Yeelirrie Uranium Project

Response to Submissions

Attachment 8

Revised Proposal for the Protection of Atriplex Yeelirrie

1. Introduction

Cameco Australia Pty Ltd (Cameco) proposes to develop the Yeelirrie Uranium Project (the Project). Implementation of the Project will have an impact on the species *Atriplex yeelirrie* (*A. yeelirrie*). The plant is known from two populations, one of which occurs on the orebody (known as the Western Population or western genotype) and would be removed by mining. The second population (known as the Eastern Population or eastern genotype) is situated approximately 30 km southeast of the Western Population and will not be impacted. If the impact of mining was assessed at species level, the Project would result in the removal of approximately 30.7 % of the known population. However, published literature has shown that the two population's exhibit significant levels of genetic diversity and as a result it has been determined that the two populations need to be managed as if they were separate species.

In the Public Environmental Review (PER), Cameco presented plans for the preservation of the western genotype. The proposal would involve taking seed from the Western Population and re-establishing a population at another location (described in the PER as translocation). A number of sites at Lake Mason were proposed as potential translocation sites. This proposal was supported by a discussion on the suitability of the Lake Mason sites based on field inspections and analysis of soil samples.

The PER also presented a number of other commitments to collect seed for long term protection of the genotype and to protect the Eastern Population. Cameco also proposed to implement a research and trials program to better understand the eco-physiological requirement for successful translocation.

The PER for the Project was made public in September 2015 and Cameco received a summary of submissions, made by the general public and key decision making agencies, in February 2016. Based on the comments received from the Department of Parks and Wildlife (DPaW) and the Office of the EPA (OEPA), it is apparent that the measures proposed by Cameco do not provide sufficient evidence and options to provide confidence that successful translocation can be achieved. Since receiving the comments, Cameco has reviewed the proposals presented in the PER and have investigated a number of additional measures and options in an attempt to address the issues raised. This revised proposal is presented as a response to the submissions and for the consideration as part of the assessment of the Project.

The objective of the actions outlined in this revised proposal is to lower the risk to the species by increasing the likelihood of successful translocation. This will be achieved through a more thorough scientific based approach to translocation across a broader range of sites.

Cameco Australia would like to acknowledge the contribution of Mr Kevin Thiele of Eubio Consulting to the preparation of this proposal. The proposal includes significant material taken from the work undertaken by Mr Thiele for Cameco.

2. Consideration of options for the conservation of *Atriplex yeelirrie*

There are a number of options available that could positively impact the conservation of the western genotype of *A. yeelirrie* if the Project proceeds. These are:

1. Retain the existing population in its current location (that is, mine around it);
2. Re-create suitable habitat at its current location, during or post-mining, and re-introduce the genotype to this re-created habitat;
3. Locate suitable new habitat elsewhere, and establish one or more new (translocated) populations;

4. Bring the genotype into long-term *ex situ* conservation;
5. Introduce the western genotype's genetics into the eastern genotype.

In considering each of these options it is important to understand that each option presents a set of risks. Therefore to increase the likelihood of success deploying two or more options is the preferred strategy. Supporting the options with sound science and with a long lead time for implementation are also factors that contribute to lowering the risk to the conservation effort. The five options are considered in more detail below.

2.1 Option 1

Retain some of the habitat of the Western Population in the current location to ensure the habitat persists after mining.

Retention of some of the existing population would require the creation of a no mining zone. Exclusion zones have been used in other projects for the protection of flora and fauna habitat and this option should be considered the one most likely to succeed in ensuring the conservation of the western genotype.

At Yeelirrie, populations of *A. Yeelirrie* Western genotype occur across the ore body. No sub-populations occur outside of the current mining zone. None of the sub-populations occur on the edge of the ore body, where they could be protected by a buffer between the sub-population and the open pit, which will be backfilled with tailings. Therefore any protected zone would ultimately be surrounded by tailings storage and need to survive under significantly different hydrological regimes. Therefore, survival of the retained populations during and after mining may be difficult.

A. yeelirrie also occurs over some of the highest grade of ore in the Pit and preserving an area would have a significant financial penalty.

Therefore, given the post mining hydrological conditions and the financial penalty, Cameco does not consider this to be a viable option.

2.2 Option 2

Re-create suitable habitat at its current location, during or post-mining, and re-introduce the genotype to this re-created habitat.

Post-mining re-establishment of habitat, where technically feasible, may be a good option for the conservation of *A. yeelirrie.* Advantages centre around the potential for re-creating the soil profile known to be suitable for the species, using stockpiled soil or movement of soil blocks. Given the planned mine schedule and lifetime, habitat reconstruction could be done relatively early in the Project, with soil from the natural habitat essentially moved down-mine. This option was not considered in the PER, however, after a review of the mining plan and the post closure surface drainage there are two opportunities to implement this option on a large scale.

The first opportunity comes from reconfiguring the mine plan to mine the far south-eastern corner of the pit first, an area that was previously planned to be mined in years 14 and 15. This creates a void on the south-eastern tip of the ore body adjacent to a population of *A. yeelirrie*. Following completion of mining of the first cell, it is considered feasible to backfill it using surface and subsoil taken from the *A. yeelirrie* area from within the next cell to be mined.

A second opportunity involves back filling the cell on the north-western end of the open pit with stockpiled material taken from *A. yeelirrie* habitat earlier in the mining sequence.

Both of these areas are considered suitable as they are not required for tailings disposal and are on the extremities of the open pit, which will allow for better reinstatement of suitable surface hydrological conditions. The areas are shown on Figure 1 of Appendix 1.

2.3 Option 3

Find suitable new habitat elsewhere, and establish one or more new (translocated) populations.

Translocation is a well-established mechanism for reducing the risk of extinction of threatened species. Establishment of translocated populations in areas that are safe from threatening processes has been used for approximately 60 plant taxa in Western Australia. While it has been used successfully to reduce the risk of extinction for species threatened in the wild by processes such as weed invasion and *Phytophthora* dieback, it has not been a well-established or accepted procedure for mitigating impacts from mining and other developments.

It is noted that success criteria for translocation and rescue of species endangered in the wild by diseases and similar threatening process are often relatively low – establishment of even small numbers of plants in one or more small populations may be considered a win, if it reduces extinction threat for a critically endangered species. However, it is expected that different success criteria may apply to *A. yeelirrie*, where a large population with no current threats other than the proposed mine is proposed to be cleared. In this case, success should be taken to mean that one (or preferably more) populations equal in size to (or larger than) the original population are successfully established, with demonstrated recruitment, at the translocation sites. Successful translocation at two or more sites, with an increase in the total number of populations and plants and hence reduction of extinction risk, would provide a net benefit to the species and genotype.

It is also noted that in *Recommendation 2* of the DPaW response: "*That the proponent and the EPA note that the proposed full removal and translocation of the western genotype of A. yeelirrie sp. Yeelirrie Station from the proposal area represents a high risk strategy with a low likelihood of success*" and Cameco considers that more research and translocation at multiple sites would result in better risk management and go some way to address the DPaW's concerns.

In preparing the PER Cameco considered this option to be viable and using ASTER remote sensing imagery, located a number of areas of ground exhibiting similar land surface reflectance signatures including areas on the fringe of Lake Mason and on Yakabindie Station. Believing that land tenure at Lake Mason was more secure for long term conservation of the sites there (when compared to the sites on Yakabindie and elsewhere), Cameco investigated the sites at Lake Mason and the findings were reported in the PER.

In the time since the PER was presented, further consideration has been given to finding additional translocation sites and additional analysis has been completed to compare habitat and soil conditions between the native population sites and the proposed translocation sites. Cameco has now undertaken additional soil sampling at potential sites on Yakabindie Station as well as completing further analysis of soils from the native sites and the proposed translocation sites. Based on this work Cameco believes there are more potential translocation sites than those presented in the PER.

The results of the soil analysis is presented in Appendix 2 of this Attachment and discussed in the following section.

2.4 Option 4

Bring the genotype into long-term ex situ conservation.

This option would see seed or other propagation material of *A. yeelirrie* stored permanently in *ex situ* facilities such as seedbanks, botanic gardens or seed orchards.

2.5 Option 5

Introduce the western genotype's genetics into the eastern genotype.

This option would see introduction (by seed and/or pollen) of genetic material from the western genotype of *A. yeelirrie* into the eastern genotype, in order to conserve the species' genetic (allelic) diversity despite the loss of its genetic structuring in two distinct genotypes.

2.6 Summary

Of the option listed above, Cameco believes there is the potential to implement options 2, 3 and 4 and considers that a research program aimed at identifying the key landscape, soil and hydrological factors required for success prior to implementation will provide the best chance of successful translocation.

3. The Proposal

3.1 Re-creation of habitat (option 2)

3.1.1 Trial Program

In the PER, Cameco reported on a small population of Atriplex that has grown on a rehabilitated area of disturbed land from the historical exploration program. The area of land is understood to have been rehabilitated in 2004. A review of the population and the site on which it has established shows has identified that the soil type is marked different than the soil of the natural sites, and because the site is not saline, there is significantly more competition from plants that do not normally compete with it in its natural location. Despite these factors over 100 plants have persisted at the rehabilitation site, providing some confidence that new populations could be established by direct seeding in suitable conditions.

Prior to undertaking large scale habitat re-creation, Cameco proposes to undertake a trial program to develop techniques for soil profile establishment and to test a number of techniques and options for seeding. A number of sites have been identified in the paleochannel upstream of the mining area and are shown on Figure 1 of Appendix 1. These sites are depressions (claypans) within the surface calcrete with sparse vegetation cover and have been identified using a combination of the regional soil investigations undertaken by Blandford and Associates (Appendix M1 to the PER), aerial photos and the regional topography contours.

Existing soil information is available for one site (Site 16 in Appendix M1) and a number of others have visual information. These sites have currently been identified for further investigations based on their soil type(s), topographical position/local surface water catchment and will be further investigated for their suitability for translocation trials.

The trial would be development on a site of approximately two hectares. A range of treatments would be trialled including the movement of soil from an *A. yeelirrie* site. Treatments would include;

1. No surface material from *A. yeelirrie* site
2. 5-10cm of surface material from *A. yeelirrie* site on top of what is considered suitable subsurface material
3. 5-10cm of surface material from an *A. yeelirrie* site on top of a deep profile (50-100cm) of sub-surface material from an *A. yeelirrie* site
4. Establishment of a deep profile using free digging and tipping techniques

The trial project would also provide an opportunity to test seeding techniques including direct seeding by hand broadcasting as well as by using seeding machines which develop niche mounding as well as other methods to develop a niche habitat, including mulching.

3.1.2 Re-creation of habitat within the mined out open pit

Two locations within the mining open pit are considered to be potential translocation sites. These sites have been identified as they are located within parts of the open pit that will not be backfilled with tailings material and are also in areas where, because they are at the extremity of the pit will have more natural surface and groundwater hydrological conditions post mining (Re-creating a population above the tailings cells is considered possible however it will impact on the design of the tailings cap and may affect the performance of it).

Mining of the ore body commences on the south-eastern end, and a site in the eastern mining cell would be established by the end of mining year 2. The cell would be backfilled with soils being mined from an adjacent cell area which hosts *A. yeelirrie*. The soil profile from the *A. yeelirrie* habitat would be removed as part of the direct handling of mined soil and placed into the adjacent mined out cell for rehabilitation. The area of this cell is approximately 36 ha.

A second translocation site would be created in the north-western cell of the Pit. Again this cell is not required for tailings deposition and could be backfilled with surface and sub-surface soil from an area that hosted *A. yeelirrie*. In this instance suitable soils would be stockpiled for a period of time as the mining sequence does not allow direct handling. The construction of habitat at this location would not occur until the end of mining. The area identified is approximately 68 ha.

3.2 Translocation (option 3)

In the PER, Cameco presented a proposal to translocate *A. yeelirrie* to sites at Lake Mason. The PER also presented the results of preliminary soil sampling from a number of sites at Lake Mason and the Eastern and Western Populations. Since the PER was finalised, Cameco has undertaken additional work and considers there is the potential to translocate *A. yeelirrie* on multiple sites at Lake Mason and Yakabindie.

The additional work has included a multi variant analysis of both surface and subsoils from the proposed translocation sites and current populations, in order to consider the suitability of the soils from the proposed translocation sites with the soils from the naturally occurring populations.

In summary, the investigation, which is presented in full in Appendix 2 to this document, involved additional detailed laboratory analysis on soil samples collected from field plots associated with the original 15 sites from Yeelirrie and 6 sites at Lake Mason along with an additional 5 sites located on the fringes of Yakabindie Lake. As substantial differences were identified between upper profile soil units and deeper soil units (duplex profile) at the Yeelirrie Station investigation locations, it was expected that important differences would exists in key soil properties between the surface and subsoils encountered.

Analysis included particle size distribution, EC, pH, Total metals, Mehlich Suite metals, Nutrients, and Exchangeable cations. These analyses were chosen as each is accurate, repeatable and together cover the range of soil characteristics which are important to general plant growth and health.

Multivariate statistical analysis using the PCA ordination technique was carried out on physical and chemical data collected from 46 samples representing Shallow soil (upper profile soil unit) and Subsoil (lower profile soil unit) samples taken from 26 separate investigation locations. The investigation locations included sites within the *A. yeelirrie* Eastern and Western Populations, sites adjacent to the Western Population at Yeelirrie Station and sites with similar geomorphological characteristics in neighbouring stations (Lake Mason and Yakabindie Stations). Ordination plots were generated using those variables which displayed higher variances for both the Shallow soil and Subsoil sample data sets.

An analysis of these plots has yielded the following observations:

- Shallow soil samples taken from within the clay pan / playa areas at Yeelirrie Station displayed a relatively close grouping, with further sub groups identifiable based on the individual clay pan or playa area where the samples were taken. The majority of variability between these samples and the remainder from outside the clay pan / playa areas and Yakabindie and Lake Mason Stations is caused by total Sulfur and Calcium content.
- The Subsoil samples taken from sites located at Yeelirrie Station showed a similar lack of variation, highlighting the consistency of the calcareous loam subsoil unit encountered at the investigation locations on Yeelirrie Station.
- Yakabindie Subsoils reported considerably lower concentration of Arsenic, Vanadium and Potassium (both total and Mehlich method) than the majority of Subsoil samples taken from Yeelirrie Station; however Yeelirrie Site 1 displayed comparable levels of these analytes and supports *A. yeelirrie*.
- Surface soil samples taken from Lake Mason sites 2 and 6, and Yakabindie sites 1 and 3 plotted within the grouping of the Yeelirrie Station sites, indicating these soils are within the range tolerated by *A. yeelirrie* for the parameters measured.
- Subsoil samples taken from Lake Mason Sites 6 plotted within the grouping of the Yeelirrie Station sites, indicating the subsoils at this location are within the range tolerated by *A. yeelirrie* for the parameters measured.

