9.10 Terrestrial Environmental Quality

9.10.1 EPA Objective

The EPA's objective with regards to terrestrial environmental quality is:

- To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.

9.10.2 Relevant Legislation and Policy

The following documents are relevant in setting the framework for the identification and assessment of potential impacts to terrestrial environmental quality from the Project:

- Department of Industry Tourism and Resources (2007) Managing Acid and Metalliferous Drainage, Leading Practice Sustainable Development Program for the Mining Industry, Canberra, Australian Capital Territory.
- Department of Industry Tourism and Resources (2007) Guideline for Tailings Management, Leading Practice Sustainable Development Program for the Mining Industry, Canberra, Australian Capital Territory.

9.10.3 Studies and Investigations

The ESD outlines a series of studies and investigations required to be undertaken by Cameco to address Terrestrial Environmental Quality. These studies are also relevant to other factors as outlined in Table 9-74.

Table 9-74: Terrestrial environmental quality studies

ESD Requirement	Study	Also relevant to:
Characterisation of wastes, including intermediate wastes, tailings and decontamination waste, according to contaminant and leachable concentrations	Conceptual Mine Closure Plan for the Yeelirrie Uranium Project (Cameco 2015a; Appendix O1)	Rehabilitation and Decommissioning (Section 9.12)
	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit (Cameco 2015d; Appendix I1). Yeelirrie Tailings Storage Facility Design and Management (Cameco 2015e; Appendix D).	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)
Physical and geochemical characterisation of process residues, waste rock and overburden including an assessment of 'dustiness' of bulk materials to the relevant standards in consultation with DER	Soils and Soil Landscapes of the Study Area (Blandford & Associates 2011; Appendix M1). Landform Evolution Modelling (SWC 2015a; Appendix O2)	Rehabilitation and Decommissioning (Section 9.12)
	Atriplex sp. Yeelirrie Station Investigation (SWC, 2015b; Appendix E5)	Flora and vegetation (Section 9.1)

ESD Requirement	Study	Also relevant to:
	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Geochemical Assessment of Tailings and Mine Waste (URS, 2011) Assessment of Tailings and Mine Waste Source Terms (SRK, 2011)	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)
	Air quality assessment of the Yeelirrie Uranium Project (Katestone, 2014a; Appendix L1)	Air Quality (Section 9.8)
Contaminant pathways modelled to assess potential leaching of contaminants from waste dumps/stockpiles and risks of acid metalliferous and neutral drainage.	Development of Tailings and Mine Waste Source Terms for the Proposed Yeelirrie Mine (Cameco 2015c; Appendix I2). Numerical Groundwater Flow and Solute Transport Model of the Yeelirrie Uranium Deposit (Cameco 2015d; Appendix I1).	Hydrological Processes and Inland Water Quality (Groundwater) (Section 9.5)

Collectively, these studies provide the background to characterise waste rock, overburden, soils and process residues to understand potential pollution risk, and plan rehabilitation and closure of the Project.

9.10.4 Existing Environment

9.10.4.1 Soil Characteristics

D. C. Blandford & Associates Pty Ltd was engaged to conduct a soil and soil landscapes survey as part of BHP Billiton's studies for the original project (Blandford D.C. & Associates 2011; Appendix M1). The objectives of this survey were:

- to identify the major soil types and associated soil landscapes and to define soil and soil profile characteristics; and
- to identify the soil profile characteristics associated with individual vegetation communities to develop an understanding of the soil-landscape-vegetation systems present.

The soil resources of the Study Area were defined using a soil landscape approach, where the major landscape units were identified and the characteristics of soils from representative positions within each landscape were defined. Within the Study Area, three soil landscapes were defined:

- the Colluvial/Alluvial Sand Plain System;
- the Playa System; and
- the Calcrete System.

In addition the Granite Breakaway System was identified as occurring outside of the Study Area.

Colluvial / Alluvial Sand Plain System

The Colluvial / Alluvial Sand Plain System is an extensive soil landscape that extends from the central valley to the Granite Breakaway System. Soil gradients range from 0.3 – 0.4% on the lower surface of the plain to 3.5% on the northern valley side slope and 5% on the southern valley side slope. The system is underlain by weathering granitoids, with the saprolite zone ranging in thickness from tens of centimetres to zero. The surface of the plain is intruded by granitoid bedrock at isolated locations where it forms very low relief 'granite' rises. Throughout this soil landscape there is variability in soil profile characteristics.

