds will be restricted around the Project site and sensitive habitats (Appendix D10).

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 TMF and 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.

A fire ban will be in place across the Project area, 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 area, which will include response to fire. Cameco will also prepare a Fire Prevention and Management Plan.

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.

Training on the identification and reporting of conservation-significant fauna species will be included in the Cameco site induction. Ongoing awareness of significant species present will be conducted through environmental induction and environmental awareness sessions and, posters, and will be discussed regularly in toolbox meetings. Training on vegetation clearing procedures will be included in the environmental induction.

8.6.6 Commitments

Cameco will implement the Fauna Management Plan which includes specific measures for conservation significant species.

Cameco commits to working with DPaW and Martu to assist in the implementation of a landscape scale fire management programme, to create a mosaic of fire ages that would favour rare mammal species.

8.6.7 Outcome

Cameco does not anticipate that the Project will affect the conservation status of any fauna species. With the proposed management measures outlined above and presented in the Fauna Management Plan, Cameco believes the Project can be constructed, operated and closed in a way which maintains the abundance, diversity, geographic distribution and productivity of native fauna species in the area.

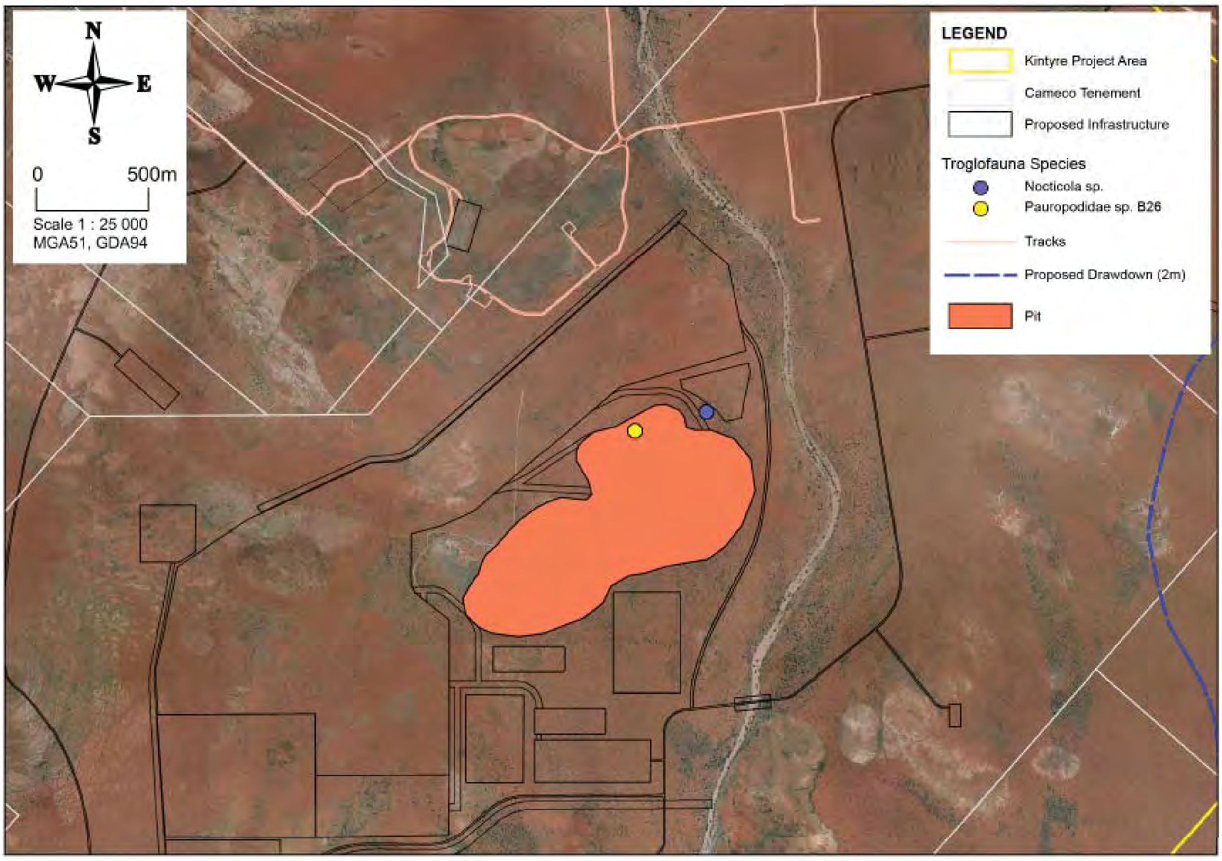


Figure 8-16: Troglofauna species known only from the proposed mine pit.

8.7 Subterranean Fauna

8.7.1 Objectives

The objective agreed to within the ESD with regards to subterranean fauna is to maintain the abundance, diversity, regional distribution and productivity of subterranean fauna at the species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

8.7.2 Relevant Legislation and Policy

An overview of the legislation and policies applicable to native fauna, including subterranean fauna are discussed in Section 8.6.2. The principal pieces of legislation are WA *Wildlife Conservation Act 1950* (WC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

8.7.3 Proponent Studies and Investigations

Subterranean fauna includes both terrestrial (troglofauna) and aquatic (stygofauna) species. Troglofauna occur in underground cavities, fissures and interstitial spaces above the water table whereas stygofauna inhabit groundwater environments. Most subterranean fauna are invertebrates, although both troglofaunal reptiles and stygofaunal fish have been recorded in Western Australia (Whitely, 1945; Aplin, 1998). The Pilbara is home to abundant communities of both stygofauna and troglofauna with new species being recorded frequently during investigations conducted for large scale mining projects. While troglofauna seem to be the most abundant in the Pilbara, they can occur in most regions of Western Australia and have been recorded from the Kimberley (Harvey, 2001), Cape Range (Harvey *et al*., 1993), Barrow Island (Biota, 2005b), the Mid-West (Ecologia, 2008), Yilgarn (Bennelongia, 2009), South-West (Biota, 2005a) and Nullarbor (Moore, 1995). Stygofauna species density appears relatively uniform across the region in the Pilbara with an estimated 500 to 550 species (Eberhard *et al*., 2009).

About 70% of stygofauna in the Pilbara meet the range criterion for SRE species (Eberhard *et al*., 2009) and the proportion of troglofaunal SREs is

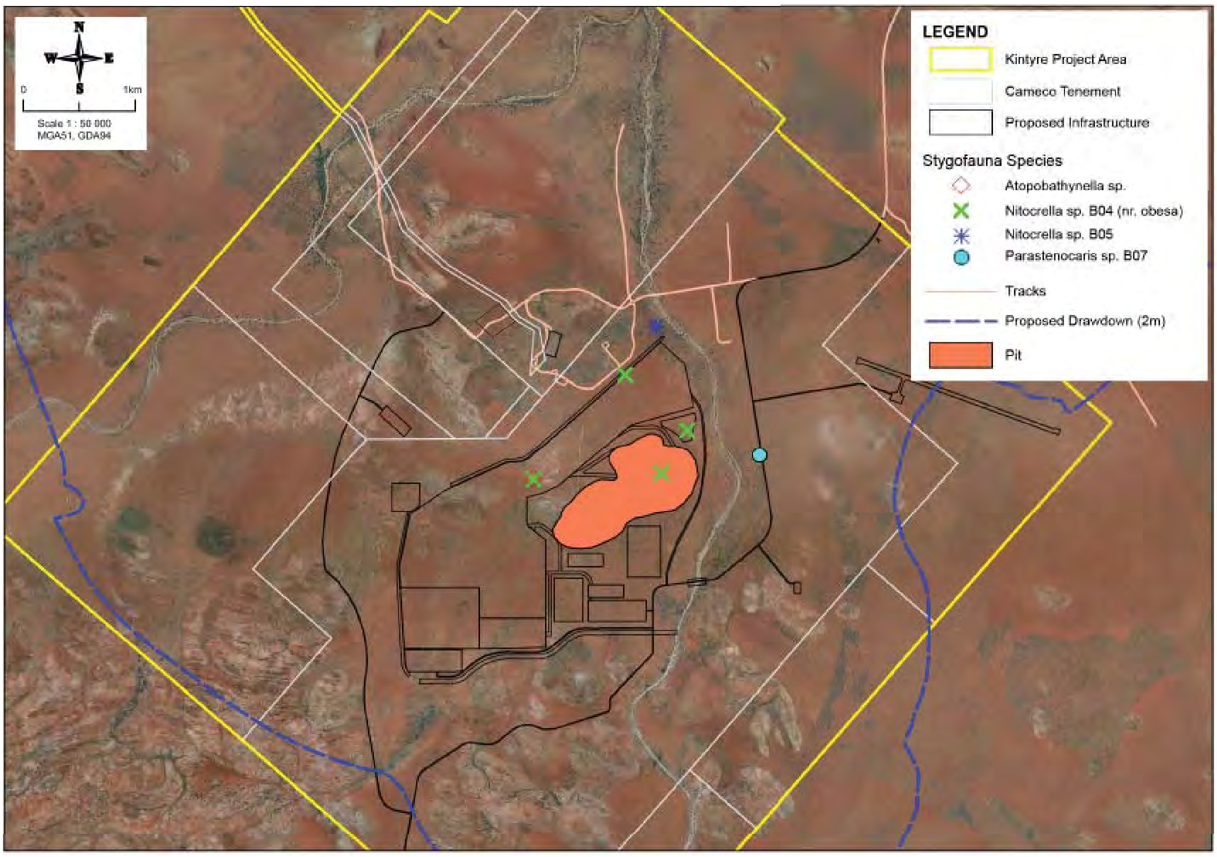


Figure 8-17: Stygofauna species known only from the proposed drawdown cone.

likely to be even higher (Lamoreux, 2004). This is a much higher proportion of restricted species than found in any group of surface invertebrate species. It highlights the fact that subterranean fauna represent an extreme example of SREs with very poor dispersal capacity.

Cameco commissioned an investigation into the subterranean fauna communities of the Project area and surrounds. This information was used to assess the likely impact of the Project on the subterranean fauna communities and their species and aid in further management of these communities during the life of the Project. The assessment was undertaken by Bennelongia Pty Ltd (Bennelongia, 2012b) and the report is presented as Appendix N.

The troglofauna survey was conducted in accordance with the general principles in EPA Guidance Statements Nos. 54 and 54A (EPA, 2003 and 2007b). Sampling was conducted both inside and outside of the proposed impact area over three sampling rounds in 2010. Troglofauna sampling involved both trapping and scraping techniques and collected 82 samples from proposed impact areas and 108 reference samples from outside the proposed impact area.

The stygofauna survey was conducted in accordance with the EPA Guidance Statements listed above (EPA, 2003 and 2007b). Samples were taken from 54 boreholes within and outside of the proposed impact area (defined as the extent of more than 2 m of groundwater drawdown). At each bore, six net hauls were collected using weighted plankton nets; three hauls with a 50 µm mesh net and three with a 150 µm mesh net. One hundred and forty-six samples were collected across the Project area during four sampling rounds in April and September 2010, December 2011 and April 2012.

8.7.4 Existing Environment

The proposed disturbance footprint and surrounding Project area contains geology that is generally similar, however can be variable, both laterally and vertically on a scale of tens to hundreds of metres. The survey recorded 23 troglofauna species of 12 Orders, and 15 stygofauna species of seven higher level groups. These represent a moderately rich troglofauna and a relatively sparse stygofauna community for the Pilbara region. The survey results are summarised below and presented in detail in Bennelongia's report in Appendix N.

8.7.4.1 Troglofauna

Troglofauna presence is dependent highly on geology, specifically the presence of fissures or voids below ground. If subterranean spaces are present, the pattern of their occurrence will largely determine the abundance and distribution of the troglofauna. Troglofauna habitat is usually considered to occur from the lower layers of sand and soil at the ground surface to the interface with the groundwater table (Juberthie, *et al*., 1981).

Vertical connectivity with the surface is important for supplying carbon and nutrients to maintain subterranean fauna populations (plant roots are an important surface connection), while lateral connectivity of voids is crucial to underground dispersal. Geological features such as dykes may block off the continuity of habitat and act as barriers to dispersal which leads to species having highly restricted ranges.

Prospective geological environments for troglofauna that occur in the Project area and surrounding landscape are relatively patchy and quantifying habitat connectivity for troglofauna in the Project area is inherently difficult. Connectivity has been inferred due to the lack of obvious barriers to troglofauna dispersal. Habitat characterisation suggests prospective troglofauna habitat is present within the Project area at depths between 1 m and 15 m as the water table generally occurs between 12 m – 15 m depth.

The community composition and abundance of troglofauna that was found in the survey areas is unremarkable (Bennelongia, 2012b). Pseudoscorpions, palpigrads, spiders, isopods, centipedes, millipedes, pauropods, symphylans, diplurans, silverfish, cockroaches and hemipterans are all commonly collected in the Pilbara (Biota, 2006; Bennelongia, 2009). Notably, schizomids and coleopterans were absent from the area surveyed. Two species of troglofauna; the pauropods *Pauropodidae* sp. B26 (eight specimens from one bore) and the cockroach *Nocticol*a sp. (a singleton), are currently known only from within the proposed mine pit at Kintyre (Figure 8-16) and mining poses potential conservation risks for these species. However, based on the small size of the proposed mine pit in relation to the likely ranges of both species (inferred from ranges of related species), it is unlikely that this potential risk will be realised.

8.7.4.2 Stygofauna

Stygofauna are also highly dependent on geological features, specifically hydrological environments consisting of karst, porous and fractured-rock aquifers, springs and the hyporheic flow of streams (a region beneath and along a stream bed, where mixing of ground and surface water occurs) (Eberhard *et al*., 2005). Stygofauna, like the troglofauna, inhabit the interstitial spaces, fissures and voids, but in the groundwater. Similar restrictive ranges are common to the stygofauna due to lateral connectivity or the absence thereof, as a result of impermeable geologic layers. Subbterranean species prefer fresh to brackish groundwater but may occur in salinities up to 60,000 mg/L TDS (Watts and Humphreys, 2006; Reeves *et al*., 2007; Ecologia, 2009). Stygofauna are known to be rich in calcareous systems where the pH is typically between 7.2 and 8.2 (Humphreys, 2001).

The aquifers in the survey area form part of the extensive regional aquifer system of the Yandagooge Creek. Extensive survey of the Pilbara region has indicated that most stygofauna species in the Pilbara have catchment scale ranges (Finston *et al*., 2007; Biota, 2010; Finston *et al*., 2011). However this cannot be assumed in the Project area due to the variable geological environment.

The hydrogeology of the Project area has limited connectivity with other watersheds, including those of the drainage systems entering Lake Dora, the Rudall River and Lake Waukarlycarly. These surface water features are remote from the Project area and lie upon low permeability sedimentary rocks at the southern edge of the Canning Basin. The palaeovalley within the Project area discharges to these low permeability formations north of the Broadhurst Range, but flow will be obstructed by the presence of extensive aquitards and faulting.

The stygofauna community composition within the Project area is unremarkable, with all of the commonly collected higher order groups recorded, with the exception of ostracods (Bennelongia, 2012b). Nine undescribed species were recorded in the survey area, but this may be expected in an area not previously sampled. Stygofauna habitat within the survey area appears to have a high degree of heterogeneity, although the hydrogeological units are repeated.

Four of the species recorded within the area of predicted groundwater drawdown from mining activities, are not known to occur elsewhere (Figure 8-17). The planned mining activity poses potential conservation risks for these species. The species are the copepods *Nitocrella* sp. B04 (nr *obesa*), *Nitocrella* sp. B05, *Parastenocaris* sp. B07 and the syncarid *Atopobathynella* sp.

Based on the ranges of related species, it is considered likely that *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp. (which were all collected in low abundance) have ranges extending beyond the zone of groundwater drawdown. Thus, the potential threat from mine development will not be realised for these species. The likely range of the more abundant *Nitocrella* sp. B04 (nr *obesa*) is unclear. However, it should be recognised that, depending on the aquifer in which the species occurs, groundwater drawdown will not necessarily adversely impact stygofauna. Information about the aquifers used by different species is not currently available. Further work on the geology of individual holes and lowering the net to different depths during sampling may provide more information on the aquifer being used by *Nitocrella* sp. B04 (nr *obesa*) but it would be a complex iterative process.

8.7.5 Potential Impacts and Management

8.7.5.1 Troglofauna

As highlighted during the survey the conservation status of only two troglofauna species, *Pauropodidae* sp. B26 and *Nocticola* sp., is possibly threatened by mine development. Irrespective of whether the ranges of these are centred on the proposed mine pit, the threat to both will be small because the mine pit will occupy only 75 ha. There is only one troglofauna species in north western Australia with a known range as small as the proposed mine pit which is a schizomid in a Robe Valley mesa. Its range is delimited by the extent of the mesa (Biota, 2006; Harvey *et al*., 2008) whereas other schizomids in the same landscape have ranges up to 1,970 ha. The likelihood of either species having a range this small is very low.

8.7.5.2 Stygofauna

The conservation status of four stygofauna species, *Nitocrella* sp. B04 (nr *obesa*), *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp., is possibly threatened by mine development. Based on the ranges of related species, it is considered likely that the three species collected in low abundance, *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp., have ranges extending beyond the zone of groundwater drawdown. Thus, the species are unlikely to be threatened by proposed mine development. However, the range of *Nitocrella* sp. B04 (nr *obesa*) is unclear. Depending on the aquifer in which the species occurs, groundwater drawdown will not necessarily adversely impact stygofauna. Species in deeper aquifers will remain unaffected by small drawdowns.

8.7.5.3 Habitat Mapping for Stygofauna and Troglofauna

It is believed that the potentially restricted Stygofauna species within the Kintyre Project area are associated with three geological environments, which are:

- the Permian/Quaternary cover sequences;
- the contact areas between chlorite-garnet-chert schists and pelitic schists; and
- the potential presence of Coolbro sandstone near the contact of the chlorite-garnet-chert schists and pelitic schists (note: this only applies to two of the sampling points that contained the restricted stygofauna species).

Cameco has mapped potential regional habitat locations (Figure 8-18) that are consistent to the above description through the use the Geological Survey of Western Australia (GSWA) 1:250,000 geological map products and geophysical information mapped by Cameco. Figure 8-18 shows three areas with similar geological sequences as the habitat sampled in the Project area, within close proximity to the Project area, but outside the impact zone (2 m draw down contour).

Using airborne magnetic datasets approximate depths to basement were estimated for the Kintyre tenements, and the three similar geological environments. A summary of the minimum, maximum and mean depth to basement is summarised in Table 8-18.

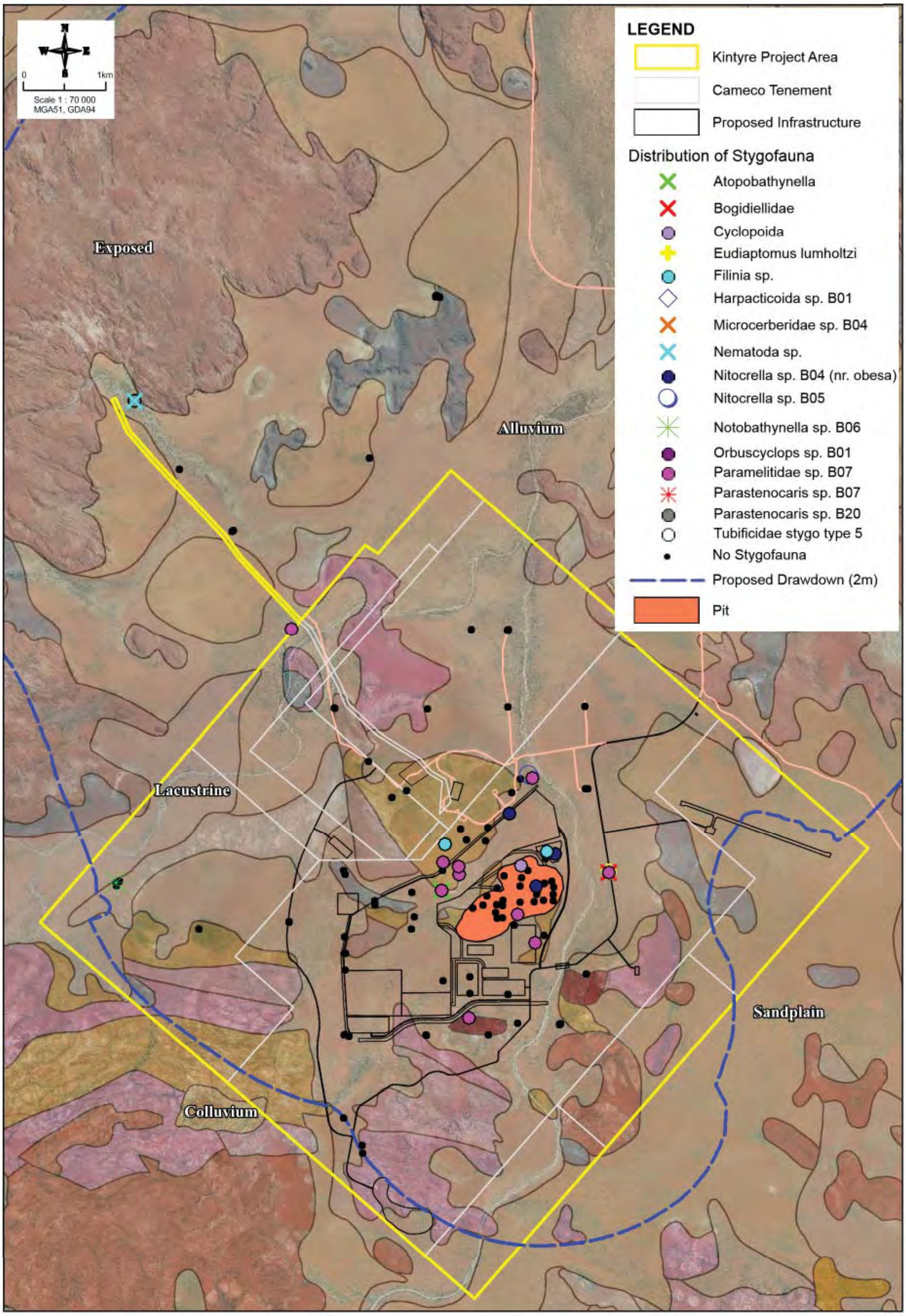


Figure 8-18: Distribution of stygofauna in the survey area in relation to geology

Table 8-18: Estimated depth to basement

Area	Estimated Depth of Basement		
	Min	Max	Mean
Kintyre Lease	10.5	443.8	101.6
Area 1	0.3	360	89.3
Area 2	6.3	395.2	56.4
Area 3	0	536.3	118.1

Permeability, porosity and other groundwater aquifer properties of basement rocks are a function of secondary geological fracture defects such as joints, faults and shears. From the drilling conducted at Kintyre, these fractures tend to close with depth, with significant water bearing fractures diminishing below around 60 m depth. The regional distribution of fractures is independent of geological boundaries; instead following the trend of faults and shears which cut straight across geological boundaries. Regional structural trends have developed in a dominant NW direction, which is coincident with the trend of the Kintyre Shear, however, there are also a number of other cross cutting structural directions which provide a degree of hydraulic connection in other directions. Therefore, it is likely that the groundwater depths in these areas are similar to those encountered in the impact zone.

While not conclusive, this work suggests there are a number of areas outside the impact zone where the hydrogeological conditions are similar and may represent likely suitable habitat outside of the impact zone.

Groundwater abstraction rates and groundwater levels will be monitored to confirm predicted drawdown levels. Groundwater abstraction rates will be maintained at the minimum required for safe operation and for Project water supply.

Cameco will undertake periodic ongoing sampling for subterranean fauna in existing bores.

Ground vibrations will be minimised where practicable to reduce impacts on subterranean fauna. The risk of groundwater contamination will be minimised through measures outlined in the groundwater section (Section 8.4.5), the Groundwater Management Plan (Appendix D8) and the Chemical and Fuel Storage Management Plan (Appendix D1).

8.7.6 Commitments

Cameco will implement the Subterranean Fauna Management Plan (Appendix D11). The Plan would include the following:

- Monitoring of groundwater levels to confirm predicted drawdown levels; and
- Ongoing periodic sampling in existing bores

8.7.7 Outcome

Cameco does not anticipate that the Project will significantly affect the conservation status of any subterranean fauna species for the following reasons:

- Many of the species found within the areas of impact (e.g. the pit) have also been found outside the areas of proposed impact;
- There are large areas of suitable habitat for subterranean fauna outside of the pit area (Figure 8-18);
- Many species identified in the pit area were present in low numbers and there is uncertainty in the sampling of stygofauna with low abundances in multiple locations; and
- Cameco has contributed to the improved understanding of subterranean fauna communities in the Pilbara region.

With the proposed management measures outline above, Cameco believes the Project can be constructed, operated and closed in a way which maintains the abundance, diversity, regional distribution and productivity of subterranean fauna at the species and ecosystem levels. Cameco has also contributed to the improved understanding of subterranean fauna communities in the Pilbara region.

8.8 Aquatic Fauna

8.8.1 Objectives

The objective agreed to within the ESD with regards to aquatic fauna is to maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

8.8.2 Relevant Legislation and Policy

An overview of the legislation and policies applicable to native fauna, including aquatic fauna

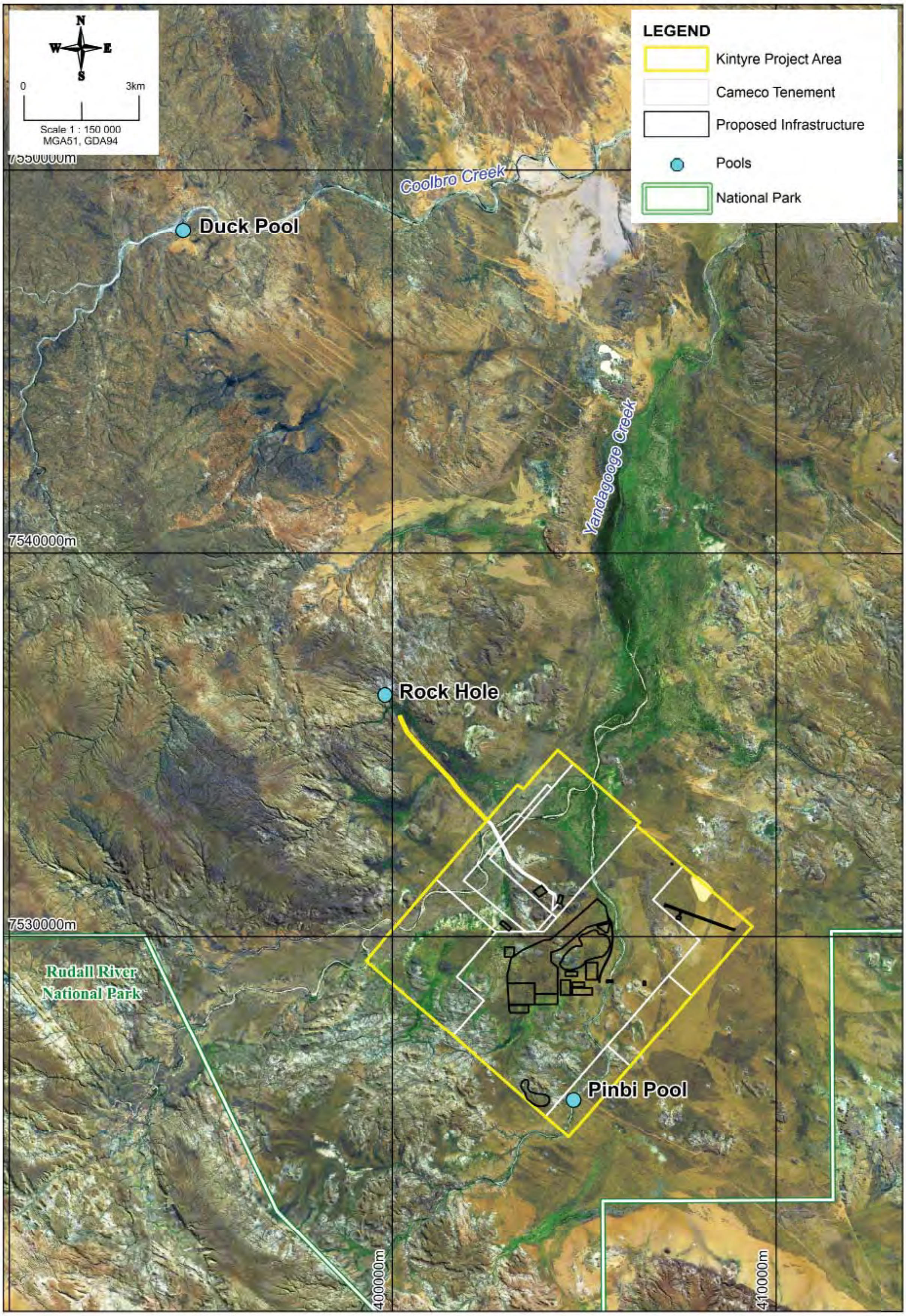


Figure 8-19: Location of the three pools sampled at Kintyre

are discussed in Section 8.6.2. The principal pieces of legislation are WA *Wildlife Conservation Act 1950* (WC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

8.8.3 Proponent Studies and Investigations

There are several pools which occur within the Yandagooge Creek and Coolbro Creek catchments. Whilst these are not expected to be affected by the Project (Section 8.3.5) Cameco has commissioned fauna surveys of three pools as part of a programme of due diligence. The pools are Duck Pool, Pinpi Pool and Rock Pool, which occur 21.5 km, 8.5 km and 4 km respectively from the Kintyre mine site (Figure 8-19).