3.2.1 Lake Mason

The attributes of the Lake Mason site were presented in the PER. The additional analysis show that the surface and sub-soils profiles of the proposed Lake Mason Site 6 are within the range of characteristics from the natural sites suggesting medium risk. (See Appendix 2). Surface soils from Lake Mason Site 2 also fall within the grouping of the Yeelirrie Station sites, but subsoils occur outside the range.

On this basis these sites would be further investigated along with other sites that have been identified from aerial imagery but not yet sampled. As presented in Figure 3 of Appendix 1, digitised polygons around Lake Mason Sites 2 and 6 represent an area of 43.7 ha.

3.2.2 Yakabindie

The Yakabindie Site occurs within the Yakabindie Pastoral Lease, which is owned by BHP Billiton and managed for pastoral purposes. The site is within a large claypan and is approximately 12 km southeast of the Eastern Population. The underlying tenure is Pastoral Lease and there is a granted

Exploration Licence over part of the area of the claypan. The site was identified using ASTER remote imagery and with permission from BHP Billiton, Cameco has completed a site inspection and taken soil samples for multi variant analysis and comparison with soils from the natural sites

In summary the surface and subsoils characteristics on Yakabindie sites 1 and 3 are within the range of the values recorded at the native populations.

A preliminary investigation suggests that approximately 72 ha occurs within sites 1 and 3 and a further 106 ha has been identified by remote and aerial imagery but is yet to be sampled. See Figure 2 of Appendix 1.

3.3 Ex situ conservation (option 4)

Of the ex situ conservation opportunities, the most appropriate at this time is ensuring there is a quantity of seed stored in a seed bank.

In the PER, Cameco reported that seed had been collected and was in storage. It also included details on germination viability testing on seed that had been in storage for up to five years. This seed is currently held by a contractor to Cameco.

While Cameco understands that *ex situ* conservation cannot be regarded as a conservation goal in its own right, it is important to ensure that any likely risks to the viability of the stored propagation material is maintained for the long term, ensuring sufficient genetic diversity in stored material. So far, the seed harvested meets these criteria.

It is important that the seedbank facilities are long-term operations (that is, that the facility and the seeds remain for the term required for success of the option) and Cameco proposes to work with the DPaW seedbank to look at storage parameters for long term storage for a quantity of seed. Cameco proposes to collect seed for storage from both genotypes, but primarily from the Western Population which will be removed by mining.

The last sub-population on the mine site would be removed for mining by year 7 of the mine plan, providing at least 13 years from the decision to mine which will allow the opportunity to collect seed over that long period of time.

3.4 Translocation Site Risks

Cameco understands that, quite apart from whether the soils are suitable, there are a number of other risks presented by each site. These include:

- **Eco-physiological risk:** while Cameco has completed a round of sampling and multivariate analysis to provide more information about the comparative suitability of the soils at the translocation sites, the work completed is preliminary and further research is proposed to provide additional understanding of the new sites. The proposed program is discussed below.
- **Tenure risk:** the ability to ensure long term protection of the translocation represents a risk to the long term protection of the plantation. Re-creation of habitat on Yeelirrie Station presents the lowest level of tenure risk, while sites on Yakabindie have a higher risk. Lake Mason, given the intention to establish a reserve probably represents a moderate risk. Prior to committing to significant work at Yakabindie and Lake Mason, further consideration would be given to how the translocation sites could be made more secure for long term conservation.
- **Technical risk:** technical risk arises from the level of landscape modification required to establish the site for translocation. The two sites proposed to be re-created within the mining

pit present a higher technical risk than sites at Lake Mason and Yakabindie. The proposed trial is aimed at addressing this risk by providing a small scale opportunity to test techniques.

- **Environmental risk:** the impact on the receiving site also presents a risk to the suitability of the translocation site. The sites within the mining footprint do not present a risk because the land will be cleared for mining, however the sites at Yakabindie and Lake Mason will be assessed for the environmental impact of the proposal.

4. Research Program

While Cameco has completed some preliminary investigations and analysis into the soils of natural sites and potential translocation sites, key questions about why *A. yeelirrie* is so restricted largely remain unanswered. A research plan has been developed to address the key questions and to guide and support the translocation plan. The research has been designed to address the key knowledge gaps:

1. Why is *A. yeelirrie* so ecologically restricted, and what are the factors that limit its distribution?
    a. What habitat factors (edaphic, hydrological, landscape), if any, of the red soil patches occupied by *A. yeelirrie* are unusual in the context of the remainder of the palaeodrainage channel?
    b. What ecological and ecophysiological factors allow *A. yeelirrie* to be competitive on these sites?
    c. What ecological and ecophysiological factors are likely to limit its competitiveness on differing sites?
    d. Is *A. yeelirrie* an "extremophile", allowing it to persist in a habitat that is unsuitable for most other species?
2. What environmental factors determine recruitment and successful establishment of mature plants during recruitment events?

The research plan outlined below is designed to address, as effectively as possible, these knowledge gaps. The research would be commenced as soon as possible following a decision to commence the definitive feasibility study (the next phase of mine planning) to ensure that knowledge gaps are addressed before conservation actions need to be taken. The research plan comprises 5 related and mutually informative experiments.

Experiment 1: Characterisation of the critical habitat of *A. yeelirrie* in a landscape context

Aim: To characterise the habitat of *A. yeelirrie* in the context of adjacent habitats within the Yeelirrie palaeodrainage channel, and through this to determine the boundaries of the environmental space that supports current populations of the species.

Why we need this research: Identification of unique aspects of the habitat currently occupied by *A. yeelirrie*, and delimitation of its environmental space in nature, will allow better understanding of critical habitat parameters for translocation sites and for landscapes reconstructed for its reintroduction.

Experiment 2: Characterisation of critical salinity limits for germination and seedling growth of A. *yeelirrie*.

Aim: To experimentally establish critical salinity limits for germination and seedling growth of *A. yeelirrie*, in the field and glasshouse.

Why we need this research: The palaeodrainage channel occupied by *A. yeelirrie*, and potential translocation sites, are naturally saline environments. The species will be limited in the range of environmental salinities it can successfully germinate and grow in. Salinity is likely to be a critical factor in choosing potential translocation sites, and salinity ranges during germination and early seedling growth are likely to be limiting, so characterising the species' salinity limits will help in choosing sites. Salinity limits may be different for germination (which is likely to be limited by imbibition and hence osmotic potential of the germination medium) and seedling growth (which may be determined by physiological mechanisms for dealing with salinity).

Experiment 3: Characterisation of soil parameters affecting growth and survivorship of *A. yeelirrie* and co-occurring taxa.

Aim: To determine soil parameters that may explain the limitation of *A. yeelirrie* to its critical habitat.

Why we need this research: Three key and inter-related questions are: (1) why is *A. yeelirrie* restricted to the red clay playas; (2) can it grow successfully elsewhere; and (3) why are most other species absent from those flats. While Experiment 1 may provide some answers to these questions in the field, this experiment is likely to provide a further characterisation of key soil physical and chemical limits to growth for *A. yeelirrie* and co-occurring taxa (that is, taxa that occur in the general vicinity but not on the red clay flats). Answers to these questions will in turn allow a better understanding of the competitive ability of *A. yeelirrie* and other taxa on different soil types, and address the broad ecological question as to whether *A. yeelirrie* is an "extremophile" that is successful in its niche because most other taxa cannot grow there. This will have direct consequences for understanding the likely success or failure of translocation trials on other habitat types.

Experiment 4: Characterisation of drought and flooding on growth and survivorship of *A. yeelirrie* and co-occurring taxa.

Aim: To determine parameters other than soil chemistry that may explain the limitation of *A. yeelirrie* to its critical habitat.

Why we need this research: Experiment 3, which assesses growth and survivorship of *A. yeelirrie* and co-occurring species on a range of soil types from the Yeelirrie palaeodrainage channel under favourable moisture conditions, will result in an understanding of soil chemistry factors that may be controlling the distribution of *A. yeelirrie*. This may in turn lead to improved assessments of potential translocation sites. However, it may be that drought and/or flooding are key parameters that determine the narrow ecological niche of *A. yeelirrie* and explain the low species diversity on its sites. This experiment will build on Experiment 3, and assess differential mortality caused by drought and flooding on the same soils and same species as used in Experiment 3.

Experiment 5: Characterising natural population dynamics in the field.

Aim: To determine critical population metrics, including recruitment and mortality, of *A. yeelirrie* in the field.

Why we need this research: While the experiments above may give some indications as to necessary conditions for germination, recruitment, survival and growth, they do not account for natural demographic processes in the field. This experiment will lead to a Population Viability Analysis (PVA) for the western genotype of *A. yeelirrie* under natural conditions. A PVA is a mathematical model that predicts the likelihood of extinction of a given population over a given time frame, based on the measured demographic parameters. This in turn will be an important benchmark for translocated or re-created populations – the ultimate measure of success of a translocation program for *A. yeelirrie* is for the likelihood of extinction of the genotype to be lower (or at least no higher) than the original population.

The research proposal is presented as Appendix 3 of this document. At this stage Cameco considers it to be a draft proposal and it will be developed in consultation with DPaW, the research organisation chosen to implement the program and Cameco's consultants. The research proposal would be funded as part of the Project definitive feasibility study (DFS).

5. Protection of the Eastern Population

Protection of the Eastern Population is also considered important. Not only is it the only population of its taxon and genotype, it can also provide valuable information on the function of a natural population of the species to guide and assess the re-establishment of the Western genotype in the new translocated populations.

5.1 Current status

The population occurs within Yeelirrie pastoral lease. The lease is held by Cameco and is destocked. Some areas of Yeelirrie are grazed by livestock straying from adjoining leases. Historically the Yeelirrie Lease was held by BHP Billiton and was part of a group of adjoining leases held by BHP Billiton.

The collective management of the leases as one pastoral operation has likely contributed to the management issues now faced, where livestock from neighbouring Yakabindie and Albion Downs stations are watered from a watering point previously established by BHP Billiton on Yeelirrie. Similarly the recently constructed fences have not been built on the pastoral lease boundaries but on other alignments further complicating access and control of livestock within properties, such that the observed effects of grazing on the *A. yeelirrie* are attributed to livestock from neighbouring properties.

Cameco understands the importance of excluding livestock from the eastern population and has commenced work on the following measures to protect the population.

5.2 Proposed measures to protect the Eastern Population

Further to discussions in the PER, Cameco proposes the following measures in order to ensure protection of the Eastern Population of *A. yeelirrie*:

- **Exclusion of Livestock:** Cameco has commenced discussions with BHP Billiton about decommissioning the watering bore and proposed new fencing to exclude cattle from the population. Cameco has committed to constructing new fences to exclude cattle but this would be more effective if done in conjunction with BHP Billiton. Discussions with BHP Billiton are ongoing.
- **Seed collection:** Cameco will collect seed from the eastern population for storage in the Seed Bank for protection against a catastrophic event such as a wildfire or drought. Cameco will work with the Seed Bank to determine how much seed should be stored.
- **Population dynamics studies:** Cameco proposes to undertake population dynamics survey every second year to identify population condition and trend. The results from the surveys will also be used in modelling to determine the population characteristics required for a sustainable translocated population. Some population mapping has been undertaken and Cameco will work with PVA specialists to ensure that the data collected is suitable for future analysis.

- **Establish tenure or ownership arrangements for long term security of the Eastern Population area:** While ever Yeelirrie Station is held by Cameco, the property can be managed to achieve the conservation outcome. In the long term, however, it may be necessary to establish new arrangements that continue to support long term protection of the Eastern Population from grazing. This could include the establishment of a reserve for protection of the area or a change in ownership that results in part or all of the property being managed for conservation purposes. While Cameco does not have all of the options at this time, it will work with land and conservation agencies during the life of the Project to determine the most suitable arrangements for the long term.

6. Project Timing

One aspect of the Project not presented in the PER is the long lead time for the development and commencement of the Project. The long lead time and the fact that some of the Western Population would not be disturbed until after halfway through the 15 year long mining schedule, means there is a long lead time for Cameco to undertake works and demonstrate successful translocation before the last of the plants within the Western Population would be removed.

Following approval, if Cameco were to move directly into a definitive feasibility study and then directly through into design and construction there would be a four to five years before the commencement of ground disturbing activity within the mine open pit area. Other than for the purposes of translocation trials, the Western Population would not be disturbed during this time. Under the mine plan, mining will commence in the south eastern end of the open pit. The southernmost plants of the *A. yeelirrie* (Western Population) will be cleared during year 1 of mining and the last plants would be cleared by the end of year 7.

This means there is a minimum of 12 years of Project implementation post approval before the last *A. yeelirrie* plants (Western Population) would be cleared, providing a significant period for the completion of the proposed eco-physiological studies and commencement of translocation field trials.

6.1 Project Implementation Timeline (indicative)

Table 1 details the indicative timeline for Cameco to implement *A. yeelirrie* commitments.

Table 1: Project Implementation Timeline (Indicative)

Phase 1 - Post approval and pre commitment to Definitive Feasibility Study
Year 1-3: A budget of $50,000.00 per year for three years has been allocated to advance preliminary investigations. In Year 1 (2016) Cameco will commence the translocation trial program outlined in Section 3.1.1 above. Year 2. Continue with the trial program. Undertake a population survey of the Eastern and Western populations. Year 3. Continue with the trial program as required. If funds are available commence the research program outlined in Section 4 above.
Phase 2 –DFS

Complete the research program Continue to monitor the trial program Secure access to translocation sites Seed translocation sites
Phase 3 – Post commencement of Mining
Year 2 of mining: backfill south-eastern mining cell and seed End of mining: backfill north-western mining cell and seed

7. Summary of Commitments

In summary the following commitments are provided for both the Eastern and Western Populations.

7.1 Eastern Population

Cameco's objective for the Eastern Populations is to protect the eastern genotype by maintaining a viable Eastern Population. Cameco considers that the following commitments and measures of success will enable them to meet this objective.

