Section 7

Regional Overview

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

7. Regional Overview

7.1 Regional Setting

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

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

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

7.2 Social Setting

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

7.2.1 Mid West

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

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

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

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

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

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

7.2.2 Shire of Wiluna

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

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

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

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

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

7.3 Land Use

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

7.3.1 Pastoralism

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

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

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

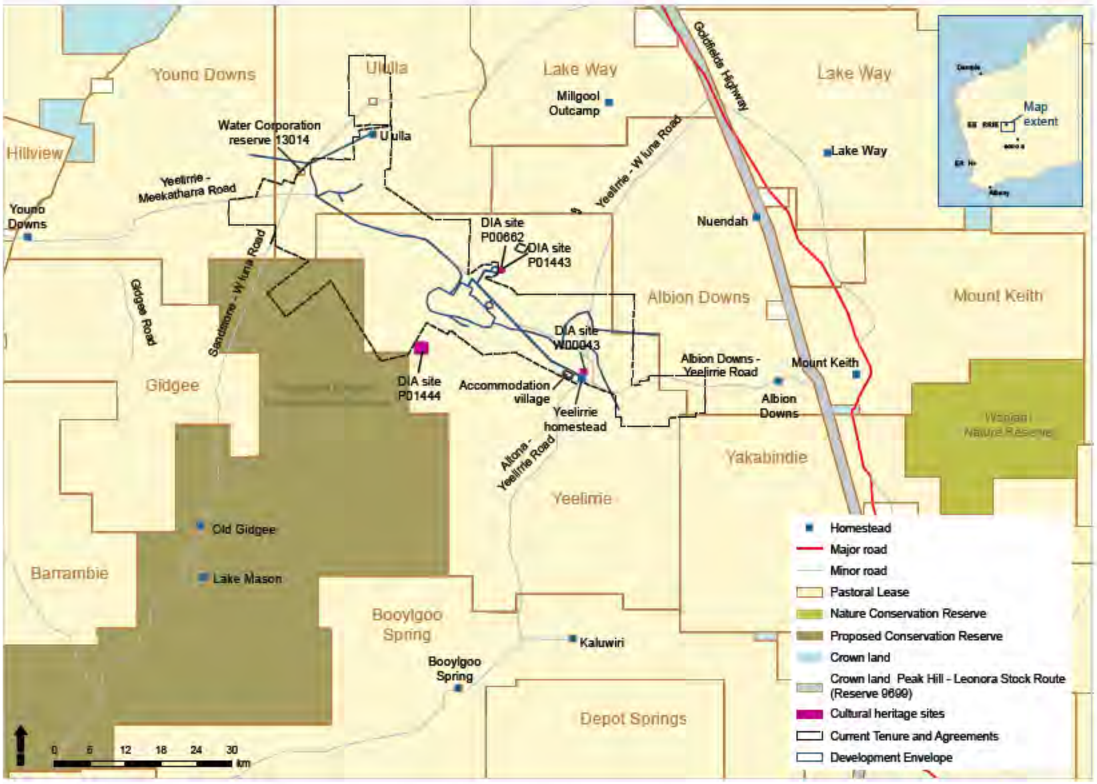


Figure 7-2: Land use near the proposed Yeelirrie development

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

7.3.2 Conservation

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

7.3.3 Traditional use

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

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

7.3.4 Historic mining activities at Yeelirrie

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

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