An aquatic invertebrate fauna survey was undertaken by Bennelongia Pty Ltd (Bennelongia, 2012a). The report is provided as Appendix O to this ERMP. By comparing the fauna assemblages at these sites with assemblages at 38 other river pools across the Pilbara region, an assessment of the conservation significance of the three pools was made. Each of the pools was surveyed three times during 2011 during the periods 28 - 30 June, 23 - 24 November and 16 - 17 December. Benthic invertebrates were collected by kick and sweep sampling. Planktonic invertebrates were collected by sweep sampling with a 50 µm mesh net. All aquatic habitat types were sampled at each site and water samples were also collected and analysed.

8.8.4 Existing Environment

An extensive survey of 98 wetlands across the Pilbara found the diversity of aquatic invertebrates is high compared to most arid regions, with more than 1,000 species spread across the region. The average number of species at these pools per spring and autumn sample was just over 100, although one wetland (Pelican Pool on the De Grey River) supported 226 species (Pinder *et al*. 2010). The innate diversity of the Pilbara aquatic invertebrate community is not matched by high levels of endemism within the region, with approximately half of the species widespread in Australia, with a further quarter known from across northern Australia and/or inland regions.

The Kintyre mine site lies between two branches of Yandagooge Creek, referred to as the South Branch and the West Branch. The tributaries converge north of Kintyre and continue to flow on a northerly course to Coolbro Creek, which flows east towards the Great Sandy Desert where the surface drainage dissipates into dune systems.

Pinpi Pool is located approximately 4 km south and upstream of the Project area on the South Branch of Yandagooge Creek. Rock Pool is approximately 8.5 km northwest of the Project area on a tributary to the West Branch of the Yandagooge Creek, in a separate sub-catchment to the Project area. Duck Pool is located approximately 21.5 km northwest of the Project area on the Coolbro Creek upstream of the confluence where it joins with Yandagooge Creek (Figure 8-19). The Yandagooge Creek System catchment is separated from pools in the Rudall River catchment by low hills.

A total of 270 invertebrate aquatic fauna were identified from 25 major taxonomic groups from the three river pools. The pattern of species richness among taxonomic groups was similar at all three sites. The most abundant species groups were the insect orders of Diptera, Coleoptera and Hemiptera with the invertebrate assemblages also characterised by significant proportions of mites and rotifers.

Six potentially conservation significant species were identified. The anostracan *Branchinella* nr *wellardi* is either a new species or at the periphery of its known range at Pinpi Pool. The status of *Branchinella wellardi* as vulnerable on the IUCN Red List and its designation as a Priority 1 species by the DPaW makes the record of *Branchinella* nr *wellardi* an important one that contributes to the conservation significance of Pinpi Pool. The other five potentially conservation significant species were the copepod Thermocyclops sp. B3 and four water mite species (*Encentridophorus* sp. B1, *Unionicola* sp. B1, *Limnesia* sp. B2 and *Hydrachna* sp. B1). It is considered quite likely that *Limnesia* sp. B2 and *Hydrachna* sp. B1 have been previously collected at other sites in the Pilbara. It is considered likely that further sampling will show all six species occur in other wetlands around the Kintyre area or in the north eastern Pilbara.

An assessment undertaken by Pennington Scott (2012a) on Rock Pool and Pinpi Pool determined it highly unlikely that a hydraulic connection exists between the water table and these Pools (Section 8.4.4). Analysis of water table elevations at the pools, ground elevations at the pools and hydrographs from several bores in the vicinity of


Plate 8-10: The site at Pinpi Rockpool in March 2012 (left) and July 2012 (right) during both inundated and dry conditions respectively.

Plate 8-11: Rock Pool

Plate 8-12: Duck Pool

Photos courtesy of Bennelongia Pty Ltd

the pools indicated the presence of an intervening unsaturated zone between the pool beds and the water table, meaning there is no hydraulic connection present. The lack of hydraulic conductivity is further evidenced by an absence of any relationship between water level fluctuations in the pools due to streamflow and groundwater levels. If the Pools were hydraulically connected to the groundwater, water levels in monitor bores should show a relationship to streamflow. The evidence indicates that the Pools are surface water features that are filled following significant streamflow events, and then gradually emptied through seepage and evaporation. Water levels in the Pools fluctuate significantly depending on the season and rainfall events. Pinpi Pool has been observed in a dry state (Plate 8-10), while very high and low water levels have been observed at Duck Pool and Rock Pool at different times of the year (Plates 8-11 and 8-12 respectively).

8.8.5 Potential Impacts and Management

As the pools occur either upstream from (Pinpi Pool) or in separate sub-catchments (Duck Pool and Rock Pool) to the Project, there are not expected to be any direct impacts on these pools as a result of the Project.

Duck Pool is accessible from the Telfer to Kintyre Track and is a popular camping place for locals and cross country 4WD tour operators. It is the most used of the three pools sampled. Pinpi Pool is occasionally visited by local Martu and the Rock Pool is rarely visited. There is the potential for indirect impacts should improved access to the Kintyre Project area result in an increase in visitors to the pools. Cameco will manage access to Pinpi Pool and Rock Pool by applying restrictions on the use of the pools by employees at the mine site. However, as both Duck Pool and Pinpi Pool are accessible to the public, there is limited scope for Cameco to manage the use of these places by people outside of its workforce.

The results of the aquatic invertebrate study indicate that the three pools are typical of the Pilbara region in terms of species richness and distribution. Only the June sample from Duck Pool contained species numbers that exceeded the sample average for autumn surveys across the region. Even the closest sites to the three surveyed pools (sites 27 and 28 – Desert Queen Baths and Watrara Creek Pool in the Rudall River catchment), appeared to be characterised by higher species richness than the Kintyre sites (DEC, 2009).

The pattern of samples containing high proportions of dipteran, coleopteran and hemipteran insects, together with the significant representation of ploimid rotifers and mites, was consistent with the three Kintyre pools and the overall river pool pattern in the Pilbara region. None of the Kintyre pools appeared to support a unique aquatic invertebrate assemblage that could be considered to have special conservation significance. However the presence of *Branchinella wellardi* contributes to the conservation significance of Pinpi Pool.

Comparisons with other river pools in the Pilbara region showed that species richness, and distribution of species among taxonomic groups, at all three sample sites are typical, in general, of the Pilbara region and do not represent special or unique assemblages.

8.8.6 Commitments

Cameco does not expect the Project will result in any impacts on the pools in the area. However, periodic water quality monitoring of Duck Pool, Pinpi Pool and Rock Pool will be undertaken in accordance with the Surface Water Management Plan.

8.8.7 Outcome

Cameco expects that there will be no significant impact on aquatic fauna within the site area, due to the proposed activities associated with the Kintyre Project.

8.9 Conservation Areas

8.9.1 Objectives

The objective agreed to within the ESD with regards to conservation areas is to protect the environmental values of areas identified as having significant environmental attributes.

8.9.2 Relevant Legislation and Policy

The Karlamilyi National Park (formerly Rudall River National Park) is an "A" Class Reserve under the *Land Administration Act 1997* (formerly the Land Act 1933). It is located south of the Project area (Figure 8-20) and managed by the Department of Parks and Wildlife (DPaW) under the *Conservation and Land Management Act 1984*. Under Sections 24 and 25 of the *Mining Act 1978*, mining cannot be carried out on various types of reserved land without the prior written consent of the Minister for Mines. This consent can only be given after consultation with the responsible Minister and the vested authority. In the case of National Parks and Class "A" conservation reserves the Minister for the Environment must give concurrence with the grant of title. Cameco is not proposing to mine within the Karlamilyi National Park.

The Rudall River National Park was listed on the Register of National Estate in 1978 (Place ID number 10054) and the boundary follows the old Rudall River National Park boundary which included part of the Project area (Section 7.4.2).

The site has been transferred to the State Register of Heritage Places (Place No. 18725) listed under the *Heritage of Western Australia Act 1990*.

The site is also listed as an Environmentally Sensitive Area (ESA) under regulation 6 of the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 (Clearing Regulations).

The Project area occurs within a Priority 1 Wild River area identified by the Department of Water (DoW, 2009) (Section 7.4.3) and listed under Schedule 1 clause 4 of the Clearing Regulations. Both ESAs and Schedule 1 areas are not subject to the exemptions for exploration and low impact mineral and petroleum activities listed under Regulation 5 of the Clearing Regulations. Any ground disturbing activities therefore require a Clearing Permit under the Clearing Regulations. All exploration and associated ground disturbing activities undertaken by Cameco within the Project area to date, have been in accordance with clearing permits issued under the Clearing Regulations. As assessment of this Project will consider the impacts of clearing vegetation (Section 8.5.5) any approval that may be granted under Part IV of the *Environmental Protection Act 1986* will not require further Clearing Permits under the Clearing Regulations.

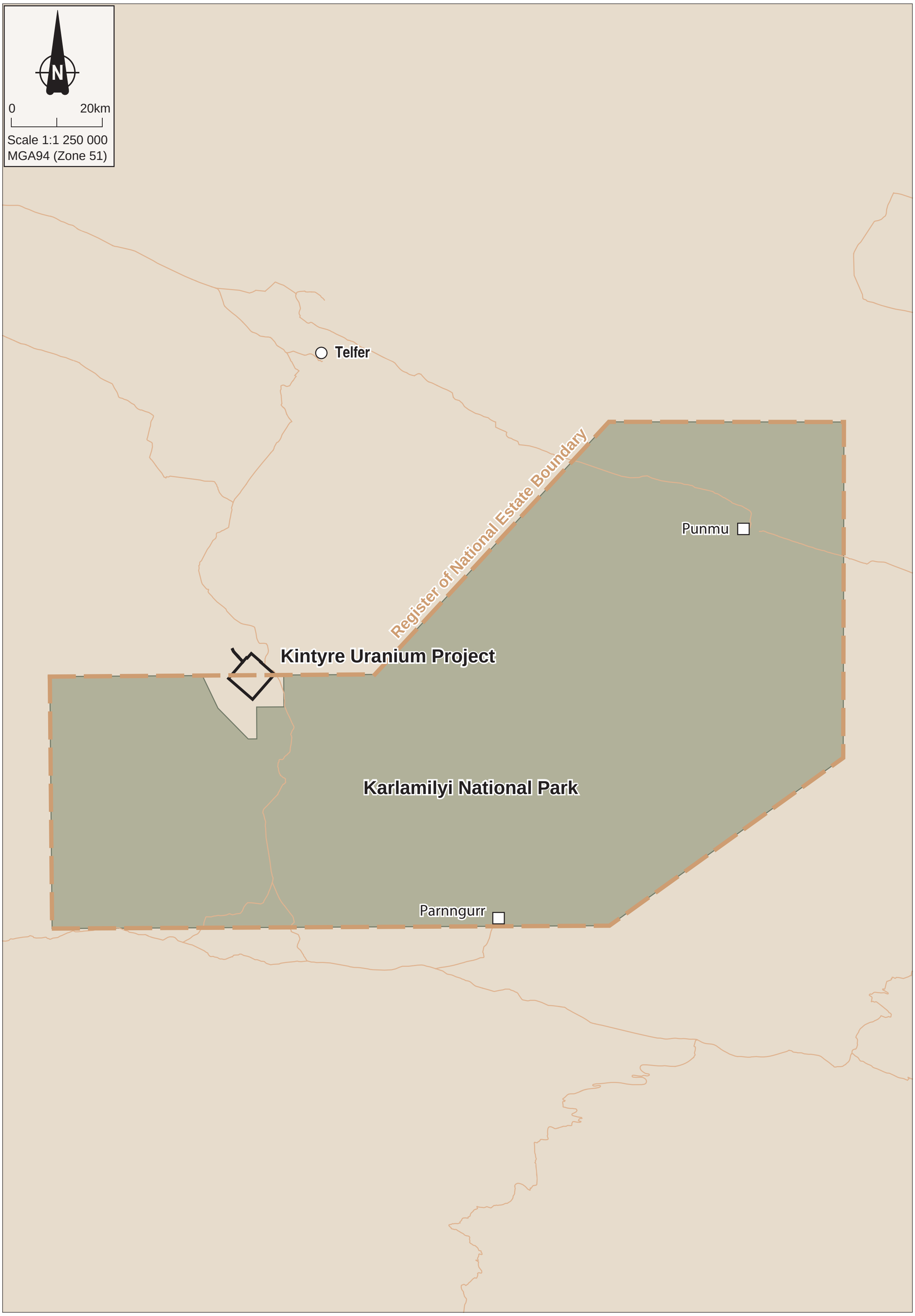


Figure 8-20: Karlamilyi National Park and Register of the National Estate Area

8.9.3 Karlamilyi National Park

The Karlamilyi National Park represents a transition zone between the Little Sandy Desert in the southwest and the Great Sandy Desert in the northeast with a central belt of stony hills and flattish plains in between (DPaW Parkfinder website http://www.dpaw.wa.gov.au/parkfinder accessed 26 September 2013). The park was created in 1977 as the Rudall River National Park, for the purposes of conserving the arid river system and environment of the Rudall River. The boundary of the park was changed in 1994 and the name changed to Karlamilyi National Park in 2008.

The park has limited road access and no public facilities such as fresh water, fuel or camping facilities. The main tracks into the park are from Telfer in the north, the Talawana Track in the south, and from the Rudall River crossing to Hanging Rock, on the western boundary of the park.

The southern boundary of the Project tenements is 5 km from the National Park boundary (Figure 8-20).

8.9.4 Register of the National Estate

As stated in Section 8.9.2, the Rudall River National Park (1978 boundary) was listed on the Register of National Estate (site 10054) and included the Project area. The Register of National Estate is no longer active, and is now considered a non-statutory archive. Site 10054 has now been transferred to the State Heritage Register of Western Australia (Place No. 18725). A complete description of the site is available on the Register of National Estate archive (http://www.environment.gov.au/cgi-bin/ahdb/search.pl accessed 22 June 2012). An excerpt on the significance of the site is provided below.

> The place contains a large number of landform types and vegetation communities representative of the south western part of the Great Sandy Desert and the north eastern part of the Little Sandy Desert.
>
> It is a significant transition zone for flora and fauna between the Great Sandy Desert to the north, the Little Sandy Desert to the south and the semi-arid Pilbara to the west. A number of species are at their southern or northern limits of distribution are found in the place. The place is particularly important to the southern Eremaean bird population associated with low Mulga woodland.
>
> It is an area of diverse flora with over 400 species, more than half of the known flora of the Great Sandy Desert.
>
> It contains the Rudall River system which acts as a refugium habitat for species of plants and animals uncommon or rare in the Great Sandy Desert.
>
> The Rudall River system maintains significant communities of *Eucalyptus camaldulensis*, *E. aff. microtheca* and *Melaleuca leucadendra* not represented extensively elsewhere in the Great Sandy Desert.
>
> The place is important as a waterbird habitat with high numbers of water birds using Lake Dora.
>
> It has a number of relict bird populations of sacred kingfishers (*Halcyon sancta*), Port Lincoln ring-necked parrots (*Barnardius zonarius*), and peaceful doves (*Geopelia striata*).
>
> The area contains an important population of the rare Greater Bilby (*Macrotis lagotis*) on the eastern side of Lake Dora.
>
> The place has the highest recorded diversity of frogs in the Great Sandy Desert.
>
> The place has well preserved geological formations associated with Permian glaciation. It contains a very diverse number of landscape features typical of Australian tropical deserts which are highly valued by members of the community.

8.9.5 Potential Impacts and Management

Whilst part of the Kintyre Project area occurs within a state heritage listed area (Figure 8-20) and is therefore considered an ESA, the values for which the site was listed are protected within the Karlamilyi National Park located 5 km south of the Project area. The risk of direct impacts from the Project on Karlamilyi National Park from dust (Section 8.10.5) and visual impacts (Section 9.2) are considered extremely low or negligible.

The Project area is also covered by an area listed in Schedule 1 of the Clearing Regulations as a Priority 1 Wild River area. It is identified as the Rudall River area and includes the Rudall River catchment and the Coolbro Creek catchment. The Project is located in the Coolbro Creek catchment (Section 8.3.4).

Surface water impacts of the Project on the Coolbro Creek catchment are discussed in Section 8.3.5. The Project is not expected to have any impacts on the Rudall River catchment.

The access road to the Project area will be from the north. However, improved access to the area may encourage more people to visit Karlamilyi National Park and place pressure on natural resources and increase the risk of fire. Tracks within the National Park are not regularly maintained and would not support a significant increase in vehicles without damage to soil structure and vegetation. Any weeds which may be growing near the access road may also be transported into the National Park from seeds picked up by vehicles using the access road.

DPaW is responsible for management of the National Park. Cameco is proposing to work with DPaW and indigenous stakeholders to manage potential indirect impacts on the National Park such as increased access, risk of fire and risk of weeds. Consultation regarding these aspects has commenced (Section 4.2). Cameco will prepare and implement a Fire Prevention and Management Plan (Appendix D4) and weed management measures within its Flora and Vegetation Management Plan (Appendices D9) to reduce the risk of these aspects on the National Park.

8.9.6 Commitments

Cameco will implement the Flora and Vegetation Management Plan and the Fauna Management Plan.

Cameco will undertake progressive rehabilitation of the Project area in accordance with the Mine Closure and Rehabilitation Plan.

Cameco will work with DPaW and indigenous stakeholders to manage any indirect impacts on the National Park such as increased access, risk of fire and risk of weeds.

8.9.7 Outcome

There are not expected to be any direct impacts on Karlamilyi National Park or the Rudall River catchment area. Any indirect impacts such as improved road access and increased risk of fire and introduction of weeds to the park are considered manageable.

Cameco believes the environmental values of Karlamilyi National Park and the Rudall River catchment area will be protected with implementation of the proposed management measures for the Project.

8.10 Air Quality

8.10.1 Objectives

The objective agreed to within the ESD with regards to air quality is to ensure that emissions from the Project do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

8.10.2 Relevant Legislation and Policy

The key emission of concern for the Project is dust (or particulates). Dust is generally defined as particles that can remain suspended in the air by turbulence for a period of time and can consist of a range of matter including crustal material, pollens, sea salts and smoke from combustion products. 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 with an equivalent aerodynamic particle size below 50 µm diameter. 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 below 10 µm in equivalent aerodynamic diameter; and
- $PM_{2.5}$, particulate matter below 2.5 µm 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 soiling of washing. PM_{10} and $PM_{2.5}$ are associated with the potential for health impacts as finer particle fractions can enter deeper into the lungs.

The National Environment Protection Council (NEPC) has produced national ambient air quality standards for the protection of human health relevant to particulates. These include the National Environment Protection (Ambient Air Quality) Measure (NEPM) (NEPC, 1998), which sets national air quality standards for criteria pollutants including particulate (as PM_{10}), and the Variation to the National Environment Protection (Ambient Air Quality) Measure (NEPC, 2002) which sets an advisory reporting standard for $PM_{2.5}$. These standards have been derived from health studies

Table 8-19: Particulate ambient air quality standards

Pollutant	Averaging Period	Standard (µg/m³)	Goal	Reference
TSP	1 day	Area A – 150[1]	NA	EPA (1999)
		Area B – 90[2]		
		Area C – 90[3]		
Particles as PM_{10}	1 day	50	5 days a year	NEPC (1998)
Particles as $PM_{2.5}$	1 day	25	To gather sufficient data to facilitate a review of the standard	NEPC (2002)
	1 year	8		

Notes:

[1] Kwinana EPP Area A (Industrial Zone) standard
[2] Kwinana EPP Area B (Buffer Zone) standard
[3] Kwinana EPP Area C (Residential and Rural Zone) standard.
[4] $PM_{2.5}$ standards listed are advisory reporting standards.

in major urban centres where the particulate matter primarily consisted of combustion products from vehicles, industry and smoke from various burning activities. The purpose of the $PM_{2.5}$ advisory standard is to gather sufficient data to facilitate a review of the standard as part of the review of the ambient air quality NEPM that is currently underway. The Western Australian State Government has adopted the NEPM standards for ambient air quality as part of the draft State Environmental (Ambient Air) Policy 2009 (EPA, 2009b) and the NEPM standards for PM_{10} and $PM_{2.5}$ have subsequently been applied in this assessment.

In addition to the NEPC NEPMs, the EPA has established an Environmental Protection Policy (EPP) which provides ambient air quality standards for TSP and sulphur dioxide (EPA, 1999) for Kwinana. These standards were established in order to maintain acceptable air quality within and around the Kwinana Industrial Area. The Kwinana EPP defines three regions which are covered by the policy; the industrial zone (Area A), the buffer zone surrounding heavy industry (Area B) and the rural and residential zone (Area C). In the absence of national ambient air quality standards for TSP, the EPA's standard for TSP within the industrial zone (Area A) has been applied within operating areas at the mine site and the standard for TSP within rural and residential areas (Area C) has been applied at sensitive receptors, namely the onsite accommodation camp.

The NEPC and Kwinana EPP ambient air quality standards for particulates relevant to this study are provided in Table 8-19.

In addition, the New South Wales Office of Environment and Heritage (NSW OEH) has defined dust deposition criteria which are presented in Table 8-20. 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.

Table 8-20: Dust deposition criteria

Pollutant	Averaging Period	Criteria (g/m²/month)
Deposited Dust [1]	Annual (increase) [2]	2
	Annual (total) [3]	4

Notes:

[1] Dust is assessed as insoluble solids as defined by AS 3580.10.1-1991 (AM-19).
[2] Maximum increase in deposited dust level. Kwinana EPP Area B (Buffer Zone) standard.
[3] Maximum total deposited dust level.

The NEPC's (1998) national air quality standards for the criteria pollutants carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) are presented in Table 8-21. As noted above, the NEPM standards for ambient air quality have been adopted by the State Government as part of the draft State Environmental (Ambient Air) Policy 2009 (EPA, 2009b).

Table 8-21: Ambient air quality standards

Pollutant	Averaging Period	Standard (µg/m³)	Maximum Allowable Exceedances	Source
CO	8-hour	11,100	1 day per year	NEPC, 1998
NO_2[1]	1-hour	246	1 day per year	
	Annual	62	none	
SO_2[1]	1-hour	571	1 day per year	
	24-hour	228	1 day per year	
	Annual	60	none	

Notes:
[1] NEPM standards for NO_2 and SO_2 have been converted from ppm to µg/m³ at STP

Guideline NORM-4.1 Controlling NORM-dust control strategies- provides guidance on a variety of strategies that may assist in minimisation of radiation exposure from dust inhalation. These include principles for dust control in surface mining, engineering controls and respiratory protection.

8.10.3 Proponent Studies and Investigations

Cameco commissioned ENVIRON Australia Pty Ltd (ENVIRON) to undertake air dispersion modelling of emissions of dust and other pollutants generated by the proposed mining, processing and power generation facilities at the Project site, to assess the potential ambient air quality impacts associated with the proposed Kintyre Uranium Project. The complete report for the air quality study is presented in Appendix G.

The assessment focused on fugitive dust emissions associated with mining operations, truck loading, stockpiling, reclaiming, primary and secondary crushing, radiometric sorting, vehicle movements on unpaved roads and wind erosion of unpaved surfaces including the ROM pad and WRL; as well as point source emissions of pollutants such as NO_2 and SO_2 from the diesel-generated power station. The calciner stack will be fitted with a wet scrubber and dust collectors will be fitted to the grinding and milling circuits. Particulate emissions from the process plant are therefore expected to be negligible.

The air quality impacts from the Project were modelled using the Victorian Environmental Protection Agency (VEPA)'s Gaussian plume dispersion model Ausplume (Version 6.0). Ausplume is regularly used for assessing impacts from industrial sites within Australia and has been used for a number of dust modelling assessments at mine sites and port operations throughout Western Australia, including a DMP funded study that included cumulative particulate modelling of the Port Hedland area (SKM, 2007).

Emission factors were estimated from process and throughput information provided by Cameco and factors provided by the Australian National Pollutant Inventory (NPI) Emission Factors (NPI, 2011) and the US Environmental Protection Agency AP 42 'Compilation of Air Pollutant Emission Factors' (USEPA 2004a, 2004b, 2006).

Meteorological data for input into the Ausplume model was provided by Bureau of Meteorology (BoM) monitoring data for Telfer for the 2009 calendar year. Whilst Cameco has established a meteorological monitoring station at Kintyre, problems with continuity of power at the site meant the dataset was insufficient for use in the air dispersion modelling. A comparison of the dataset from Telfer and data available for Kintyre indicated a good correlation in the data. Upper air data (temperature) were extracted from CSIRO's 'The Air Pollution Model' (TAPM).

Air dispersion modelling has been completed to predict the short-term and long-term ambient ground level concentrations (GLCs) of TSP, PM_{10}, and $PM_{2.5}$ associated with a peak production scenario. Particulate deposition rates have been predicted to assess the impact of dust deposition on the surrounding environment. The air dispersion model has also been utilised to predict GLCs of pollutants associated with emissions from the power station to assess these impacts on ambient air quality.

8.10.4 Existing Environment

The Project area has an arid climate with hot summers and warm dry winters. Meteorological monitoring programmes commenced in 1987 and continued until 1992 when the Project was put into care and maintenance. Monitoring recommenced in 1996 with the advancement of a full feasibility study and ended in 1998 as the Project was once again placed under care and maintenance. While an on-site meteorological monitoring programme was established in 2010, there were initial ongoing problems relating to the provision of a stable power supply that affected on data recovery. A summary of the site's climate is provided in Section 7.5 and Appendix G.

Monitoring of dust deposition levels was undertaken at five monitoring sites in and around the Project area between June 1996 and July 1998. The monthly deposition data collected at these sites showed that the natural dust deposition level in the area were relatively high and regularly approached or exceeded the guideline of 4 g/m^2/month listed in Table 8-20.

The average monthly deposition rates measured during the current monitoring programme are generally well below those measured between 1996 and 1998, with the average deposition rate over the first 12 months of the monitoring programme being less than 2 g/m^2/month with a maximum deposition rate of 2 g/m^2/month. The lower dust deposition rates currently being recorded may be attributable to higher rainfall during 2010 and 2011 than occurred between 1996 and 1998. It is also possible that greater levels of vegetation cover were present during 2010/2011 than between 1996 and 1998 due to the higher rainfall that has occurred in the region.

The maximum 24-hour average PM_{10} concentration recorded at the Kintyre Project site between August 2010 and June 2011 was 39 $\mu g/m^3$ and was recorded under moderate (4 m/s) south-westerly winds. Although there were no recorded exceedances of the PM_{10} 24 hour average NEPM standard (50 $\mu g/m^3$), compliance with the standard cannot be demonstrated reliably due to the low data recovery rates throughout the monitoring period.

8.10.5 Potential Impacts and Management

A complete description of the results of the air quality study is presented in Appendix G.

Short-term and long-term ambient ground level concentrations (GLCs) of TSP, PM_{10} and $PM_{2.5}$ were predicted for the peak production scenario. Particulate deposition rates were predicted to assess the impact of dust deposition on the surrounding environment. GLCs of pollutants associated with emissions from the power station were also predicted to assess these impacts on ambient air quality.

A summary of the maximum offsite TSP, PM_{10} and $PM_{2.5}$ concentrations predicted for the proposed Project in isolation from background concentrations is presented in Table 8-22. The maximum concentrations predicted at the onsite accommodation camp are also presented.

The results of the air dispersion modelling show that the off-site impacts of TSP, PM_{10} and $PM_{2.5}$ concentrations are predicted to be below the ambient guidelines with exceedances of these guidelines predicted to be localised to the immediate vicinity of the Project area (Figure 8-21 to Figure 8-24). The Project is expected to comply with the ambient air quality guidelines for TSP, PM_{10} and PM2.5 at the accommodation camp. The maximum 24-hour average TSP and $PM_{2.5}$ concentrations predicted at the accommodation camp are associated with moderate, north-northwesterlies.

A summary of the highest monthly average TSP deposition rates predicted for the proposed Project at the site boundary and at the accommodation camp is presented in Table 8-23.

