SOILWATER CONSULTANTS

ATRIPLEX SP. YEELIRRIE STATION INVESTIGATION

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Soilwater Consultants (Perth Office)

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Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake an investigation into the soils where *Atriplex* sp. Yeelirrie Station is present and areas identified as potential translocation sites. This work was conducted in accordance with the Scope of Work presented to Cameco Australia Pty Ltd ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the soil investigation was confined to the Eastern and Western populations of *Atriplex* sp. Yeelirrie Station and potential translocation sites surrounding Lake Mason. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

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1 BACKGROUND

The Yeelirrie Project is a proposed uranium ore mine located on the Yeelirrie Pastoral Station (Yeelirrie), 700 km northeast of Perth and 70 km southwest of Wiluna (Figure 1.1). The Threatened Flora *Atriplex* sp. Yeelirrie Station (Western Botanical, 2011) occurs at Yeelirrie; with a Western population within the proposed mine footprint and an Eastern population approximately 30 km to the east-southeast (Figure 1.2).

The Eastern and Western populations have been recorded to be genetically distinct, and therefore the two genotypes are treated separately with regard to potential conservation measures. The Western population occurs over the orebody of the Yeelirrie Project and encompasses two sub-populations that are located in close proximity and has been surveyed (Western Botanical, 2011) to contain 84,542 plants covering an area of 76 ha (representing 30.71% of the overall population and 36.69% of the overall area of occupancy of the species). The Eastern population has been surveyed to comprise 190,755 plants over an area of 130 ha, occurring outside the development envelope of the Yeelirrie Project and will not be impacted.

Cameco Australia engaged Western Botanical and Soilwater Consultants to conduct an ecosystem analysis of the *Atriplex* sp. Yeelirrie Station and investigate the soil geochemistry where this species occurs. Western Botanical began the investigation with a population and demography study of *Atriplex* sp. Yeelirrie Station (Western Botanical, 2015a). The purpose of the study was to collect population and demography information of *Atriplex* sp. Yeelirrie Station to assist the management of existing populations and any future translocated populations.

To support this study and aid in the identification of areas which may be suitable for translocation efforts, Soilwater Consultants (SWC) conducted a soil investigation into the soil geochemistry and profile characteristics which exist where populations of *Atriplex* sp. Yeelirrie Station are present. In addition, soil investigations were conducted in areas within the nearby Lake Mason Pastoral Station identified as having similar geomorphic characteristics to those areas where *Atriplex* sp. Yeelirrie Station are present.