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

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

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

7.4 Climate

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

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

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

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

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

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

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

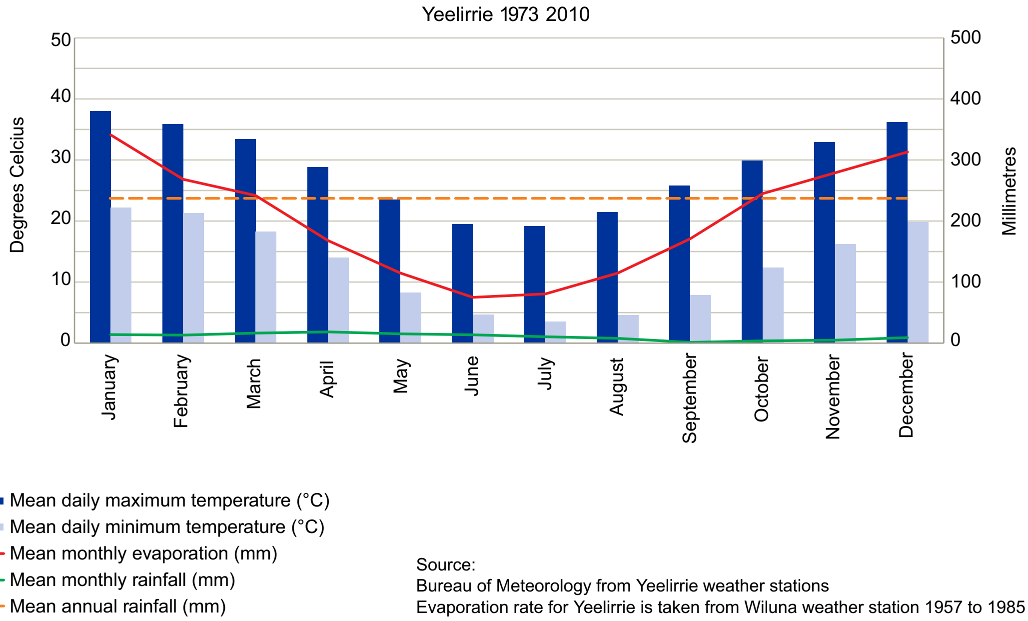
Summer rains are normally of high intensity, caused by localised thunderstorm activity or much larger weather systems associated with cyclones and tropical lows. On average, there are 42 rain days per year at Yeelirrie.

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

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

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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Rainfall (mm) (1928 – 2014)													
Ave. rainfall	29.7	31	31.4	24.4	25.3	22.8	17.4	12.4	4.8	9.7	10.1	20.4	239
Temperature (°C) (1973 – 2014)													
Mean max	37.9	35.9	33.2	29.0	23.5	19.5	19.3	21.7	25.8	30.1	33.0	36.1	28.8
Mean min	22.2	21.3	18.2	13.9	8.3	4.7	3.5	4.7	7.9	12.6	16.3	19.9	12.8
Max	47.9	46.0	44.0	38.5	36.8	29.9	28.6	33.4	37.5	41.5	43.2	45.4	47.9
Min	12.0	10.0	6.0	3.0	-2.8	-5.0	-5.1	-4.8	-2.2	-0.4	1.9	7.6	-5.1
Solar Exposure (MJ/m²) (1990 – 2010)													
Mean daily	27.8	24.5	21.6	17.3	14.3	12.3	13.5	17.4	21.8	25.4	28.0	28.8	21.1
Relative Humidity (%) (1973 – 2010)													
Mean 9am	34	42	43	52	59	68	66	56	44	36	33	32	47
Mean 3pm	21	27	27	34	37	42	41	33	26	20	19	19	29