The incremental guideline for particulate deposition is predicted to be exceeded within the tenement boundary, although the average TSP deposition rate predicted at the onsite accommodation camp remains well below the incremental dust deposition guideline. Wind erosion from the western WRL is the primary source contributing to the maximum deposition rates predicted to the north-west of the Project site and at the onsite accommodation village.

No exceedances of the ambient air quality objectives for sulphur dioxide, nitrogen dioxide, or carbon monoxide are predicted to occur as a result of the Project's proposed power station emissions.

The air dispersion modelling results indicate that the proposed Kintyre Project is not expected to result in any significant issues with regards to potential ambient air quality impacts.

Table 8-22: Summary of predicted TSP, PM_{10} and $PM_{2.5}$ GLCs

Particulate Faction	Averaging Period	Standard (µg/m³)	Predicted GLC (µg/m³)	
			Tenement Boundary	Accommodation Camp
TSP	24-hour	150[2]/90[3]	87	40
PM_{10}	24-hour	50	47	29
$PM_{2.5}$	24-hour	25	20	9.5
	Annual	8	1.3	0.4

Notes:

1 Maximum predicted GLC at Project boundary.
2 Kwinana EPP Area A (Industrial Zone) standard.
3 Kwinana EPP Area C (Residential and Rural Zone) standard. NEPM standards for NO_2 and SO_2 have been converted from ppm to µg/m³ at STP.

Table 8-23: Summary of predicted TSP deposition rates

Particulate Faction	Standard (µg/m³)	Tenement Boundary	Accommodation Camp
TSP	2 (increase)[2]	1.5	0.7
	4 (total)[3]		

Notes:

1 Maximum predicted GLC at Project boundary.
2 Maximum annual increase in deposited dust level.
3 Maximum annual total deposited dust level.

A Dust Management Plan has been prepared for the Project (Appendix D5). The Project has been designed with a strong focus on minimising dust emissions. Within the mining and WRL 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 8.11.6.2). The Dust Management Plan includes ambient monitoring of PM_{10} concentrations and dust deposition rates.

8.10.6 Commitments

Cameco will comply with the Ambient Air Quality NEPM which will be used as the basis for developing regulatory limits and management targets for the Project.

Cameco will implement the Dust Management Plan to ensure dust levels are kept as low as reasonably achievable. This will include particulate monitoring throughout operations.

8.10.7 Outcome

Cameco expects that the Project will comply with all air quality standards for particulates and dust deposition and will not adversely affect environmental values or the health, welfare and amenity of people and land uses within the vicinity of the Kintyre Project.

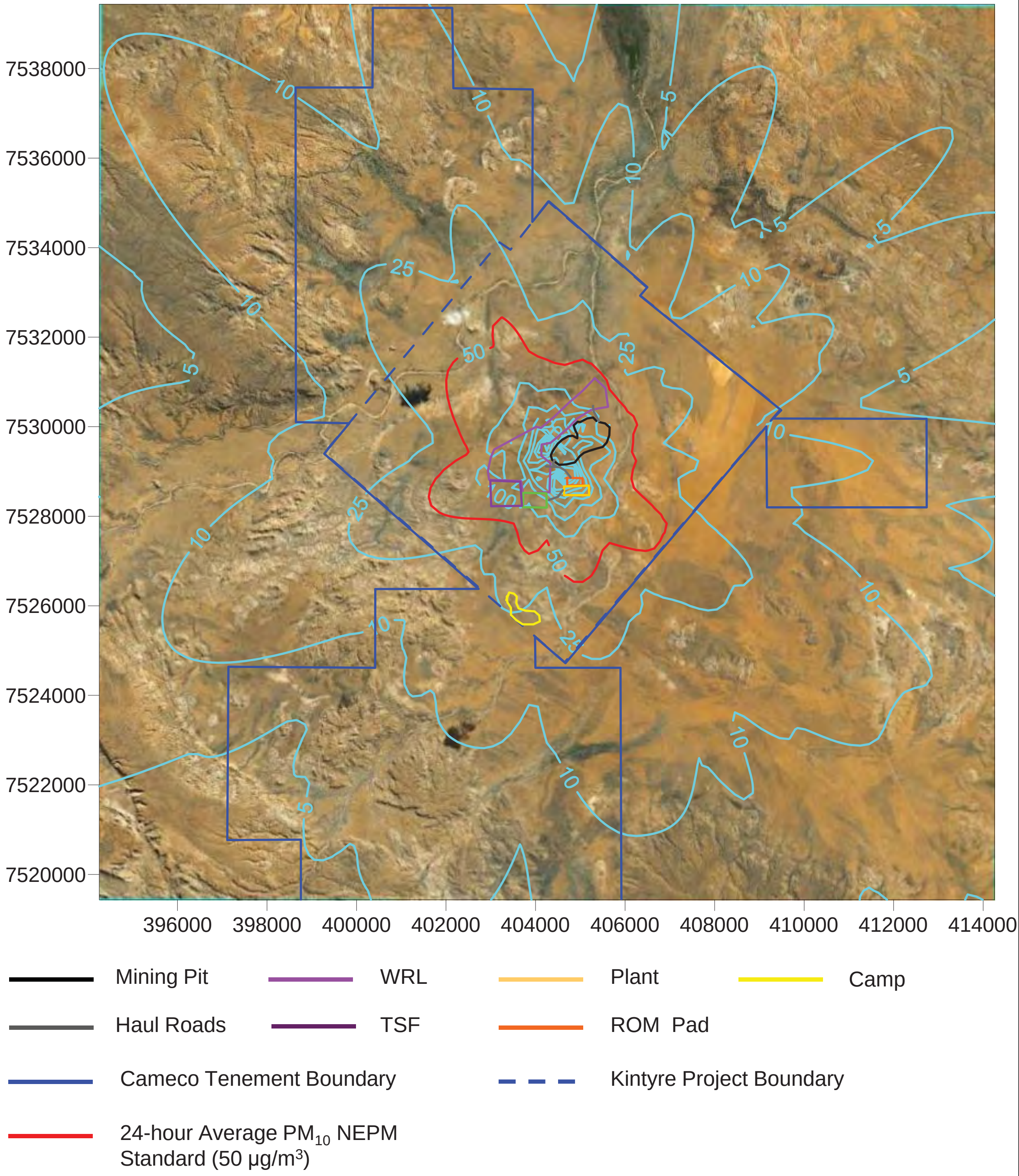
8.11 Radiological Environment

This section discusses the radiological environment of the Project including consideration of the natural levels of background radiation as well as impacts from operating the Project on public, environmental and 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 F.

8.11.1 Objectives

The objectives agreed to within the ESD with regards to radiation exposure are to:

- minimise potential human and ecological radiation exposure to as low as reasonably achievable (ALARA);



Cameco Australia Pty Ltd Kintyre Air Quality Assessment	Maximum Predicted 24-hr Average PM_{10} GLCs (µg/m^3)
ENVIRON JOB NO: AS110500C	DATE: May 2013

Figure 8-21: Maximum predicted 24-hr average PM_{10} GLCs (µg/m^3)

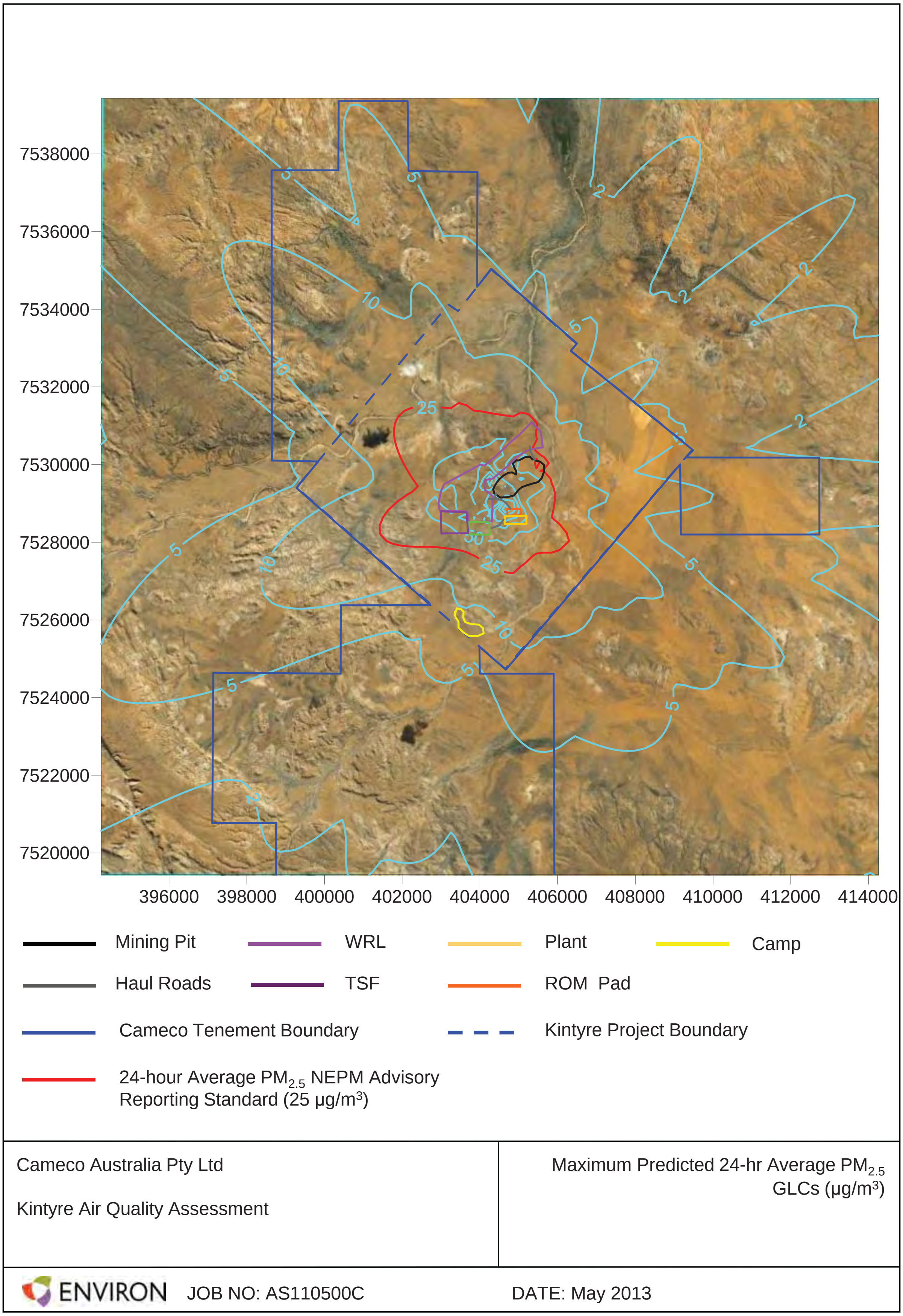


Figure 8-22: Maximum predicted 24-hr average $PM_{2.5}$ GLCs (µg/m³)

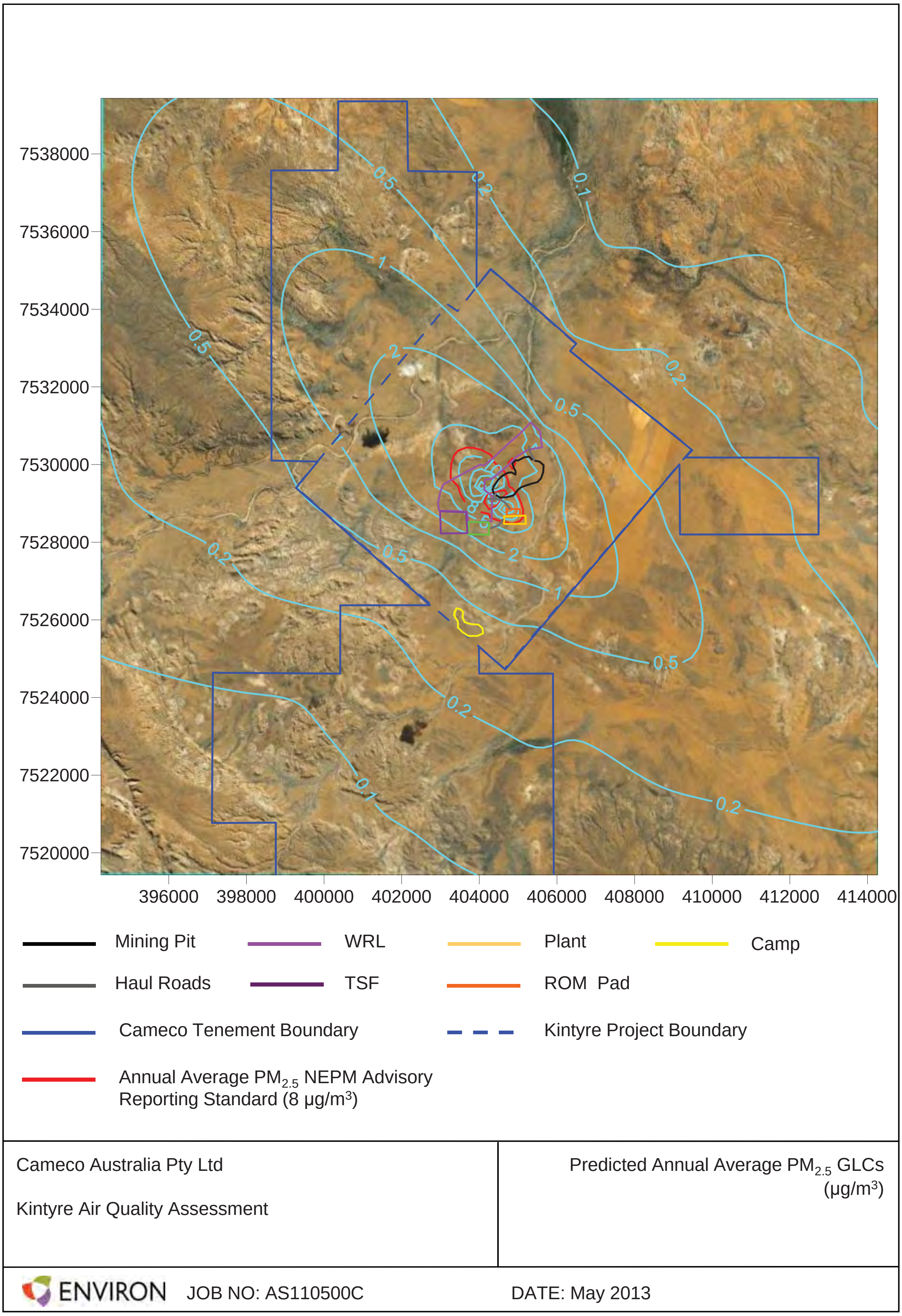


Figure 8-23: Predicted annual average $PM_{2.5}$ GLCs (µg/m^3)

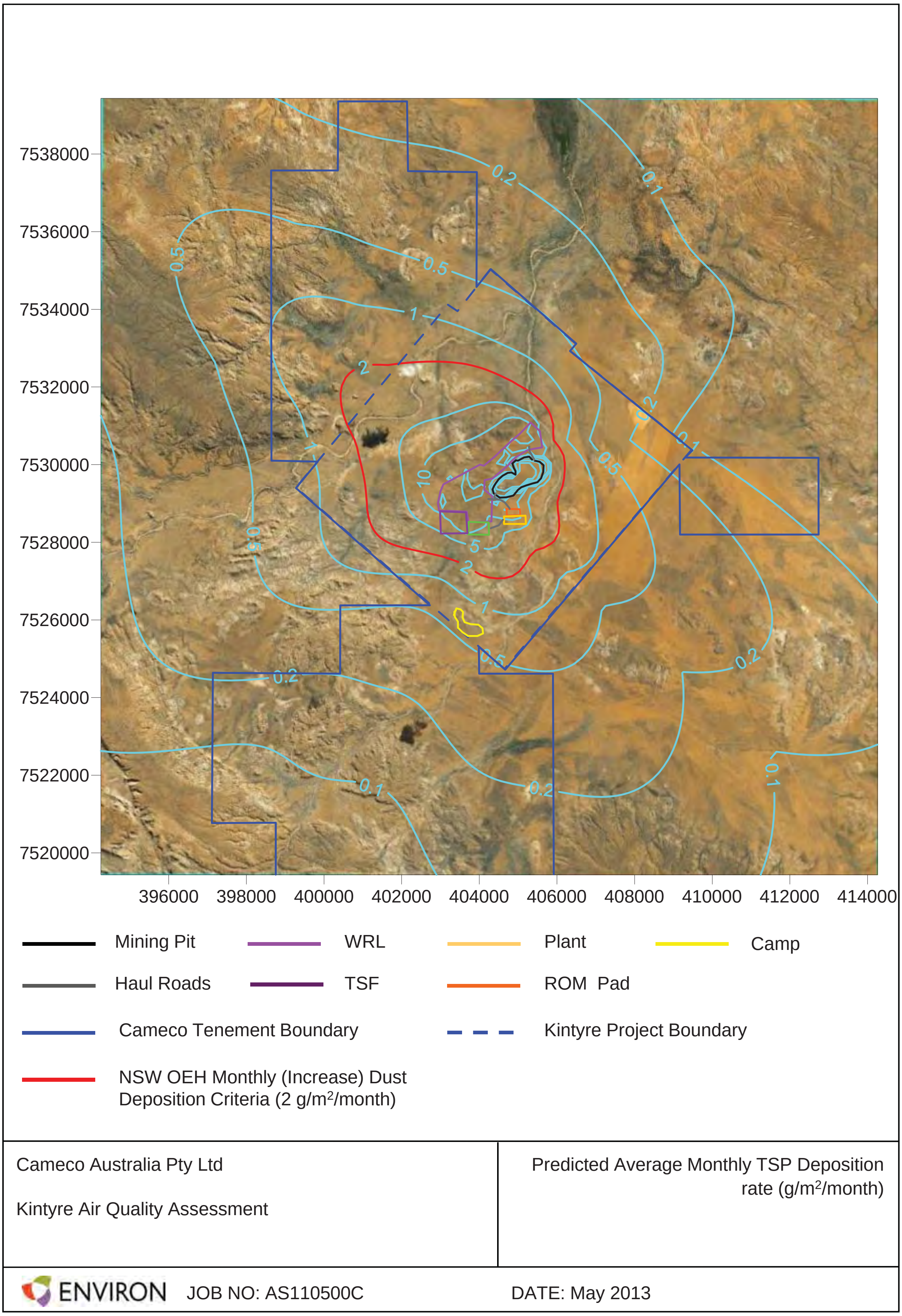


Figure 8-24: Predicted average monthly TSP deposition rate (g/m²/month)

- limit radiation exposure to members of the public to less than 1 mSv per year over and above background; and
- estimate and minimise emissions and potential radiation exposures to workers and the public through design and management measures.

8.11.2 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 and 3.2 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.

In 1998 the Federal government passed the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act). This 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.

Australia is a signatory of the international uranium regulatory legislation; the *Treaty on the Non-Proliferation of Nuclear Weapons or Non-Proliferation Treaty* (NPT) which is enforced in conjunction with Australian Nuclear Safeguard Agreements. This ensures that all uranium ore mined in Australia is exported for use in scientific or peaceful purposes. Australia has 22 bilateral Safeguard Agreements, covering 39 countries. Two main international advisory committees provide recommendations and guidance on radiation protection; the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). The IAEA was founded in 1953 to both regulate and promote the peaceful use of uranium for nuclear power. The ICRP was founded in 1928 and is an advisory body providing recommendations and guidance on radiation protection. It is a non-profit organisation in the UK but currently based in Canada.

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.

8.11.3 Proponent Studies and Investigations

Several radiation and radiation-related parameters have been monitored at Kintyre at various times dating back to early exploration undertaken by

Table 8-24: Background radiological data acquisition programme

Parameter	Method	Frequency
Long lived alpha (LLA)	Medium-volume air sampling, gross alpha counting	Monthly at two monitoring sites
Radon (Rn) in air	Passive track-etch devices	3-monthly at 50 sites
Radon Decay Products (RnDP)	Environmental Radon Daughter Monitor	Continuously at two monitoring sites
Surface gamma	Environmental Thermo Luminescent Dosimeter (TLD) Badges	100 sites over 141 days
Soil	Laboratory radionuclide	100 sites
Radon emanation	Accumulator drum and flow-through cell	Five replicates in three soil types
Groundwater	Laboratory radionuclide determination	Six monthly
Surface water	Laboratory radionuclide determination	Opportunistically

Table 8-25: Soil radionuclide content (Bq/g)

	U-238*	Ra-226	Pb-210	Th-232	Ra-228	Th-228	K-40
Kintyre							
Average	0.024	0.021	0.049	0.013	0.032	0.032	0.23
Maximum	0.055	0.052	0.11	0.029	0.064	0.065	0.57
Median	0.020	0.018	0.046	0.013	0.029	0.03	0.24
Global**							
Median	0.035	0.035	na***	0.03	na***	na***	0.40
Average	0.033	0.032	na***	0.045	na***	na***	0.42

Notes:
*From Th-234
**UNSCEAR, 2000.
***Results not available (not reported in UNSCEAR, 2000).

Canning Resources in the 1980s. The background monitoring programmes were recommenced by Cameco following its acquisition of the Project.

The principal purpose of undertaking background monitoring is to understand natural variation in radiation and the impact that the operations might have on this. It is useful when setting rehabilitation targets. In parallel with direct measurements of various radiation parameters, the background monitoring programme included several parameters that are known to influence the radiation environment such as meteorological conditions and groundwater flow.

The radiation related parameters measured directly are:

- 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;
- radon emanation rates from various soil types;
- concentration of radionuclides in groundwater; and
- concentration of radionuclides in surface waters

Parameters inferred from other data sets, that assist with the expression of baseline radiological conditions were:

- meteorological data (from on-site weather station and Bureau of Meteorology regional stations), in particular:

Table 8-26: Radon emanation results (Bq/m²/s)

Location / soil type	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1. Red deep sand on flat plains	0.07	0.04	0.05	0.05	0.07	0.05
2. Red sandy loam on silty sands over claypan areas and old drainage lines	0.14	0.08	0.05	0.05	0.11	0.07
3. Red deep sand on flat plains	0.08	NA	0.03	0.04	0.03	0.04
4. Rock fragments in sandy loam matrix on stony hills and scree slopes	0.08	0.16	0.14	0.17	0.09	0.14

  - wind speed;
  - wind direction; and
  - sigma theta (or atmospheric stability class);
- land-use and traditional food gathering (from interviews with land owners and from a literature review);
- distribution of native vegetation (from aerial imagery and field surveys); and
- distribution of habitats suitable for native animals (from field surveys, topography, geomorphology and aerial photography).

Cameco also undertook a radiation impact assessment to determine the potential exposure to workers and members of the public from the Project, and estimated potential radiation doses above background levels. This study used meteorological data available from the Bureau of Meteorology (BoM) site located at Telfer and the monitoring station on site, and findings of the Air Quality Assessment (Section 8.10) fauna surveys (Section 8.6) and cultural information regarding use of the Project area (Section 9).

8.11.4 Existing Environment

Many measurements of the various radiation parameters have been made at Kintyre and its surroundings. While some results of measurements made by previous leaseholders are available, in many cases the supporting documentation (for example calibration data) are not. Thus this section describes only measurements of the pre-existing radiation background that have been made by Cameco.

Cameco is committed to continuing a comprehensive programme of environmental radiation monitoring, including monitoring of radon and radon decay products, radioactivity in dust, and surface and ground waters prior to commencement of operations, and continuing throughout the operational period through to closure and rehabilitation. An outline of the proposed operational environmental radiation monitoring programme is provided in the Radiation Management Plan attached in Appendix D2.

8.11.4.1 Soils

Gamma Dose Rates

Gamma dose rates on the surface arise principally from soil radionuclides and cosmic rays. As the cosmic ray flux is quite uniform, the gamma dose rates measured in the Kintyre area are an indication of the underlying soil radionuclide concentrations.

An airborne gamma survey of the Project Area was conducted in 1997. The results of the survey are shown as Figure 8-25.

The figure shows the gamma signature in the Project Area in units of nGy/hr. The conceptual project layout is superimposed. The survey forms part of the baseline radiation survey and when replicated in the future will highlight changes in gamma levels as a result of constructing and operating the Project.

An array of 100 TLD gamma detectors was deployed from October 2009 to March 2010 (141 days exposure). The average dose rate was 0.092 ± 0.018 µSv/h, with a maximum of 0.14 µSv/h. These results are typical of normal background dose rates throughout Australia (UNSCEAR, 2000). The location of the badges across the Project Area is shown on Figure 8-26.

Soil Sampling

Soil sampling and analysis for radionuclides has been undertaken at 22 sites. Samples were analysed for uranium and thorium series radionuclides and potassium (K-40). Results are shown in Table 8-25. Average and median world average concentrations are also shown.

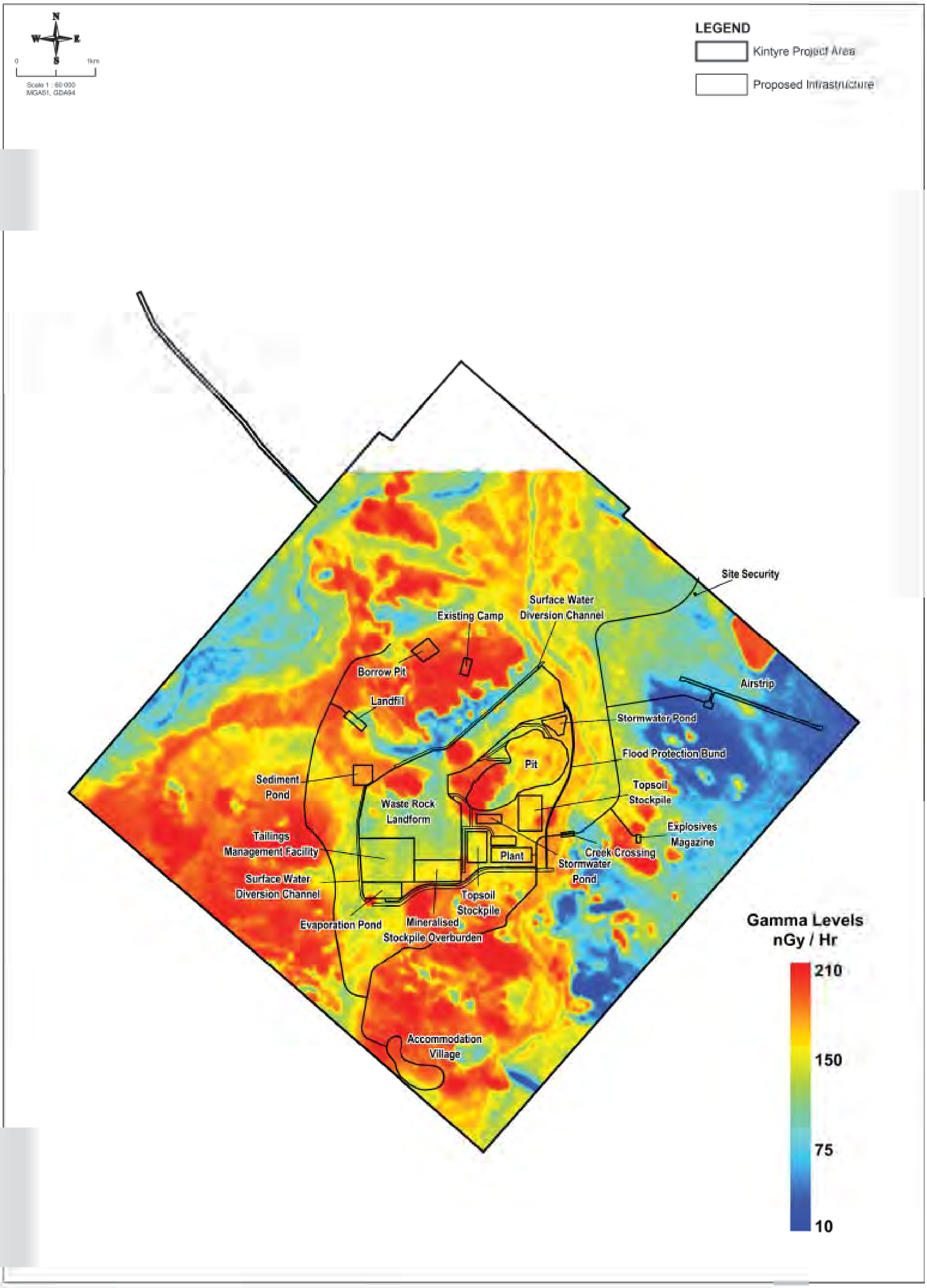


Figure 8-25: Geophysical gamma map of Kintyre project area

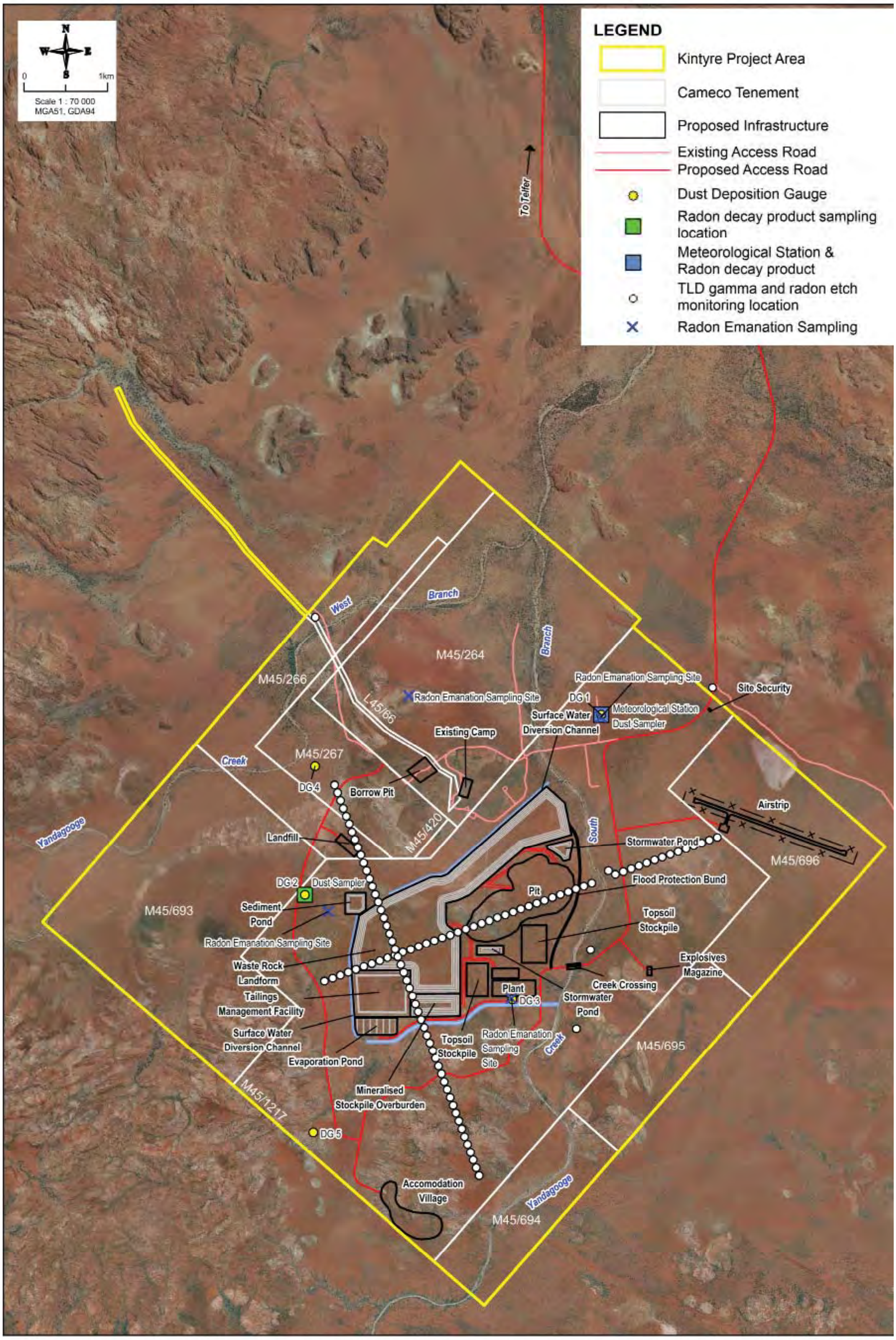


Figure 8-26: Radon monitoring sites

8.11.4.2 Airborne radionuclides

Airborne Dusts

A programme of sampling airborne radioactive dusts has been undertaken at Kintyre. The average concentration for total activity was 0.22 mBq/m^3. Sampling of airborne dusts is continuing.