CAMECO AUSTRALIA PTY LTD	Figure 1.1: Location of the Yeelirrie Project	soilwater GROUP
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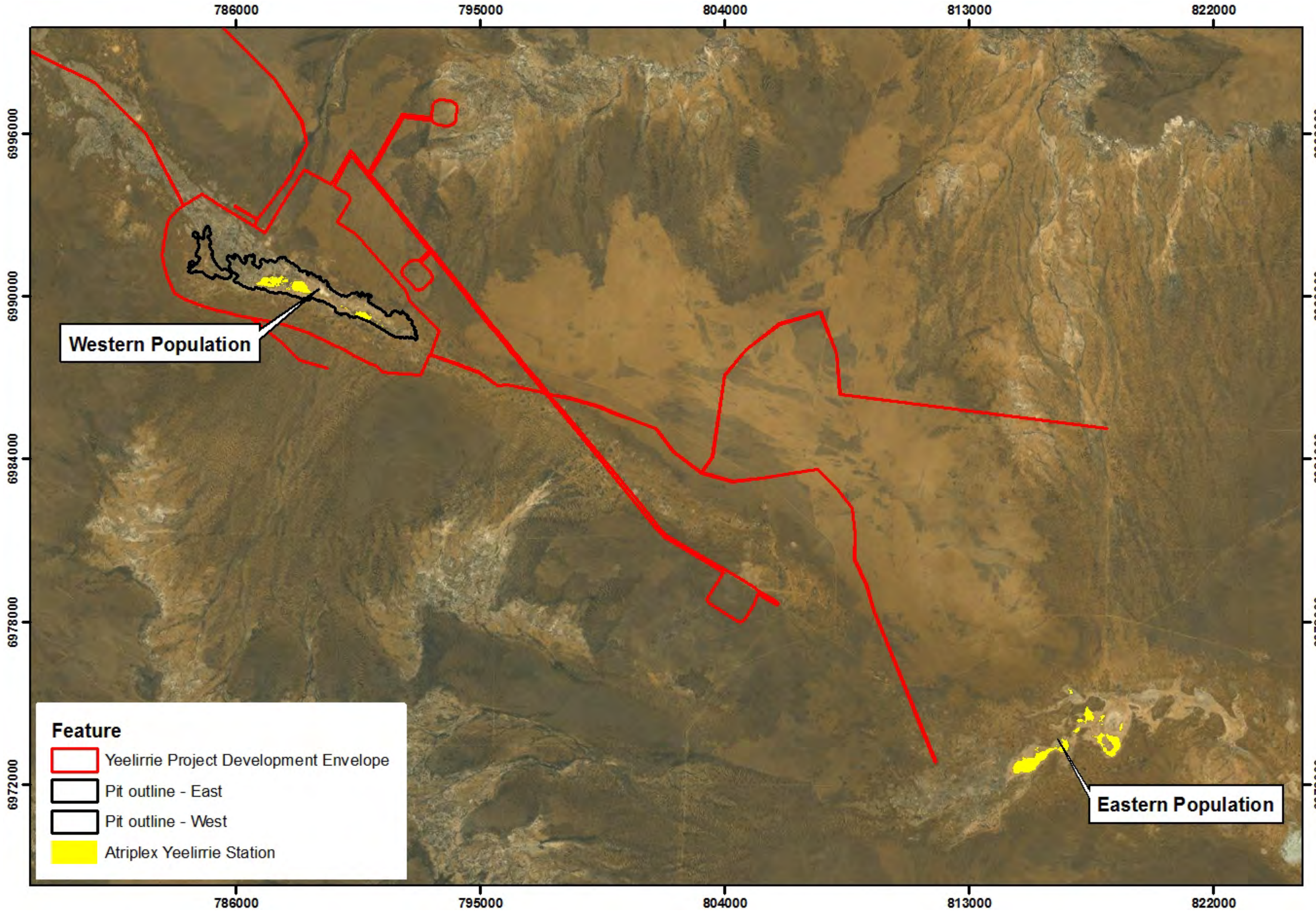

CAMECO AUSTRALIA PTY LTD	Figure 1.2: Location of *Atriplex* sp. Yeelirrie Station populations
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2 STUDY METHODOLOGY

2.1 FIELD SURVEY

Fieldwork for the soil investigation was conducted in the first half of April 2015 and was preceded by significant rainfall (~120mm cyclonic event) in mid-March. The soil profile was investigated via the excavation of a number of shallow trenches (utilising a backhoe; Plate 2.1). The locations of the trenches were selected to allow coverage over both areas (Eastern and Western) where populations of *Atriplex* sp. Yeelirrie Station are present. Where possible, sites were located adjacent to the strip plots developed by Western Botanical (2015a) to monitor population demographics to allow data comparison with the flora analysis being conducted.

A total of 21 trenches were excavated during the investigation, 15 within or adjacent to areas where *Atriplex* sp. Yeelirrie Station is present and 6 at potential translocation sites around Lake Mason. The details of these trenches are provided in Table 2.1, whilst their locations are shown in Figure 2.1 and 2.2.

Samples were collected at 10 cm or 20 cm intervals from the exposed face of trenches down the surficial profile to characterise the change in pedologic organisation and horizonation, and for subsequent laboratory analyses. In addition hand samples were collected within each horizon and at regular depths down the surficial profile for qualitative assessment of root length.