The 'sands' of the sand plain, tend to contain a range of grain sizes from fine sand to gravel (up to 50 mm in size). These 'sands' demonstrate varying degrees of induration, which indicates high soil moisture retention at varying depths below the surface.

Ferricrete, occurs throughout the sand plain soils with the thickness of ferricrete horizons ranging from 0.25 m to 1.0 m. The ferricrete present ranges from a true ferricrete gravel with well sorted and well-rounded gravels to 35 mm in diameter, to ferricrete that is in the form of secondary cementation. Elsewhere, the ferricrete is typified by massive, recemented forms (Blandford D.C. & Associates 2011).

Playa System

The Playa System is a key soil landscape within the Study Area. The Playa System is a transition zone from the Sand Plain System to the Calcrete System and a major conduit for surface runoff along the valley.

This is a highly variable soil landscape, which reflects the complex interaction between the sand plain and central valley drainage with peripheral calcrete influence.

The Playa System comprises the following units:

- Depressions: Low relief shallow structures (< 0.5 m deep) varying in diameter from tens of metres to hundreds of metres;
- Flats with scalds: Areas devoid of vegetation where wind erosion is the major degradation factor. These areas tend to pond water temporarily; and
- Flats with sink holes.

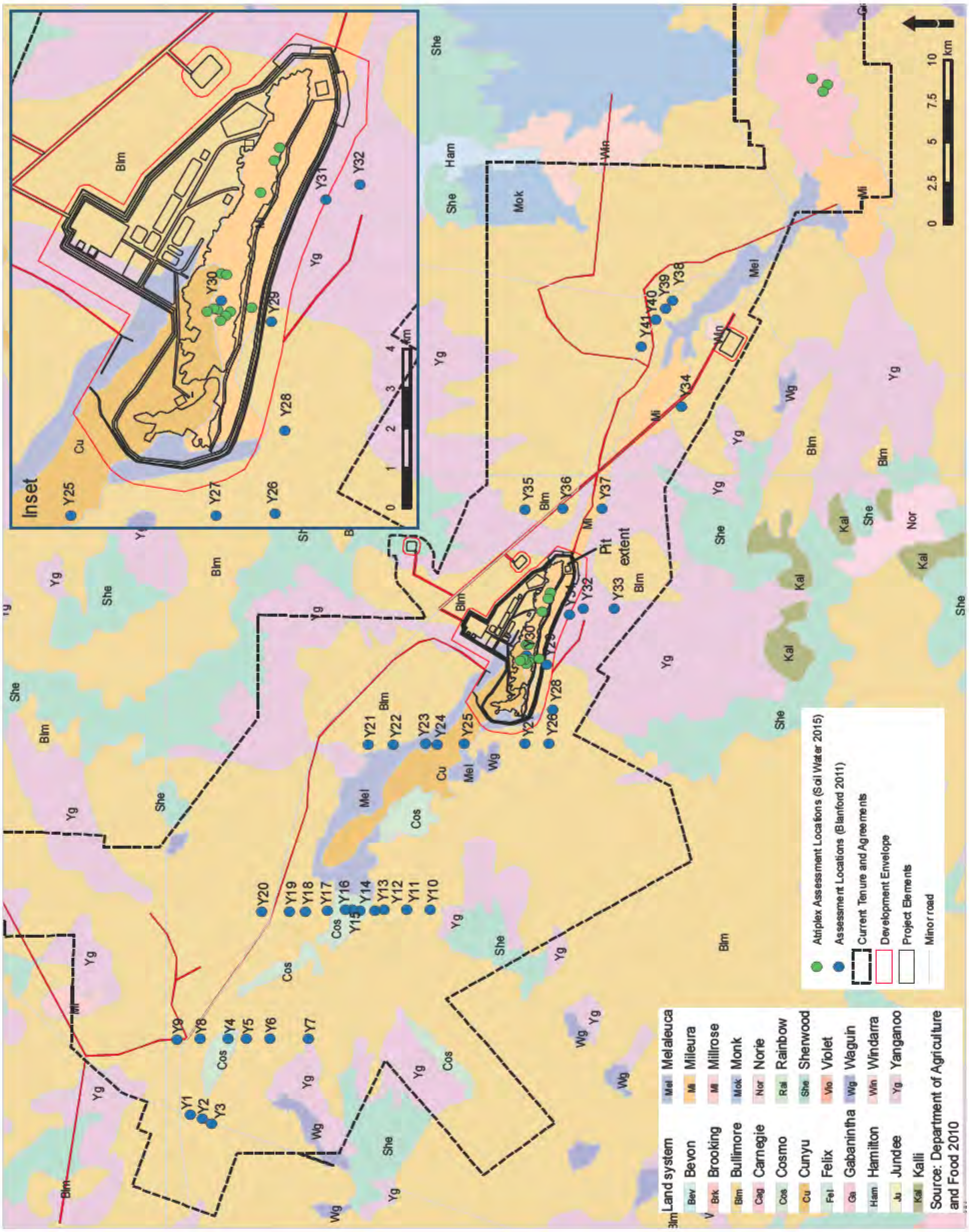
Within the Playa System the depressions are not continually interconnected and there are no obvious preferred surface drainage routes. At the valley scale, surface discharge patterns pass both sides of the Calcrete System, which is topographically higher relative to the Playa System.