Dust Deposition

Dust deposition monitoring was conducted at five locations around the Kintyre site between May 2010 and October 2010. Samples were changed approximately every eight weeks (due to accessibility during floods), and there was no alignment with the seasons. For the whole sampling period, across the five sampling sites, the average dust deposition was 1.5 g/m^2/month (with a range of 1.2 to 1.9 g/m^2/month). The small sample masses collected precluded radiometric analysis. Further sampling is continuing, and samples will be amalgamated to provide sufficient sample for radionuclide analysis. The location of the dust gauges is shown on Figure 8-26.

8.11.4.3 Radon emanation

Radon (^{222}Rn) is a ubiquitous component of the atmosphere and the atmospheric radon arises from emanation from the soil. Radon emanation has been measured at four locations with five measurements taken at each site (Figure 8-26). The results are shown in Table 8-27.

Radon emanation rate is very variable spatially, depending on soil radium content, porosity and permeability of the soil, moisture content, and atmospheric conditions. The world average emanation rate is reported as 0.018 Bq/m^2/s (UNSCEAR, 2000) and the Australian average is estimated as 0.023 Bq/m^2/s (Griffiths et al., 2010). The Project results appear to fall into two groups, with the emanation rate on plains soils being comparable with Australian and world averages, while the hillside values are above these averages. This may be because mineralised material is more likely to be exposed on hillsides and covered with alluvium in floodplains.

Radon

Radon concentrations were monitored at 100 sites (Figure 8-26) using passive detectors (alpha track detectors). These devices are deployed for a period of three months, and after collection are returned to the laboratory for assessment to give the average radon concentration over the period. Results are summarised in Table 8-27.

Table 8-27: Radon concentrations in air at Kintyre

Statistic	Concentration (Bq/m^3)
Average	16
Maximum	47
Median	14

The world average concentration is reported as 10 Bq/m^3 (UNSCEAR, 2000). The Kintyre results are somewhat higher, as is expected in an inland area due to the naturally low radon concentration of “oceanic” air compared with “continental” air.

Radon Decay Products (RnDPs)

Radon decay products have been monitored at two sites shown in Figure 8-26.

These monitors have been run continuously for more than 12 months at two sites. The average radon decay product concentration over the period May 2011 to May 2012 was 0.035 µJ/m^2. Ground level radon and radon decay product concentrations are very variable over time (Figure 8-27).

There are several sources of this variation. One is related to the mixing of radon emanating from the ground with the general atmosphere. During daytime, convection usually means that the atmosphere is well mixed to altitudes of several thousand metres, and consequently ground level radon concentrations are relatively low. At night, atmospheric mixing is significantly reduced, and particularly on still clear nights, temperature inversions can form in the atmosphere, often within 10 m or so of the ground. Such inversions will trap the emerging radon near the ground surface, and under these conditions the radon and radon decay product concentrations at ground level can rise rapidly and may be several orders of magnitude above daytime levels. Soon after dawn when the sun warms the ground and convection is re-established, inversions break up and the radon concentration falls rapidly. Thus radon concentrations vary on three timescales: diurnal, as discussed above; on a scale of a few days to a week as different weather systems establish; and seasonally as the frequency of different weather patterns changes.

In inland Australia inversion conditions are most frequent in the winter months, and Figure 8-28 shows this effect at Kintyre. In January the average night-time radon concentration is only

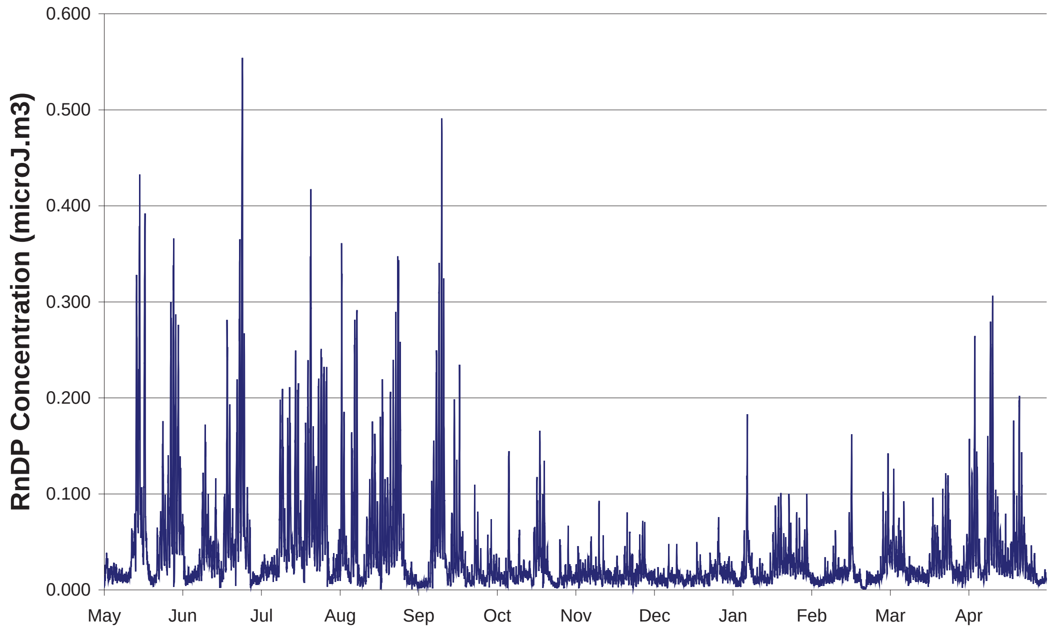


Figure 8-27: Variations in radon decay product concentration May 2011 to May 2012

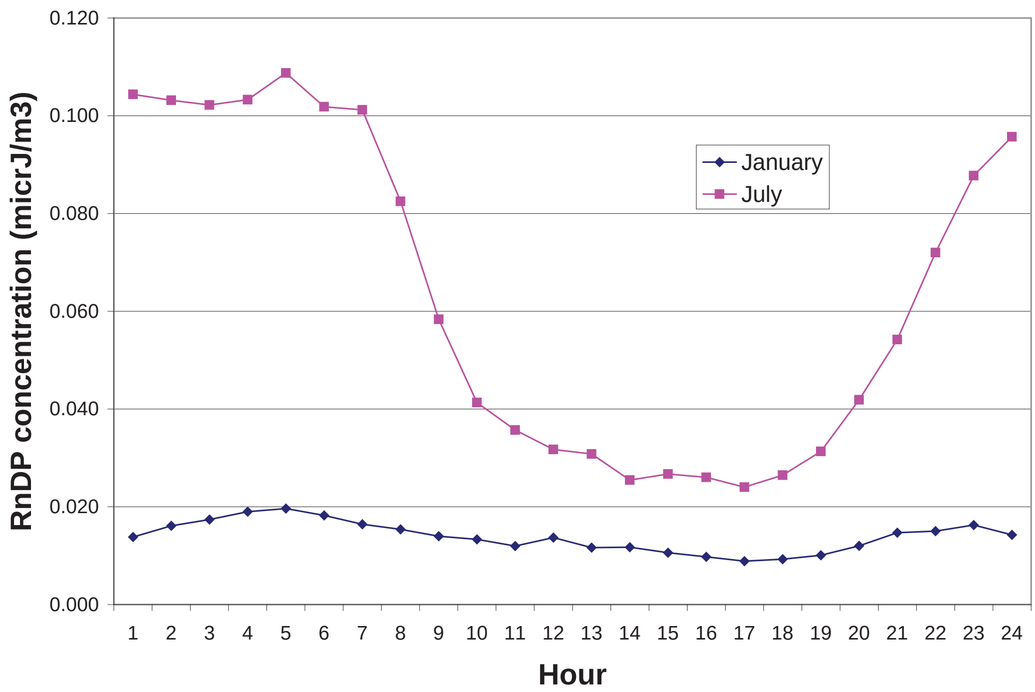


Figure 8-28: Diurnal variations in radon decay product concentrations

Table 8-28: Groundwater radionuclide results

Bore location / parameter	Median value (Bq/L)	Number of samples
Bores in or near ore zones		
Gross alpha	0.7	21
Gross beta	1.7	20
U-238	1.5	23
Pb-210	0.04	7
Po-210	0.007	7
Ra-226	0.08	1
Bores distant from ore zones		
Gross alpha	0.21	17
Gross beta	1.7	20
U-238	0.34	27
Pb-210	0.04	90
Po-210	0.007	67
Ra-226	0.065	10
All bores		
Gross alpha	0.226	38
Gross beta	1.700	40
U-238	0.39	50
Pb-210	0.031	97
Po-210	0.007	75
Ra-226	0.066	11

approximately 30% higher than the daytime concentration, but in July, when night-time inversions are much more common, the average night-time concentration is about four times that during the day.

8.11.4.4 Radionuclides in water

Groundwater

Water samples have been taken from various types of bores, including monitoring bores, potable water bores and non-potable production bores (i.e. those used to obtain water for drilling). In many cases, 'nests' of bores are drilled in close proximity, these being 'shallow', 'intermediate' and 'deep'. A summary of the results for radionuclides from all bores is shown in Table 8-28.

There is significant variation in groundwater radionuclide concentrations which is typical of inland Australia (Long *et al.*, 2008). It is expected that ground water concentrations in the vicinity of the orebody will be higher than elsewhere.

Surface Water

There are no permanent waterbodies in the immediate vicinity of the Kintyre Project area and surface water only occurs following heavy rain. One set of samples was collected on 10 January 2012 and the analysis results are shown in Table 8-29. Th-228 and Pb-210 were less than 0.1 Bq/l in all samples. Opportunistic monitoring of water after heavy rainfall is difficult because when sufficient rain falls to make the creeks flow, access is difficult. Water usually contains significant amounts of sediment during flood events, which makes interpretation difficult. Most of the radionuclide content is likely to be associated with the sediment, and values are therefore higher than groundwater results shown in Section 8.11.4.4. Automatic, raising-stage, water samplers are being installed to overcome this problem.

Table 8-29: Surface water analysis

Sample	Ra-226 (Bq/L)	Ra-228 (Bq/L)
Yandagooge Nth. Crk No. 1	0.42 ± 0.15	0.0.16 ± 0.06
Yandagooge Nth. Crk No. 2	0.17 ± 0.03	< 0.1
Yandagooge Nth. Crk No. 3	< 0.1	0.41 ± 0.16

8.11.4.5 Summary

The measurements of natural background levels at Kintyre indicate that they are consistent with those found generally world-wide and throughout Australia, and that general radiation levels in the area are not significantly influenced by the presence of the uranium deposit.

8.11.5 Potential Impacts

8.11.5.1 Radiation Exposure of Workers

As discussed in more detail in Appendix F, 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 arise to Cameco's Kintyre workforce.

Mine

The following estimates of doses to pit workers are based on a pit 1,500 m long, 1,000 m wide and 220 m deep. A total of 152 Mt of material will be excavated, made up of 142 Mt of non-mineralised overburden, 6 Mt of mineralised overburden and 4 Mt of ore. The pit will be operated on a continuous roster for 24 hours/day, seven days a week.

External Gamma Exposure

Pit 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 pit as a whole, the average concentration of uranium in all excavated material is 214 ppm (0.021%), and so the dose rate is estimated to be 1.4 µSv/h. A worker who spends 2000 hours per year on "average" material is expected to receive an annual dose of about 2.8 mSv.

There will be some workers who spend a significant fraction of their time on high grade material. In particular, it is intended that the ore zones are mined with dedicated equipment allowing more detailed ore extraction with less contamination from non-ore material. The dose rate on ore is significantly higher than that for average material with a dose rate of approximately 32 µSv/h for the ore. If a miner were to spend one tenth of the time (i.e. 200 hours) on ore then the total gamma dose would be about 6 mSv per year.

This means that those workers who are extracting ore will need to be monitored more closely with regular rotation to other jobs, to ensure that their doses do not approach the statutory limits. Mine truck drivers who regularly drive dedicated ore haulage trucks will also need to be closely monitored. More detail on this management is discussed under Section 8.11.6.2.

In practice, the expression used for dose rate substantially overestimates the actual doses received by miners. For example, applying this equation to underground workers at Olympic Dam yields an estimated annual dose approximately four times that actually received by the most highly exposed group (production chargers), and similar results are found at Ranger uranium mine (Arup and ENSR Australia, 2009). A substantial part of this of this difference may be due to the effect of shielding of gamma radiation by heavy equipment. In, practice then, actual doses at the Project are likely to be less than these estimates. However, Cameco has taken the conservative approach to ensure appropriate management of its workforce.

On this basis the maximum probable gamma dose to mine workers is estimated to be approximately 2.8 mSv/year.

Inhalation of Radioactive Dusts

Drilling, blasting and manual handling will expose workers to airborne dust. The mechanics of these operations at the Project will be similar to those found at open pit mining and quarrying operations. While data from personal dust exposure in open pit uranium mining, available on the public record, is limited, an estimate of dose may be made based on dust levels recorded at other mining operations and calculating the radiation dose.

For the purpose of a conservative estimate in the calculation of an annual dose from the dust exposure pathway, published data of 3,000 personal dust samples from 157 quarrying operations has been used. From this data 99% of the 3,000 measurements taken were of a concentration less than 3 mg/m^3 (Creely *et al*., 2006).

Assuming that the uranium content of dust at the Project is that of the average of all mined material, then the radionuclide content of the dust is calculated to be 8 mBq/m^3. Using these gravimetric and radiometric estimates along with dust conversion factors in the Code of Practice (ARPANSA, 2005a), the resulting dose received from inhaling that dust cloud for a full (working) year is approximately 0.7 mSv on the basis that the dust concentration was high at 3 mg/m^3.

Irrespective of this conservative estimate, Cameco will ensure that dust suppression strategies will be a priority during operations as part of an overarching occupation health and hygiene programme.

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 Kintyre ore is not known. In low porosity compact rock, the emanation rate is primarily a function of the uranium content. At Olympic Dam, an emanation rate of 2.5 Bq/m^2/s was derived, for 500 ppm U ore, and this value is consistent with other measured emanation rates, notably at Northern Territory uranium mines. This figure, scaled for the relevant uranium grades, was applied to the Kintyre operation. The ventilation rate was calculated from an expression derived as:

$$T=33.8*(V/U.L.W)*(0.7\cos(x)+0.3)$$

where T is the air residence time;

V is the pit volume;

U is the wind velocity;

L and W are the pit length and width; and

x is the angle between the pit axis and the wind velocity (Thompson 1993).

For the Project, the mean wind velocity is 4.9 m/s, and the prevailing wind is at 80° to the pit axis. The resulting pit ventilation rate is approximately 15 air changes per hour, and the calculated radon concentration 2.4 Bq/m^3. Assuming that the inhalation of radon decay products (RnDP) is in equilibrium with the radon (the most conservative assumption) the resulting RnDP concentration is 0.02 µJ/m^3. Using the dose conversion factor in the Code of Practice, the dose for a miner exposed to that concentration in the pit for a full (working) year is approximately 0.05 mSv.

The other ventilation situation considered is the case where there is no wind, and an atmospheric inversion prevents vertical mixing of the pit contaminants. As noted above (Section 8.11.4) under these conditions the radon emerging from soil can be trapped under the inversion, and concentrations can increase significantly. This situation was modelled in two ways. Firstly, it was assumed that an inversion formed at ground level and extended above the pit at this level, with all radon released in the pit thus being trapped inside. The second case was that the formation of an inversion within the pit, 100 m above the base. In both cases it was assumed that the inversion persisted for 10 hours. The resulting RnDP concentrations were 2.7 µJ/m^3 for the surface inversion and 5.9 µJ/m^3 for the in-pit inversion. The average concentrations over the 10 hour period would be one half of these final concentrations.

Work completed at other central Western Australian mines indicates that in-pit inversions may form on 25% of winter nights (Hibberd, 2010). This would be an over-estimate, as measurements were mainly made on nights when an inversion was likely, but the conservative approach was taken to apply this to the whole year.

Based on this scenario, a miner working 2,000 hours per year on a rotating roster would work 1,000 hours at night, and on 25% of these nights an in-pit inversion would occur and the annual dose arising is estimated as 1.2 mSv.

The dose conversion factor used in this assessment in based upon that published in the Mining Code (ARPANSA 2005).

The overall approach by Cameco towards the management of radiation is consistent with the recommendations of the ICRP and the Safety Guides of the IAEA, in particular, the principle of optimisation (ensuring that doses are As Low As Reasonably Achievable: ALARA).

With the ICRP proposing to double the dose conversion factor for inhaled radon decay products, this would result in an estimated RnDP dose of 2.4 mSv per annum. This would result in an increase in the total dose estimate (discussed below) to 6mSv per annum.

Cameco Corporation has expressed its view on the proposed change to the ICRP dose conversion factor for RnDP. This can be found at (http://www.icrp.org/consultation_viewitem.asp?guid={9E1F67F6-AFB0-4D1D-8D54-F1E883BD5FD3}.

The results derived for doses from RnDP include several other conservative factors and are considered overestimates. Firstly, it is assumed that the material exposed on the pit walls is representative of the average material excavated. This overestimates the amount of ore left exposed, as the mining process, by its very nature will preferentially remove ore. The calculation implicitly assumes that approximately 3% of the pit walls will be ore, but the detailed pit design estimates this fraction will be about 1%. Secondly, as in the case of dust exposures, a large proportion of the workforce will spend most of their time in air conditioned cabins, and the filtration associated with the air-conditioning will significantly reduce RnDP concentrations in the cab.

Total Dose

Estimated maximum probable doses to miners at the Project derived above are estimated as approximately 2.8 mSv from gamma, 0.7 mSv from inhalation of radioactive dust, and 1.2 mSv from inhalation of radon decay products, resulting in a total of approximately 5 mSv/year.

The assumptions in estimating the doses at the Project are conservative, with no allowance for such factors as shielding of gamma radiation by heavy equipment, or reduction in airborne contaminants by cab air-conditioning. Accordingly, it is considered that the maximum probable dose to miners will be below 5 mSv/year, in agreement with 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 more fully in the Radiation Management Plan (Appendix D2).

Comparison with Other Projects

Northern Territory

The Ranger mine in the Northern Territory is an open pit uranium mine which has operated since 1980. Its production rate is similar to that expected from Kintyre.

Annual occupational dose data from Ranger Mine for the period 2009 to 2011 show that workers in the mine and plant are exposed to low levels of radiation. 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).

The Nabarlek mine was a small but high grade deposit, which was completely mined in four and a half months in 1979. The ore grade involved was approximately 2%, about four times that at Kintyre. The average gamma dose to miners over this period was 2.3 mSv (Leach, Lokan, and Martin, 1980). Allowing for the difference in grade and the length of the operation, this infers that the gamma dose from mining Kintyre ore for a full year would be approximately 1.8 mSv, which is consistent with the gamma dose estimate in Section 8.11.5.

Canada

Canada is a major uranium producer, mainly from high grade uranium deposits in northern Saskatchewan. Statistics collected by Health Canada for “surface mine worker” give an average total annual dose of approximately 0.3 mSv, with all doses below 5 mSv/annum (Health Canada, 2007).

Processing

The processing proposed for the Project is a conventional acid leach process. For estimating doses, the plant can be considered in three sections: crushing and grinding, hydromet (leaching and solvent extraction) and product precipitation, calcining and packing. Generally radiation doses in the plant are less dependent on ore grade than in the mine, and more closely related to overall rate of production. For the same production rate, a higher grade will mean less material passing through the plant, and thus doses will not scale directly with ore grade as is the case in the mine. At a production rate of 4,400 t per year the Project has a similar output and therefore workers are expected to receive similar levels of radiation dose to those measured in the processing areas at Ranger and Olympic Dam.

It is more difficult to calculate expected doses from plant sources than from the mine because of the more complicated geometry of sources such as tanks, pipes, vats and other structures in the plant.

As a consequence, more reliance will be placed on comparisons with doses at other operating processing plants.

External Gamma Exposure

Gamma doses in the concentrator and hydromet sections of the plant are generally low, in part because there are, at any one time, relatively small quantities of ore present (compared with in the mine), and in part because of shielding afforded by vessel walls, and the water content of slurries. Significant gamma dose rates can be found near ore stockpiles but these are generally areas with low occupancy. After packing, significant dose rates are found near stacked product drums, but this is also an area of low occupancy.

Inhalation of Radioactive Dusts

The two parts of the processing plant where significant exposures to radioactive dusts can occur are in the crushing and grinding circuit, and in product packing. Crushing is recognised as a potential source of dust, and dust can arise from transfer points such as those on conveyors. Potential dust release areas will be fitted with dust extraction hoods, and the exhausted air will be cleaned before release to atmosphere.

Product packing can result in significant exposures to product dust. The product packing area will be carefully designed, with drum filling taking place in an enclosed ventilated booth, and all exhaust gases from this section being cleaned before discharge to air. Respiratory protection will be required before entering the packing booth.

Inhalation of Radon Decay Products

Australian uranium processing plants are in the open air, and are naturally well ventilated. As a consequence radon decay product exposures are generally very low, and comparable with natural levels. In contrast, Canadian processing plants are generally enclosed as a consequence of the severe climate, and thus less well naturally ventilated and rely on engineering controls.

Exposure from Tailings

The tailings produced from processing will have a radionuclide content comparable with that of the ore, and so potential exposure from tailings needs to be considered.

The gamma exposure above the surface of the tailings is expected to be similar to that derived for ore (the main gamma emitters in the U-238 decay chain are Ra-226 and the radon decay products. Removing U-238 and U-234 hardly changes the gamma dose rate as tailings will contain Ra-226 and associated decay products. However under normal operating circumstances, personnel managing tailings deposition would spend very little time working on the tailings surface and those involved in tailings deposition will be working only on the banks of the tailings management facility. Spigot point controls will be set back from the lip of the impoundment to reduce "line-of sight" exposure to gamma rays from tailings. It is expected that the occupancy of the banks of the tailings will be low and probably not more than a few hours per shift. Doses to operators from tailings exposure are thus not expected to add significantly to the exposure that they are likely to get in other areas in the plant.

Dust and radon emissions from the tailings will be minimised by keeping the tailings material moist. Deposition of tailings material will be rotated around the TMF, on a cycle that will allow new slurry to be deposited over previous deposits before they become completely dry. Should tailings deposition cease for any reason, decant water from the evaporation ponds can be released through a separate discharge line to keep the material damp, if this is required.

Comparison with Other Projects

The most detailed analysis of doses in processing has been provided for the Olympic Dam project (Arup and ENSR Australia, 2009). With the exception of the smelter (which is not relevant to Kintyre) average doses in all sections of the Olympic Dam plant have been at or below 2 mSv/year, with the average 90th percentile of doses being 2.5 mSv/y. While the ore grade at Olympic Dam is very much less than that at Kintyre, the production rate is similar, and as noted, production rate is a better indicator of processing plant doses than ore grade.

Similar results are seen at the Canadian processing plants, where grades are similar or higher than those at Kintyre. The average annual dose to a "mill worker" is approximately 1.4 mSv, with the highest annual dose being approximately 5 mSv. "Mill maintenance" workers receive slightly lower doses (Health Canada, 2007).

At the Ranger Mine, average doses recorded in the processing plant are 1.3 mSv/y, with the maximum being 4.1 mSv/y. For both the mine and plant, on average, gamma made up approximately 50%

of the total dose, with approximately 40% of the dose coming from radionuclides in dust for the plant workers (ERA, *pers. comm.*, September 2012). Note that all these estimates include the doses to product packers, who make up the group with the greatest potential for high doses amongst plant workers.

Total Dose

The maximum probable dose to mill workers is estimated to be approximately 5 mSv, based on comparison with maximum dose results from other projects.

Transport of Product

Based on dose rate measured in the cabin of product transport vehicles and assuming a driver operates a truck for 2000 hours per annum, a maximum predicted radiation dose to the drivers of uranium product trucks would be 0.4 mSv. Dose modelling for the general public that might be impacted by transport operations is presented in Section 9.5 and Appendix U.

Off-site Exposure

Exposure of people outside of the Project area of operations can only occur if there is an exposure pathway that takes radioactive contamination to their location. There are a number of potential exposure pathways, however, the only significant pathway is airborne dust. Exposure from the water pathway is very unlikely because the Kintyre operation will be designed to capture all process discharges and potentially contaminated surface water runoff from within Project area for use by the Project. All ponds will be constructed with adequate freeboard to contain rainfall, operational areas will be bunded to contain run off, and facilities will be provided to contain any spillage and return it to storage. The Project will be designed to withstand a 1-in-100 year 72-hour storm event (Table 8-2). For the gamma radiation pathway, gamma from stockpiles is usually only detectable above background at distances less than 100 m. The stockpiles will be located well inside the fenced perimeter of the site.

The approach used to estimate doses to those off-site is to calculate the releases of airborne contaminants (radioactive dusts and radon), then use dispersion modelling to estimate the concentrations of dusts and RnDPs in potentially occupied areas. From these, estimates of the doses that might arise can be made.