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

Figure 7-3: Climatic averages

7.4.1 Climate Change

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

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

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

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

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

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

7.5 Geology

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

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

7.5.1 Archaean Stratigraphy

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

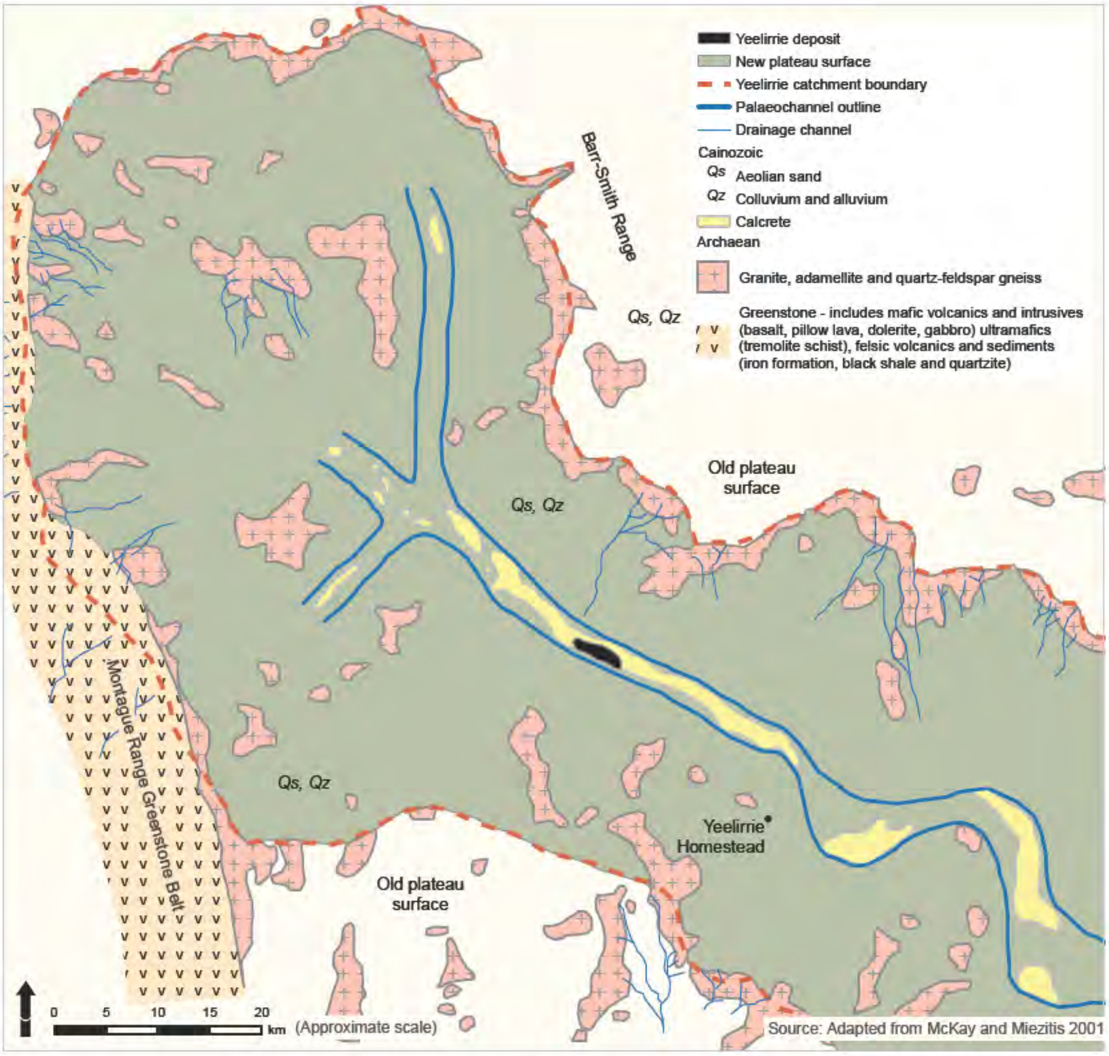


Figure 7-4: Yeelirrie deposit showing north west trending palaeochannel

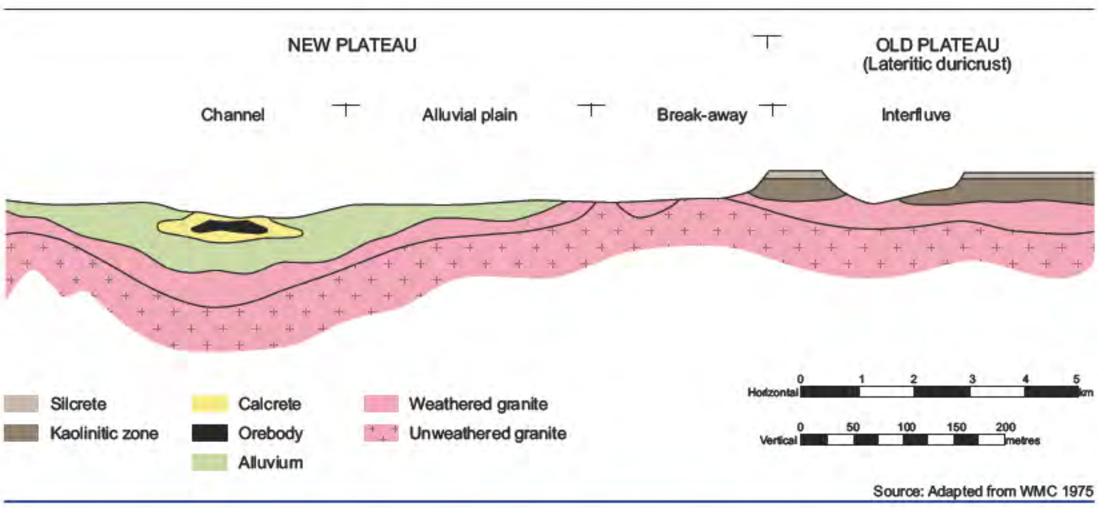


Figure 7-5: Diagrammatic geomorphic profile of the Yeelirrie deposit

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

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

7.5.2 Mesozoic Stratigraphy

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

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

7.5.3 Cenozoic