The soils of this system often show a complex stratigraphy due to a highly varied geomorphic pre-history. Some profiles contain silty clays at depth below the surface, which is usually a platy sandy loam. Gypsum is also present is some profiles as either crystal growths or as a massive, structureless material (Blandford D.C. & Associates 2011).

Calcrete System

This soil landscape, which occupies the central zone of the valley floor, generally comprises outcropping calcrete in its various forms and is quite variable. The Calcrete System comprises four units:

- Calcrete rises: discrete areas of outcropping, weathered calcrete. The weathered material is generally present as a discontinuous surface lag gravel. The calcrete rises are characterised by a thin veneer of residual soil overlying massive to platy calcrete;
- Depressions: In some areas, solution of the underlying calcretes has resulted in collapse of the surface, forming small-scale pseudo-karstic topography, while in other areas, low relief depressions are present. These tend not to be filled with sediment but are more typically small scale hollows in the surface, probably the result of differential collapse of underlying solution cavities;
- Flats: The surface of the calcrete may contain 'flats' where sediment is retained on the structure and where it generally forms a thin veneer of sandy loams to loam, fine sandy; and
- Clay flats: distinctive clay flats are present where the clays tend to be high ranking, self-mulching, and display seasonal cracking (Blandford D.C. & Associates 2011).



Source: Department of Agriculture and Food 2010

Figure 9-64: Soil landscapes and assessment locations

Aggregate Stability and Dispersion

Dispersive soils are present within the study area. However, they are generally associated with the Playa System, and with scald areas at the interface of the Sand Plain and Playa Systems. When dispersion occurs at or near the surface, and the dispersed clays dry in situ, they set hard. This hard, fine-grained layer results in differential permeability. Vertical permeability is greatly reduced resulting in increased horizontal permeability, or water ponding at the depth of the dispersed clay layer. If the hard clay layer occurs at the surface, accelerated runoff occurs due to decreased infiltration, and evaporation rates will increase, resulting in a reduction of effective rainfall (Blandford D.C. & Associates 2011).

Surface Infiltration Rates

Surface infiltration rates were measured at two locations using a constant head infiltrometer. The range of surface infiltration rates from zero to 756 mm/h which is considered within the normal range for these soil landscapes (Blandford D.C. & Associates 2011).

Soil Chemistry

Soil chemistry was investigated at nine sites to assess the trend in soil chemical status. The results are presented in Table 9-75.

Table 9-75: Summary of soil chemistry in the Study Area

Site ID	Depth (m)	pH	EC (mS/m)	TSS (% Salt)	Org C (%)	Soil Landscape
1	0.5	4.2	2.0	0.006	0.1	Sand Plain
2	0.95	4.7	1.0	0.003	0.08	Sand Plain
12	0.6	5.1	<1	<0.001	0.09	Sand Plain
13	0.8 – 1.5	5.3	11.0	0.035	0.08	Sand Plain
15	0.0 – 0.3	8.0	11.0	0.035	0.54	Calcrete
23	1.0	8.4	370	1.184	0.09	Playa
30	0.0 – 0.2	8.0	270	0.864	0.23	Calcrete
36	1.0	6.4	11.0	0.035	0.11	Sand Plain
41	0.3 – 0.4	5.7	2.0	0.006	0.08	Sand Plain

Soil Characteristics of *Atriplex* sp. Yeelirrie Station.

Soilwater Consultants were engaged in 2015 to conduct a soil investigation aimed at characterising the ecophysiological requirements of *Atriplex* sp. Yeelirrie Station. The study involved the excavation of 15 soil investigation trenches (Figure 9-64), with 12 of those trenches occurring within the proposed pit development. The study followed a similar field methodology to the survey conducted by Blandford and Associates (2011).