8.11.5.2 Potential pathways

Sources

Dust

Dust emissions from the Project are expected to be primarily generated from the following sources:

- Drilling and blasting;
- Material handling (i.e. excavating and in-pit loading, stockpiling, bulldozing, reclaiming, conveyor transfers);
- Primary and secondary crushing circuits;
- Radiometric sorting and associated material handling;
- Vehicle generated dust on unpaved surfaces (i.e. heavy vehicle movements along the haul roads); and
- Wind erosion of unpaved surfaces including the ROM pad and WRL.

Table 8-30: Estimated radioactive dust releases

Dust source	Emission Rate (Bq/s)
Pit	81
Waste Rock Landform	7.8
Mineralised Overburden Stockpile	35
Tailings Management Facility	0
Processing Plant	28
Run of Mine Ore Stockpile	138
Haul Roads	7.1

Table 8-31: Estimated radon releases

Source of Radon	Emission Rate (MBq/s)
Pit	1.15
Waste Rock Landform	0.61
Mineralised Overburden Stockpile	1.79
Tailings	1.83
Processing Plant	1.59
ROM ore stockpile	3.66

Fugitive dust emissions are not expected to be generated from the TMF as the tailings will be deposited as a slurry and kept damp to manage radiation. The processing circuit is similarly not expected to generate fugitive dust emissions. The primary and secondary crushing circuits will be enclosed, as will conveyors and transfer stations within the processing circuit and ventilation gases from buildings will be scrubbed before release to the atmosphere. Dust emissions from these sources are subsequently expected to negligible.

The estimated releases of radioactive dust are shown in Table 8-30, which were derived by multiplying the estimated dust releases from the source (in g/s) (ENVIRON, 2013) by the radionuclide content (Bq/g) of the relevant material.

Radon

Radon sources include the pit, mineralised waste rock and waste rock storage areas, plant operations and the tailings management facility. The sources of radon are calculated using the radon emanation rates outlined in Section 8.11.4.3, with an additional factor of five included to allow for the greater rate of emanation from broken rock where appropriate. The emanation rate from the tailings was taken to be 1 Bq/m^2/s for 1,000 ppm ore, derived from measurements at Olympic Dam (Arup and ENSR, 2009). The estimated radon releases are shown in Table 8-31.

8.11.5.3 Dispersion modelling

Dust

The dust sources identified in Section 8.11.5.2 were included into the atmospheric dispersion model, and the predicted annual average radionuclide concentrations are shown in Figure 8-29.

Radon

The radon sources were also modelled, and the resulting contours of radon concentration are shown in Figure 8-30. The RnDP concentration was estimated by assuming that the RnDPs were in equilibrium with radon (the most conservative assumption) and the resulting annual doses were estimated using appropriate dose conversion factors.

8.11.5.4 Exposed groups

Camp Workers

The accommodation village will be established approximately 2 km south of the proposed operational area (see Figure 6-2). The dispersion models estimate average annual concentrations from project operations of approximately 2.5 µBq/ m^3 for dusts and approximately 3.7 Bq/ m^3 for radon. Using the dose conversion factors recommended by the IAEA (IAEA, 1996) and ICRP (ICRP, 1996) and assuming an exposure time of 4,000 hours/year, the doses arising as a result of inhaling these concentrations are <0.5 µSv/y from dusts, and 25 µSv/y from radon decay products.

Nearby Residents

The nearest permanent residents to the project are approximately 80 km from the Project. At this distance, doses from emissions from the Project are negligible. Consequently, for the purposes of demonstrating an impact, the doses to a hypothetical group spending time near the Project area have been calculated.

Transient Visitors

An assessment was made of the doses that might arise to transient visitors to the Project area. The location selected for the visitors' location was near Yandagooge Creek approximately 1 km east of the proposed accommodation village. From Figure 8-29 and Figure 8-30 it can be seen that annual average radioactive dust and radon concentrations will be very similar to those for the camp, at approximately 2.5 µBq/m^3 for dusts and approximately 3.7 Bq/m^2 for radon. It was further assumed that people were resident at these sites for a total of 2 months per year. The estimated doses for this group as a result of the Project are less than 0.1 µSv and less than 10 µSv respectively.

An assessment was also made of the doses that such a group might receive from consumption of bush foods collected from the local area. The atmospheric dispersion modelling results were used to estimate the dust deposition, and from this the increase in soil radionuclides was estimated (see Section 8.11.5.5). The estimated radionuclidie deposition rate for the assumed location was 2 Bq/ m^2/year. As most bush food would be expected to be collected from areas to the south and east (i.e. further from the Project operating area) where deposition is lower, this figure was used as a conservative estimate of deposition throughout the collection area. The resulting soil concentration, after 12 years operation was estimated to be 0.16 Bq/kg (each U-238 series radionuclide). This soil radionuclide concentration was then used with the "concentration ratios" used in the ERICA programme (see Section 8.11.5.5) to determine the expected increases in radionuclide concentrations in vegetation and animals as a result of Kintyre operations.

Cameco has used the ERICA database for consistency. It is understood that the ERICA tool was not designed for human impact assessment however Cameco recognises that the ERICA database uses the most up to date transfer values. Cameco understands that the database is an evolving source of information to be used in assessments.

There seems to be little information on the relative quantities of various bush foods that might be consumed. Cane (Cane, 1987) suggests 20% of bush diet may be grass seeds, but that game, tubers and fruit are preferred. UNSCEAR (UNSCEAR, 2000) uses a “reference diet” including 370 kg/y of vegetable matter, and 65 kg/y of meat (including fish). For the purposes of this study, it was assumed that in the two month occupation of the area, 60 kg of vegetable material and 20 kg of meat was collected from the environs of the Project and consumed, reflecting a greater reliance on hunting.

From these estimates of diet, the intakes of radionuclides were calculated, and using the IAEA recommended dose conversion factors (IAEA, 1996), the resulting doses were calculated as shown in Table 8-32.

Summing the doses received from the intake of food (Table 8-32), the total dose is estimated at approximately 2.5 μSv, predominantly from Pb-210 and Po-210 in vegetable material.

Overall, the total dose that transient visitors to the area would receive over a period of approximately two months, including dose from dust, radon and food intake, is estimated at approximately 13 μSv, predominantly from the inhalation of radon decay products. Over the same two month period, a visitor would be expected to receive approximately 300 μSv from natural background radiation (see Appendix F for a discussion on natural background radiation).

8.11.5.5 Radiation exposure of non-human biota

This section discusses the potential radiological effects on non-human biota (NHB) of the Project operation. As noted above, the only plausible pathways for off-site effects are airborne ones; specifically the deposition of radioactive dusts on the soil, and the subsequent incorporation of them, and so that is the only one discussed here.

Cameco has undertaken an initial assessment for project impact for Radon and its decay products using the tool of Vives i Batlle *et al*. (2008;2012) . The approach used a conservative estimated annual Radon gas concentration level of 25 Bq/m^3 (see Figure 8-30 of the ERMP which shows predicted radon contours). The results of this assessment indicated that for all featured organisms dose rate were less than 10 uGy/hr which is the trigger level a tier 2 assessment in the ERICA tool.

The ERICA Tool

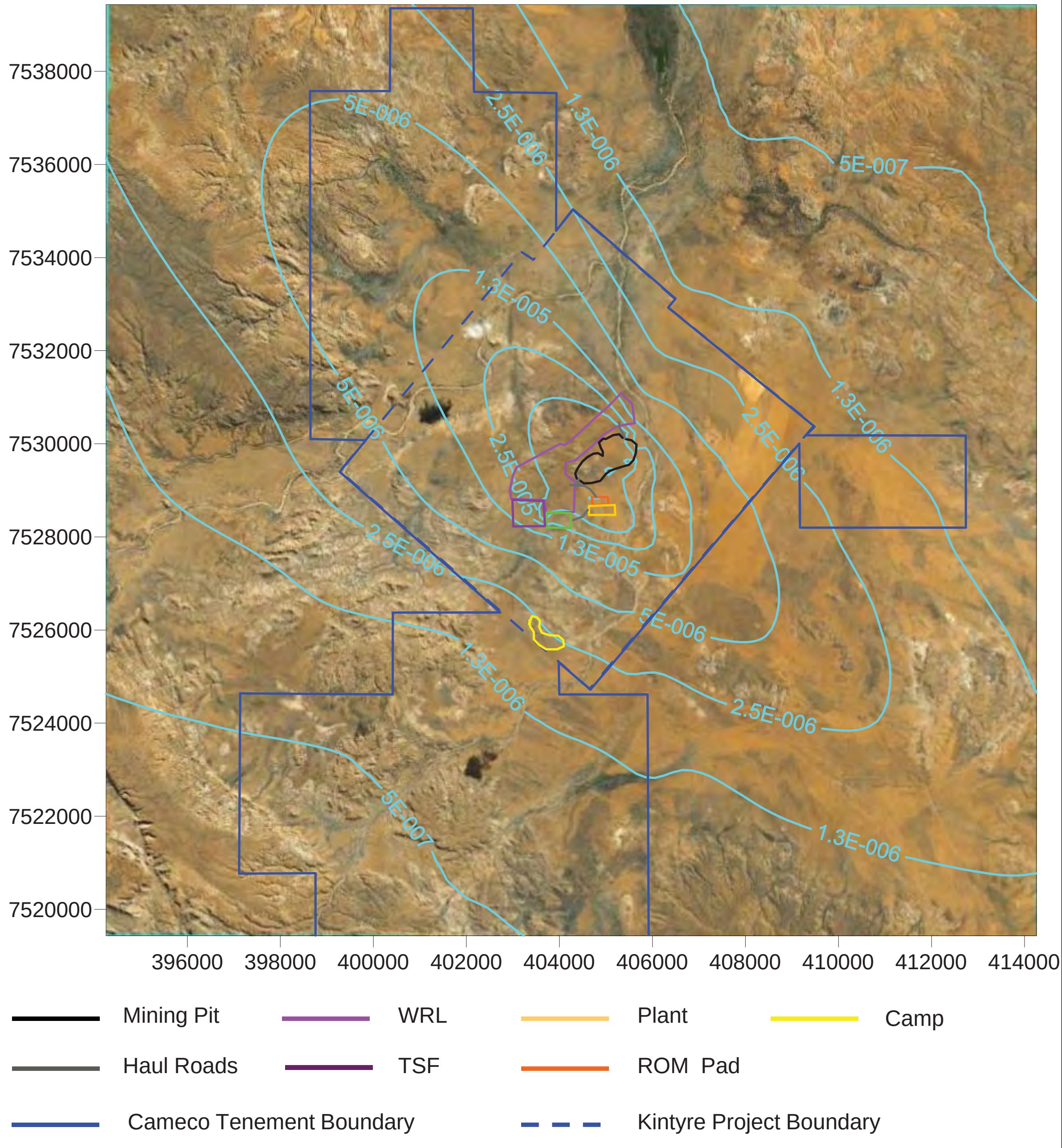
The ERICA (Environmental Risk from Ionising Contaminants) assessment tool was developed under the European Commission to provide a method of assessing the impact of radiological contaminants on the natural environment (Brown *et al*., 2008; Larsson, 2008). The tool contains two major data sources. The 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 the reference organisms are living, in this case soil. This allows the external dose rate for the organisms to be derived, and in addition

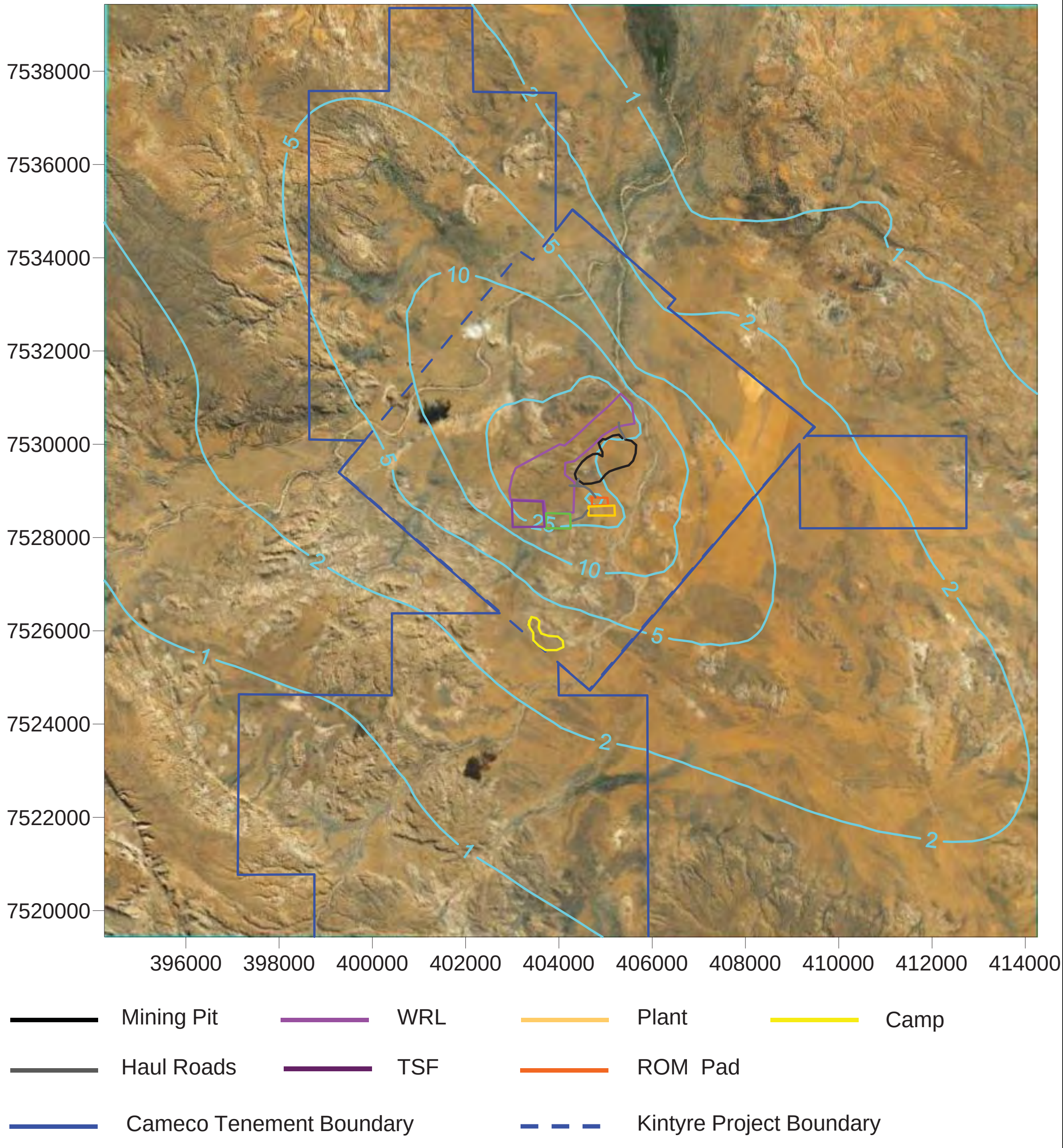
Table 8-32: Estimated intakes and doses from consuming bush foods

Radionuclide	U-238	U234	Th230	Ra226	Pb210	Po210
Intake (Veg) (Bq)	0.09	0.09	0.19	0.21	1.44	0.84
Intake (Meat) (Bq)	0.01	0.01	0.01	0.16	0.52	0.01
Dose (Veg) (μSv)	0.004	0.004	0.041	0.057	0.994	1.003
Dose (Meat) (μSv)	0.000	0.000	0.002	0.046	0.361	0.011



Cameco Australia Pty Ltd Kintyre Air Quality Assessment	Estimated Annual Average Radioactive Dust Concentration (Bq/m³)
ENVIRON JOB NO: AS110500C	DATE: May 2013

Figure 8-29: Estimated annual average radioactive dust concentrations (Bq/m³)



Cameco Australia Pty Ltd

Kintyre Air Quality Assessment

Estimated Annual Average Radon Gas Concentration (Bq/m^3)

ENVIRON JOB NO: AS110500C DATE: May 2013

Figure 8-30: Estimated annual average radon gas concentrations (Bq/m^3)

"concentration factors" from the ERICA database are used to calculate the radionuclide concentrations in the organisms to be calculated, and hence the internal dose rates.

The 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; US Dept 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 disadvantage in using the ERICA tool for Australian situations is that many of the parameters are derived for temperate northern hemisphere conditions. The most obvious is the case of kangaroos. ICRP has recommended as one of the set of reference animals a "large mammal", and deer were chosen because of their widespread occurrence in the northern hemisphere, and the large amount of radioecological data available for them (ICRP, 2003). In Australia, the equivalent niche (grazing mammal) is filled by kangaroos, but the radioecological data for them is relatively sparse (Johansen and Twining, 2010). For the purposes of this assessment, the kangaroo is assumed to have the same radiological parameters as the deer. As will be noted below, this assumption is not likely to affect the overall conclusions of the assessment.

Environmental radionuclide concentrations

The only pathway of significance in this assessment is dispersion of Project-generated radioactive dust. Waterborne pathways are not considered to be significant because of the Project's location and design. However radon, being gaseous, is widely dispersed in the environment and its subsequent decay products do not accumulate in the vicinity of the Project.

Atmospheric dispersion modelling has been conducted for the Project (see Section 8.10) and as part of this radionuclide deposition contours were calculated and are shown in Figure 8-31.

After depositing on the soil surface, dust will mix with the soil through a combination of physical, chemical and biological processes. For the purposes of this assessment, it was assumed that the mixing depth was 10 mm, which is consistent

Table 8-33: Derived dose rates for the reference organisms based on a soil concentration of 40 Bq/kg

Organism	Dose rate (μGy/h) (expected value)	Dose rate (μGy/h) (conservative value)
Lichen & bryophytes	9.18	27.54
Detritivorous invertebrate	0.55	1.66
Soil Invertebrate (worm)	0.55	1.65
Flying insects	0.53	1.58
Grasses and herbs	0.45	1.34
Gastropod	0.30	0.89
Shrub	0.29	0.88
Bird	0.23	0.68
Bird egg	0.21	0.64
Amphibian	0.21	0.64
Reptile	0.21	0.64
Mammal (Rat)	0.18	0.55
Mammal (Deer)	0.16	0.48
Tree	0.07	0.21

with measurements in southeast Australia and in grasslands (Kaste *et al*., 2007). The soil density was assumed to be 1.5 t/m^3.

Figure 8-31 shows that the deposition was less than 50 $Bq/m^2/y$ in all areas outside the actual area of operations, and so this value was adopted for the assessment. Over a 12 year operational life, the amount deposited would be 600 Bq/m^2 and the resulting increase in soil radionuclide concentration would be 40 Bq/kg for each uranium series radionuclide.

A Tier 1 assessment was conducted, using this soil radionuclide concentration (40 Bq/kg) (each uranium series radionuclide). The result of this assessment was that at least one organism (lichen and bryophytes) was above the 10 μGy/h screening level, and accordingly a Tier 2 assessment was conducted.

The Tier 2 assessment again used the 40 Bq/kg soil radionuclide concentration and used the ERICA default values for concentration ratio, and the 10 μGy/h screening level. The resulting derived dose rates are shown in Table 8-33.

The dose rates for all organisms are significantly below the screening level (10 μGy/h) with the exception of lichen and bryophytes. The expected value for lichens and bryophytes is slightly below the screening level, but the conservative rate is above.

Raptors

A separate assessment was conducted to estimate the doses and potential radiological effects to raptors eating animals from areas adjacent to the proposed operations.

Wedge-tailed eagles (*Aquila audax*) were selected for study. The method adopted for this assessment was to use the ERICA tool to estimate the radionuclide content of prey species living in contaminated areas, then estimate the radionuclide content that would arise in eagles feeding on them, and finally calculate the doses arising from those radionuclide concentrations. The "small mammal" group was considered to be representative of prey, although wedge-tailed eagles have a wide range of food sources (Brooker and Ridpath, 1980). Prey was assumed to be gathered approximately uniformly across the eagles' territory, which can range from 30-100 km^2 (Ridpath and Brooker, 1987). A 30 km^2 territory was selected, equivalent to a circular area approximately 6 km across, and it was assumed that this area was centred 3 km from the centre of the Kintyre operation. From the dust deposition plot (Figure 8-31), it can been seen that even in the worst (highest deposition) case, that is to the north-west of the site, most of the range would be outside the

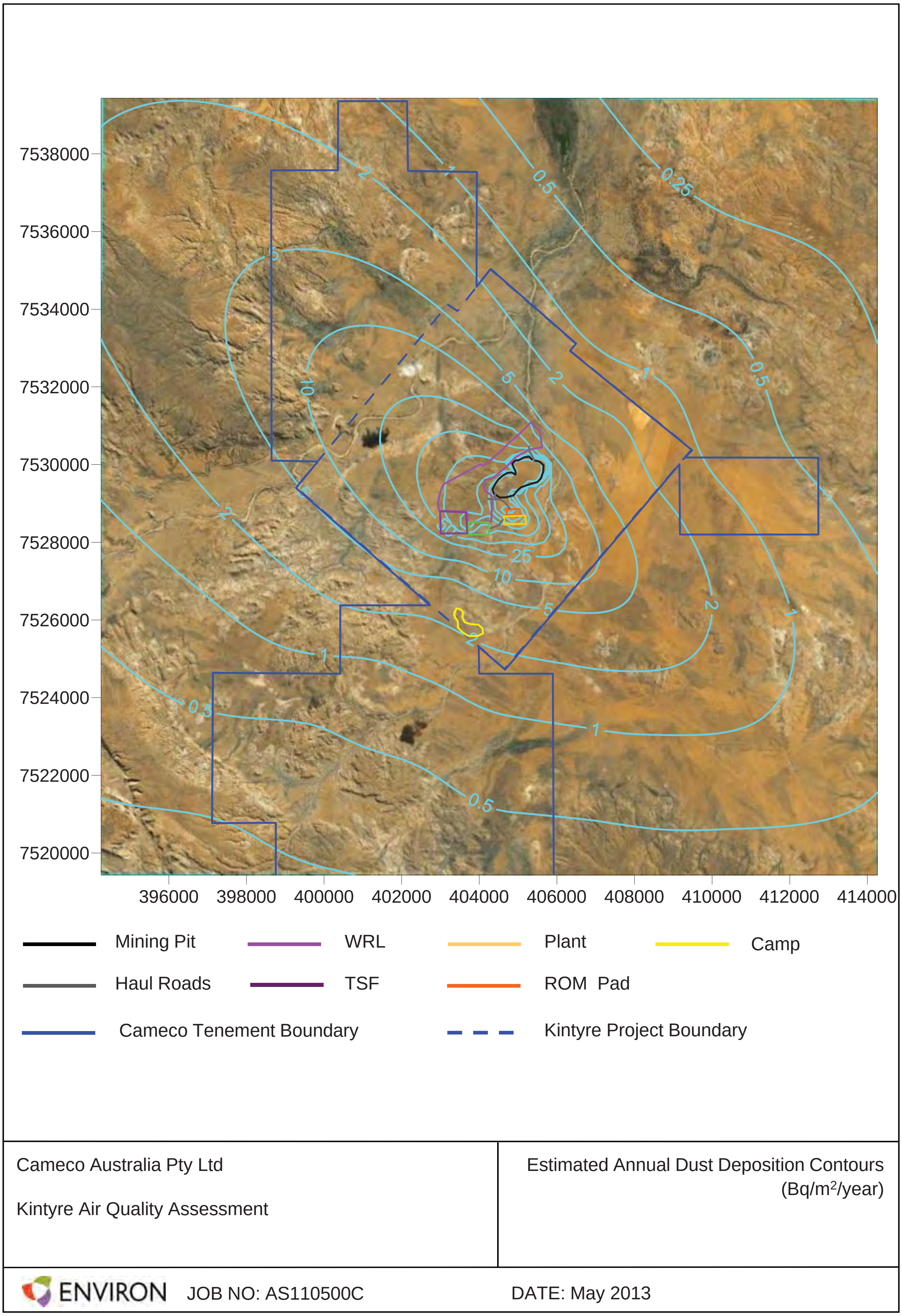


Figure 8-31: Estimated annual dust deposition contours (Bq/m²/year)

50 g/m²/year contour. Accordingly, an average dust deposition over the eagles' territory of 25 g/m²/year was adopted. Using the concentration factors in ERICA, the estimated radionuclide concentrations in the eagles' diet are shown in Table 8-34.

The estimated food intake of a wedge-tailed eagle is approximately 130 kg per annum. Not all of the radionuclides consumed in food will be absorbed from the gut: for humans the maximum absorption factor (for radium and lead) is 0.2. This figure will be adopted for eagles for all radionuclides. The annual uptake was then calculated as 20% of the product of the radionuclide content of prey and the 130 kg annual food intake. It was further assumed that this radionuclide content accumulated over five years to give the total radionuclide content of an eagle. This is likely to be an overestimate as it does not allow for excretion of radionuclides over that period. It should also be noted that, particularly in the important case of radium, radionuclides may preferentially accumulate in the bone of prey, which is largely rejected by feeding eagles.

Table 8-34: Radionuclide concentration factors and resulting wedge-tailed eagle prey radionuclide content

Radionuclide	Concentration factor	Radionuclide content (Bq/kg)
U-238	0.0001	2.13E-03
U-234	0.0001	2.43E-03
Th-234	0.0001	2.43E-03
Th-230	0.0265	5.30E-01
Ra-226	0.0265	5.30E-01
Pb-210	0.0388	7.77E-01
Po-210	0.0028	5.56E-02

The resulting wedge-tailed eagle radionuclide concentrations were then used as input to a Tier 2 ERICA assessment, and the resulting doses to the eagles were calculated. The expected dose was approximately 0.6 µGy/h with the only significant contribution being from Ra-226. Both the expected value and the conservative value (1.7 µGy/h) were well below the screening level of 10 µGy/h.

8.11.5.6 Summary

Lichen and Bryophytes

The conservative dose rate derived for lichen and bryophytes is approximately three times higher than the screening level (at a deposition rate of 50 Bq/m²/year), and is more than fifteen times higher than any other organism. 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 upon them. Consequently they might be expected to receive a higher dose from the fallout of mine and processing dusts than is the case for other organisms.

To investigate the consequences of this higher dose rate, the radiosensitivity of the group was considered. Lichen and bryophytes are considered extremely radioresistant: 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 at all would be expected from any doses that are potentially achievable in uranium mining. Lichen and bryophytes can therefore be considered not to be at any significant risk.

Non-vertebrates

The (expected) dose rate to the non vertebrate groups is less than 0.6 µGy/h, one fifteenth of the ERICA screening rate. Thus at the 50 Bq/m²/year deposition rate, no effects would be expected.

Vertebrates

All vertebrate groups gave expected doses of less than 0.3 µGy/h and conservative doses of less than 0.7 µGy/h at the 50 Bq/m²/year deposition contour, approximately one half that of the invertebrate groups, and less than one tenth of the screening level. It is relevant to comment on the use of "deer" to represent the doses to kangaroos. The (conservative) dose that is derived for deer is approximately 0.5 µGy/h. Therefore the choice of "deer" to represent "kangaroos" would have to underestimate the kangaroo doses by an approximate factor of 20 for the conservative kangaroo dose to exceed the screening level at the 50 Bq/m²/year contour. It should also be noted that kangaroos generally range widely, and thus would be expected to only spend a fraction of their time in the potentially affected areas adjacent to the Project, which would significantly reduce their annual doses from Project emissions.

Raptors

Estimated conservative doses to raptors subsisting on prey from the Project area were less than one fifth of the screening level indicating that the risk of radiological harm was negligible.

The risk of radiological harm is assessed as "negligible" for all reference organisms in all areas outside of the of the Project area.

8.11.6 Proposed Management

As is discussed in Section 2.3.4 of this document, Cameco has extensive experience in managing radiation exposures in uranium mining, and has a strong commitment to radiation protection. Based on this experience, a corporate Radiation Protection Programme has been developed, and this will be used to set minimum requirements for radiation protection at Kintyre. Cameco's Corporate operation provides services and technical advice to support the radiation protection programmes of individual operations.

As part of the approval and authorisation process, a draft Radiation Management Plan (RMP) has been developed for the Project (Appendix D2), which will be provided to the Radiological Council prior to construction. The final RMP will include details of radiation protection and radioactive waste management specific to the plant and equipment to be installed, and the way in which is to be operated. A Transport Radiation Management Plan (TRMP) has also been developed which includes an Emergency Response Assistance Plan (ERAP) (Appendix D3). The transport carrier will be required to develop a plan consistent with the Cameco plan.

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.

8.11.6.1 Principles

The fundamental principles of radiation protection have been articulated by the International Commission on Radiological Protection (ICRP). The ICRP is the international authority on radiation protection and has established the standard for radiation protection, which is outlined in its "system of dose limitation" which has been incorporated into Commonwealth and State legislation as described in Appendix F.