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

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

7.5.4 Palaeosands

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

7.5.5 Calcrete

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

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

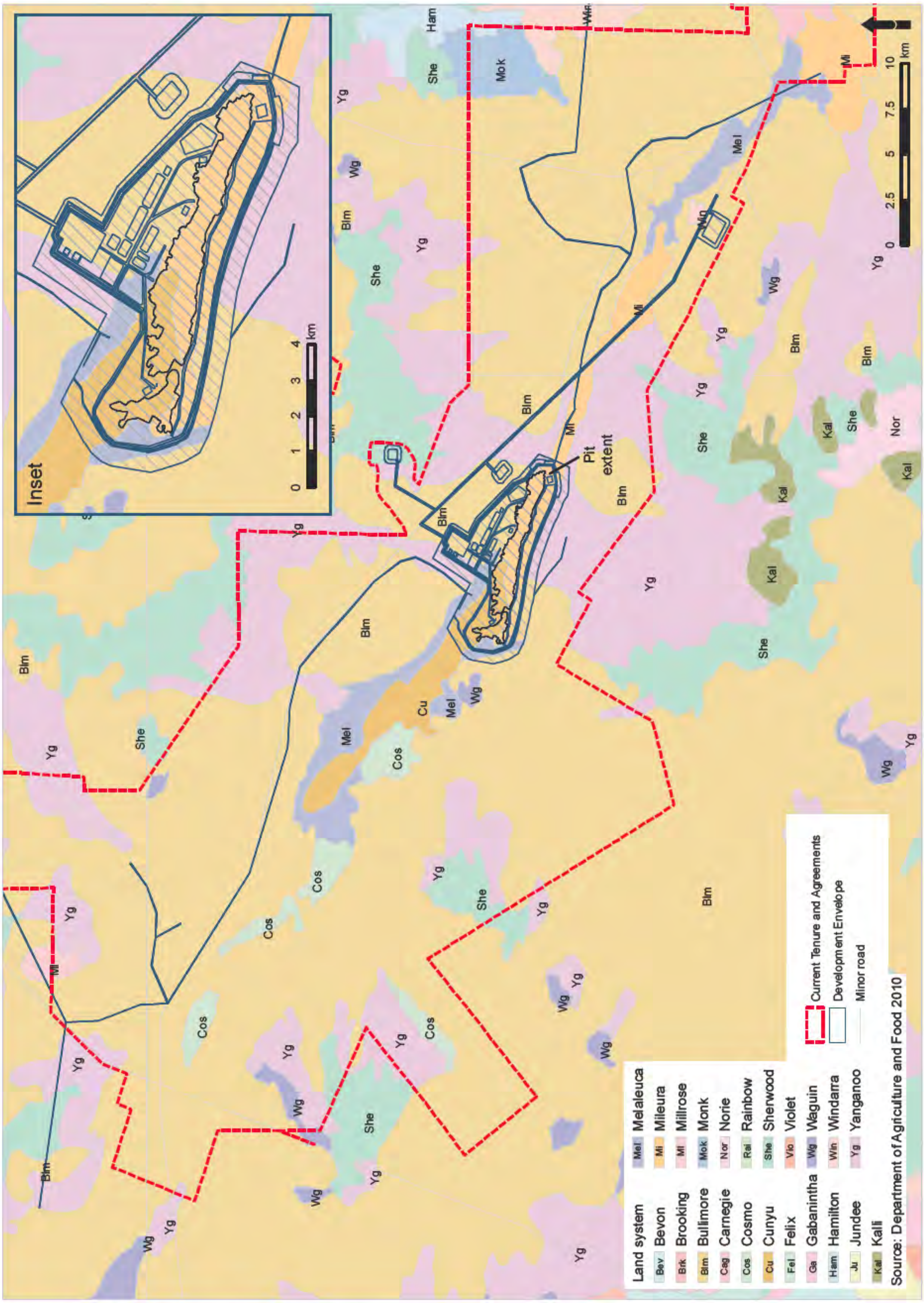


Figure 7-6: Land systems of the Yeelirrie region

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

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

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

7.5.6 Surface Alluvium and Evaporites

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

7.6 Land Systems, Landforms and Soils

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

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

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

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

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

7.7 Natural Hazards

7.7.1 Fire

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

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