A typical soil profile encountered consisted of calcareous loam of variable thickness over transitional calcrete (Plate 9-5). The calcareous loam is rarely evident on the surface and is instead covered with either a variable thickness of clay (approximately 0.4 m) or a thin cover of loamy sand depending on the position within the landscape. These soils are indicative of the overburden (waste rock/soil) material that will be generated by the mining of the Yeelirrie ore.

Four distinct soil units occur within the calcrete system consisting of:

- Loamy Sand - This material occurs on the surface directly above the carbonated loam in areas outside of the clay flats and calcrete outcrops. It generally consists of a loosely packed, friable silty loam to loamy sand, with common gypsum crystals and rounded quartz grains. The material

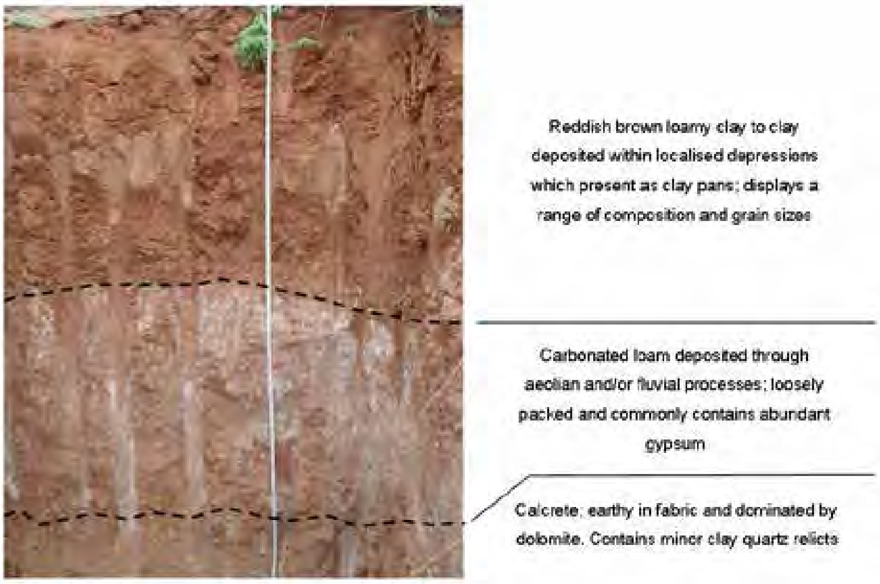


Plate 9-5: Typical soil profile encountered within the calcrete soil-landscape system

has an alkaline pH between 8 and 9 and low salinity < 100 mS/m. It generally exists in an unsaturated condition and is freely draining;

- Loamy Clay - This material occurs on the surface directly above the carbonated loam in the clay flats and depressions of the calcrete system. It consists of a cracking clay to clay loam, with high plasticity. The cation exchange capacity (CEC) indicates that the clay mineralogy is mostly likely to be made up a mixture of illite and chlorite, with minor kaolinite and smectite, and have a moderate to good structural resilience (i.e. shrink/swell potential). The material generally displays a slightly alkaline pH around 8 and highly variable salinity from < 100 to > 2000 mS/m. Significant rainfall had occurred prior to the time of investigation and the material displayed a dry, fluffy and sometimes crusty upper layer of aggregates approximately 5 to 10 cm thick, below which the clays retained more moisture and had not aggregated;
- Carbonated loam - This alluvial material underlies the loamy sand and clays and is aeolian and/or fluvial in nature. It consists of a very to moderately friable brownish white to pale brown loam with occasional pisolitic nodules and abundant carbonate nodules. It consistently displays an alkaline pH between 8 and 10 and generally has a moderate to high salinity, ranging from approximately 200 to 800 mS/m; and
- Calcrete - The upper calcrete material is earthy and composed of dolomite, calcite and smectite, with common amorphous black silica. It varies in hardness from soft to hard where porcelaneous silica alteration has occurred, but is dominantly medium to soft in hardness with < 10 % clay quartz present. Where the material has outcropped weathering has removed the finer fractions, leaving behind hardened and indurated gravel to sand size fractions.

A summary of the key physical characteristics measured from the various soil units identified within the calcrete landform system is provided in Table 9-76 whilst the key chemical characteristics are summarised in Table 9-77. The results highlight the abrupt changes in texture and structure that are present within the investigated soil profile, with large changes in sand and clay fractions between the different horizons. The majority of material contain low larger particle size or gravel fractions, with the exception of the blocky and sometimes vuggy transitional calcrete materials. Each of the three ‘soil’ materials was tested for water retention capacity using five point pressure plate analysis. The summarised results below show that the plant available storage capacity of the three materials tested are all substantial, with little difference between the carbonated loam and the loamy clay materials despite their different textural compositions.