The overall approach by Cameco towards the management of radiation is consistent with the recommendations of the ICRP and the Safety Guides of the IAEA, in particular, the principle of optimisation (ensuring that doses are As Low As Reasonably Achievable).

Radiation and radioactive waste will be optimally managed and controlled at Kintyre 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.

8.11.6.2 Radiation Control in Design

An essential element of radiation protection is ensuring that appropriate radiation protection measures are incorporated in the earliest stages of design.

The designs for radiation control and radioactive waste management facilities will be developed with a risk management approach, based on the ALARA principle. Moreover, initial plans of the equipment to be installed will be examined to determine where radiation protection may be required, and options for control will be developed for those areas where requirements have been identified. These 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. A similar approach will be used in the development of operating procedures. These will be examined to see what tasks may require protection measures, available options will be considered, and from these an optimum procedure will be developed.

The ALARA principle will also be applied during operation. The radiation monitoring plan will collect data on radiation exposures and waste management. As these data are accumulated, they will be examined to determine if there are ways in which further reductions in exposure can be reasonably achieved. Where such changes can be identified, the management plan will be adapted to incorporate these. This approach will be continued throughout the operation of the Project.

Radiation Control in the Mine

Access to the main mining areas will be restricted to ensure that only appropriately trained and qualified personnel are able to access the work areas.

The main aspect of the mine requiring radiation protection controls is gamma radiation from high grade areas. As noted above, dose rates on the ore will be substantial, and it will be necessary to limit the time spent in these areas by individual workers. This will be achieved by careful rostering and scheduling of those workers operating ore recovery equipment, backed up by detailed monitoring. 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.

In addition to the traditional TLD gamma monitors, modern direct-reading personal electronic dosimeters will be issued to potentially affected workers and these will allow real-time readout and dose assessment. The results of this monitoring will be regularly reviewed and individuals whose doses may be approaching the relevant limits will be assigned to other duties. Results will also be used to improve other radiation management measures where necessary.

As noted previously, circumstances giving rise to high concentrations of RnDP from natural processes (e.g. formation of inversions) and are thus not easily controlled. 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, with direct real-time display of concentrations in the control room. Control limits will be set, in consultation with regulatory authorities, and should RnDP concentrations exceed these levels, all workers not working in air conditioned cabs with effective air filtration will be removed from the pit until levels fall to below the control limit (generally when inversions are broken up after sunrise). Should essential work be required outside of cabs then respiratory protection will be required.

Measures will also be taken to minimise doses from inhalation of radioactive dust. These will include standard dust suppression techniques (e.g. wetting of materials before handling, wetting of roadways, provision of dust collection systems on drills etc.), and measures to reduce subsequent exposure (use of respiratory protection and air conditioned cabs).

Radiation Control in the Plant

The main aspects of processing that will require particular attention to radiation protection are the crushers and associated facilities, and the uranium product handling.

Wet and dry material will be handled in the processing plant and require careful design consideration. The front end of the plant will house the crushing and grinding circuits where dust control is important.

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 start-up, the area will be subject to intensive dust monitoring, to establish exposure levels and to identify any remaining dust sources. Based on the results of monitoring, additional dust control measures may be implemented. In situations where engineering solutions cannot be found, respiratory protection will be used.

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 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 uranium precipitation, drying, calcining and packing section of the plant handles a product of up to 85% uranium concentration. Due to the high uranium concentration specific radiation protection is required, 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'. Only authorised personnel are 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.

8.11.6.3 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 estimated radiation exposures indicate that the supervised areas will include offices, laboratory 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, ore reception, crushing and grinding circuit, the ore sorters, product precipitation drying and packing areas and the tailings management area.

To facilitate the control of people, vehicles and contamination, the Project 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 high 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 checked for contamination by suitably trained staff.

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. 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.

Radiation Safety Expertise

Cameco has access to suitably qualified and experienced radiation safety professionals to assist during the design, construction and operational phases of the Project. Cameco is one of the world's largest producers of uranium and has considerable corporate experience managing uranium operations.

Qualified radiation protection personnel would be employed to implement the Radiation Management Plan (RMP) and the Radioactive Waste Management Plan (RWMP). The nominated Radiation Safety Officer would directly report to the site General Manager.

Induction and Training

All employees will receive an induction informing them of the hazards associated with the workplace, including radiation. The level of the induction material will reflect the magnitude of the potential risk. For example, workers who may enter high exposure areas will receive more intensive radiation training. Specific training will be provided to personnel involved in the handling of uranium concentrates.

Managers and supervisors will receive radiation training to manage situations that have the potential to increase a person's exposure to radiation. This is similar to the Hazard Observation (HAZOB) reporting system.

A specific radiation safety work permit system will be implemented before any non-routine work is undertaken in a potentially high exposure situation such as maintenance in the product packing area, whereby a work permit will be required.

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 made available to the CEO of ARPANSA via the Australian National Radiation Dose Register (ANRDR), in accordance with confidentiality requirements.

Incident Response

Should radiological emergencies arise, plans for incidents or accidents that may result in radiation exposure or loss of containment of radioactive material will be prepared as part of the overall site emergency response plan. These 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
- de-contamination of the person(s) and the area.

The plan will also include requirements for post-incident response, such as 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).

8.11.6.4 Monitoring

As part of the management of radiation for the Project, an occupational and environmental radiation monitoring programme would be developed and implemented. The final programmes will form part of the RMP and the RWMP and would be submitted to the Radiological Council for approval prior to operations. The plans would include support systems such as servicing and calibration of monitoring instruments.

Monitoring will depend on the expected levels of exposure. For those who may receive more than 5 mSv per year (sometimes called 'designated' employees), monitoring will be more intensive, and directed to determining the doses that individuals receive. For those not expected to receive as much as 5 mSv/y (non-designated) monitoring will be less intensive, and doses will be assessed from the average results of workgroups.

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 8-35 provides an outline of a proposed occupational monitoring programme.

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 do not form any part of the dose limitation system. 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

Table 8-35: Outline of the proposed occupational radiation exposure monitoring programme

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. Representative monitoring of other work groups.
Direct (external) gamma	Personal electronic dosimeter	All mine operators that might be spending significant periods on high grade areas.
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 (audit) monitoring of work groups.
Inhalation of radon decay products	Continuous radon decay product monitor	Representative (audit) monitoring of work groups.
Ingestion of water containing radionuclides	Gamma or Alpha spectroscopy or chemical analysis by external laboratory	Annual check on potable water supplies.

from one task to another to reduce exposure. Table 8-36 provides an indication of action levels that may be set, and the remedial actions that would be required.

Cameco will establish action levels for environmental impacts as part of the RMP to ensure worker and public dose remain As Low As Reasonably Achievable, with all social and economic factors taken into account.

Environmental monitoring programme

In addition to the occupational monitoring programme, an environmental radiation monitoring programme will continue at sites established during the baseline studies and at other sites considered to be locations where the highest dose might be recorded. The aims of this programme are to provide data for the assessment of doses to the public 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. An outline of the elements of such a plan is shown in Table 8-37.

Appropriate meteorological monitoring will continue to support both the broader environmental monitoring program, and the environmental radiation monitoring programme.

Contaminated Objects

Under normal operating conditions some equipment, typically ground engaging equipment and vehicles, will become "contaminated" with radioactive ore and dust and must be decontaminated or cleaned before it leaves the Project Area.

Cameco will use the specification for a "surface contaminated object" as defined in the Code of Practice for the Safe Transport of Radioactive Material (ARPANSA 2008) as the clearance level for equipment leaving site. The specific requirement is that the non-fixed contamination on the external surface on any package will be kept as low as practicable and not exceed 4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters. This limit is averaged over any area of $300cm^2$ of any part of the surface.

The commitment to achieve this standard will be provided in the RMP and RWMP for approval by the appropriate state regulator.

Support Systems

The support system for the monitoring programmes will also include:

- recognised sampling methodologies that are documented and regularly reviewed;
- routine instrument calibration programmes, including auditing of calibration sources;
- instrument maintenance and repair programmes;
- 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 programme and system.

8.11.6.5 Radioactive Waste Management

Overview

There are four main categories of radioactive waste that will be generated at Kintyre:

- Mineralised waste: material that contains uranium at an average grade of 500 ppm which may be blended with higher grade ore and processed or may be encapsulated for long term storage at the conclusion of mining;
- Process tailings: material that has passed through the processing plant. The uranium is extracted and the radionuclides remain 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
- Contaminated wastes: miscellaneous material that may have become contaminated through contact with ores and process residues, including discarded conveyor belts, rubber lining material, pipes, maintenance parts and residuals, filter media and used protective equipment.

Mineralised Overburden 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, while mined and mineralised material will undergo further analysis using a radiometric scanner.

Mineralised overburden is defined as material containing less than the economic cut off grade but above 200 ppm U_3O_8, and on average containing approximately 500 ppm U_3O_8. This material will be managed separately from waste rock. It will be stockpiled on an engineered pad and may be used to blend with higher grade ore for treatment in the processing plant. If at the end of the life of mine a stockpile remains, the material will be capped with non-mineralised waste and rehabilitated.

Radiological Controls for Tailings Management

Tailings from the processing facility will be radioactive and contain the decay products of uranium in approximately the same concentration as in the original ore. Indicative concentrations of uranium in the solid tailings will be 10-15 Bq/g. Other radionuclides will exhibit concentrations of approximately 60 Bq/g. Concentrations of radionuclides in the liquid fraction of tailings are expected to be in the range of 0.02 mBq/L (Ra-226) to 50 mBq/L (Th-230).

Tailings handling will be similar to other uranium mines. Tailings will be pumped from the processing plant to the TMF in a slurry form and deposited in thin layers. The tailings discharge points will be rotated around the tailings area 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 TMF will be designed as a permanent, zero-discharge, single-use facility with a geomembrane lining and leak detection system, using best available technology. Specifically, the TMF will be designed to ensure that tailings are effectively contained in the long term and radiological doses to the proposed workforce, members of the public and non-human biota are as low as reasonably achievable (ALARA) during operations and following closure.

Waste Water Management

Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or 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.

Table 8-36: Examples of action levels and responses

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.
Dust Concentrations	3 mg/m^3	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	5 uJ/m^3	Limit occupancy to air conditioned cabins, require respiratory protection.

Table 8-37: Outline environmental radiation management programme

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 locations.
Dispersion of dust containing long-lived, alpha-emitting radionuclides.	High volume samplers.	Monitors will rotate between approved off-site locations.
Dispersion of dust containing long-lived, alpha-emitting radionuclides.	Dust deposition gauges.	Sampling at identified locations. Samples composited for one year then radiometrically analysed.
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

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 waste control

This material includes contaminated equipment and wastes from operational areas that 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 WRL in a similar manner to mineralised overburden;
- disposal into the mine pit at the end of operations; or
- storage on a purpose built pad and encapsulation within the footprint of the waste rock landform at the time of mine closure.

In all cases records of the disposal, including type of material, quantities and locations will be kept.

8.11.6.6 Closure and Rehabilitation

A Mine Closure and Rehabilitation Plan for the operation will be submitted to DMP for approval before commencement of operations. 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 consistent with natural background levels.

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 within the waste rock landform as described above.

The tailings will be allowed to dry sufficiently to allow access for machinery and then covered with inert waste rock to a depth agreed to minimise the emanation of radon. The walls of the TMF will be armoured to reduce the potential for erosion and appropriate structures for run off control will be constructed. A detailed closure plan for the facility will be included in the Mine Closure and Rehabilitation Plan.

The waste rock storage areas would also be contoured to reduce the risk of erosion.

The site will be monitored after rehabilitation to ensure that it is free of contamination. Surface monitoring and groundwater monitoring would continue for a period of time post-closure until agreed Completion Criteria had been achieved to the satisfaction of the appropriate regulatory agencies.

8.11.7 Commitments

Cameco will design, construct and operate the proposed Project to ensure that human and ecological radiation exposures comply with Australian standards, codes of practice and guidelines.

Cameco will 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.

8.11.8 Outcome

Cameco has extensive experience in the uranium mining and processing industry and maintains high standards to ensure that impact from radiation on workers, the public and the environment are as low as reasonably achievable, and certainly within all recognised standards. Cameco will comply with all legislative requirements relating to radiation. Cameco considers the risk of adverse impacts from radiation during exploration and construction, operation, closure and post-closure of the Project are extremely low.

8.12 Tailings Management

8.12.1 Objectives

The objectives agreed to within the ESD on the management of environmental aspects related to the TMF are to:

- maintain the integrity, ecological functions and environmental values of the soil and landforms;
- maintain structural integrity of the facility and limiting erosion by water;
- limit fugitive dust and radon emissions from the facility; and
- limit seepage to groundwater.

8.12.2 Background

The waste slurry produced by the metallurgical plant following extraction of uranium (termed tailings) will be placed in an above ground TMF positioned immediately adjacent to the WRL effectively forming an integrated waste landform (IWL) (Figure 6-2). The total mass of tailings to be produced during the proposed life of the operation is 7 Mt.

The TMF has been designed as a single celled facility. The cell is bounded by an embankment, with a maximum height of approximately 20.5 m, to be constructed from compacted earth and waste rock. The TMF will be lined with an HDPE geomembrane with independent leak collection and recovery systems and liner overdrain systems to contain and collect tailings supernatant and additional precipitation.

When discharged into the cell the tailings solids will settle out and form a beach sloping from the embankment to the central area of the cell. The water released from the slurry will pool in the centre where it will be pumped to the evaporation pond. The facility would have a minimum 1 m of freeboard for the management of stormwater at the conclusion of tailings deposition.

A cross-section of the TMF is illustrated in Figure 6-12, and the indicative features of the proposed TMF are provided in Table 6-4.

8.12.3 Relevant Legislation and Policy

The TMF design process was conducted in consideration of the following regulatory codes and guidelines as minimum design standards and Cameco's internal design standards.

For all mining projects in Western Australia, a TMF design report is to be produced in accordance with *Guidelines on the Safe Design and Operating Standards for Tailings Storage (DME (WA) 1999)*. A TMF design report will be submitted as part of the secondary approvals processes for approval by the DMP. The Kintyre TMF has been designed in accordance with a 'high' hazard rating, which requires the highest standards of design, construction and operational aspects in compliance with the Guidelines for a Category 1 TMF.

The regulatory framework for the management of radioactive substances and legislation specific to mine sites in Western Australia is detailed in Section 8.11.2.

The following policy documents were also referenced in developing the TMF design:

- Guidelines on Tailings Dam Design, Construction, Operations and Closure 2012. (ANCOLD (2012)).
- Scientific Basis for the Near Surface Disposal of Bulk Radioactive Waste. Technical Report TR No 141. (ARPANSA 2005b).
- Code of Practice for the near-surface disposal of radioactive waste in Australia (1992), Radiation Health Series RHS No 35, 1992. (ARPANSA 1992).
- Guideline for Tailings Management, Department of Industry, Tourism and Resources, February 2007. (DITR, 2007).
- Guideline for Action Leakage Rates for Leak Detection Systems (U.S EPA 1992).
- Regulatory Guide 3.64: Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers (U.S Nuclear Regulatory Commission 1989).

8.12.4 Existing Environment

The Project area has an arid climate with hot summers and warm dry winters, low precipitation and high evaporation. The region can also receive significant rainfall associated with cyclonic activity. A detailed discussion of the climatic conditions of the Project area is provided in Section 7.5. The TMF and evaporation ponds have been designed to contain runoff from historic extreme storm events.

The geology of the area on which the TMF would be placed was investigated by Dames & Moore (1996) who concluded that the upper sand layer is suitable for use as engineered fill and has low permeability. This is underlain by highly plastic clay with lower permeability.

8.12.4.1 TMF Design

The design process started with the development of a set of design parameters followed by a range of sample tests and site investigations that provided further input parameters for engineering analyses and impact assessment. The following sections provide detail on the TMF design and some of the key studies and investigations that informed the iterative design process.

The main components of the TMF cell are:

- embankments;
- liners;
- tailings deposition system;
- liner overdrain system;
- leak collection and removal system; and
- central decant system.

The TMF has been designed to meet the total required capacity. The plan area of the lined cell is approximately 38 hectares. The perimeter embankment will have internal slopes of 2.5H:1V, external slopes of 3H:1V and a nominal crest width of 14 m. The design includes an access causeway that extends from the centre of the divider embankment to the central reclaim towers.

Cameco undertook a review of the available materials in selecting components for incorporation to the liner design. It is anticipated that the TMF liner system will consist of the following main components:

- a layer of compacted Liner Bedding Fill (prepared subgrade);
- a composite liner of HDPE geomembrane and Geosynthetic Clay having a permeability of no greater than 10-6 cm/s;
- a HDPE drain liner on side slopes and an HDPE Geonet drainage layer on the cell base; and
- a 1.5 mm HDPE primary (top) liner.

Tailings Deposition System

Tailings pumped to the TMF will be discharged from numerous spigots connected to a pipe that encircles the top of both embankments. This type of tailings discharge is known as 'sub-aerial deposition'.

Liner Overdrain System

In order to limit the amount of water pressure on the liner of the TMF and to decrease the time to consolidate and dewater the tailings, a liner overdrain system will be constructed. The overdrain system will consist of a bifurcating pattern of primary and secondary diameter perforated HDPE collection pipes placed on top of the uppermost liner. These pipes will be encased in a layer of course drainage gravel. A layer of fine filter sand will then be placed over the gravel to prevent piping of tailings into the drainage gravel. The overdrain system will be constructed at the base to collect downward seepage from the tailings and promote settling of the tailings mass. The pipe network will drain by gravity to a sump pump and the captured tailings supernatant will be pumped to the evaporation pond.

Leak Collection and Removal System (LCRS)

The LCRS is designed to intercept seepage that passes through any construction defects in the primary (top) liner. The LCRS consists of a drain and drain liner overlying the secondary composite liner. The LCRS will carry fluid to a sump within the TMF and the evaporation pond. The leak detection system is designed to handle flow significantly greater than the established Action Leakage Rate (ALR) as determining by the USEPA (1992) methodology. Cameco has designed the collection system assuming a small hole diameter of 2 mm, a total head of 0.3 m, and a hole density of 2-3 holes per hectare resulting in an ALR of 1,469 L/day/ha. The volume of tailings supernatant collected from the LCRS sump will be monitored.

Central Decant System

The expected discharge rate of tailings from the metallurgical plant to the TMF will be approximately 93 m^3/hr of slurry containing approximately 69 m^3/ hr of fluid. A large portion of this fluid (estimated to be about 70% of the total tailings fluid discharged) will be available for reclaim as supernatant. A portion of the supernatant entrained in the tailings pore spaces will be squeezed out of the tailings mass during consolidation under self-weight loading and report either to the supernatant pond (upward seepage) or the overdrain system (downward seepage). A hollow concrete tower or comparable structure will be constructed at the centre of the cell. This structure will contain a submersible pump and associated pipework to reclaim the supernatant and deliver it to the evaporation pond.

The key characteristics of the TMF design are presented in Table 8-38.

8.12.4.2 Tailings Water Recovery and Evaporation Pond

Cameco has completed TMF water balance and related studies to determine the total capacity and number of evaporation ponds required to evaporate tailings discharge water. The TMF has been designed based on the assumption that none of the available tailings water will be reclaimed for reuse in the metallurgical plant. However, Cameco will endeavour to maximise recycling in so far as is economically practical. As part of the 'basis of design' definition process, it was concluded that a multi-cell evaporation pond system was optimal for maintenance, leak detection and removal of accumulated residual solids. The evaporation pond was designed to be large enough to contain peak operational tailings deposition and a design storm event and have a volume of 150,500 m^3. The main components of the evaporation pond design are:

- pond embankments;
- pond liners;
- leak collection and removal system.

It is envisaged that the evaporation pond will be constructed using a cut and fill methodology to create the pond embankments and a pond void. Each of the ponds will have approximate dimensions of 75 m x 200 m with 2.5H:1V inner and outer slopes. They will be connected with internal spillways (openings in the divider berms) so that

Table 8-38: Key characteristics of the TMF design

1.0 Basic Data

1.1 Tailings produced at 600,000 tonnes per year.

1.2 Storage requirement is nominal 9 years of production tailings.
7 Mt capacity based on assumed tailings in-situ average dry density of 1.5 t/m^3

2.0 Slope Stability

2.1 Static

2.1.1 Minimum factor of safety (FS) of 1.5 for operational and closure conditions.

2.2 Dynamic (earthquake)

2.2.1 Use Maximum Design Earthquake (MDE) seismic coefficients as determined by site-specific Seismic Hazard Assessment (SHA):Maximum Design Earthquake Peak Ground Acceleration = 0.18 g
Operating Basis Earthquake Peak Ground Acceleration = 0.14 g

2.2.2 Minimum factor of safety (FS) of 1.0 for pseudo-static condition.

2.2.3 Foundation must be checked for liquefaction potential under earthquake loading.

3.0 Surface Water Management

3.1 During operations, contain run off resulting from an Extreme Storm Event (400 mm in 72 hours). The TMF shall contain run off from the extreme storm event that considers consecutive cyclone associated events, in addition to the normal operating level and required minimum 0.5 m residual freeboard.

3.2 Discharge, safely pass, or shed flows from the design storm at post-closure.

4.0 Seepage Control

4.1 The TMF liner system and final cover systems will be designed, constructed, and installed to limit migration of wastes out of the impoundment to the adjacent subsurface soil, ground water, or surface water at any time during the active life of the impoundment.

4.2 Lining of the entire TMF area with a double composite liner with leak detection system and overdrain collection system to protect the liner and collect seepage flows at the base of the facility.

4.4 Design liner and overdrain system to minimise hydraulic head on the geomembrane.

5.0 Water Balance

5.1 Use normal average conditions to evaluate monthly fluid levels throughout the life of the tailings impoundment and evaporation pond requirement.

5.2 The evaporation pond was sized to handle the extreme storm event of 400mm in 72-hours during average climatic conditions.

5.3 Assume no water reclaim to plant.

6.0 Radiation Protection and Dust Control

6.1 ALARA radiation protection and prevention of airborne release of tailings solids to the environment by limiting the active disposal area to meet air quality standards

6.2 Use Best Management Practice to further control dusting including flooding of active and/or inactive disposal cells, as needed

7.0 Tailings Deposition

7.1 Tailings slurry to be conveyed by pipeline to TMF at 50 per cent solids content by dry weight.

7.2 Sub-aerial deposition with rotational spigotting will be utilised. Deposition strategy will be designed to minimise beach angles to reduce segregation.

8.0 Closure

8.1 Decommission so as to not pose an unacceptable risk to public health and safety or the environment while limiting the need for ongoing maintenance and providing a sustainable land and water use that meets stakeholder and community objectives.

8.2 Design final cover system to provide long-term radiation and wind and water erosion protection and to limit water infiltration into the tailings mass.
The cover will be designed to be effective for 1,000 years, to the extent reasonably achievable.
Ensure that potential doses to public are as low as reasonable achievable and certainly less than the member of the public dose limit of 1 mSv/y.
Limit infiltration of moisture into, and release of contaminated liquid from the tailings to mitigate environmental effects to downstream receptors.

water from one pond can spill into the adjacent pond. The pond liners and LCRS will have the same configuration as the liners used in the TMF. As a contingency measure, the pond will have one or more emergency spillways to allow controlled discharge from the ponds in the event that the system is overwhelmed by a storm greater than the design storm event. In such unlikely circumstances, supernatant discharged from the ponds will be directed to the mine pit.

8.12.4.3 TMF Construction and Operation

Based on a production rate of 600,000 tpa and an average tailings dry density of 1.5 t/m^3, the TMF has a design life of approximately 9 years and capacity to accommodate storage of 7 Mt of tailings with 1 m of freeboard. (See Appendix E; page 4)

The TMF will be constructed concurrent with the period of pre-strip mining. The facility will be constructed to final height during pre-strip to maximise the efficiencies of dumping non-mineralised overburden during pre-strip. The maximum height of the TMF will be approximately 20 m. Concurrent with the construction of the TMF, Cameco will also construct the evaporation pond and associated infrastructure.

The depositional sequence will be governed by the following objectives:

- The tailings beach will generally slope to the supernatant pond area at an approximate 1% grade.
- Sub-aerial deposition with rotational spigoting will be used to maximise densification of the tailings.
- The tailings beaches will be managed so as to ensure that the supernatant pond is kept in the central area of the impoundment, from where the water reclaim system will be operated.
- The size of supernatant pond will be limited as far as practical.

Tailings reclaim water will be applied to the surface of the cell that is not in active deposition as required to serve the multiple roles of providing an additional evaporative surface whilst inhibiting radon gas and dust emissions.

8.12.4.4 Closure of the TMF

The TMF will be rehabilitated at the end of project life in accord with an approved Mine Closure Plan. In overview the rehabilitation of the TMF is expected to involve:

- removal of all surface pipework and related tailings distribution infrastructure;
- excavation of all residual salt and fines within the evaporation pond and the placement of this residue to the TMF;
- backfill of voids left by the removal the evaporation pond so as to prevent the retention of surface water post-closure;
- removal of the reclaim tower and related infrastructure;
- construction of a Closure Cover over the final tailings surface;
- landscaping the IWL and the TMF to a final planned landform inclusive of surface drainage; and
- revegetation of the TMF area.

It should be noted that the cell liners, Liner Overdrain System, and LCRS will remain in place under the deposited tailings post-closure. The Closure Cover and a TMF surface water drainage design are further discussed in the following sections.

8.12.4.5 Closure Cover Design

A closure cover will be constructed over the TSF cell such that the final landform is water shedding. The cover will comprise three layers. The primary cover will consist of a ≥2 m layer of non-mineralised waste rock that will be placed directly onto the tailings surface. The final thickness of material will be designed to control radon emissions to acceptable levels. The layer will be placed to create a minimum 0.5% slope (post-settlement) from the cell centre to its perimeter so as to achieve water shedding. The actual constructed thickness may be greater than 2 m in places to ensure the minimum desired surface slopes to the cell perimeter are achieved. A 2 m layer of salvaged sub-soils and topsoils will be placed on top of the waste rock. The final layer of the cover will be an erosion control layer consisting of a minimum of approximately 100 mm of crushed rock mulch for protection. It is anticipated that this armouring will be integrated into the soils by shallow ripping. Finally the surface will be revegetated.

8.12.4.6 Surface water drainage design

The post-closure surface water drainage will be designed to prevent ponding of water on the surface of the TMF and safely pass peak flows from the extreme design rainfall event. Inevitably, surface flows on any above-grade landform will tend to concentrate in various locations. Therefore, Cameco will survey the final TMF landform to ascertain where defined surface channels and or any additional armouring, down-chutes or energy dissipation structures may be required. Surface water drainage designs will be developed as part of subsequent updates of the Mine Closure Plan.

8.12.5 Proponent Studies and Investigations

8.12.5.1 TMF Foundation Assessment

Preliminary geotechnical assessments of the TMF foundation materials have been completed (Dames & Moore, 1996, Golder, 2011). The results support the general TMF design as presented.

8.12.5.2 Tailings Characterisation

At the point of discharge the tailings will comprise 50% solids and 50% supernatant by mass. The geotechnical and geochemical properties of the tailings have been characterized on the basis of samples obtained from pilot plant trials. An analysis of the geotechnical and physical properties of the tailings (Golder, 2012) revealed;

- No asbestiform fibres were identified in fibre characterisation of the tailings sample using scanning electron microscope (SEM).
- The particle density of the tailings sample was measured to be 2.75 while the supernatant density was measured to be 1.07 g/mL.
- The PSD curve indicates that the tailings sample has 69% fines passing the 75 µm sieve.
- The segregation threshold occurs at approximately 35% solids concentration.
- The settled tests indicated that the tailings will achieve a dry density of about 1.05 to 1.10 t/m^3 and that 95% of the settled dry density is likely to be achieved within 1 day of deposition.
- An air dried density of 1.66 t/m^3 is achievable in both winter and summer conditions, and cycle times that allow the tailing to air dry for more than 12 days in winter are likely to be required to achieve this dry density.
- The consolidation test results indicate that the sample has a permeability ranging from 6.9 x 108 m/s to 1.7 x 108 m/s for the tested pressures ranging from 40 to 640 kPa. The initial dry density and the dry density at the maximum pressure tested are 0.98 t/m^3 and 1.66 t/m^3, respectively.
- The dry density at the maximum pressure tested in the consolidation test is consistent with the maximum air dried density, suggesting that loading or air drying could be adopted to achieve a dry density of 1.66 t/m^3.
- The air entry valve (AEV) estimate from the drying path is 60 kPa and the tailings appear to desaturate quite quickly beyond this point. The permeability of the material is also expected to reduce significantly.