Commitments:

- Collect seed and store with the DPaW seed bank;
- Undertake bi-annual population dynamics survey to identify population condition and trend and analyse the status of the population through PVA statistical analysis;
- Improve the protection of the population. Currently the population is subject to some grazing by cattle from an adjoining pastoral lease. Cameco is working with the neighbour on a range of options, including, improvements to exclusion fencing, moving a nearby watering point, and re-establishment of boundary fences. These measures would reduce the grazing pressure on the plant; and
- Investigate and implement options for the long term protection of the area, including through changes in land tenure and/or land ownership.

Measures of success:

- Eastern Population protected from grazing by cattle;
- Increased understanding of the population dynamics of the Eastern Population;
- Functioning population showing consistent rates of recruitment and deaths subject to normal seasonal variations; and
- Progress towards permanent protection of the land through changes in land tenure or land ownership.

7.2 Western Population

Cameco's objective for the Western Populations is to preserve the western genotype through translocation and create new populations at several locations. Cameco considers that the following commitments and measures of success will enable them to meet this objective.

Commitments:

- Implement a comprehensive research program to investigate the ecology, ecophysiology, habitat requirements and determinants for *A. yeelirrie*, to feed into the habitat reconstruction and translocation options and to answer current uncertainties;
- Undertake and report on the potential suitability of each site. Investigations would include, soil investigations, drainage, land tenure and potential for long-term protection of the site.

- Undertake a trial translocation program, testing surface and sub-surface soils through relocation and potential seeding techniques;
- Implement translocation at tested and approved sites;
- Implement site re-creation at two sites within the Yeelirrie mine area; and
- Collect seed and store at the DPaW seed bank.

Measures of success:

- Research program completed and reported. Results published in an appropriate journal;
- Trial translocation site established based on the learnings from the research program;
- Translocation conducted at several sites away from the mining area prior to the commencement of mining;
- Re-creation of the sites within the mining area included in the mine schedule and implemented as planned;
- Seed in storage; and
- *A. yeelirrie* growing on translocation sites.

8. Approval and Conditioning

Cameco is seeking approval to develop the Yeelirrie Uranium Project. Implementation of the Project will ultimately involve clearing the entire western genotype of A. yeelirrie.

As discussed above, Cameco has considered the potential to retain a part of the population but has concluded that a reserved population encompassed by an open pit is unlikely to survive long term and will also have a significant impact on the project economics as most of the Atriplex sub-populations are situated over the high grade areas of the ore body.

The proposals outlined above are considered likely to achieve successful translocation to replace the removed population.

Submissions to the PER have put forward a staged approach to mine development - that is, staging the approval of the full impact on the western population following demonstration of successful establishment of (translocated) a viable self-sustaining population. Such a condition would have a significant impact on the economic viability of the Project, as there is no certainty Cameco could access the entire orebody. Without this certainty it is unlikely Cameco would commit to the Project.

Cameco considers there is an alternative position, which will provide both certainty to the company and confidence to regulating agencies that Cameco will implement the work outlined above. This alternative would require Cameco to demonstrate completion of the trials, research and translocation tasks as agreed with the agencies to their satisfaction prior to disturbing the final 50% of the western population.

Appendix 1

Figures illustrating potential translocation sites

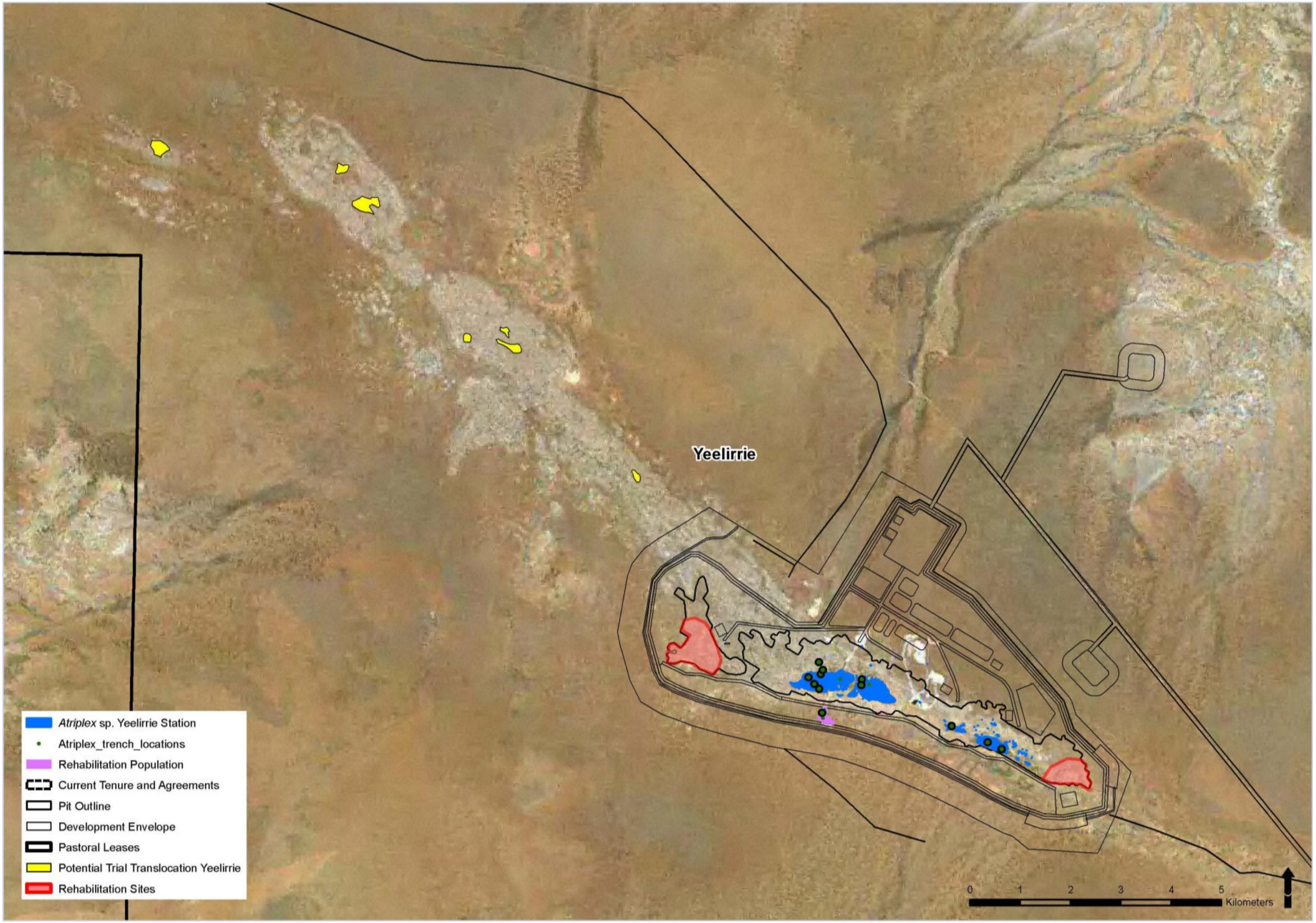


Figure 1: Location of potential translocation sites - Yeelirrie

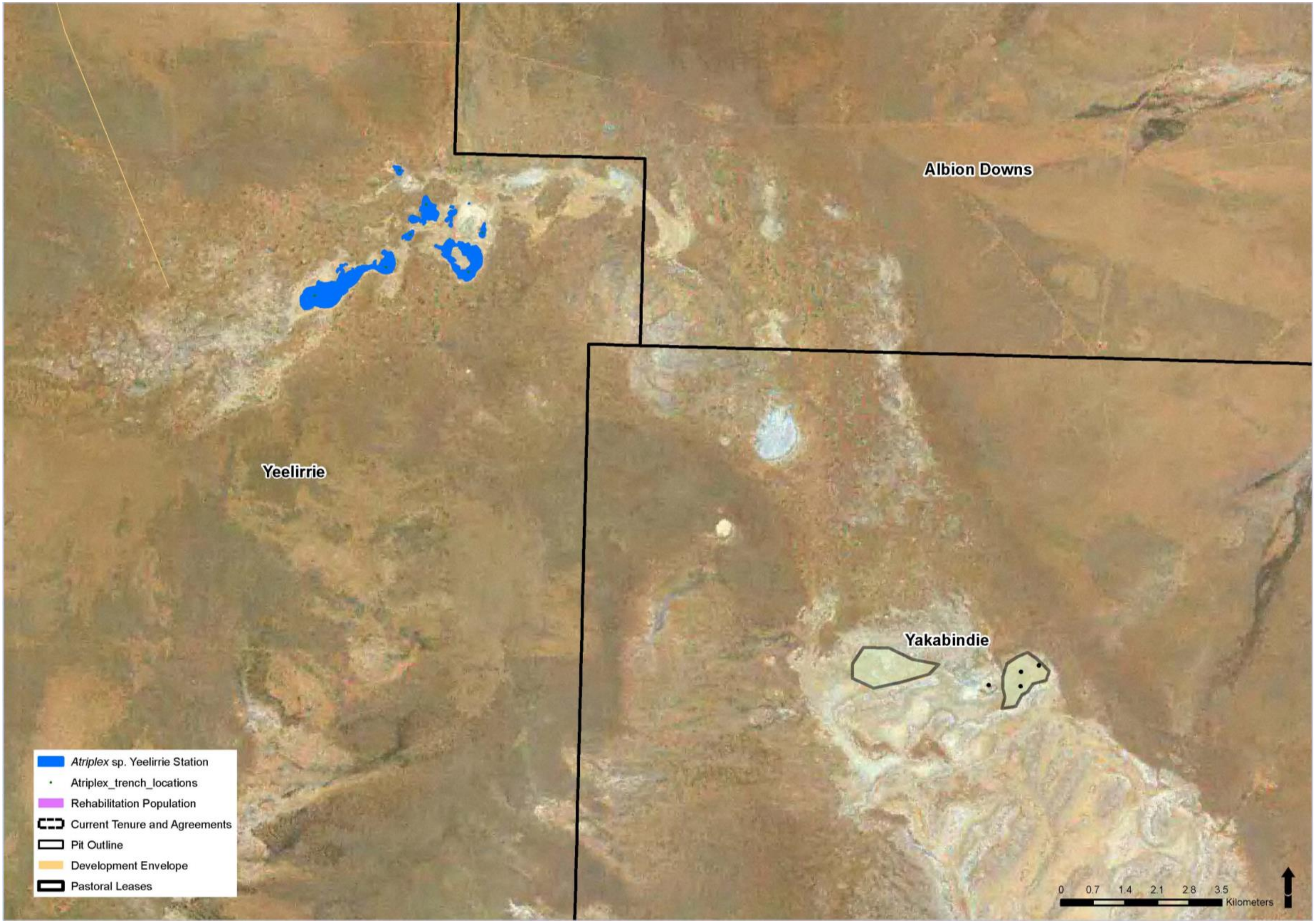


Figure 2: Location of potential translocation sites - Yakabindie

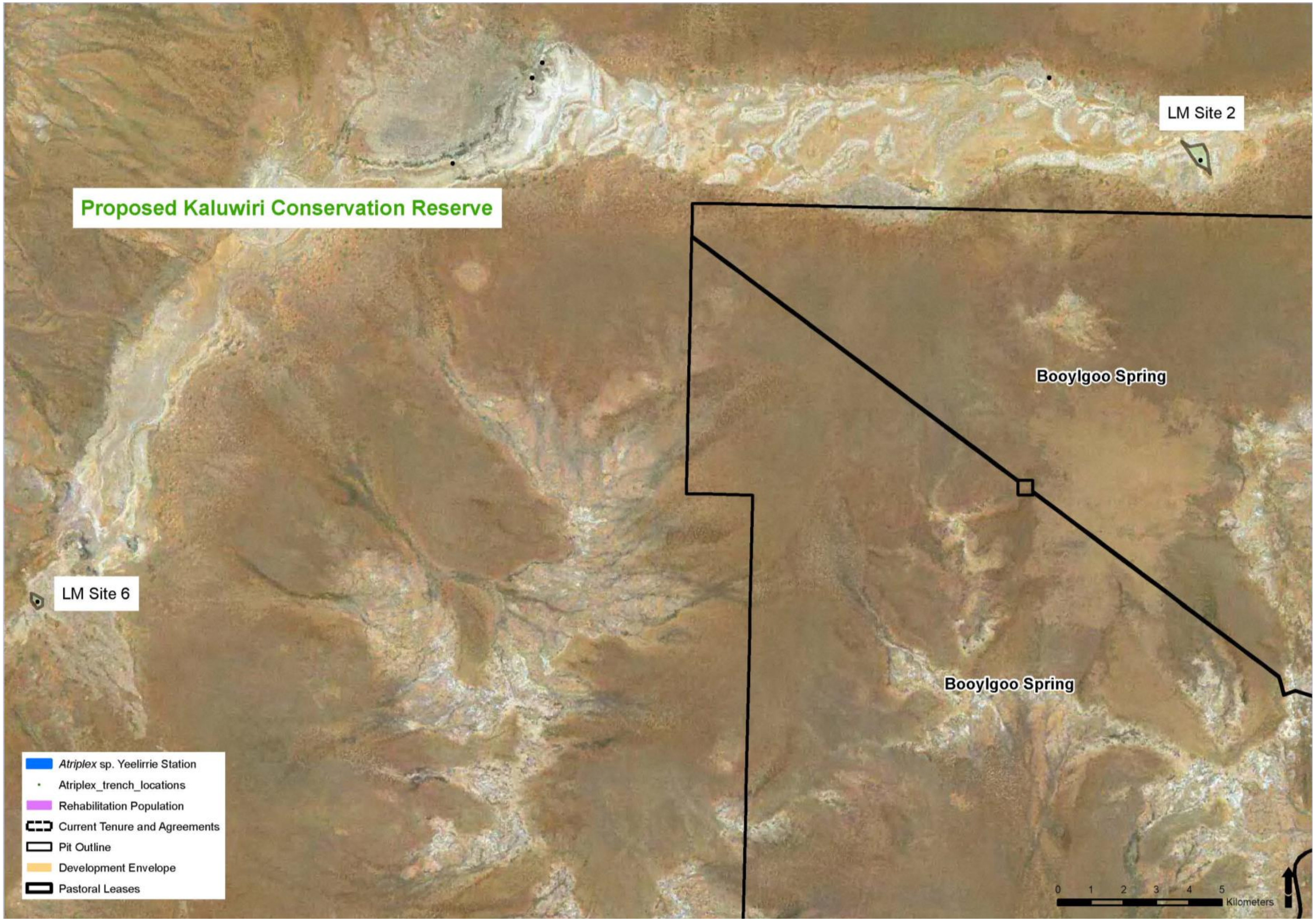


Figure 3: Location of potential translocation sites - Lake Mason

Appendix 2

Soilwater Group Memo regarding Multivariate Analysis Results

t: +61 08 9228 3060
f: +61 08 9228 3210
a: 45 Gladstone St,
East Perth, WA 6004
e: admin@soilwatergroup.com
w: www.soilwatergroup.com

SOILWATER CONSULTANTS

MEMO

TO:	Tim Duff	COMPANY:	Cameco Austalia	
FROM:	Sam Collins	PROJECT TITLE:	Atriplex yeelirrie Investigation	
DATE:	15/03/2016	PROJECT & DOCUMENT NO:	CAM-002-1-2	003
SUBJECT:	Multivariate Analysis Results			

An ecophysiological study was undertaken for the known populations of *Atriplex yeelirrie* on the Yeelirrie pastoral station. The study was restricted to investigation of physical, (geo) chemical, hydraulic and mineralogical properties of the soils which support the *Atriplex yeelirrie* population (SWC, 2015). Deep trenches 2-3 m in depth were excavated within the known *Atriplex yeelirrie* population area and in adjacent or identified similar geomorphological areas which do not support *Atriplex yeelirrie.* This work is intended to allow comparison of the different soil profile characteristics in an effort to determine which factors are likely to be important in controlling the distribution of the species.