Table 9-76: Summary of measured physical parameters within the calcrete landform system

Soil unit	Particle size distribution (< 2mm)			Gravel %(>2mm)	Plant Available Water (v/v)
	Sand %	Silt %	Clay %		
Loamy Sand	84.6	15.2	0.2	<1	12.1
Loamy Clay	53.0	11.2	35.8	<1	20.1
Carbonated Loam	74.2	9.5	16.3	5-10	23.1
Calcrete	68.5	10.1	21.4	50-90	na

Table 9-77: Summary of measured chemical parameters within the calcrete landform system

Soil-landscape	pH	EC mS/m	Exchangeable Cation meq/100g				CEC meq/100g	ESP (%)
			Ca	K	Mg	Na		
Loamy Sand	8.1	10-80	10	1.3	3.1	0.1	14	0.1
Loamy Clay	8.8	100-2000	14.7	3.3	7.6	4.9	30.6	0-50
Carbonated Loam	8.3	200-800	11.2	2.9	5.5	4.8	24.4	4-30

The measured pH of the various soil units was alkaline, reflecting the dominance of carbonate ions in the finer fractions. The salinity was widely variable and closely linked to landform position, with slightly elevated positions in the landscape generally recording significantly lower levels, particularly in the upper 40 – 50 cm of the profile. This suggests that these areas are very rarely inundated after rainfall events and so the surface salts have been leached from the profile. The exchangeable sodium percentage (ESP) is an indicator of a given materials tendency to disperse. In simple terms, dispersion is the movement of clay from an aggregated state to one where the clays move freely into suspension. In materials where the sodium ion dominates the cation exchange complex to such an extent that the ESP is larger than 6, they are considered to be vulnerable to dispersion. Salinity will act to limit dispersion (through the inclusion of Na as an electrolyte) to some degree by promoting flocculation of suspended soil particles. The wide ranges of ESP and salinity recorded throughout the various samples tested indicates that some portions of the Clay and Carbonated Loam materials are likely to contain dispersive properties.

9.10.4.2 Ore, Mineralised Waste and Tailings Characteristics

SRK Consulting was commissioned by BHP Billiton to complete a geochemical assessment of ore and mine waste material. The scope of assessment included detailed chemical characterisation of selected Yeelirrie materials (ore, mineralised waste and tailings), and the completion of a series of bottle roll contact and column tests including assessment of neutral drainage conditions procedures.

A total of 199 Samples were collected from a range of material types from the Yeelirrie site taken at various depths (max depth 30 m) from drill cuttings for drill holes located within and downstream of the proposed mining area. In addition to these 199 samples, two samples of palaeochannel sand from below the proposed pit (depths between 55 and 65 m).

Forty one samples of tailings (comprising both tailings and underlying sediments) were taken from the historic WMC tailings storage facility located at the Kalgoorlie Research Plant, where WMC undertook testing on tailings produced from mining and processing the Yeelirrie ore in the mid-1960s and early 1990s.

Twenty of the 199 samples from the proposed mining area along with all palaeochannel and tailings facility samples underwent detailed geochemical characterisation as follows:

- Bottle roll testing: Tailings and waste samples were contacted with solution (either de-ionised water or 'barren liquor' solution) for 72 hours. The tests were undertaken at a liquid- solid ratio of 3:1;

- Column testing: Four column pairs were set up to operate in series. The first column in each pair is open to air and operated such that the material drains down and becomes unsaturated between flushing events. The second column is not open to air and is maintained saturated with solution at all times. Effluent from the first column is used as inflow for the second column in that pair; and
- Aging tests (tailings): Fresh tailings slurries were placed in open and sealed flasks, to represent atmospheric as well as anoxic conditions respectively. After 1, 2, 4 and 8 months of contact time pore water from selected flasks was recovered for analysis.

In addition the following static geochemical test work was conducted:

- metal content via Inductively Coupled Plasma (ICP) analysis;
- mineralogical determination via X-ray Diffraction (XRD) analysis;
- mineral surface characterisation using the Brunauer–Emmett–Teller (BET) method for surface area, and Cation Exchange Capacity (CEC) testing;
- radiological investigation to determine key radionuclide concentrations.

The bulk chemistry of the ore and waste rock samples tested shows that U_3O_8 contents were significantly elevated in comparison with mean crustal abundances published by Bowen (1979).