An analysis of the geochemical properties of both solid and supernatant components of the tailings has been completed. It is important to note that the acidic tailings initially produced by the metallurgical plant will be neutralised to pH 8 prior to delivery to the TMF. The indicative total metal concentrations within the solid tailings component are presented in Table 8-39. The indicative total metal concentrations within the tailings supernatant are presented in Table 8-40.

8.12.5.3 Radiological Characteristic of Tailings

The metallurgical process extracts uranium and leaves the other radionuclides in the tailings. As a consequence, approximately 85% of the radioactive material associated with the original ore is left in tailings. The majority of the radionuclides are from the U-238 decay series.

The radiological properties of the tailings have been characterized on the basis of samples obtained from pilot plant trials. The indicative radionuclide activity in the solid components of the tailings is presented in Table 8-41 alongside radionuclide concentrations in leach solution and ore used in the pilot plant tests.

The supernatant will be transferred to the evaporation pond. As the salts build up in the bottom of the ponds, they will be regularly cleaned out and the material placed back on the TMF.

8.12.5.4 Liquefaction and Stability Analyses

The TMF design process included various engineering analyses such as trafficability, slope stability, liquefaction potential, and seepage analyses.

Liquefaction can be generally defined as the loss of shear strength in loose, saturated, and

Table 8-39: Indicative total metal concentrations from solid tailings component

Analyte	Units	Value	Analyte	Units	Value
Si	%	26.6	U	mg/kg	108
Fe	%	9.8	Ni	mg/kg	102
Mg	%	5.8	Zr	mg/kg	58
Al	%	3.5	Zn	mg/kg	50
Ca	%	2.4	Ba	mg/kg	47
S	%	2.3	Sr	mg/kg	28
K	mg/kg	3470	B	mg/kg	25
Mn	mg/kg	1190	Co	mg/kg	20
Ti	mg/kg	1051	Mo	mg/kg	20
Na	mg/kg	450	As	mg/kg	10
Cu	mg/kg	360	Se	mg/kg	<10
P	mg/kg	360	Th	mg/kg	6
Pb	mg/kg	238	Be	mg/kg	5
Cr	mg/kg	143	Ag	mg/kg	<0.5
V	mg/kg	121	Cd	mg/kg	<0.5

Table 8-40: Indicative total metal concentrations within the tailings supernatant

Analyte	Units	Value	Analyte	Units	Value
SO_4	mg/L	6000	Zn	µg/L	26
Mg	mg/L	2360	Ni	µg/L	23
Na	mg/L	777	As	µg/L	17
Ca	mg/L	427	Ti	µg/L	14
K	mg/L	68	Co	µg/L	5
Mn	mg/L	24	Cr	µg/L	<5
Si	mg/L	8.4	Zr	µg/L	4
U	mg/L	3.4	Sb	µg/L	3
Sr	mg/L	1.4	V	µg/L	2
Al	mg/L	<0.1	Pb	µg/L	1
B	µg/L	356	Th	µg/L	<1
P	µg/L	225	Ag	µg/L	<0.5
Li	µg/L	159	Cd	µg/L	0.2
Fe	µg/L	56	Be	µg/L	<0.2
Ba	µg/L	47	Sn	µg/L	<0.2
Se	µg/L	46	Tl	µg/L	<0.2
Mo	µg/L	41	Bi	µg/L	<0.1
Cu	µg/L	28			

cohesionless soils due to the generation of excess pore pressures as a result of large shear strains induced by undrained cyclic loading. Liquefaction is common in loose, saturated, and cohesionless sand but has also been noted to occur in material such as low plasticity clay and silt or cohesionless gravels. Site investigations completed in the Project area revealed that the majority of native sandy surficial soils encountered were dense and consisted mainly of sand with varying amounts of silt and clay. Furthermore, groundwater encountered in geotechnical borings was below the sandy layer in a hard clay layer. It was concluded that soils underlying the TMF are not susceptible to liquefaction.

The stability analyses for the TMF structures included static and pseudo-static methods at the maximum dam embankment section using the SLOPE/W component of the GeoStudio computer programme (Geo-Slope, 2004). The analyses were conducted on various embankment sections. The planned tailings facility was evaluated for both static and pseudo-static (earthquake) conditions using the Maximum Design earthquake and a 66% horizontal ground acceleration factor for the analyses. The slope stability analyses indicate the TMF can be safely constructed and operated with 3H:1V outer slopes to at least the design height of 21 m.

8.12.5.5 Seepage into the TMF Cells Post Closure

The closure cover for the TMF has been designed to limit infiltration to the underlying tailings. Infiltration through the closure cover and the seepage to Liner Overdrain System beneath the tailings was evaluated using the VADOSE/W programme from the GeoStudio 2007 software package (GEO-SLOPE, 2007). Model results suggest that a negligible volume of water, if any, will wet the tailings for the range of storm events examined. No discharge from the liner overdrain system is expected in the longer term post-closure.

8.12.5.6 Radon Emission Modelling

The closure cover for the TMF has been designed to limit radon gas from exiting the tailings. The movement of radon gas through the TMF closure cover was modelled using RADON computer software, (U.S. Nuclear Regulatory Commission [USNRC], 1989). In applying this model, Cameco has used the NRC Regulatory Guide 3.64 (NUREG 3.64) (USNRC, 1989) to define an emission limit (known as an 'exit flux') of less than 0.74 Bq/m^2/s. While Cameco is aware that NRC has no regulatory role in Australia it does provide a useful guidance document on Radon attenuation figures that could easily be used in Australian conditions. Based on this limit, the model was used to determine the thinnest cover required to achieve this result. RADON code modelling determined that a 1.6 m thick layer of salvaged topsoil is sufficient to limit radon attenuation to less than 0.74 Bq/m^2/s when combined with a 1 m layer of waste rock. As discussed in Section 8.12.4.5 the planned closure cap will generally exceed 4 m in thickness.

8.12.5.7 Compatibility of HDPE Materials to Leachate

The liners, geonet, and piping will be constructed from HDPE. In addition to the structural and strength related parameters, specifications related to UV and environmental stability, as well as chemical and radiological resistance of the HDPE will be included in technical specifications. The acidification of the process stream is considered the primary chemical alteration that has the potential to affect the liner. The acidic tailings slurry (and various other waste streams) are neutralised to a pH of 8.0. Based on the review of available data, no measurable degradation of the HDPE materials is expected from chemical or radionuclide parameters. Importantly the management of leachate is only material for the period of operations and the decade or so following closure. Thereafter the tailings will remain effectively dry (given the design functionality of the Closure Cover) and hence a sound post-closure environmental outcome is not dependent on the very long term integrity of the HDPE liners.

8.12.5.8 Further trials, testing and detailed TMF design

Sufficient trials and testing have been completed to present a comprehensive description of the design and construction of the proposed TMF. However, Cameco will complete further laboratory testing on the tailings (as produced by subsequent pilot plant tests), the overburden to be extracted from the proposed pit area, and the foundation materials underlying the proposed TMF in the subsequent design phases. This additional information will be used to shape decisions on the final detailed design for the TMF and the final TMF cover. A summary of this additional work is provided in Table 8-42.

Table 8-41: Indicative radionuclide concentrations in tailings, ore and leach solutions*

		Tails solids Bq/g	Sample Ore Bq/g	Leach Solution Bq/L
U-238 Series	U-238	6.6	103	18700
	Th-230	61.0 ± 9.4	151 ± 14	20400 ± 1200
	Ra-226	136.4 ± 8.7	133.9 ± 5.6	4.5 ± 0.21
	Pb-210	165 ± 14	132 ± 13	< 30
	Po-210	117.7 ± 6.5	111.0 ± 6.3	10.5 ± 1.7
Th-232 series	Th-232	10.1 ± 1.2	134 ± 13	24200 ± 1800
	Ra-228	< 0.4	0.35 ± 0.10	1.04 ± 0.62

* *Pilot plant sample contained 11500ppm of Uranium

8.12.6 Potential Impacts and Management

8.12.6.1 Sources of radiation from the TMF

Gamma Radiation

Gamma radiation levels from the tailings will be consistent with the equivalent amount of ore. This is because the main gamma emitting radionuclide in uranium ore is Ra226 and this radionuclide remains with the tailings. When the tailings have been disposed and covered, the terrestrial gamma radiation dose rates will be similar to the existing background levels.

Radioactive Dusts

Radioactive dust from tailings is not expected to be problematic during operations as the tailings will maintain moisture as they dry and consolidate into a competent mass. Once dried, dust is expected to be insignificant due to the competency of the tailings and the surface crusting with salts. The TMF will be designed to provide the opportunity to apply tailings liquor back onto dry surfaces of the tailings should further controls for dusting or radon emanation be required.

Radon and Radon Decay Product

When tailings are wet, radon emanation is low as radon is unable to escape from the pore space of the tailings particles. When tailings over-dry, there is potential for increased emanation if consolidation has not been effective. The estimated emanation has been assumed for the worst-case conditions. During operations, the radon concentrations in the region of the tailings cell may be elevated due to the presence of radon from the exposed tailings.

Radionuclides in Seepage

The risk of seepage resulting in the transport of radionuclides from the TMF is very low given the integrity of the TMF liner is maintained whilst the tailings remain free draining. In the unlikely event that a leak does occur (i.e. as a consequence of both liner and drainage system failures), fate and transport modelling has shown that any seepage will drain towards the mine pit as the pit acts as terminal sink for groundwater in the Project area during operations and in the long-term post-closure environment. It should be noted that the travel time for any seepage would exceed the life of the project. Therefore, there are no direct exposure pathways to the regional groundwater.

8.12.6.2 Controls of radiation

The IWL-TMF will be operated to minimise the exposure pathways:

- Liners, drainage and a leak detection system to minimise the likelihood of any seepage and hence release of tailings supernatant to groundwater;
- Deposition of the tailings as a slurry to maintain pore water levels and hence limit the release of radon gas;
- Secondary discharge system to apply decant liquor to maintain moist conditions of non-operational parts of the IWL-TMF;
- Subaerial deposition of tailings is a simple well understood technology that requires relatively little operational intervention thus limiting the number of people who will need to work on the facility; and

Table 8-42: Anticipated tailings, overburden and clay laboratory investigations

Aspect	Design Areas	Design Criterion	Measured by
Classification testing	All – behaviour of materials	Soil classification systems	Particle size distribution Atterberg Limits Specific gravity (solids) Specific gravity (water) Dispersivity
Radiological characterisation of the tailings solids and supernatant	Radiological exposure management and closure planning	Determine deportment between tailings components of various U decay chain elements	Radionuclide testing
Settling behaviour	Storage capacity, water return, deposition methodology	Dry density Time required to achieve dry density	Settling tests
Beach rheology	Storage capacity; spigot spacing; outlet size (flow rate)	Beach angle Viscosity Yield shear stress	Slump tests Flume tests Rheometer
Pipe flow rheology – friction losses	Pumping and pipeline design	Friction losses for different slurry solids concentrations	Pump loop tests
Drying rate & drying behaviour	Rate of rise; seepage rate; surface crusting; dusting potential; radon exhalation potential	Drying rate	Air drying tests Shrinkage limit Radon exhalation
Strength, permeability, consolidation, shrinkage	Embankment design; settlement (closure); seepage; cover design	Moisture/suction Compaction Consolidation Permeability	SWCC Fredlund device Rowe cell Triaxial
Dusting	Prevention of dust from TMF surface	Hardness and durability of salt crust; Dusting vs drying time	Bench scale surface brushing tests Wind tunnel testing
Radon emanation	Public dose assessment	Radiation dose	Laboratory testing
Tailings geochemistry (follow up testing)	Leachability Radioactivity Water quality	Radioactivity; Potential contaminants	Chemical assays Mineralogy Leach testing

- Supernatant pond levels will be managed to minimise the attractiveness of the ponds to wildlife. Should bird visitations become frequent, best available technologies would be used to minimise interaction.

For further discussion on radiation and its management, see Section 8.11.

8.12.6.3 Surface Water Management

Stormwater collected from the TMF will be managed via two primary systems. The provision of 1 m freeboard within the TMF together with the installation of a central decant system; and, the construction of two diversion channels to redirect TMF runoff flows to the evaporation pond. The provision of 1 m of freeboard on the TMF allows stormwater to accumulate without risk of overtopping and provides additional area for the evaporation of accumulated stormwater. A central decant structure will be installed , allowing accumulated stormwater to be collected and removed from the TMF and directed to the evaporation pond for management. Runoff from the TMF slopes will be captured in one of two diversion channels. These will direct the runoff to the evaporation pond.

8.12.6.4 Ground and Surface Water Monitoring

A conceptual monitoring programme has been designed to give advance warning of TMF leakage and unexpected changes in groundwater levels and chemical composition in monitoring bores. The monitoring programme, will be defined in the

TMF Operating Plan to be submitted as part of the Mining Proposal will require:

- A network of monitoring wells located down-gradient of the TMF and evaporation pond. Perimeter wells will be located within 100 m of the facility to facilitate early warning of leakage. Groundwater levels would be recorded and groundwater would be sampled monthly for pH and electrical conductivity. Samples would be analysed in an independent laboratory for radionuclides and metals on an annual basis.
- Sampling weirs and associated instrumentation in downstream stormwater drains.
- Monitoring of the TMF embankment and leak detection system instrumentation.
- The development and maintenance of an TMF Instrumentation Management Plan.
- Definition of Action Trigger Levels pertaining to changes in flow rates, groundwater levels and chemical composition.
- Routine inspections undertaken by appropriately qualified people, of the TMF and evaporation pond. These will be instituted at the time of construction and will proceed quarterly with additional inspections in the event of a process upset or a major storm/surface water flow or seismic event. Inspections of the LCRS sump liquid level in the TMF and evaporation pond will be performed weekly. All inspections will take the form of a visual assessment of integrity along with a physical appraisal of pond design capacity. Inspection records will remain onsite for a period deemed necessary by the authorities.
- Development of a facility surveillance program, to be carried out by mine personnel, with the intent of making ongoing observations relating to the conditions and performance of the tailings structure and associated facilities, upstream diversion structures, as well as tailings disposal and evaporation pond management operations, so that any changes to conditions or performance, or a hazardous condition can be identified and promptly addressed.

8.12.6.5 Bird and Animal Deaths

The proposed routine inspections of the TMF will include a daily inspection of the surface of the tailings and evaporation pond for wildlife visitation. Records will be kept of the frequency and numbers of birds and other wildlife visiting these facilities. Any fauna deaths potentially resulting from interaction with the facilities, for example, entrapment in mud, will be reported. Should the number of visitations be considered unacceptable, methods to deter and or exclude fauna would be implemented.

8.12.6.6 Dust Control

Dust from the tailings surface may create a potential exposure pathway to people and non-human biota. The risk posed by dusting will be actively managed in accord with the TMF Operating Plan. Specifically, the TMF will be operated in such a way so as to maintain a moist cover on the tailing beaches. Dust emissions from the TMF will be monitored by visual observations.

Cameco will incorporating dust management procedures during final drying of the tailings. This may include the use of sprays and a progressive or a “celled” rehabilitation approach where only a partial surface area is not flooded.

8.12.7 Commitments

The TMF will be operated in accordance with an approved TMF Operating Plan which will include commitments to a monitoring programme.

The TMF has been designed and will be constructed, maintained and closed:

- as a fully lined zero-discharge facility; and
- to ensure that the radiological exposure of people and biota, will be well below applicable limits during operations and post closure.

8.12.8 Outcome

It is anticipated that the risk to the environment arising from radiological and other factors related to the TMF will be low. Cameco has considered the risk associated with the TMF during operations and closure of the Project. Further details on the final landform design are provided in the Mine Closure and Rehabilitation Plan (Appendix D17). Cameco believes that the long-term integrity, ecological functions and environmental values of the soil, landforms and groundwater of the Project area and surrounding areas will not be affected by the TMF.

8.13 Geochemistry

8.13.1 Objectives

The primary objective according to the ESD is to maintain the integrity, ecological functions and environmental values of the soil and landforms.

To achieve this objective, a thorough understanding of the geochemistry of liquid and solid wastes, and transport pathways such as air, surface water and groundwater, are required. This section details the information collected and predictions made concerning the solid wastes that are expected to be generated, the existing conditions and potential post closure conditions.

Pit water geochemistry, the interaction of final pit void water with groundwater and discussion relating to the behaviour of the pit lake is covered in Section 8.4.5.3.

8.13.2 Background

The disturbance of the ore body results in geochemical changes to the rocks, surface water, groundwater and sediment in the surrounding environment, by introducing oxygen, introducing or removing water and changing the surface areas of particles that are exposed. These processes have the potential to cause the following harmful effects:

- Generation of acidic water can dissolve additional metals from the soils and rocks to higher than normal concentrations, making the water metalliferous and saline;
- The secondary effects of these changes in the water can result in lower oxygen concentrations, higher dissolved or suspended solids, turbidity and colour; and
- With a uranium ore body there are the additional hazards of high radioactive metal concentrations in the natural water and increased radioactivity.

The likelihood of these geochemical conditions occurring can be assessed, quantified and incorporated into planning and management strategies to minimise or negate the risks. In order to evaluate the acid generating potential of the rocks that will be disturbed, the amount and location of sulphide minerals, such as pyrite (FeS_2), chalcopyrite ($CuFeS_2$) and arsenopyrite ($AsFeS_2$), has been assessed. The occurrence of acid generating minerals is offset by the occurrence of acid-neutralising minerals which commonly occur as carbonates (CO_3) such as dolomite ($CaMg(CO_3)_2$), calcite ($CaCO_3$), siderite ($FeCO_3$) and rhodochrosite ($MnCO_3$).

The potential for rocks to release metals in higher concentrations than normal has been assessed and the existing environmental conditions have been established.

8.13.3 Relevant Legislation and Policy

In Western Australia, prevention of pollution is legislated under the *Environmental Protection Act 1986* (EP Act). Specifically, Part V Division 1 of the EP Act deals with prevention of pollution and unreasonable emissions, dumping or discharge of waste and matters of environmental harm. Section 72 of the EP Act requires the occupier of a site to notify DER of any unauthorised discharges that are likely to cause pollution, material environmental harm or serious environmental harm.

Classification and treatment of sites where contamination has occurred is dealt with under the *Contaminated Sites Act 2003* (CS Act) and the Contaminated Sites Series Management Guidelines which outline investigation and remediation requirements throughout the life of a site. The DER has provided a set of guidelines based on the CS Act, where mining and extractive industry are automatically classified as 'Potentially Contaminated', as a result of the nature of the work undertaken on the site.

Nationally, the ANZECC/ARMCANZ Water Quality Guidelines for freshwater ecosystems, marine ecosystem, irrigation water, livestock drinking water, aquaculture, recreational use and aesthetics as well as National Health and Medical Research Council (NHMRC) apply. The quality of natural waters is highly variable and site specific baseline conditions will be established to inform water monitoring guidelines at the Kintyre site. The following are additional policies that will guide waste management:

- Managing Acid and Metalliferous Drainage, (DITR, 2007b);
- NORM-3.1 Monitoring – pre-operational monitoring requirements;
- NORM-3.2 Monitoring – operational monitoring requirements;
- NORM-4.2 Controlling – management of radioactive waste;

- NORM-4.2 Controlling – management of radioactive waste;
- Evaluating the Reliability of Predictions Made Using Environmental Transfer Models IAEA Safety Series No. 100;
- Radiation Monitoring in the Mining and Milling of Radioactive Ores (Jointly Sponsored by IAEA, ILO and WHO) IAEA Safety Series No. 95; and
- The Application of the Principles for Limiting Releases of Radioactive Effluents in the Case of the Mining and Milling of Radioactive Ores IAEA Safety Series No. 90.

8.13.4 Proponent Studies and Investigations

The Project area has been extensively investigated by Cameco and the Project's previous owners. A large amount of work has been conducted and the information compiled for use in this assessment. The following is a brief description of the investigations that are relevant to the geochemistry of the site.

A summary report was compiled for Canning Resources in 1993 (Dames & Moore, 1993). This report detailed the hydrogeological environment and compiled the groundwater quality results from 45 monitoring wells, five observation bores and eight pre-existing wells.

A geochemical investigation analysed 25 core samples for acid-base accounting, mineralogy, leaching potential and total elements (Graeme Campbell & Associates, 1997) (Appendix P).

In preparation for the ERMP submission Cameco contracted MWH in 2009 to provide an updated hydrogeological investigation (MWH,2010). This study consisted of a drilling and sampling programme, which extensively characterised the aquifers underlying the site. This included a large amount of chemical analyses to assist with the determination of the baseline water quality.

CSA Global was contracted in 2011 to conduct a review of existing data and identify gaps in the Project from a geochemical perspective (CSA, 2011) (Appendix P). In addition to the review, geochemical analyses of the acid neutralising potential in terms of carbonate minerals was assessed in waste rock as well as in the ore body.

In 2012 Tetra Tech reviewed existing drill core data and undertook static and kinetic geochemical testing on waste rock, mineralised overburden and tailings samples. Geochemical characterisation and a geochemical predictive model for the pit lake were also undertaken (Tetra Tech, 2012b).

The following is a brief description of the analytical methods employed in these investigations:

- Mineralogical analyses by x-ray diffraction (XRD) were conducted to identify minerals that could contribute to neutralisation or acidity potential.
- Acid-base accounting (ABA) assessed the potential of a sample to either produce or neutralise acid through the analysis of total sulphur concentrations and titration to determine neutralising capacity.
- Total element analysis compared the solid phase concentrations of selected elements to the average geochemical abundances to assess the potential for metalliferous drainage.
- The static leaching tests provided an assessment of the potential for metal leaching from short-term contact with water simulating rainfall.
- Total carbon attributed to carbonate minerals was determined to assess the complete neutralising potential of waste rocks, tailings and ore body.
- Kinetic testing comprised several humidity cells which simulated long-term weathering conditions over the course of 22 months.
- A database of pH, salinity, dissolved major ions, and metals in the groundwater at the site has been maintained.
- Radionuclide analyses were undertaken including concentrations of uranium and selected daughter elements, selected elemental radioactivity and gross alpha and beta levels.

In conjunction with the prefeasibility study a post closure pit lake model was constructed to assist in predicting the long-term water quality the lakes that are expected to form at the end of the mine life and the effect of the pit on the surrounding water quality (Section 8.4.5.3).

8.13.5 Existing Environment

The ore body is hosted within the Yandagooge Formation which occurs between the basement gneisses and the overlying Coolbro Sandstone. The uranium mineralisation occurs as pitchblende veins in the chert banded chlorite garnet magnetite schist. The ore body comprises five deposits: Kintyre, Kintyre East, Whale, Whale East and Pioneer. The non-mineralised host rock comprises glacial till, biotite-chlorite schists, chlorite-graphite schists, meta-carbonate rocks quartz-muscovite schists.

Non-mineralised rock from the Kintyre, East Kintyre, Whale and East Whale deposits are mildly alkaline and are classified as non-acid forming (NAF). The rock samples also have element concentrations below or close to the average geochemical crustal abundances (Graeme Campbell & Associates, 1997). The glacial tillite was moderately enriched in bismuth, and two samples of the quartz-chlorite-graphite schist classified as potentially acid forming (low-capacity) sulphite concentrations near 1% were moderately enriched in selenium. Provisional estimates indicate that the quartz-chlorite-graphite-schist may comprise 20% to 30% of the total volume of non-mineralised rock produced from mining of the Whale and East Whale deposits. Small amounts of sulphide minerals, which are visible to the eye, are present in lenses. The salinity of a slurry sample of glacial clay indicated that this formation is likely to have the biggest influence on the composition of groundwater with an electrical conductivity of 34 – 60 mS/m.

In order to determine the predicted acid consumptions for the uranium leaching process, the carbon content and neutralisation potential for each deposit was evaluated by CSA Global (2011) using the assay data of approximately 10,130 samples. This study confirms the finding of Graeme Campbell & Associates (1997) that acid generation potential of ore is low with a high neutralising potential.

- At Kintyre the neutralisation potential ranges from 50 kg H_2SO_4/t to maximum of 110 kg H_2SO_4/t;
- At Whale the neutralisation acid consumption ranges from a minimum of 70 kg H_2SO_4/t to maximum of 140 kg H_2SO_4/t;
- At Whale East the neutralisation potential ranges from 50 kg H_2SO_4/t to maximum of 180 kg H_2SO_4/t;
- The data set at Pioneer ranges from a minimum of 50 kg H_2SO_4/t to maximum of 450 kg H_2SO_4/t;
- The overall average of 122 kg H_2SO_4/t is a weighted average of all the zones intercepted by the respective drill hole.

Trace elements with concentrations in the mineralised interval greater than five times their corresponding values in non-mineralised rocks are considered anomalous. Most anomalous trace elements were between ten to 50 times enriched in the ore intervals. The elements that show a positive correlation with uranium mineralisation are As, Ag, Au, Bi, Cr, Cs Cu, Mo, Pb, Sb, V, and W. In addition, the rare earth elements, Dy, Eu, Gd, Ho, Nd, Pr, Sm, Tb, Tm, and Yb are closely correlated to mineralisation but at low concentrations. Co and Ba show a negative correlation or depletion in the ore zone.

A soil survey was conducted in 1996 to identify and map soils in the Project area (Dames & Moore, 1997). Soil samples had a generally neutral pH, low salt content and element concentrations below or close to, those recorded for non-mineralised soils and rocks (Graeme Campbell & Associates, 1997).

8.13.6 Potential Impacts and Management

The lithologies present in the proposed pit are predominantly metamorphic schist and meta-carbonates, with some unconformable overlying glacial tillites and sediments. Three independent investigations found that the overall assessment of the system indicates that any localised acid rock drainage will be neutralised by the relatively abundant carbonate minerals present. This is supported by acid-base accounting data from static testing and from kinetic testing where pH values fluctuated between 7.0 and 8.5. The pH in the first 20 weeks of kinetic testing were as high as 9 indicating a high neutralisation capacity (Tetra Tech, 2012b). The potential impact from the low concentrations of potentially acid forming minerals is considered to be low, and may be further mitigated by encapsulation within the waste rock dump, surrounded by carbonate rock types.

8.13.7 Commitments

Cameco is committed to ensuring best practice management and mitigation of environmental impacts. The following commitments are made with regards to the geochemical aspects of the project. Cameco will:

- prepare a waste rock dumping schedule to manage and segregate potentially acid/metalliferous minerals and prevent acid rock drainage from occurring; and

Table 8-43: Kintyre fibrous samples

Sample Date	Flow Rate (L/min)	Volume Sampled (L)	Number of Detected Fibres	Exposure Fibre/mL	Activity
4/08/2010	2	510	5	<0.01*	In core shed
4/08/2010	2	500	6	<0.01*	Cutting and bagging of core in normal conditions
4/08/2010	2	630	15	0.02	In core shed
7/08/2010	2	1,070	2	<0.01*	In core shed
7/08/2010	2	1100	2	<0.01*	In core shed
11/08/2010	2	870	2	<0.01*	Drilling on Kintyre Hill in suspected fibrous zone
11/08/2010	2	1,190	4	<0.01*	Drilling on Kintyre Hill in suspected fibrous zone
14/08/2010	2	710	3	<0.01*	Drilling on Kintyre Hill in suspected fibrous zone
17/08/2010	2	760	0	<0.01*	Drilling on Kintyre Hill in suspected fibrous zone
18/08/2010	2	680	3	<0.01*	Cutting and bagging of core in normal conditions

* 0.01 Fibre/ml is the limit of detection for the analytical method used.

- advance further pit lake models to include additional backfill scenarios.

8.13.8 Outcome

It is anticipated that with the accurate delineation of sulphides and proposed management measures for PAF materials, that the risk to the environment from acid and metalliferous drainage (AMD) will be low. Cameco has considered the risk of AMD in closure of the Project and final landform design is provided in more detail in the Mine Closure and Rehabilitation Plan (Appendix D17). Cameco believes that the long-term integrity, ecological functions and environmental values of the soil and landforms of the Project area and surrounding areas will not be affected by AMD.

The modelling undertaken predicts that the pit lake water will be of poor quality. However, as a result of high evaporation rates, the pit will remain a terminal sink with no outflows, and it is not expected to have a negative impact on the surrounding environment.

8.14 Fibrous Minerals

8.14.1 Objectives

The objective from the ESD relevant to fibrous minerals is to ensure that emissions from the Project do not adversely affect environmental values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.

8.14.2 Relevant Legislation and Policy

In Western Australia, the principal controls for fibrous materials are the *Mines Safety and Inspection Act 1994* (MSI Act) and the Mines Safety and Inspection Regulations 1995 (MSI Regulations). Further guidance is provided through the DMP Guideline 'Management of fibrous minerals in Western Australian mining operations 2010' (DMP, 2010b) and the 'Code of practice for the management and Control of Asbestos in Workplaces' (NOHSC, 2005).