Following on from the work described above, additional detailed laboratory analysis was undertaken on soil samples collected from field plots associated with the original 15 sites from Yeelirrie and 6 sites at Lake Mason along with an additional 5 sites located on the fringes of Yakabindie Lake. As substantial differences were identified between upper profile soil units and deeper soil units (duplex profile) at the Yeelirrie Station investigation locations, it was expected that important differences would exists in key soil properties between the surface and subsoils encountered. During sample selection, emphasis was placed on obtaining representative data for each soil unit (upper and lower profile) at each location. For the purpose of this assessment, the analytical results have been divided using these morphological divisions and will be referred to as “Shallow soil” and “Subsoil” from here on.

The additional samples were selected to both maximise the coverage of data across the different investigated sites and rationalise the existing data set which did not contain complete statistics for each soil profile. The data set was expanded to allow the use of multivariate statistical analysis (PCA Ordination).

Laboratory Analysis

The following key soil physical and chemical properties were assessed for all 46 samples at Soilwater Analysis (SWA) and Chemcentre laboratories in Perth:

- Particle size distribution (sand, silt, clay content)
- Electrical conductivity (EC)
- pH

- Total metals (Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, V, Zn)
- Mehlich Suite metals (Al, As, B, Ca, Cd, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Zn)
- Nutrients (Total N, Total P, and extractable P, K, and S)
- Exchangeable cations (Ca, K, Mg, Na) These analyses' were chosen as each is accurate, repeatable and together cover the range of soil characteristics which are important to general plant growth and health.

Multivariate statistical analysis (PCA Ordination) was undertaken on the results of this analysis with the following objectives:

1. Determine if soil properties differ between sites that have a native *Atriplex yeelirrie* population and those that do not
2. Identify the common soil properties linked to successful *Atriplex yeelirrie* growth

Ordination Approach

The broad objective of multivariate data analysis in ecology sciences is to summarize associations among species (the dependent or response variables), and to elucidate species responses to one or more environmental factors (the independent or predictor variables). This objective is achieved by reducing the dimensionality of variable space to an efficient, low-dimensional summative model of the underlying data structure that reflects the coordinated response of species to environmental factors (Kenkel, 2006).

Ordination methods achieve this goal by producing a statistically optimized arrangement of the sampling units along a reduced number of derived ordination axes. In addition, useful ordination methods produce weights and/or biplot scores for variables along these derived axes. Ordination is typically used to reduce variable dimensionality to a much smaller number of interpretable dimensions, to summarize variable inter-correlations, to determine the relative contribution of variables to the underlying data structure, and to quantify variable redundancy (Kenkel, 2006).

Principle Component Analysis (PCA) is considered to be one of the primary ordination approaches appropriate for this type of environmental data set (Kenkel, 2006). PCA ordination axes are derived through rigid (and therefore linear) rotation of the axes such that the proportion of variance accounted for is maximized. The first axis maximizes linear variance (i.e., it summarizes the dominant linear trend), the second maximizes the residual variance not accounted for by the first axis (i.e., subdominant linear trend), and so forth. The method is somewhat analogous to simple linear regression, but extended to multiple dimensions and without distinguishing between dependent and independent variables (Kenkel, 2006).

The statistical software package "R" was used to perform the ordination using the identified list of key soil parameters (as listed above).

Site Classification

As discussed above the first step in ordination is to define the dependent and independent variables within the data set of interest. As detailed flora statistics (dependent variables) were not available at all of the sites investigated, the dependent variables have been simplified to the presence/absence of *Atriplex yeelirrie* and the physical location of the site. A further sub-set of categories has been used to further refine categories based on the plant health (Western Botanical, 2015) and fringe locations of the claypan. Using these criteria a total of 7 different site classifications (or dependent variables) were assigned:

- A1 – *Atriplex yeelirrie* present within claypan / playa (healthy)
- A2 – *Atriplex yeelirrie* present within claypan / playa (unhealthy)
- B1 - *Atriplex yeelirrie* not present (within claypan / playa)
- B2 - *Atriplex yeelirrie* not present (outside claypan / playa)
- F1 - *Atriplex yeelirrie* present on fringe of claypan / playa
- F2- *Atriplex yeelirrie* not present on fringe of claypan /playa
- R – Rehabilitation site

The sample sites and coverage using this classification and the additional laboratory analysis results are shown below in Tables 1 and 2. Yeelirrie sites are categorised by their location within either the eastern or western populations.

Table 1: Sample summary by major category:

Site Name	Site Classification	Site Name	Site Classification
Yeelirrie 1 - (Eastern Pop.)	A1	Yeelirrie 14	B2
Yeelirrie 2 - (Eastern Pop.)	A1	Yeelirrie 15	B2
Yeelirrie 3 - (Eastern Pop.)	A2	Lake Mason 1	B1
Yeelirrie 4 - (Western Pop.)	A1	Lake Mason 2	B1
Yeelirrie 5 - (Western Pop.)	A1	Lake Mason 3	B1
Yeelirrie 6 - (Western Pop.)	A1	Lake Mason 4	B1
Yeelirrie 7 - (Western Pop.)	A1	Lake Mason 5	B1
Yeelirrie 8 - (Western Pop.)	A1	Lake Mason 6	B1
Yeelirrie 9 - (Western Pop.)	A1	Yakabindie 1	B1
Yeelirrie 10	R	Yakabindie 2	B1
Yeelirrie 11 - (Western Pop.)	F1	Yakabindie 3	B1
Yeelirrie 12	B1	Yakabindie 4a	B1
Yeelirrie 13	F2	Yakabindie 4b	B1

Table 2: Sample summary by major category:

Site category	Number of samples
Shallow soil (upper 30 cm*)	
Atriplex yeelirrie present within claypan (A1, A2, F1)	10
Atriplex yeelirrie not present within claypan (B1, F2)	13
Atriplex yeelirrie not present outside claypan (B2)	2
Rehabilitation site (R)	1
Subsoil (below 30 cm*)	
Atriplex yeelirrie present within claypan (A1, A2, F1)	9
Atriplex yeelirrie not present within claypan (B1, F2)	7
Atriplex yeelirrie not present outside claypan (B2)	3
Rehabilitation site (R)	1
TOTAL	46

*Depth used for classification where clear morphological division between A and B horizons not apparent

Data Transformation & Standardization

During the data standardization process, some analytes were removed from the statistical analysis because (1) the majority of values were below detection limit, or (2) the majority of values were the threshold limit of the Mehlich extraction process.

All data was log transformed (apart from pH which already exists on a log scale), and normality was confirmed through a combination of methods, including histogram analysis and a Shapiro-Wilk test (p threshold of 0.05). The data were then standardized by z-score using the in-built “standardize()” function in Excel. This standardization renders the variables scale-free and dimensionless, with each having zero mean and unit variance, and allows them to be compared using multivariate statistics (Kenkel, 2006).

The transformed and standardized data were then assessed to determine if any of the measured shallow soil or subsoil properties differed between sites that have a native Atriplex population and those that do not (Figures 1 and 2). This was achieved by comparing the standardized means (± standard error) of the two sample populations, and was used to narrow the selection of variables to be used in the PCA ordination analysis.

Significant differences (defined by no overlap of the two mean ± standard errors) were observed between plots with and without an *Atriplex yeelirrie* population for the following Shallow soil properties:

- Sand %
- Total Al, Ca, Cr, Co, Fe, Mn, Mo, Pb, Zn
- Mehlich Co, Mn
- Total K, S
- Extractable K, P
- Exchangeable Ca

Significant differences (defined by no overlap of the two mean ± standard errors) were observed between plots with and without an *Atriplex yeelirrie* population for the following Subsoil properties:

- Total As, V
- Mehlich As, Mo
- Total K
- Extractable K

As the number of soil variables measured was greater than the number of plots or sites investigated, it was necessary to reduce the number of variables included in the PCA analysis. This was done by selecting only those variables for which a significant difference was observed between plots with and without an *Atriplex yeelirrie* population (as discussed and defined above). As a result, sixteen variables were assessed for the Shallow soil profile, whilst six variables were assessed for the Subsoils.

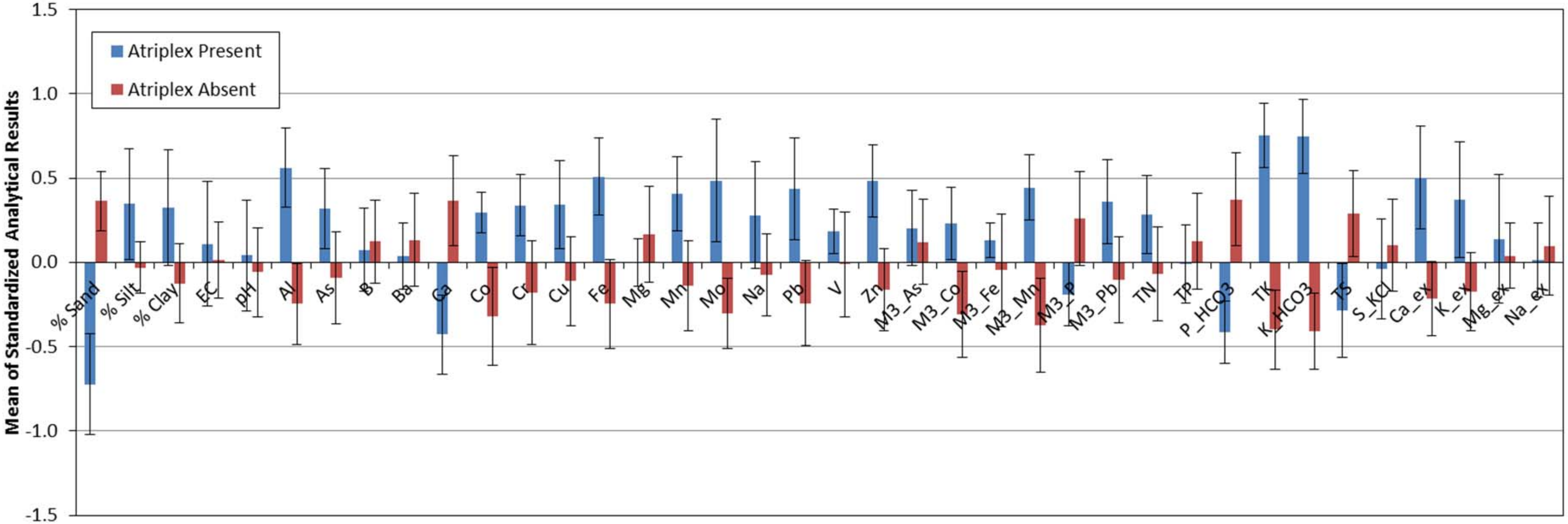


Figure 1: Comparison of standardized means for the measured range of properties in Shallow soils (upper 30 cm)

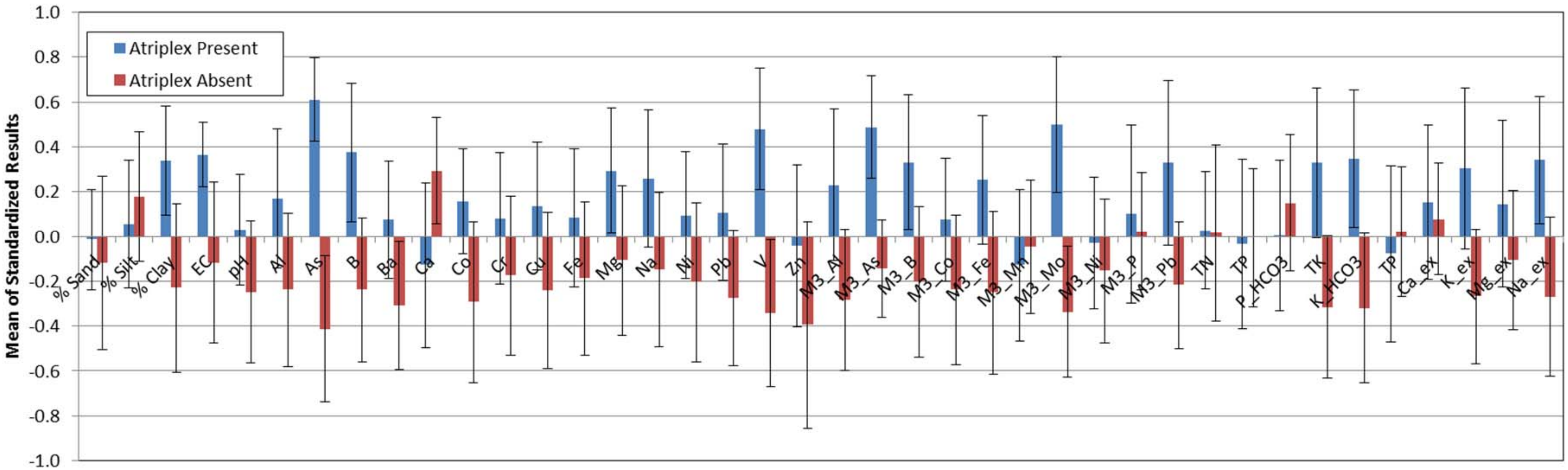


Figure 2: Comparison of standardized means for the measured range of properties in Subsoils (> 30 cm depth)

Ordination Results

Ordination results are displayed as scatter diagrams (Figures 3 and 4), showing the coordinate positions of the sampling units on the first two (i.e., most important) ordination axes. The observed distance between data points represents the "ecological distance" defined by the combined effects of the measured environmental variables. Points which are close together therefore represent sample plots which have similar soil conditions (and therefore expected to display similar growth potential), whilst points that are far apart are expected to have significantly different soil conditions.