All of the waste material samples tested by SRK had low overall sulphur contents ranging from 0.01 to 0.1 % (averaging < 0.05%) indicating the waste materials tested had a low potential to produce acid and cause acid mine drainage (AMD). These results were compared to the chemical assay database which has been generated from the drilling conducted over the Yeelirrie deposit. This comparison has shown that the samples selected for testing can be considered representative of each lithological unit.

Leach testings (Bottle leach, column and tailings age testing) was conducted on mine waste and tailings materials to simulate the onsite neutral drainage conditions. The results of leach testing on materials including various grades of ore showed that a number of readily soluble phases were released upon contact with water, with leachate dominated by salts such as halite and various sulphates. Contaminants which were released at appreciable concentrations included boron, barium, molybdenum, strontium, thallium, uranium, vanadium and zinc. Analysis of radionuclides showed that radium-226 could also be released during flushing of samples.

The testing of tailings material via leach testing showed that initial pore water quality within the tailings would be dominated by barren process water which is alkaline and contains elevated concentrations of dissolved uranium and vanadium.

These results were used to develop base-case and upper-bound (or worst case) source terms to be used in modelling of solute transport for the temporary stockpile areas and the in-pit TSFs (SRK, 2011, Cameco, 2015c) Development of the source terms for the stockpiled material contained two basic assumptions; the base case assumes that placed surfaces may leach solutes for up to one year, whereas the upper bound case assumes that all exposed surfaces remain active at all times.

The source terms for the tailings material were developed within the context of the conditions expected to develop after the cessation of operations. It was assumed that pore water release from the tailings, and therefore interaction with groundwater, could occur only after the tailings cells have been decommissioned. The tailings source terms were developed using 90th percentiles (i.e. representative of 90% of the data) from geochemical data and modelling to ensure conservative values.

Full details of the tests conducted and results are provided in Appendix I2, M2 and M3.

9.10.5 Potential Impacts and Management

Activities or aspects of the Project which have the potential to impact on terrestrial environmental quality include:

- managing topsoils to minimise erosion, sedimentation and for successful rehabilitation;
- haulage and process activities (including dust emissions) capable of spreading mineralised materials outside of mining areas;
- surface water runoff and seepage from stockpiled materials;
- seepage of pore water from the in-pit TSF's and stockpiled materials;
- flooding and / or overtopping of water storage facilities; and
- accidental spills of controlled materials.

9.10.5.1 Topsoil impacts and management

The physical and geochemical analysis of soil profiles across the deposit area provides the information to develop a detailed plan for topsoil and waste rock management for rehabilitation purposes.

The physical and chemical attributes of the loamy sand and loamy clay discussed above suggest these soil types would be suitable for use in rehabilitation and mine closure. The soils are alkaline with low to moderate salinity and the loamy clay exhibits good structure and water holding capability. The dispersive property of some of the clays and the carbonated loam make them less suitable for the final topsoil or surficial cover, so careful selection of soils will be required for rehabilitation purposes.

Topsoils will be mapped and preferentially stockpiled for use in rehabilitation and revegetation. Topsoil will be stored in low stockpiles to retain seed viability and will be protected from erosion. Topsoil will not be handled when wet to avoid damaging soil structure. Soils that are not suitable for use in rehabilitation or construction (e.g. dispersive, saline soils) will be buried within the final landforms.

Prior to commencement of construction, Cameco will have determined the availability and volumes of key materials required for rehabilitation. The results of these investigations will be presented in a revised version of the Mine Closure Plan (Appendix D1) to be submitted prior to the commencement of construction. Further detail on Mine Closure and Rehabilitation is provided in Section 9.12.

9.10.5.2 Haulage and processing impacts and management

If not appropriately managed, mineralised material may be spread out of the mine area on vehicles or machinery used in mining and processing, or through dust emissions from the mine area.

To facilitate the control of people, vehicles and contamination, the operations area will be divided by fencing into 'clean' and 'potentially-contaminated' areas. Access to the potentially-contaminated area will be via a security gate.

Egress from the potentially contaminated area by vehicle will be via a wheel-wash to ensure that contaminated material will not be transported off-site by vehicles. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation (for example mine vehicles) will be kept within the contaminated area (Section 9.6.6).

Dustiness of Bulk Materials

Cameco has reviewed the European Standards associated with EN15051 for the measurement of the dustiness of bulk materials and considers that it is not applicable as the two test methods (rotating drum and continuous drop) do not apply to the mechanical handling of ore and waste at Yeelirrie (Section 9.8.3).