Table 2.1: Details of the locations sampled during the soil investigation

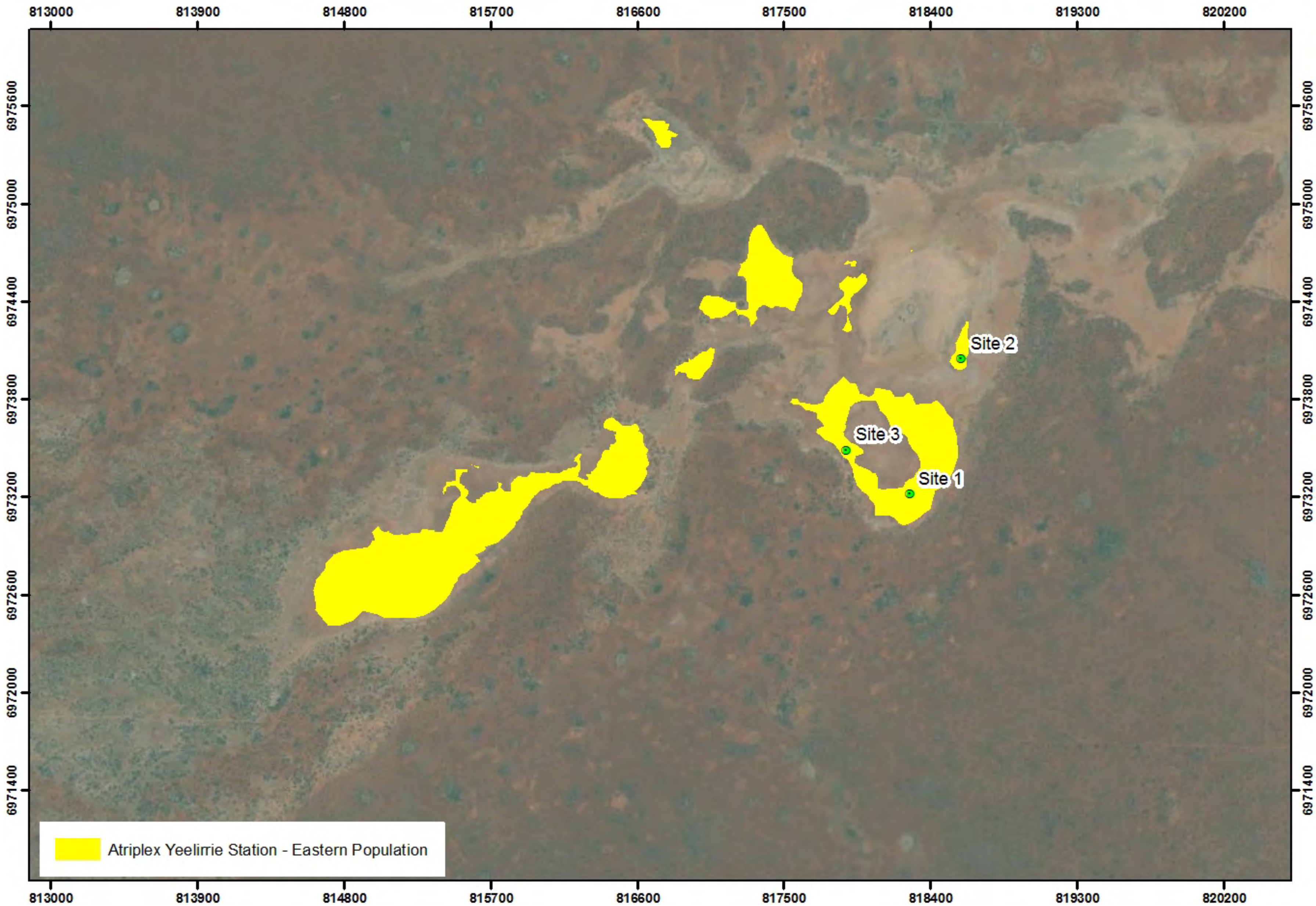
Trench	Coordinates (GDA 94)		Depth	Trench	Coordinates (GDA 94, Zone 50)		Depth
ID	Easting	Northing	(cm)	ID	Easting	Northing	(cm)
01	224,558	6,974,251	180	12	788,137	6,990,428	170
02	224,835	6,975,094	170	13	787,336	6,990,652	300
03	224,158	6,974,501	190	14	787,374	6,990,731	170
04	790,923	6,989,170	170	15	787,292	6,990,889	150
05	790,641	6,989,296	170	LM01	776,771	6,949,599	130
06	789,937	6,989,622	190	LM02	781,380	6,947,081	170
07	787,301	6,990,362	180	LM03	761,305	6,950,059	120
08	787,203	6,990,458	180	LM04	760,999	6,949,600	120
09	787,089	6,990,585	170	LM05	758,572	6,946,994	120
10	787,360	6,989,885	130	LM06	745,920	6,933,622	170
11	788,155	6,990,548	180				

All soil profiles assessed in the field were described in accordance with McDonald and Isbell (2009). Soil profiles were assessed for extent of horizonation, the nature of contacts between defined horizons, the presence and abundance of coarse fragments and mottling, and the structure, fabric and field texture of soil materials. In addition to this a semi-quantitative assessment of plant roots (abundance and structure; Table 2.2) was undertaken to assist in identifying soil characteristics, and approximate rooting depth and behaviour.