The display is rendered more interpretable by adding variable vectors (biplot scores), which are readily derived from the variable weights (Kindt & Coe, 2005). A vector, drawn from the intersection of the PCA1 and PCA2 axes out to one of the plotted biplot scores, indicates the direction of increasing weight for that variable.

As would be expected, the samples taken from Shallow soils at the sites located within the clay pans at Yeelirrie are grouped relatively closely together (largely within the first quadrant), showing markedly lower total sulfur and calcium content than the other classification groups. The remaining groups of Lake Mason, Yakabindie and Yeelirrie sites outside the clay pan areas show a much greater variability, indicative of their wider spatial extent and varied soil geomorphology. These categories show a weak grouping towards higher sand, Calcium and Sulfur contents (with the notable exception of Lake Mason Site 6). The variables which display the lowest effect on ordination positioning of the Shallow soil samples include cobalt (both total and Mehlich method) and extractable phosphorous.

The Yeelirrie sites with *Atriplex yeelirrie* present show a further grouping by their individual clay pan or playa location. Sites 1, 2 and 3 from the Eastern population show marked similarity in their ordination plot, as do sites 4 and 5 which are both from a separate clay pan to the remainder of the Yeelirrie investigation locations. A similar grouping can be seen for sites 7, 8 and 9 which occupy a similar location in the Shallow soil ordination plot to the Eastern population trenches. This sub-grouping of the data points may reflect the discontinuous and complex nature of the surface drainage catchment system along the central valley floor at Yeelirrie, which has resulted in isolated sediment deposition and formation of the upper clay layers within the clay pan / playa areas. This sub-grouping is not apparent within the Subsoil data set, which may be a result of the formational history of the calcareous loam (i.e. the surface features used in choosing the investigation locations within an active drainage system no longer represent underlying soil unit depositional history).

The Subsoil sample data ordination plot highlights the consistency of the underlying soils encountered at Yeelirrie, with the majority of the Yeelirrie sites plotting closely with one another. With the exception of Lake Mason Site 6 the remaining categories all plot outside the Yeelirrie site grouping, displaying considerably lower Potassium (both total and Mehlich method), Vanadium and Arsenic concentrations than the Yeelirrie samples.

Looking at the data points which differentiate between the presence of *Atriplex yeelirrie* at the Yeelirrie site (Yeelirrie site categories A and B) there is little differentiation evident. One exception to this is the Surface soil sample taken from Yeelirrie Site 14, which shows a significant divergence from the remaining samples. This is likely a reflection of the abundant surface litter at this location caused by the presence of an overhead tree canopy which has been shown in numerous studies to display significantly different nutrient cycling to adjacent sites outside of tree canopy areas. Considering only those sites which are the closest in geomorphological attributes to the sites with *Atriplex yeelirrie* present (Yeelirrie Sites 12 and 13) both ordination plots show little differentiation.

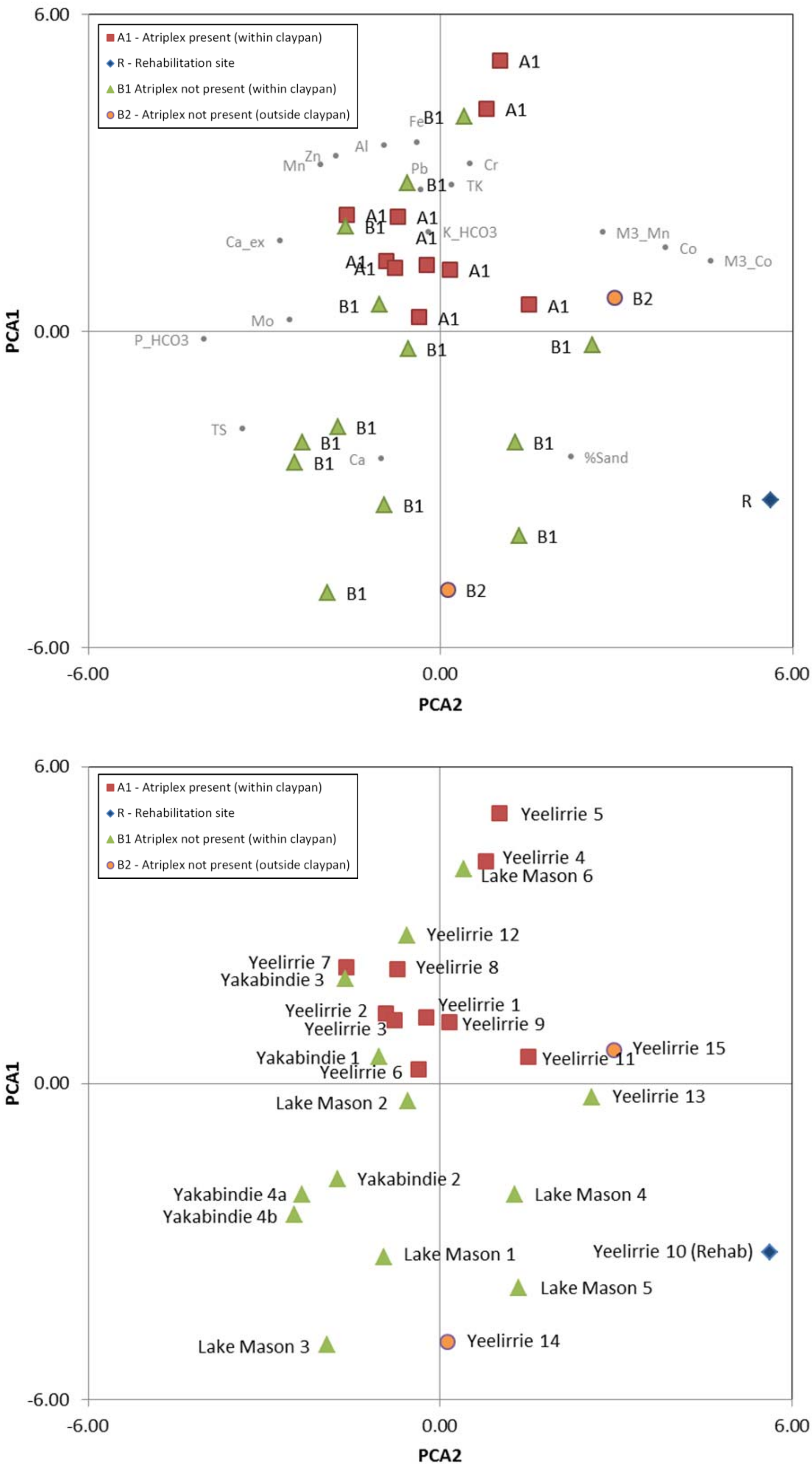
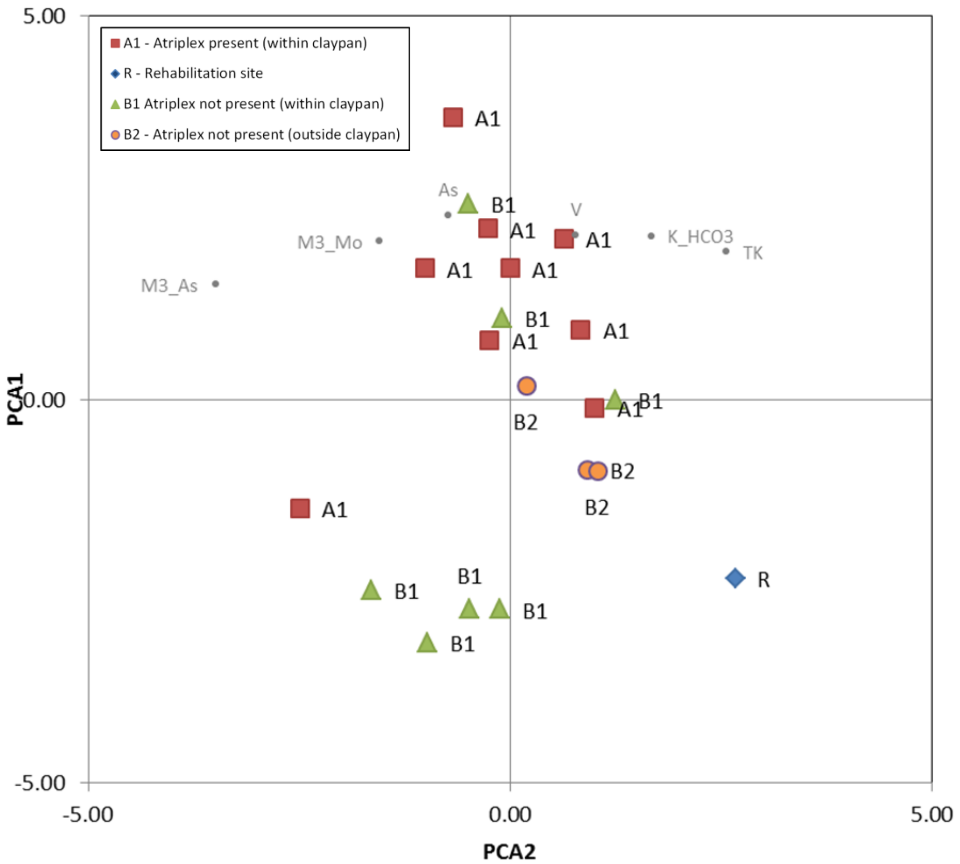


Figure 3: Shallow soil samples ordination plot



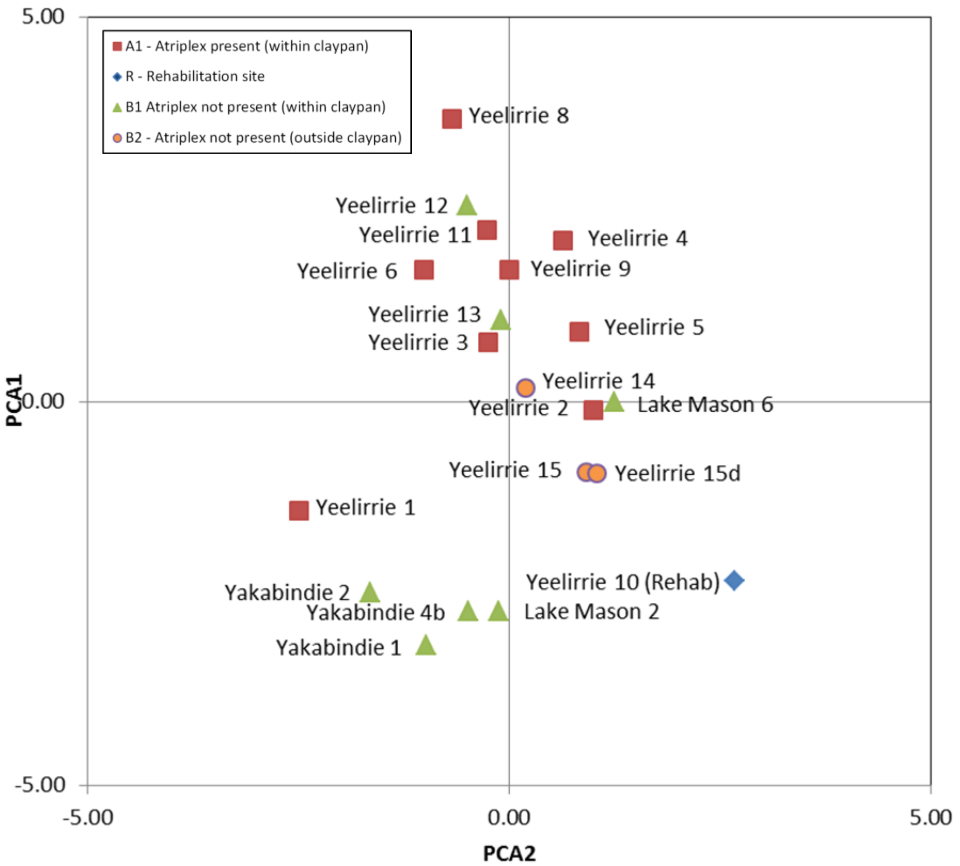


Figure 4: Sub-soil samples ordination plot

Conclusions

Multivariate statistical analysis using the PCA ordination technique was carried out on physical and chemical data collected from 46 samples representing Shallow soil (upper profile soil unit) and Subsoil (lower profile soil unit) samples taken from 26 separate investigation locations. The investigation locations included sites within the *Atriplex yeelirrie* Easter and Western populations, sites adjacent to the Western population at Yeelirrie Station and sites with similar geomorphological characteristics in neighbouring stations (Lake Mason and Yakabindie Stations). Ordination plots were generated using those variable which displayed higher variances for both the Shallow soil and Subsoil sample data sets. An analysis of these plots has yielded the following observations:

- Shallow soil samples taken from within the clay pan / playa areas at Yeelirrie Station displayed a relatively close grouping, with further sub groups identifiable based on the individual clay pan or playa area where the samples were taken. The majority of variability between these samples and the remainder from outside the clay pan / playa areas and Yakabindie and Lake Mason Stations is caused by total Sulfur and Calcium content.
- The Subsoil samples taken from sites located at Yeelirrie Station showed a similar lack of variation, highlighting the consistency of the calcareous loam subsoil unit encountered at the investigation locations on Yeelirrie Station.
- Yakabindie Subsoils reported considerably lower concentration of Arsenic, Vanadium and Potassium (both total and Mehlich method) than the majority of Subsoil samples taken from Yeelirrie Station; however Yeelirrie Site 1 displayed comparable levels of these analytes and supports *Atriplex yeelirrie.*
- Surface soil samples taken from Lake Mason sites 2 and 6, and Yakabindie sites 1 and 3 plotted within the grouping of the Yeelirrie Station sites, indicating these soils are within the range tolerated by *Atriplex yeelirrie* for the parameters measured.
- Subsoil samples taken from Lake Mason Sites 6 plotted within the grouping of the Yeelirrie Station sites, indicating the subsoils at this location are within the range tolerated by *Atriplex yeelirrie* for the parameters measured.