Both the MSI Act and MSI Regulations are enforceable and breaches may result in prosecution, fines, or directions to cease operations and undertake remedial action. The MSI Regulations provide more specific requirements for a range of activities and both the MSI Act and the MSI Regulations are supported by Guidelines. Through this framework, employers have a duty to:

- implement appropriate strategies to recognise, evaluate and control hazards to workers;
- ensure that the exposure of workers to airborne fibrous minerals is within regulatory standards and as low as reasonably practicable[7] ; and
- provide relevant information to workers and targeted training programmes.

8.14.3 Proponent Studies and Investigations

In the process of exploration drilling at the mine site, geologists observed in a small number of diamond drill cores that contained what appeared to be thin layers (bands) of fibrous minerals. Cameco then contracted an occupational hygienist and analytical company with extensive experience in fibrous minerals including asbestos, to assist in identifying, or more correctly speciating, the fibrous minerals present.

Analysis was performed on the diamond core specifically selected from hydrothermal alteration zones that were suspected to contain fibrous minerals. Scanning Electron Microscopy with Energy Dispersive Spectra showed that the minerals present were chemically correct and the fibres were of the dimensions of asbestiform minerals. It was determined that the fibres were part of the cummingtonite-grunerite asbestos series. These asbestiform minerals are known as amphibole forms of asbestos which are found in mafic and ultramafic rocks.

Subsequent to the laboratory investigations, geologists were trained to identify intersections of fibrous minerals in the drill core and records of intersections were logged and mapped across the ore body.

A programme of personal air sampling was also conducted to assess the level of risk posed by handling core containing intersections. Personal air samplers were fitted to people considered to have medium to high levels of risk of exposure to fibrous minerals. These people included drillers, geologists and geo-technicians.

The sampling programme occurred in August 2010 and a total of 10 samples were taken of workers likely to have been exposed to fibrous minerals. Of these, 9 samples recorded fibrous minerals as being detected.

8.14.4 Existing Geological Environment

The greenstone belt of Western Australia hosts amphiboles and serpentine minerals. Under certain geological conditions some of these minerals can undergo hydro-thermal processes which can transform non-asbestiform host minerals into asbestiform minerals. Asbestiform minerals have been observed in iron ore, nickel, gold, copper and other mines in Western Australia.

Blue asbestos, or more scientifically correct, asbestiform riebeckite (more commonly known as crocidolite – a commercial name) is found in the Banded Iron Formations (BIF) of the Pilbara region of Western Australia. Crocidolite is found in many layers of the BIF and any iron ore mine that is mining BIF and can be a significant hazard in some iron ore mines.

At Kintyre, the asbestiform minerals were only found at depth (usually greater than 80 m deep) in what is normally called “fresh” or “unoxidised” rocks. The asbestiform minerals were present close to the depth of rocks which will be mined for the uranium ore.

The exploration drilling using diamond core has been conducted with a small grid pattern so has provided reasonable confidence about the frequency and extent of the asbestiform minerals.

While the uranium ore is coincidental with the same rock formation which is likely to contain the asbestos host mineral, the main rock formation has been altered geologically, resulting in specific hydrothermal zones. Those hydrothermal alterations appear to be the precursor to formation of the asbestos. However, based on current understanding, the asbestos appears to be related only to the areas where the hydrothermal alterations have occurred. Also based on current observations, the hydrothermal zones in question are not related to the uranium mineralisation. As a consequence, the uranium mineralised sample intercepts, selected and presented for core cutting and for further geological laboratory analysis,

[7] Asbestos is a carcinogen and the Code of Practice for the Management and Control of Asbestos in Workplaces (NOHSC: 2018 [2005]) requires exposure of workers and other persons to asbestos is either eliminated or kept as low as reasonably practicable (known as ALARP). In all circumstances asbestos levels are to be kept below the National Exposure Standard (NES).

appear unlikely to contain the suspect hydrothermal zones, and therefore a much lower potential to contain the asbestiform minerals.

There is the possibility that other asbestiform minerals may be found in the rocks to be mined. If there are any dolerite intrusions of the ore body then they can also have asbestiform minerals such as actinolite or ferroactinolite.

The Occupational Exposure Standard (OES) for asbestiform minerals is 0.1 respirable fibres per mL of air as a Time Weighted Average (based on eight hours exposure per day and five working days per week). The adjusted OES for this site due to longer shifts is 0.07 fibres/mL. The personal air sampling programme conducted in August 2010 indicated that of the workers likely to have been exposed to fibrous minerals, one sample recorded a maximum exposure of 0.02 fibres/mL of air, and all the others were less than the detection limit of the method (<0.01 fibres/mL) (Table 8-43). While all of the fibres recorded were respirable, most did not have the elemental composition or morphology of asbestos mineral fibres.

8.14.5 Potential Impacts and Management

Based on the knowledge of the geology and the results of analysis and occupational sampling the determined occupational risk during exploration activities was considered low. The sampling and mapping of the ore body completed during exploration also suggests that the frequency and occurrence of fibrous minerals across the orebody is also low.

The handling of ore and waste rock during mining creates conditions that potentially pose a higher level of risk than exploration using diamond drilling. However, Cameco considers the overall risk to occupational health is low. Cameco has prepared a Fibrous Minerals Management Plan which considers risks related to mining and sets out procedures in relation to assessing risk in various work areas, establishing Designated Areas and developing Standard Work Procedures (Appendix D12).

This management plan includes hazard identification, evaluation and risk analysis, fibrous mineral controls and on-going monitoring and reassessment. Exposure to fibrous minerals will be maintained at an acceptable level by implementing the following key control measures and Standard Work Procedures (SWPs):

1. Identify the location of asbestiform minerals in the mining process prior to the commencement of mining.
2. Suppress dust and fibres at source using engineering and procedural dust-control techniques (e.g. dust suppression, enclosure or isolation of dust areas, local exhaust ventilation and water).
3. Immediately quarantine workplaces contaminated with asbestiform minerals until the hazard has been dealt with. Access to all areas containing fibres will be strictly controlled and monitored. Designated Areas will be established around the contamination area.
4. Implement targeted personal occupational air monitoring programme to establish level of exposure risk during normal operation.
5. Implement regular surveillance of the ore mineralogy to identify the presence of fibrous minerals and ensure their disturbance is minimised.
6. Implement regular checking of mined ore by geologists for the presence of fibrous minerals.
7. Provide appropriate information (including written SWPs), instructional training, and supervision to all employees and contractors.
8. Ensure the use of personal protective equipment will be secondary and complementary to engineering controls.
9. Conduct regular audits and air monitoring to confirm the effectiveness of engineering and procedural controls.

The hierarchy of controls states that personal protective equipment (PPE) is the least preferred method of control, but it will be necessary for employees and contractors to wear some PPE in Designated Areas and will be necessary to perform decontamination when leaving Designated Areas.

An Asbestiform Minerals Air Monitoring Programme will be implemented using a Risk Based approach. Similar Exposure Groups (SEGs) will be established and an initial baseline assessment conducted followed by on-going monitoring on a random basis. In the higher risk SEGs there will be more extensive monitoring.

An Action Level of half the Occupational Exposure Limit (currently 0.1 respirable fibres per 1 mL of air as a Time Weighted Average - based 8 hours exposure per day and 5 working days per week. An adjusted OEL for longer shifts will be determined based on the hours of work) will be used for personal monitoring to activate an assessment of the cause of the Action Level being exceeded. This may result in changes to controls.

8.14.6 Commitments

Cameco will implement the Fibrous Materials Management Plan to ensure exposure to fibrous minerals is maintained as low as reasonably practicable and levels comply with the Occupational Exposure Limit.

8.14.7 Outcome

Cameco believes that implementation of the proposed management measures will ensure that Cameco complies with all statutory requirements and standards for fibrous minerals to protect the health of people, including workers, and the environmental values within the Kintyre area.

8.15 Greenhouse Gas Emissions

8.15.1 Objectives

The objective agreed to within the ESD with regards to Greenhouse Gas Emissions is to minimise 'greenhouse gas' emissions to levels as low as practicable on an on-going basis and consider ways to reduce emissions or apply offsets to further reduce cumulative emissions.

8.15.2 Background

Gases such as water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), absorb and re-emit infrared radiation from the sun warming the Earth's atmosphere. This is a natural phenomenon that maintains temperatures suitable to support life and these gases are labelled 'greenhouse gases' (GHG).

However, since the Industrial Revolution in the 18th and 19th centuries the concentration of CO_2 within the Earth's atmosphere has increased significantly. The Fourth Assessment Report, produced by the Intergovernmental Panel on Climate Change (IPCC, 2007), states global warming is 'unequivocal' and 'most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in greenhouse gas concentrations'.

The impact of GHG emissions on the atmosphere is the combined effect of the radiative properties of the gases and the time that it takes for those gases to be removed from the atmosphere by natural processes. In order to compare the relative effects of different gases over a particular time period, Global Warming Potentials (GWP) are used, referenced in units of carbon dioxide equivalents (CO_2-e) where carbon dioxide is used as the base reference and has a GWP of 1. There are six major groups of GHGs, which are listed in Table 8-44.

8.15.3 Relevant Legislation and Policy

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 this treaty and has more powerful and legally binding measures including emission targets for developed nations.

Table 8-44: Greenhouse gas categories and indicative global warming potentials (GWP)

Greenhouse gas	GWP Range
Carbon Dioxide	1
Methane	21
Nitrous oxide	310
Hydrofluorocarbons (HFC)	150 – 11,700
Hydrofluoroethers (HFE)	100 - 500
Perfluorocarbons (PFC)	6,500 – 23,900

Note: Sourced from National Greenhouse Accounts Factors 2011. Calculated over 100 years.

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. This is the primary standard which has been followed in preparing this assessment for the Kintyre Project. GHG emissions are designated as either Scope 1, 2 or 3 emissions.

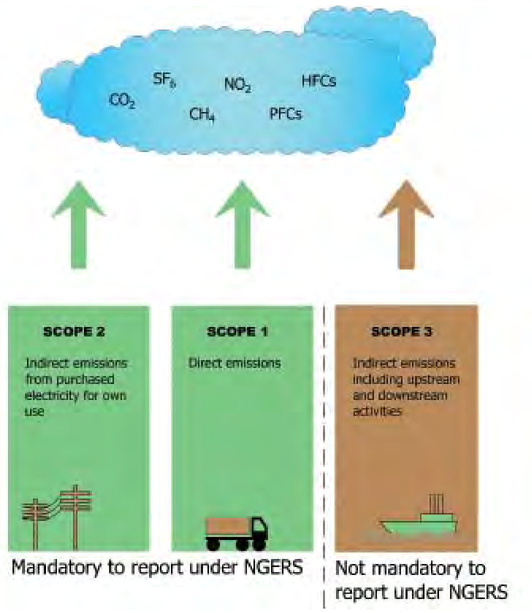
Scope 1 emissions are GHG emissions that are released to the atmosphere as a direct result of an entity's activity or series of activities.

Scope 2 emissions are GHG emissions that are released to the atmosphere as a direct result of activities that generate electricity, heating, cooling or steam that is consumed by an entity but does not form part of the entity.

Scope 3 emissions are not defined by the NGER regulations but refer to all other indirect GHG emissions other than from the consumption of purchased electricity, heat or steam. These may include emissions related to the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity or outsourced activities such as waste disposal.

The Federal *Energy Efficiency Opportunities Act 2006* (EEO Act) was developed to improve the method of identifying and evaluating energy efficiency opportunities. Participation in the EEO programme is mandatory for corporations that use more than 0.5 petajoules (PJ) of energy per year. The EEO Act requires reporting organisations to submit five year plans that set out proposals for assessing their energy usage and to identify, evaluate and report on cost effective energy saving opportunities.

Australian Federal policy for GHG emissions for commercial purposes is based on the Clean Energy Legislative Package (2011). This Federal legislation ties in various GHG abatement and management programmes whilst introducing a price on carbon emissions from commercial and industrial sectors.



Source: WRI and WBCSD (2011).

Figure 8-32: Greenhouse gas emissions scopes and sources

The government of Western Australia has two primary schemes; Greenhouse Strategy (Government of Western Australia, 2004) and Making Decisions for the Future: Climate Change Statement (Government of Western Australia, 2007) which were introduced prior to the release of the national Clean Energy Legislative Package. 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 programme to monitor and report emissions and periodically assess opportunities to further reduce GHG emissions over time.

8.15.4 Proponent Studies and Investigations

A Greenhouse Gas Assessment was undertaken for the Kintyre Uranium Project by Tetra Tech (2012c). This assessment is provided in Appendix Q and provides a summary of the standards used to undertake GHG emission calculations, sets out the boundaries for the Kintyre Project, both

Table 8-45: Diesel consumption emissions

Energy demand	Consumption (units)	Energy content (GJ/kL)	Emission factor (kg CO_2-e/GJ)			GHG emission (t CO_2-e/annum)
			CO_2	CH_4	N_2O	
Electricity generation	12.3 (ML/a)	38.6	69.2	0.1	0.2	33,000
Mobile fleet	15.3 (ML/a)	38.6	69.2	0.01	0.6	41,000

Table 8-46: Explosives consumption emissions

Energy demand	Consumption (units)	Emission factor (t/t)	GHG emission (t CO_2-e/annum)
Explosives	10,000 tpa	0.17[1]	1,700

[1] From DEH AGO (2006).

Table 8-47: Metallurgical process emissions

Carbonate type	Ore throughput (tpa peak)	Carbonate proportion (%)	Amount reacted (%)	GHG emission (t CO2-e/annum)
Dolomite	600,000	11.4	100	31,000

organisational and operational and describes the data collected, calculation methods employed and the source of energy conversion and GHG emission factors used in quantifying GHG emissions.

The GHG emission inventory for the Project was prepared in accordance with Standard ISO 14064-1:2006(E); The Greenhouse Gas Protocol; and the National Greenhouse and Energy Reporting (NGER) (Measurement) Determination 2008.

The NGER Measurement Determination does not provide guidance on the calculation of scope 3 emissions. In calculating scope 3 emissions, the Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard (WRI and WBCSD, 2011); and the National Greenhouse Accounts (NGA) Factors July 2010 (DCCEE, 2010) were used.

In the assessment, Cameco accounted for activities within its organisational boundary (i.e. all GHG emissions over which it has operational control). The construction and operation of the Kintyre Project will rely on a number of contractors. In line with Cameco's existing approach for NGERS reporting, Cameco will account for emissions associated with its major contractors under its own Scope 1 emissions (as defined below), since it has authority to implement OHS and environmental policies in relation to the activity of these contractors at the Kintyre Project area.

Figure 8-32 shows the relationship between the three emission scopes as defined in the GHG Protocol and used in NGERS reporting. Cameco will not have any Scope 2 emissions as electricity will be generated on-site as part of the Project.

8.15.5 Potential Impacts and Management

8.15.5.1 Scope 1 Emissions Estimate

Diesel consumption

Using the diesel demands described in Section 6.7 the emissions from the consumption of diesel have been estimated and the results summarised in Table 8-45.

Explosives

The emissions from the use of explosives have been estimated and the results summarised in Table 8-46.

Metallurgical emissions

The dissolution of carbonates during the acid leaching process will result in emissions of CO_2. These emissions have been estimated in accordance with Section 4.2.3 of the NGER Technical Guidelines, which states that emissions from the reaction of carbonates are:

Table 8-48: Product transport diesel consumption emissions

Energy demand	Consumption (ML/a)	Energy content (GJ/kL)	Emission factor (kg CO_2-e/GJ)	GHG emission (t CO_2-e/annum)
Transport diesel	1.8	38.6	69.81	4,900

Table 8-49: Workforce transport consumption emissions

Energy demand	Number of Pax.	Emission factor (kg CO2-e/Pax/leg)	GHG emission (t CO_2-e/annum)
Aviation Avtur	400	170	1,800

Table 8-50: Land use change-related greenhouse gas emission estimate

Carbon pool	Carbon mass (t C per ha)	Greenhouse gas emission (t CO_2-e per ha)
Soil	26.5	97.3
Woody vegetation	17.6	64.6
Herbaceous vegetation	24.3	89.2
Course woody debris	84.3	309.4
Total	**152.7**	**560.5**

Source: WA Department of Agriculture and Food (2010b).

CO_2-e (t) = Raw carbonate (t) x Carbonate Factor, where the Carbonate Factor is:

0.396 for calcium carbonate

0.522 for magnesium carbonate, and

0.453 for dolomite

The estimation of metallurgical emissions for the Project is provided in Table 8-47.

Land clearing emissions

An extensive study was undertaken by the Government of Western Australia (Department of Agriculture and Food, 2010b) in 2010 into the potential for carbon offset enterprises within the Pilbara and Kimberly. This report quantified the carbon stocks on a range of vegetation associations within the Pilbara and Kimberly region, including spinifex grasslands (identified as the Capricorn land system) common to the area around the proposed Project. A summary of the finding of this report for the relevant land system are presented in Table 8-50.

From an estimated 790 ha of disturbance, the CO_2-e emissions are conservatively estimated to be around 392,350 t assuming all three carbon pools are present within the footprint. Topsoil, incorporating course woody debris, would be stockpiled during operations and subsequently used in rehabilitation activities. Approximately 520 ha (ie. all areas except the open pit and access road) would be rehabilitated following closure of the Project, thereby potentially offsetting approximately 291,460 t of greenhouse gas emissions from clearing.

8.15.5.2 Scope 3 Emissions Estimate

Product transport diesel

Product transport diesel emissions have been estimated based on a peak UOC production rate of 4,400 tpa, a one-way trip distance of 4,600 km, an average diesel consumption of 2.66 km/L and assuming that 100 drums (at 400 kg per drum) can be transported in one trip. The emissions are summarised in Table 8-48.

Workforce transport

Emissions for a fly-in-fly-out workforce were calculated based on information provided by the International Civil Aviation Organisation (ICAO, 2012) and assuming employees travel from Perth to site on a two week-on, two week-off roster (i.e. 26 legs per employee per year). The results of the analysis are summarised in Table 8-49.

Table 8-51: Summary of GHG emissions (per annum)

Source	GHG emission ($t\ CO_2$-e per annum)
Scope 1 Emissions	
Electricity generation (diesel) †	33,000
Mobile fleet (diesel) †	41,000
Explosives †	1,700
Metallurgical emissions †	31,000
Clearing (700 ha)*	
Rehabilitation offsets (520 ha)*	
Scope 2 Emissions†	
	0
Scope 3 Emissions†	
Transport (diesel)	1,000
Workforce transport (Aviation Avtur)	2,000
Total	**118,100**

† Mandatory to report under the NGER Act

* Calculated over life of project (ie. 12 years). Actual annual emissions will vary based on the rate of clearing per year.

Uranium Life Cycle Emissions

Studies of nuclear fuel life cycle greenhouse gas emissions have shown that the generation of nuclear electricity produces about 65 g of CO_2-e per 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.

An extensive analysis of the life cycle greenhouse gas emissions of electricity-generating technologies has been undertaken (Sovacool 2008; Lenzen 2008). These studies indicated the following factors have the greatest influence on life cycle greenhouse gas emissions:

- 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); and
- the source (fossil, renewable or nuclear) of electricity used for the enrichment phase and the overall greenhouse gas intensity of the electricity mix in the countries where fuel cycle activities are undertaken.

A high-level assessment of the life cycle greenhouse gas emissions associated with the proposed development was undertaken using available literature to estimate emissions associated with uranium production, use and disposal.

Approximately 9.05 kg of UOC is required to produce 1 kg of nuclear fuel-grade UO_2 (World Nuclear Association, 2008), sufficient to generate approximately 360,000 kWh of electricity. Given the nuclear life cycle information presented above, the life cycle greenhouse gas emissions for the UOC produced by the proposed Kintyre development would be around 2.6 t of CO_2-e per kilogram of UOC, with the proposed development accounting for 0.3 t of this.

The actual generation of electricity using uranium generates no GHG emissions however this would offset emissions that would otherwise occur should the same amount of electricity be generated using traditional fossil fuel energy mixes.

8.15.5.3 Emission Estimate Summary

Table 8-51 outlines the Scope 1, 2 and 3 emissions for the Project.

In terms for management and reduction of greenhouse gas 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.

Both categories can then be mitigated via various on-site management programmes specifically designed through on-site studies. Such studies for the demand-side management would include:

- 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 mine blasting regimes to reduce the energy required to crush the resultant ore;
- 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.

Similarly supply-side management would include studies such as the use of:

- 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
- biodiesel blends in the mining fleet and for the generation of on-site steam and electricity.

8.15.6 Commitments

Cameco will implement the Greenhouse Gas Management Plan (Appendix D13), minimise vegetation disturbance and maximise energy and fuel efficiency to reduce the carbon footprint of the Project.

8.15.7 Outcome

Cameco believes that greenhouse gas emissions from the Project are as low as reasonably practicable for a Project of this scale and duration.

As the uranium produced by the Project will be used in nuclear power generation, there is a significant potential net benefit if this power generation replaces traditional fossil fuel-based electricity generation.

8.16 Noise

8.16.1 Objectives

The objective agreed to within the ESD with regards to noise and vibration is to protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards.

8.16.2 Relevant Legislation and Policy

The Project is subject to the requirements of the Environmental Protection (Noise) Regulations 1997 (Noise Regulations). As mining and the processing would be a 24 hours per day operation, noise received at neighbouring noise sensitive premises from the mining and processing plant needs to comply with the assigned L_{A10} noise level of 35 dB(A) for the night period.

Additionally, under the Noise Regulations, it is a requirement that noise received at noise sensitive premises be free of annoying characteristics including tonality, modulation and impulsiveness. However, if the annoying characteristic cannot be practically removed and noise received at the premises is deemed to contain an annoying characteristic then an adjustment is made to the 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, however, given the distance 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 noise received at a premises.

Noise levels received at the accommodation village associated with the Project are not required to comply with the Noise Regulations.

The EPA released its Draft Guidance for Assessment of Environmental Factors No. 8 – Environmental Noise in 2007 (EPA, 2007a). This guidance outlines the EPA policy for a range of proposals that may

Table 8-52: Assessment of noise level emissions

Scenario	Assessable Noise Level dB(A)	Applicable Times of Day	Applicable LA10 Assigned Level (dB)
Accommodation village	28	Day time	45
		Day time (Sunday / Public Holiday)	40
		Evening	40
		Night time	35

emit noise and provides specific guidance on the assessment of noise and presentation of information to the EPA.

8.16.3 Proponent Studies and Investigations

Cameco Australia commissioned Herring Storer Acoustics to carry out an environmental acoustic assessment of noise emissions from the Project (HSA, 2011). The objectives of the 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.

Noise impacts from the Project were predicted using the noise modelling computer programme *SoundPlan* which uses the theoretical sound power levels, determined from measured sound pressure levels to calculate the noise level received at a specific location. Data used in the model were ground contour data, weather conditions stipulated in the EPA (2007a) draft guidance and specified sound power levels based on file data of similar operations.

The report by Herring Storer Acoustics is presented as Appendix R of this ERMP.

8.16.4 Existing Environment

The Kintyre Project is located in a remote area on Vacant Crown Land with no commercial land uses in the area (Section 7.3). The Project area lies within a broad valley bounded by rocky flat-topped hills of the Broadhurst Ranges to the East, Watrara Ranges to the south and Throssell Ranges to the west (Section 7.1.1). The proposed Kintyre accommodation village will be separated from by the active mining and processing areas by low hills.

The closest noise sensitive premises to the proposed mining operations are Nifty (80 km), Parnngurr (80 km), Telfer (90 km) and Punmu (113 km).

8.16.5 Potential Impacts and Management

Single point calculations and noise contour calculations were undertaken for the mining operations, to show the level of noise distribution. The only significant results were shown to be at the proposed accommodation village where the calculated noise level was 23 dB(A). Applying a +5 dB(A) adjustment for tonality of the noise, the assessable noise level was predicted to be 28 dB(A). Noise levels at the settlements of Nifty, Parnngurr, Telfer and Punmu were predicted to be 0 dB(A) as a result of the Project and hence no further analysis was carried out for these locations.

At different times of day the applicable assigned levels required to be complied with under the Noise Regulations are presented in Table 8-52. Even though the accommodation village is not required to comply with the assigned noise levels, predicted noise levels at the accommodation village are well below the assigned noise levels, indicating the amenity of personnel at the camp will be protected.

Predicted noise emission contours under worst case noise propagation conditions are shown on Figure 8-33.

8.16.6 Commitments

Cameco will implement the Noise Management Plan to keep noise levels as low as reasonably practicable.

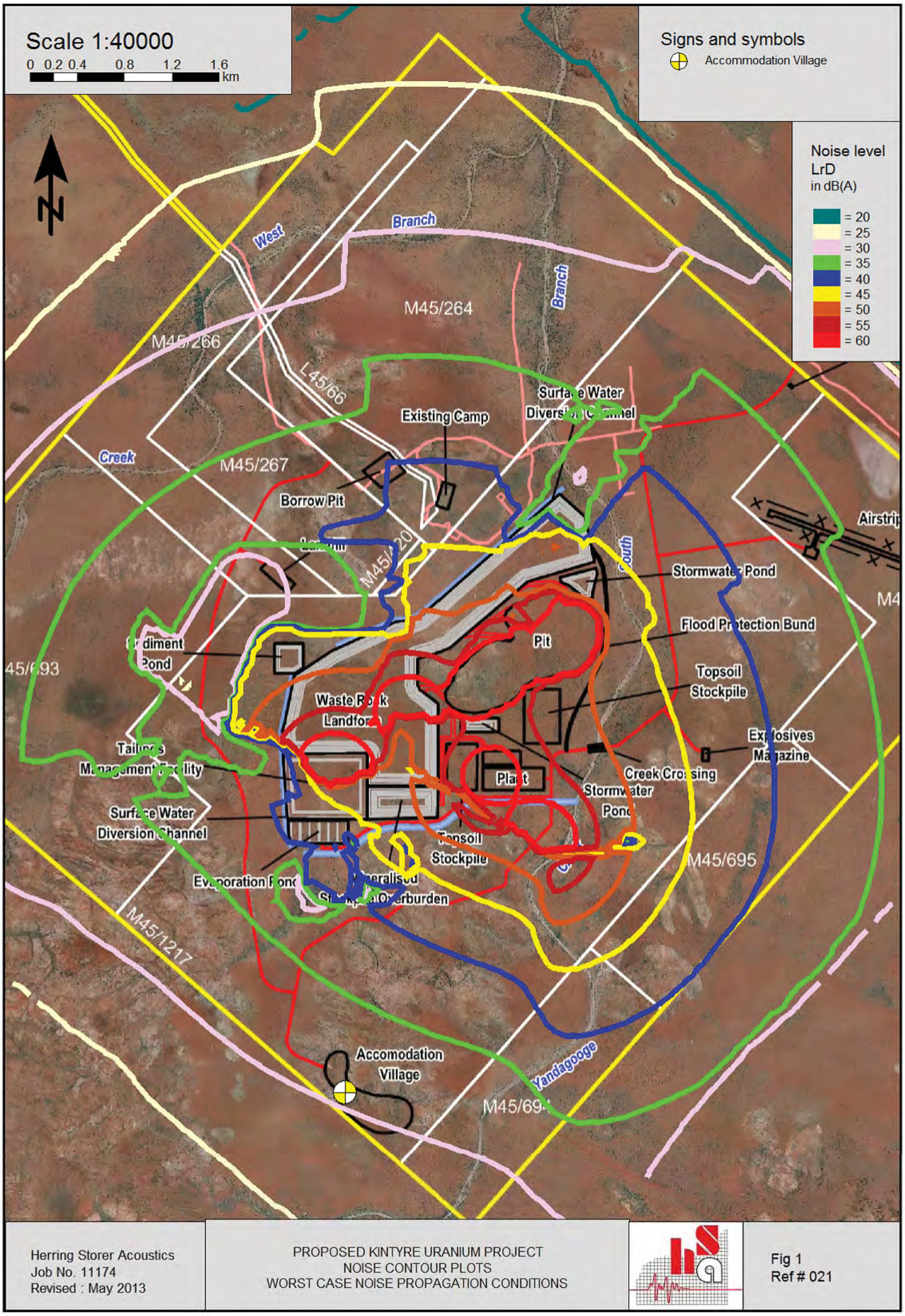


Figure 8-33: Noise contours under worst-case noise propagation

8.16.7 Outcome

Noise levels from the proposed Project area are predicted to be 0 dB(A) at the nearest noise sensitive premises and will therefore comply with the Environmental Protection (Noise) Regulations 1997. Noise levels received at the accommodation village are also predicted to be well below the assigned noise levels even though compliance with the Noise Regulations is not required. The amenity of personnel staying at the accommodation village and residents of the nearest settlements will be protected.