Dust emissions from the Project were estimated based on representative emission factors from the National Pollutant Inventory (NPI) mining handbook, USEPA AP-42 documents and source characteristics and operational activity data provided by Cameco (refer to Katestone 2014a, Appendix L1).

Incremental dust deposition rates outside the mining lease area boundary due to mine operations ranged from 0.0004 g/m^2/month at Palm Springs to 0.013 g/m^2/month at Yeelirrie Pool, well below the air quality criterion of 2 g/m^2/month (Section 9.8.5).

The following measures will be implemented to manage dust sources from the Project:

- water sprays during clearing and mining activities;
- covered conveyors, transfer points and dust extraction on crushing circuits;
- wet processing plant;
- retaining tailings in a damp state until closure; and
- water sprays and dust suppressants on haul roads and stockpiles.

9.10.5.3 Ore and waste stockpile impacts and management

Runoff and seepage from ore and waste stockpile areas could affect the quality of surface and groundwater in the vicinity. However, the potential impacts of this are considered low due to the following:

- A surface water diversion bund will retain surface water runoff generated from within the proposed mine site, including stockpile areas, with water flowing to stormwater ponds for use in the processing plant (Section 9.4.5).
- During mining, the footprint of the stockpiles will be within the groundwater production drawdown area and any solute would remain within the affected footprint (Section 9.5.5); and
- Solute releases from stockpiles occur as a result of the first rainfall event related flushes and reduce thereafter.

In the event that Cameco needs to release stormwater to maintain a safe operating environment following an extreme rainfall event, the released water would need to be of sufficient quality to minimise the accumulation of solutes in groundwater along the valley floor. Surface water modelling indicates that stormwater releases during an event larger than 1:100 year ARI would be significantly diluted by local flood waters, and recharge-related loadings to groundwater outside this floodplain would be minimal. Receding floodwaters carrying any mine-sourced loadings would be concentrated along the valley floor where the baseline groundwater is not considered suitable for stock water. However, the proposed design of the flood retention bund is expected to be sufficient to retain a 1 in 1,000 year ARI event (Section 9.4.5).

A solute transport model has been developed to examine the movement of solutes from surface into groundwater. Stockpile source terms were assessed for ore and mine waste materials and were assessed for operations only, as all ore and waste materials will be either processed or disposed of within the pit at the end of the mine life. The main control on solute loading is the exposed surface area of each stockpile, which changes over time. To ensure conservative modelling, the solute loading calculations assumed that the footprint of each planned stockpile would remain constant at its maximum planned size throughout the lifetime of that particular stockpile.

The solute loading calculations have shown that the potential release of each constituent by the stockpiled material is finite as once the solute is released it is not regenerated. Experimental results of stockpile material aging indicated that solute release occurs quickly and at a rate that all available solutes that can be flushed from exposed surfaces within a year. A full description of the method of solute load estimation and the results of modelling are provided. (Appendix M2).

The ROM pad and other stockpile areas would be compacted to control seepage and would be graded so that runoff and seepage would be directed to a storm water runoff pond. Water captured in the ponds would be used to supplement the water supply for the processing plant (Section 9.4.5).

As all stockpiles will be removed for milling or placed back into the open pit at the conclusion of milling there will be no post mining impact to ground and surface water following mine closure. The pit will be backfilled and an engineered cover constructed over the in-pit TSF. Landform-evolution modelling of the final landform has shown that under the base case (constant erosion rate over 10,000 years) and the time varying scenario (erodability decreasing after 100 years), the majority of sediment loss is predicted to occur on the valley slopes and net deposition occurring in many areas of the valley floor near the rehabilitated landform.

Under these scenarios, there are predicted to be some rill erosion gullies that form over the in-pit TSF area after a period of 10,000 years. These features are predicted to be isolated and restricted to the outer edges of the cover system and will not have a negative impact on either the stability of the TSF cover system or sediment transport downstream (Section 9.12; Appendix O2).

9.10.5.4 Seepage from in-pit TSF

Based on the geochemical analyses undertaken, chloride, uranium, vanadium, arsenic, and molybdenum were selected for solute transport modelling. These contaminants of concern (CoCs) were selected based on the geochemistry of the carnotite deposit and because they exist as negatively charged species (arsenic and molybdenum). Chloride was included because it is a non-retarding conservative tracer.