The objectives of the multivariate analysis were to determine (1) if soil properties differ between sites that have native *Atriplex yeelirrie* populations and those that do not and (2) whether it is possible to identify common soil properties linked to the presence of healthy *Atriplex yeelirrie* populations. The ordination plots show that whilst those sites which support *Atriplex yeelirrie* populations are located in a close grouping, there are a number of sites (e.g. Yeelirrie Site 12 and Lake Mason Site 6) which plot within the grouping defined by the healthy *Atriplex yeelirrie* population site for both Shallow soil and Subsoil properties. Therefore the results suggest that whilst soil properties do differ between some sites which do not support *Atriplex yeelirrie* and those that do, this response is not mutually exclusive.

As there is no clear differentiation between these site categories, a determination on which variables or soil properties are linked to the presence of healthy *Atriplex yeelirrie* is difficult. However the Shallow soil data does show that locations within the claypan at Yeelirrie contain higher total Aluminium, Chromium, Iron, Manganese, Lead, Zinc and Potassium (both total and Mehlich) than the larger data set, whilst reporting considerably lower sand (higher clay) total Sulfur and Calcium contents.

References

Kenkel, N. C. 2006. On selecting an appropriate multivariate analysis. Can. J. Plant Sci. 86: 663–676

Kindt R, Coe R (2005): Tree Diversity Analysis: A Manual and Software for Common Statistical Methods for Ecological and Biodiversity Studies. World Agroforestry Centre, 2005.

Soilwater Consultants (2015). Atriplex sp. Yeelirrie Station Investigation

Western Botanical (2015). Population & Demography Study (Phase 1) of Atriplex sp. Yeelirrie Station, May 2015.

APPENDIX A

Yeelirrie Site 1

Reddish brown clay

Calcareous loamy sandy, friable and loose talcy texture

Reddish brown calcareous sandy clay, semi-rounded quartz gravels becoming more prevalent with depth.

Earthy calcrete at base

Yeelirrie Site 2

Reddish brown clay, minor calcareous nodules throughout

70

Calcareous loam, friable and loose talcy texture

110

Gravelly, dry transitional calcrete, amorphous quartz

150

Calcrete at base

Yeelirrie Site 3

Reddish brown clay

20

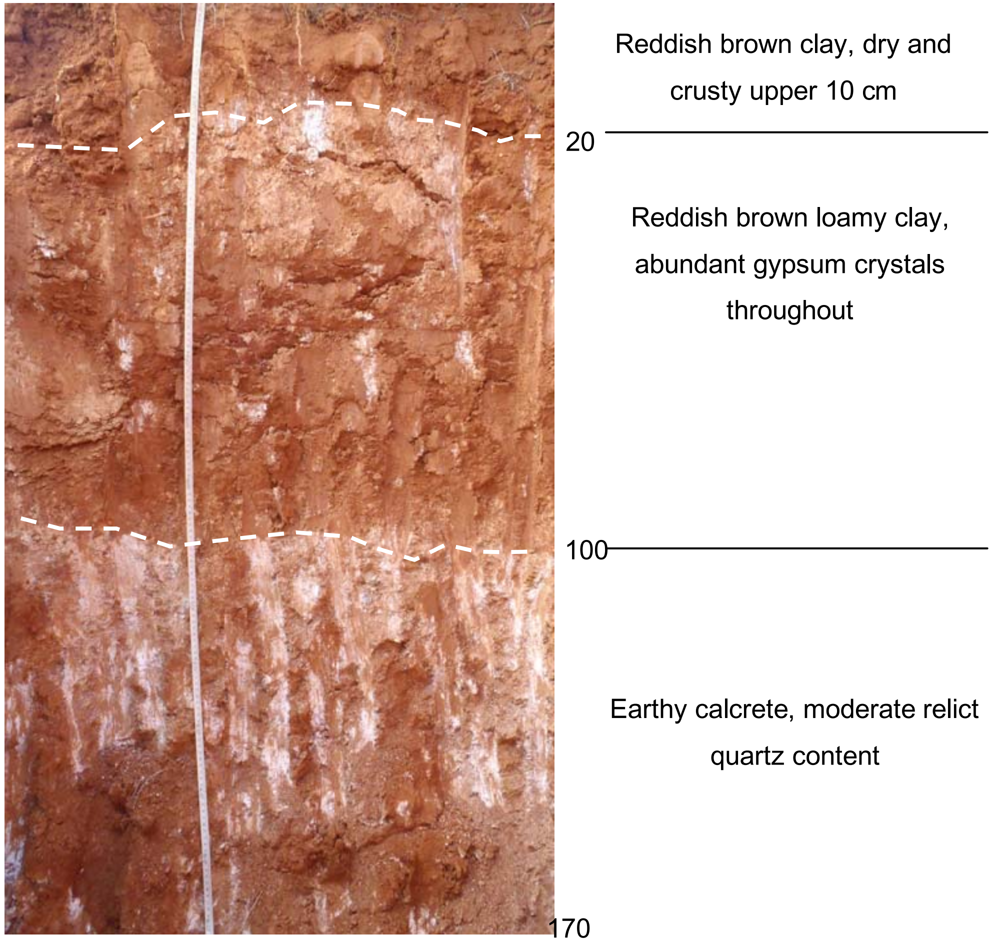
Light greyish red calcareous loam, friable texture. Gypsum crystals evident

100

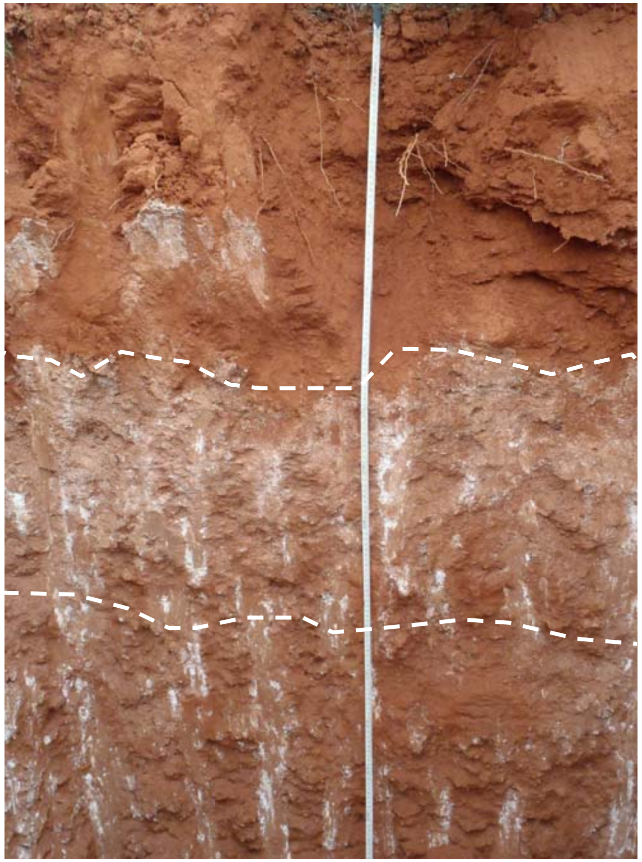
Gravelly, dry transitional loamy clay, calcrete at base

190

Yeelirrie Site 4



Yeelirrie Site 5



Reddish brown clay, moist with abundant lateral roots

50

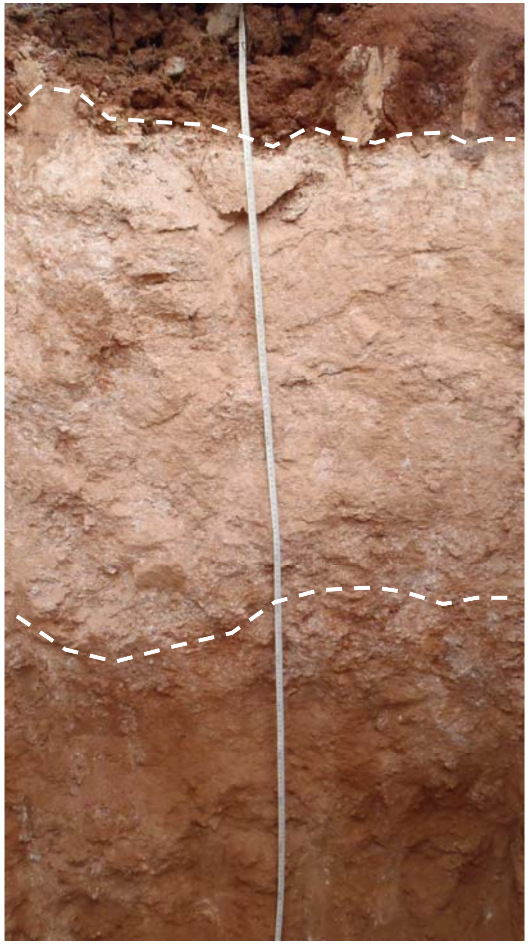
Gypsiferous loam, minor clay lenses throughout

120

Earthy transitional calcrete

170

Yeelirrie Site 6



Reddish brown clay, dry and crusty upper 10 cm

30

Pale red loam with calcrete nodules and friable texture, abundant gypsum crystals at upper boundary

120

Earthy brown transitional loam, friable texture

190

Yeelirrie Site 7

Reddish brown dry loamy clay increase in texture down profile to clay, lateral roots evident

80

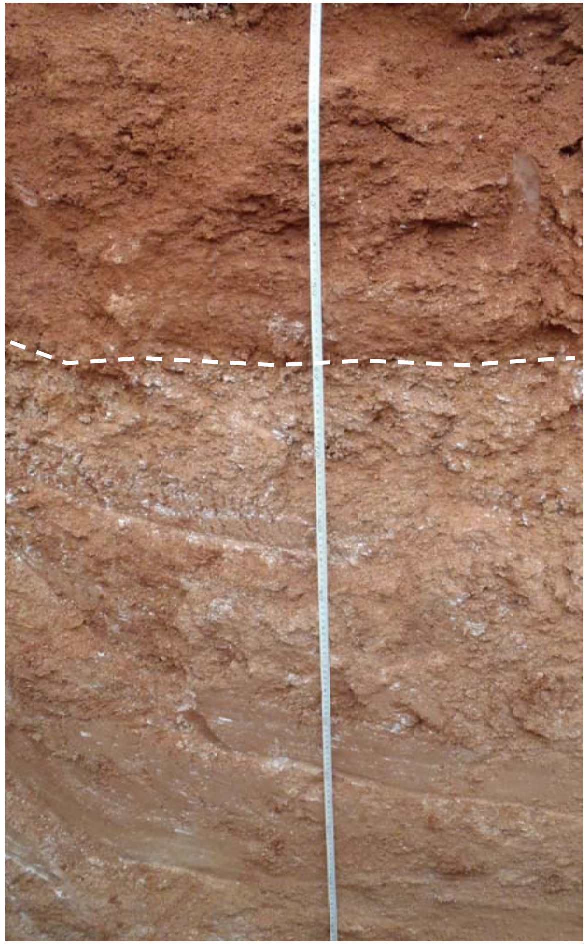
Talcy calcareous loam with calcrete nodules

140

Earthy greyish brown transitional calcrete, gravelly

180

Yeelirrie Site 8



Reddish clay, dry and crusty

10

Reddish brown loamy clay

50

Calcareous loam;
Angular to sub-rounded gravels dominate just below clay layer boundary, gravels become less evident with increasing depth

180

Yeelirrie Site 9

Reddish brown loamy clay, abundant fine roots and common large lateral roots

80

Calcareous loam; Minor sub rounded gravel and fine roots throughout

Blocky calcrete at base

170

Yeelirrie Site 10

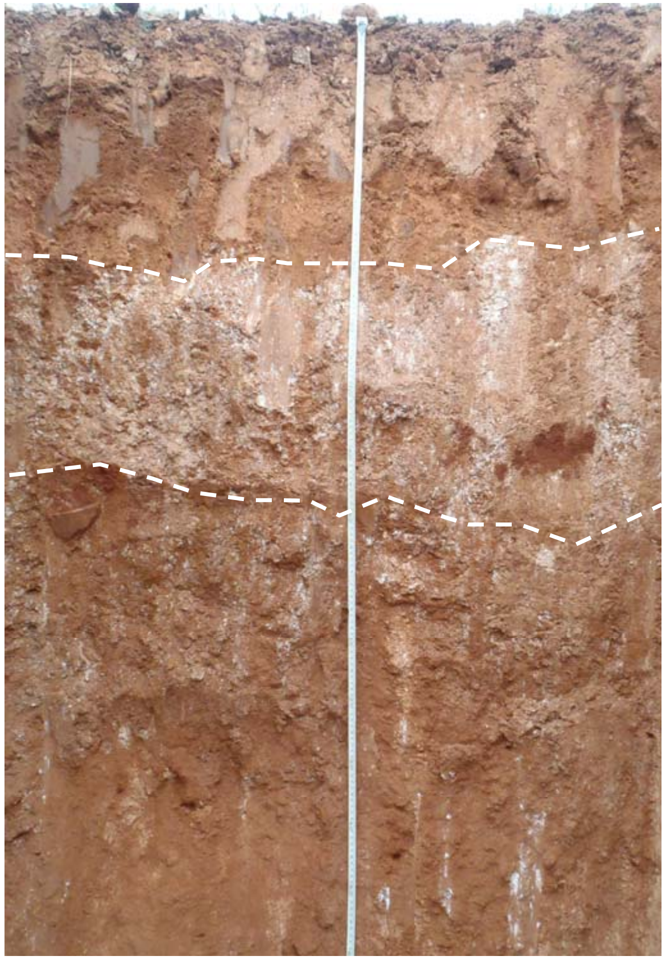
Brownish red sandy loam with moderate fine to medium sub-rounded quartz gravel

30

Highly weathered blocky subangular material of variable clay content, progressively consolidated with depth