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

7.7.2 Drought

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

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

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

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

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

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

7.7.3 Dust Storms

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

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

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

7.7.4 Tropical Cyclones and Storm Events

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

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

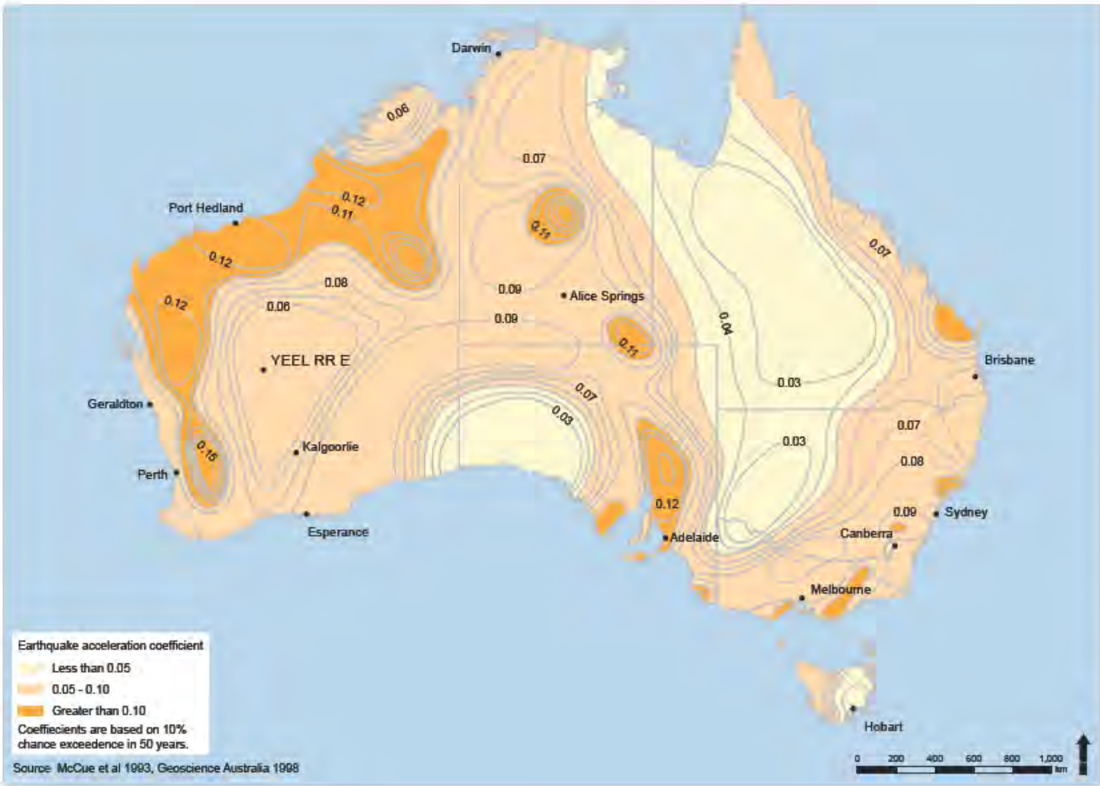


Figure 7-7: Earthquake risk

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

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

7.7.5 Seismic Activity

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

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

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

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