The results of the modelling are discussed in Section 9.5.5 and in the modelling report in Appendix I1. The in-pit TSF long term solute transport modelling predicts:

- Simulated plume fronts (at a concentration of 0.01 mg/L) for uranium, vanadium, arsenic and molybdenum may travel several hundred metres longitudinally along the valley, but typically not beyond the eastern boundary of the pit.
- The uranium, vanadium, arsenic and molybdenum plume fronts (at 0.01 mg/L) may extend up to 600 m north and 200 m south of the in-pit TSF.
- Vertically the plume fronts (at 0.01 mg/L) may reach the palaeochannel underlying the TSF.
- The chloride (conservative constituent) plume (at 0.01 mg/L) could travel as far as 50 km from the in-pit TSF. However, beyond 1,000 m from the TSF, the concentration increases negligibly compared with baseline concentrations (Cameco 2015d).

9.10.5.5 Flooding and overtopping impacts and management

The potential for flooding and / or overtopping of water storage facilities and the proposed management measures is discussed in Section 9.4.5 and in detail in the surface water study (Appendix H1). As outlined above, a surface water diversion bund designed to 1:1,000 ARI will be constructed to:

- prevent external catchment surface water from draining into the proposed Project mine site area, and
- prevent the surface water runoff that collects interior of the surface water diversion bund from discharging uncontrolled outside the bund into the natural environment.

Stormwater runoff will be captured in a series of stormwater ponds located within the minesite. These ponds will be designed to capture runoff from a 20 year ARI event. If however the rainfall exceeds design capacity, the stormwater ponds would overflow and excess water would flow to the lowest point on the minesite, which would likely be inactive pits.

The assessment indicates that providing the far eastern section of the flood retention bund is of sufficient height (i.e. 3 m high) and engineered to retain flood waters on site, the minesite is able to contain the in-bund stormwater runoff for a 1:1,000 year ARI rainfall event. Therefore, the minesite is expected to operate as a no-discharge site. However, depending on the development stage of the mine, there may be operational requirements to manage and discharge excess water.

Following mine closure the backfilled pit would not be subject to inundation up to the 1:100 year ARI event. Under the 1:1,000 year ARI scenario and probable maximum precipitation (PMP) event, the post-closure backfilled pit area would be subject to inundation for the duration of the event and surface water would potentially infiltrate the closed landform (URS 2015b).

9.10.5.6 Spill control

As outlined above, the site would be designed and operated as a no-release site. Where process chemicals and liquors are present the process plant and process materials storage facilities will be sealed and bunded to ensure that any process spills can be contained and easily cleaned up. Personnel will be trained in the control and clean-up of spills, including the specific management of spills containing radioactive materials.

Cameco will have appropriate management measures in place to minimise the risk of spills outlined in a chemical and fuel storage management plan to be developed for the Project. Management of ore or process spills will also be referred to in the Radiation Management Plan as outlined in Section 9.6.6.

9.10.5.7 Summary of Management Measures

Avoid and Minimise

- Vehicle and equipment hygiene measures in accordance with the Radiation Management Plan to ensure that contaminated material is not transported off-site. In general, vehicles that are likely to be regularly in contact with higher grade uranium mineralisation will be kept within the contaminated area (refer to Environmental Factor 6).
- Minimise dust impacts in accordance with the Dust Management Plan (refer to Environmental Factor 8).
- Implement surface water management measures in accordance with the Surface Water Management Plan to prevent release of contaminated runoff (refer to Environmental Factor 4).
- Implement spill control procedures as required.
- Ensure that all ore or mineralised waste is either processed through the processing plant, or buried in-pit at the end of mine life.
- Implement vehicle and machinery hygiene measures.

Rehabilitate

- Topsoils will be mapped and preferentially stockpiled for use in rehabilitation and revegetation. Topsoil will be stored in low stockpiles to retain seed viability and will be protected from erosion. Topsoil will not be handled when wet to avoid damaging soil structure. Soils that are not suitable for use in rehabilitation or construction (e.g. dispersive, saline soils) will be buried within the final landforms.
- Prior to commencement of construction, Cameco will have ascertained the availability and volumes of key materials required for rehabilitation. The results of these investigations will be presented in a revised version of the Mine Closure and Rehabilitation Plan to be submitted prior to the commencement of construction (refer to Environmental Factor 12).

9.10.6 Commitments

Cameco commits to :

- developing and implementing a Surface Water Management Plan;
- developing and implementing a Radiation Management Plan;
- developing and implementing a Dust Management Plan.

9.10.7 Outcomes

Taking into account the Project design and proposed management measures to be implemented, Cameco believes that the Proposal will meet the EPA's objective of maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level.