120

Yeelirrie Site 11



Reddish brown clay loam, minor calcareous nodules

40

Calcareous loam with common gypsum crystals; gradual transition to

100

Loam; minor calcareous mottling

160

Yeelirrie Site 12

Brownish red clay loam

40

Calcareous loam with abundant calcrete nodules and large gypsum crystals

160

Yeelirrie Site 13

Reddish brown loamy clay

100

Loamy calcareous layer

150

Blocky transitional calcrete

Vuggy solid calcrete, earthy in texture

280

Yeelirrie Site 14

Red brown loamy clay, abundant lateral roots in the upper 20 cm

50

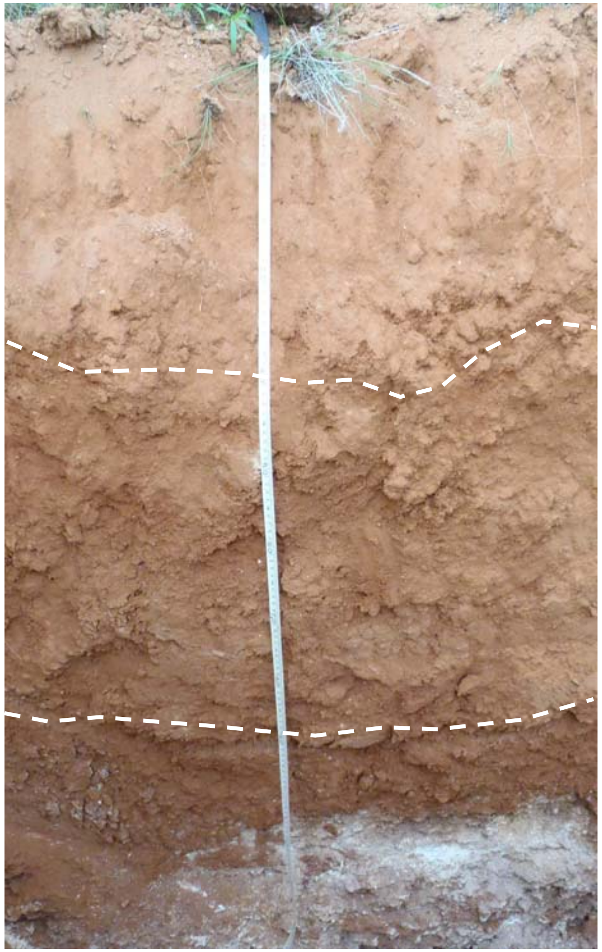
Calcareous loam

90

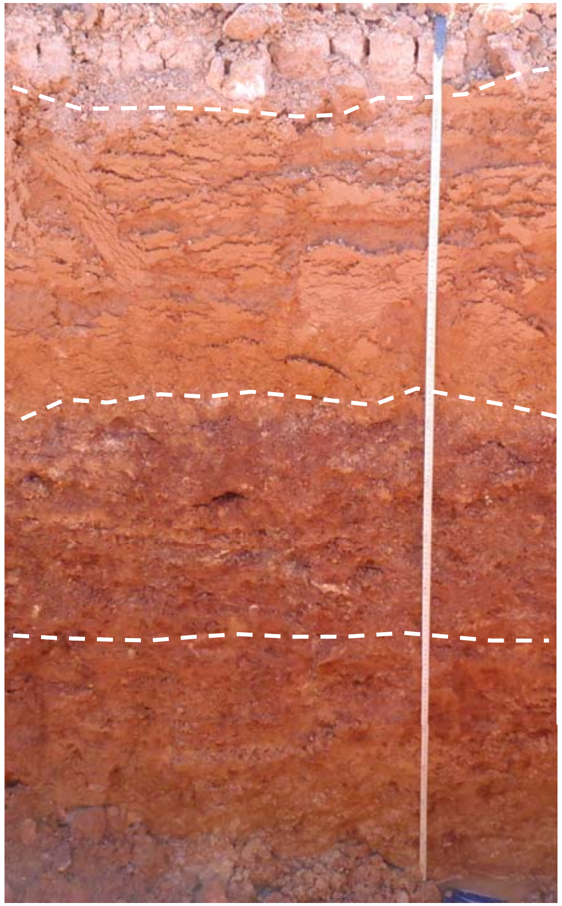
Blocky developing calcrete, sub-rounded to angular gravels throughout

160

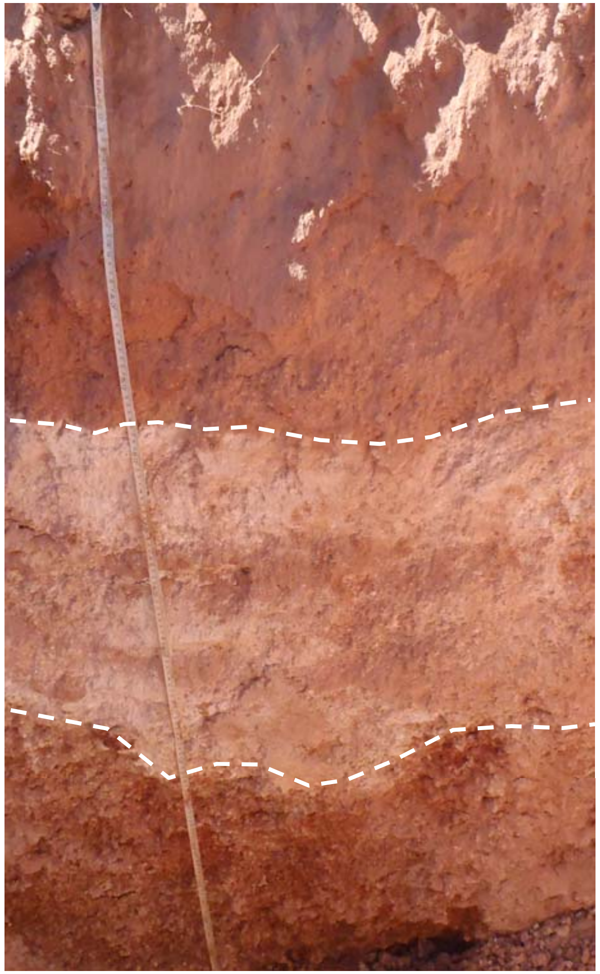
Yeelirrie Site 15



Lake Mason Site 1



Lake Mason Site 2



Reddish brown silty loam, minor calcareous nodules, abrupt boundary to

55

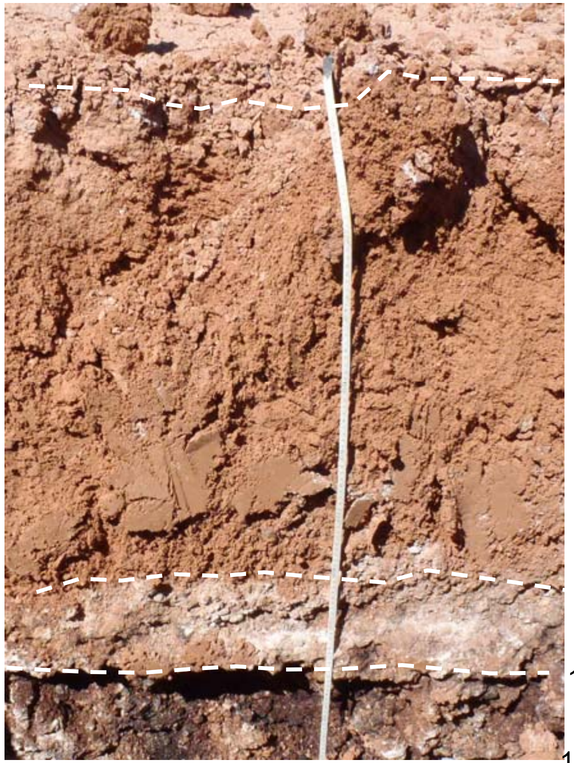
Calcareous silty loam, very dry upper portion considerably less gravel than lower profile

110

Abrupt boundary to friable pisolitic calcrete

160

Lake Mason Site 3



Blocky dry sandy clay

Plastic, stiff reddish brown clay

70

Hard indurated calcareous layer

100

120

Conglomerate with organic staining, saline water entering

Lake Mason Site 4

Coarse silty sand

20

Silty sand, subrounded ironstone gravels increasing with depth

50

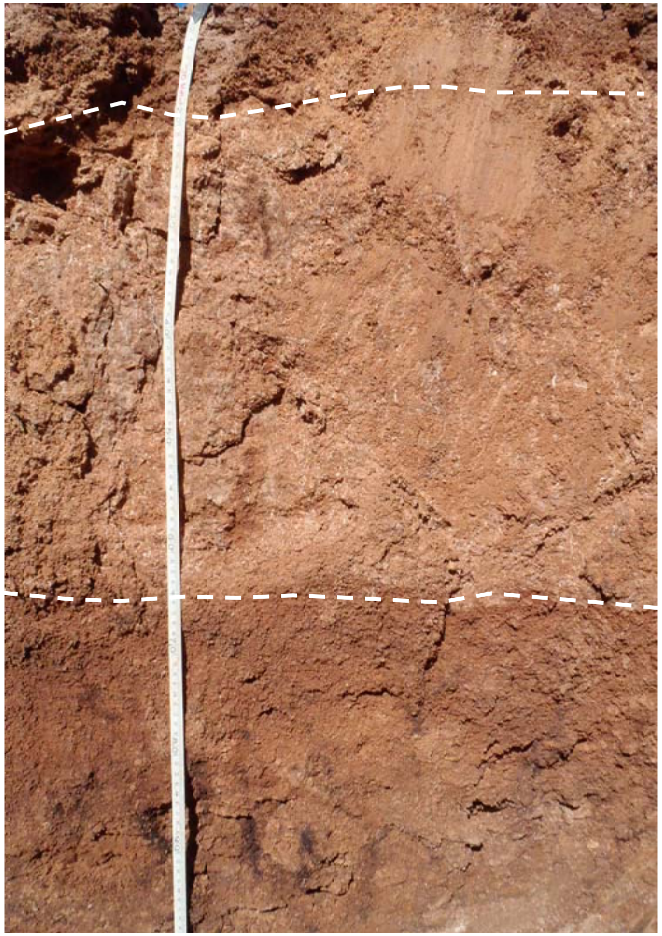
Coffee rock

60

Calcareous silty clay

110

Lake Mason Site 5



Blocky dry sandy clay

5

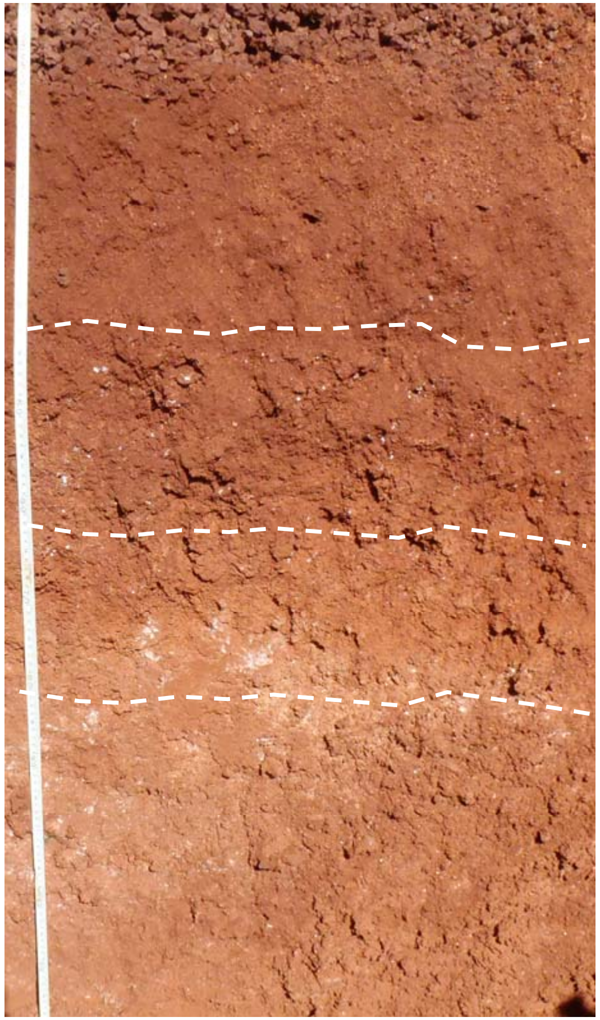
Mottled brown loam

55

Coarse, sandy coffe rock, high gravel content

120

Lake Mason Site 6



Blocky reddish brown loam to clay, very dry in upper 5 cm crust

50

Orange / red loamy clay, minor gypsum

80

Defined gypsiferous layer

110

Orange / red loamy clay

160

Yakabindie Site 1

Yellowish red medium cracking clay, dry

10

Reddish yellow chalky sand with minor gypsum crystals, moist with plant roots in upper horizon

50

Yakabindie Site 2

Thin 2 -5 cm layer of yellowish red cracking clay underlain by a hard platy gypsum layer 5 cm thick

10

Moist chalky sands

25

Loose chalky sands; dry

60

Yakabindie Site 3

No photo of profile;

Red cracking dry clay 0-5cm underlain by moist medium red clay

Yakabindie Site 4a

Thin 2 -5 cm layer of dry red medium clay

5

Firm, moist chalky gypsum sands

40

Yakabindie Site 4b

Dry, blocky red medium clay

20

Firm, moist chalky gypsum sands

50

Appendix 3

Research Proposal

Appendix 1 – A Research Plan for the conservation of *Atriplex yeelirrie*

Background

Key questions remain that need to be answered before embarking on conservation management of the western genotype of *Atriplex yeelirrie*. This section summarises current knowledge, identifies knowledge gaps, and establishes a research plan to help fill key gaps and reduce uncertainties and risks in any conservation management program.

A previous research proposal, submitted to BHP in 2013, has partially guided this section; however, the research plan below has been developed independently, and targets, as effectively and efficiently as possible, critical knowledge needs to enable the conservation of *A. yeelirrie*.

Note that this research plan is developed on the assumption that Cameco will commit to funding research prior to attempting to establish translocation populations of the western genotype of *A. yeelirrie*. The research plan is targeted to helping to assess critical habitat and ecological factors for *A. yeelirrie*, to help provide a benchmark against which potential translocation sites (or post-mining habitat recreation) can be assessed. Translocation and monitoring of translocated populations is not included in the Plan.

No views are expressed as to where the best expertise can be obtained for conducting the research. If Cameco agrees to go ahead with the research, tenders should be sought from Universities, CSIRO and environmental consulting companies etc., to conduct the research as appropriate.

Summary of current knowledge relevant to conservation management of *A. yeelirrie*

1. *A. yeelirrie* is clearly distinct from all other Australian *Atriplex* taxa.
2. It is a long-lived, sub-dioecious perennial, with female plants bearing female flowers only and “male” plants bearing male flowers but with small numbers of female flowers usually present; female and “male” plants occur at equal frequencies in the populations.
3. *A. yeelirrie* is clearly rare and geographically restricted; substantial investment in targeted surveys to try to find populations beyond the two known have failed, and it is unlikely that undiscovered populations exist.
4. The habitat occupied by *A. yeelirrie* is unusual and geographically restricted, comprising limited areas of an unusual soil type occurring in run-on claypan sites with impeded drainage within a single palaeodrainage channel; two of three known locations of this habitat type are occupied at least in part by the species.
5. Geographic restriction (short-range endemism) is unusual in *Atriplex* (that is, most species are common and widespread)
6. The habitat occupied by *A. yeelirrie* supports few other species
7. *A. yeelirrie* has an unusual seed-dispersal mechanism, with hard, woody fruits retained on old wood and perhaps usually only shed when a plant or part of a plant dies and disintegrates (most species of *Atriplex* shed their fruits often with morphologies and mechanism that facilitate long-distance dispersal).

8. Seeds have high viability and high germination rate once the fruits are >1 year old; fresh-collected seeds < 1 year old have high germination rate when excised from the bracts but low germination rate within the bracts, indicating a temporary germination inhibition following seed maturation.
9. Seeds of *A. yeelirrie* at least in some circumstances germinate abundantly in the field.
10. In the habitat in which it grows, recruitment is likely to be spasmodic.
11. Gene flow between the two known populations is limited, resulting in significant genetic structuring between them.

Key knowledge gaps

1. Why is *A. yeelirrie* so ecologically restricted, and what are the factors that limit its distribution?
    a. What habitat factors (edaphic, hydrological, landscape), if any, of the red soil patches occupied by *A. yeelirrie* are unusual in the context of the remainder of the palaeodrainage channel?
    b. What ecological and ecophysiological factors allow *Atriplex yeelirrie* to be competitive on these sites?
    c. What ecological and ecophysiological factors are likely to limit its competitiveness on differing sites?
    d. Is *A. yeelirrie* an "extremophile", allowing it to persist in a habitat that is unsuitable for most other species.
2. What environmental factors determine recruitment and successful establishment of mature plants during recruitment events?

Research Plan

The research plan outlined below is designed to address, as effectively as possible, these knowledge gaps. It would be beneficial to commence the research as soon as practicable, to ensure that knowledge gaps are addressed before conservation actions need to be taken. The research plan comprises 5 related and mutually informative experiments.

Experiment 1: Characterisation of the critical habitat of A. yeelirrie in a landscape context

Aim: To characterise the habitat of *A. yeelirrie* in the context of adjacent habitats within the Yeelirrie palaeodrainage channel, and through this to determine the boundaries of the environmental space that supports current populations of the species.

Why we need this research: Identification of unique aspects of the habitat currently occupied by *A. yeelirrie*, and delimitation of its environmental space in nature, will allow better understanding of critical habitat parameters for translocation sites and for landscapes reconstructed for its reintroduction.

Methods:

1. Establish a transect along the palaeodrainage channel, from a point *c.* 1–5 km above the western genotype to *c.* 1–5 km below the eastern genotype, following the approximate midline of the palaeodrainage channel. Using existing vegetation and landform mapping, identify all vegetation and landscape units along the transect.
2. For each vegetation/landform unit, dig one or more soil pits, characterise the soil profile and surrounding vegetation, and collect soil samples from each soil horizon. (Note that some soil pits have already been dug and samples analysed. These can be utilised for this study, the aim of which is to extend the sampling to better characterise the limits of *A. yeelirrie*.)
3. For each pit site, determine through modelling surficial and subsurface hydrogeological parameters that are likely to be important for *A. yeelirrie* (parameters should include e.g. frequency of soil saturation, frequency of inundation, depth of inundation for specified inundation events, depth to water table).
4. For each pit site, determine standard physical and chemical characteristics of each soil horizon using standard analytical methods
5. Perform a multivariate classification and ordination analysis of sites (pits) based on the combined data set, to determine the environmental envelope in multivariate space that is suitable and unsuitable for *A. yeelirrie*.

Outcomes: This component will potentially allow characterisation of unique or unusual aspects of the habitat (the red-soil claypans) with which *A. yeelirrie* is closely associated. If successful, this arm will provide clues to habitat factors that are critical for the species in its current environment. This will then allow meaningful comparisons between potential translocation sites and the *A. yeelirrie* critical habitat – potential sites for translocation can be added to the ordination and classification to see if they fall within or outside the *A. yeelirrie* critical habitat envelope.

What will success look like? Pits from sites closely associated with *A. yeelirrie* (i.e. the red-soil pits) will form a discrete group on the ordination and a discrete cluster in the classification, closely correlated with a definable and limited set of variables.

What will failure look like? The red-soil pits will not form a discrete group on the ordination or a discrete cluster in the classification. This could mean that critical habitat features were not measured.

Interpretation: If the environmental space of *A. yeelirrie* is discrete and well-bounded, then correlations between measured soil factors on the ordination space can be used to assess critical factors. If the environmental space is not well-bounded, then *A. yeelirrie* is restricted because of a parameter that was not assessed, or for other unknown reasons (e.g. the populations are located where they are by chance, or the species is recently evolved and has not had time to expand to fill its niche; note that these are both unlikely).

Experiment 2: Characterisation of critical salinity limits for germination and seedling growth of A yeelirrie.

Aim: To experimentally establish critical salinity limits for germination and seedling growth of *A. yeelirrie*, in the field and glasshouse.

Why we need this research: The palaeodrainage channel occupied by *A. yeelirrie*, and potential translocation sites, are naturally saline environments. The species will be limited in the range of environmental salinities it can successfully germinate and grow in. Salinity is likely to be a critical factor in choosing potential translocation sites, and salinity ranges during germination and early seedling growth are likely to be limiting, so characterising the species' salinity limits will help in choosing sites. Salinity limits may be different for germination (which is likely to be limited by imbibition and hence osmotic potential of the germination medium) and seedling growth (which may be determined by physiological mechanisms for dealing with salinity).

Methods:

1. Establish a germination trial with 20 seeds of each genotype of *A. yeelirrie* in each of 10 agar petri dishes, moistened with water at 10 different salinities, from distilled water to the maximum salinity likely to be experienced in a saltmarsh. Measure time to germination and percent germination at each salinity.
2. Establish a randomised replicated pot trial, using inert, sterile sand as the potting medium. Establish 10 salinity levels in the pot soils, from field salinity to the maximum likely to be encountered in the field. Germinate seedlings in agar at their optimal salinity (as determined above) to radicle emergence, then transfer to the pots at each salinity level. Water pots by weight to maintain starting salinity levels, with standard nutrients. Measure growth rate and survivorship of seedlings for 2 months.
3. Graph growth rate and survivorship to determine optimal and limiting salinities for germination and post-germination growth.

Outcomes: This experiment will salinity tolerances for germination, growth and survivorship of *A. yeelirrie*.

What will success look like? Clear response curves for germination, growth and survivorship, including limits (zero germination, death of seedlings).

What will failure look like? Response curves without apparent limits (this is unlikely if the upper salinity level is chosen appropriately).

Interpretation: Note that results from these *in vitro* and pot experiments may not be directly translatable to field conditions. For example, upper limits for germination, growth and survivorship in well-watered pots at a given salinity may be higher than for field situations where drought provides a confounding factor. Nevertheless, limits determined through this experiment are likely to provide a guide to field conditions.

Experiment 3: Characterisation of soil parameters affecting growth and survivorship of A. yeelirrie* and co-occurring taxa*.

Aim: To determine soil parameters that may explain the limitation of *A. yeelirrie* to its critical habitat.

Why we need this research: Three key and inter-related questions are: (1) why is *A. yeelirrie* restricted to the red clay playas; (2) can it grow successfully elsewhere; and (3) why are most other species absent from those flats. While Experiment 1 may provide some answers to these questions in the field, this experiment is likely to provide a further characterisation of key soil physical and chemical limits to growth for *A. yeelirrie* and co-occurring taxa (that is, taxa that occur in the general vicinity but not on the red clay flats). Answers to these questions will in turn allow a better understanding of the competitive ability of *A. yeelirrie* and other taxa on different soil types, and address the broad ecological question as to whether *A. yeelirrie* is an "extremophile" that is successful in its niche because most other taxa cannot grow there. This will have direct consequences for understanding the likely success or failure of translocation trials on other habitat types.

Methods:

1. Establish a randomised replicated pot trial, using soil from each horizon from pits in a range of vegetation types both with and without *A. yeelirrie*. (Note that it may be necessary to run a pre-trial with a limited number of pots, to determine if plants can grow successfully in the potted soil. A small amount of inert sand may need to be mixed with the soil to offset structural damage caused the soil by harvesting and potting).
2. Sow seeds of *A. yeelirrie* and of key co-occurring species (particularly other *Atriplex* species that co-occur in the general vicinity.
3. Keep the pots well-watered, and measure growth rates and survivorship of all species on all soil types. If some taxa perform poorly or do not survive, assess leaf symptoms to try to ascertain likely cause of poor performance (e.g. toxicity or deficiency).
4. Analyse growth rate and survivorship for each species on each soil type using ANOVA.

Outcomes: An understanding of differential growth rates and survivorship of different species on the different soils under favourable hydrological conditions.

What will success look like? Any clear response (differential or not) of the test species to the different experimental conditions.

What will failure look like? Plants of all species fail to thrive on all soils, or *A. yeelirrie* fails to thrive on its native soils and/or the other taxa fail to thrive in theirs. This would indicate that other environmental aspects of the experimental conditions (e.g. glasshouse temperature, humidity etc) are unsuitable for the species.

Interpretation: If *A. yeelirrie* grows well on its native soil. and other species grow well on their native soils but not on the *A. yeelirrie* soil, then *A. yeelirrie* is likely to be occupying a habitat that has edaphic factors (particularly soil chemistry) that are unsuitable for other species. Assessments of toxicity or deficiency symptoms may provide some indication of the cause of the differential response. If the co-occurring species also perform well on the *A. yeelirrie* soils under the favourable hydrological conditions of this experiment, these species must be unable to grow on the *A. yeelirrie* sites due to other (e.g. hydrological) factors rather than soil chemistry. If *A. yeelirrie* performs as well on soils that it does not naturally occur in, then its absence from these other habitats could be due to competitive exclusion rather than an inability to grow.

Experiment 4: Characterisation of drought and flooding on growth and survivorship of A yeelirrie* and co-occurring taxa*.

Aim: To determine parameters other than soil chemistry that may explain the limitation of *A. yeelirrie* to its critical habitat.

Why we need this research: Experiment 3, which assesses growth and survivorship of *A. yeelirrie* and co-occurring species on a range of soil types from the Yeelirrie palaeodrainage channel under favourable moisture conditions, will result in an understanding of soil chemistry factors that may be controlling the distribution of *A. yeelirrie*. This may in turn lead to improved assessments of potential translocation sites. However, it may be that drought and/or flooding are key parameters that determine the narrow ecological niche of *A. yeelirrie* and explain the low species diversity on its sites. This experiment will build on Experiment 3, and assess differential mortality caused by drought and flooding on the same soils and same species as used in Experiment 3.

Methods:

1. This experiment will use the same randomised pot experiment as used for Experiment 3. The experiment needs to be established with sufficient replication to allow the treatments for this experiment
2. Once plants of all species on all soil types are well-established and growing (at least on some soil types), randomly assign pots to one of three treatments (control, drought, flooding).
3. Control pots will continue to be watered optimally (these will be the plants measured for Experiment 3). Pots in the drought treatment will have watering ceased or substantially reduced. Pots in the flooding treatment will be kept at saturation.
4. Measure growth rates and survivorship, and key ecophysiological parameters such as water stress (for the drought treatment) and gas exchange (for the flooding treatment) of all species on all soil types under all treatments.
5. Before drought and/or flooding death is reached, re-establish normal watering protocols and assess recovery in growth rate or failure to recover.
6. For the flooding treatment, harvest a subset of the pots before establishing the normal watering, for morphological assessment of adaption (e.g. new roots, aerenchyma).
7. Analyse growth rate and survivorship for each species on each soil type under each treatment using ANOVA.

Outcomes: An understanding of differential growth rates and survivorship of different species on the different soils under unfavourable hydrological conditions, and potential assessment of differential adaptive responses to flooding.

What will success look like? Any clear response of the test species under the experimental conditions.

What will failure look like? No clear response, such as random mortality or poor growth not correlated with treatments.

Interpretation: If *A. yeelirrie* grows better than other species under drought and/or flooding treatments on its own soils, then it is better adapted to these conditions, providing a potential explanation of the lack of other species in its habitat. If it responds the same as other species to these treatments, then some other factor (e.g. a soil chemistry factor identified through Experiment 3) must be explanatory

Experiment 5: Characterising natural population dynamics in the field.

Aim: To determine critical population metrics, including recruitment and mortality, of *A. yeelirrie* in the field.

Why we need this research: While the experiments above may give some indications as to necessary conditions for germination, recruitment, survival and growth, they do not account for natural demographic processes in the field. This experiment will lead to a Population Viability Analysis (PVA) for the western genotype of *A. yeelirrie* under natural conditions. A PVA is a mathematical model that predicts the likelihood of extinction of a given population over a given time frame, based on the measured demographic parameters. This in turn will be an important benchmark for translocated or recreated populations – the ultimate measure of success of a translocation program for *A. yeelirrie* is for the likelihood of extinction of the genotype to be lower (or at least no higher) than the original population.

Methods:

1. Establish replicated plots in both *A. yeelirrie* populations, and count and map numbers of mature plants.
2. Monitor plots at least annually, with additional monitoring after significant rainfall, flood or drought events. For each monitoring visit, determine survival of mature plants, count seedling emergence and survivorship, and characterise demographic changes during the recruitment event.
3. Maintain the plots to characterise long-term dynamics, e.g. response to flooding, drought.

Outcomes: An understanding of the population dynamics of *A. yeelirrie* following a range of recruitment (e.g. rainfall) and mortality (e.g. drought) events.

What will success look like? Any data from this experiment will be a success.

What will failure look like? Failure to recruit and lack of mortality during the monitoring time frame (this will make a PVA impossible to perform).

Interpretation: This monitoring program will establish the fates of seedlings germinated during a range of likely recruitment events, and the fates of established plants during a series of likely mortality events. It will provide a baseline for assessing similar events in translocated populations.