Plate 2.1: Excavation of investigation trenches

Table 2.2: Semi-quantitative assessment criteria used in the root investigation (McDonald and Isbell *et al.*, 2009)

Rating	Number of roots per 0.01 m2 (10 x 10 cm)	
	Very fine – fine roots (< 2 mm diameter)	Medium – coarse roots (> 2 mm diameter)
0 – No roots	0	0
1 – Few roots	1-10	1-2
2 – Common roots	10-25	2-5
3 – Many roots	25-200	>5
4 – Abundant roots	>200	>5



CAMECO AUSTRALIA PTY LTD	Figure 2.1: Location of investigation trenches – Eastern Population, showing soil trench locations
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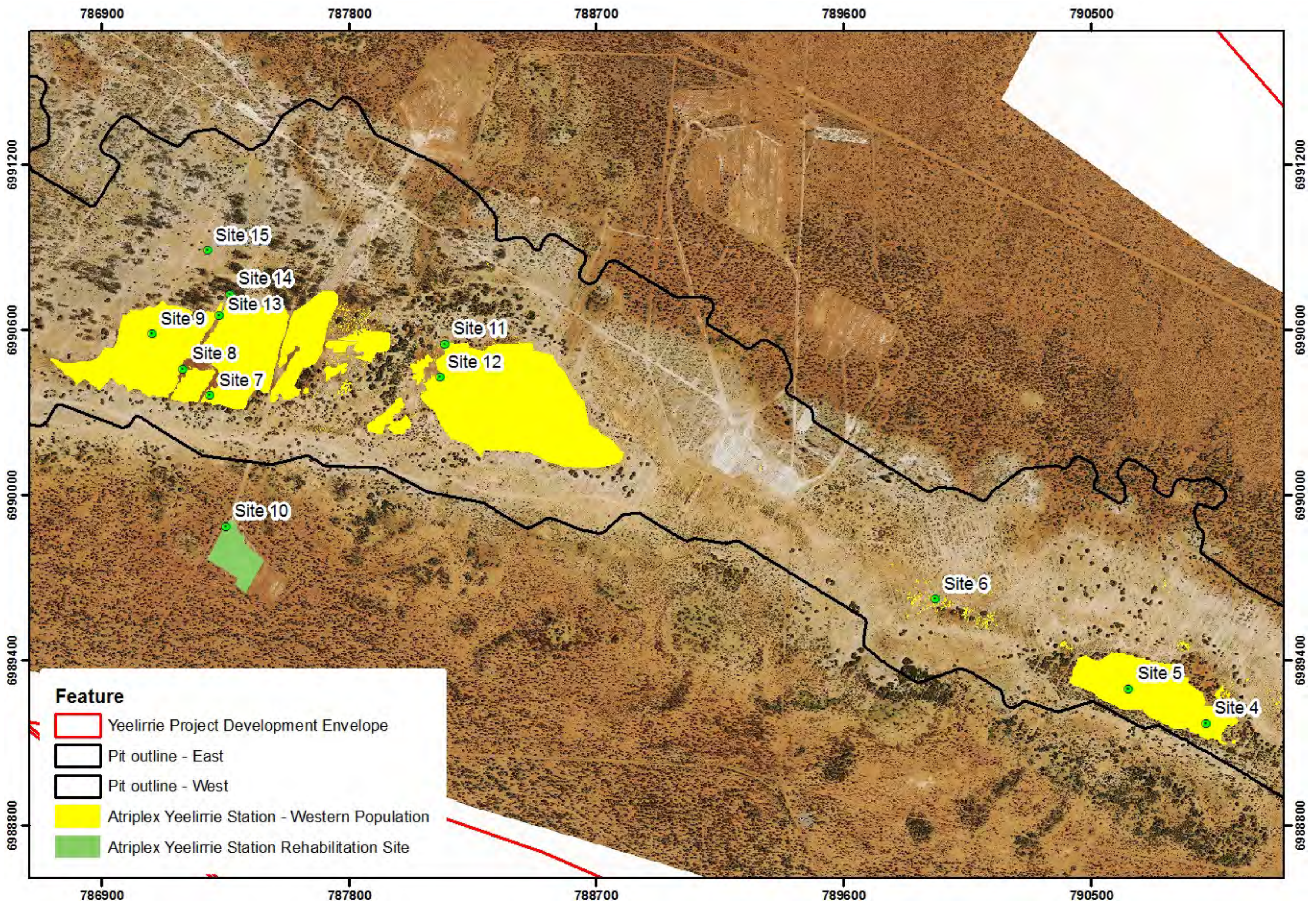

CAMECO AUSTRALIA PTY LTD	Figure 2.2: Location of investigation trenches – Western Population, showing soil trench locations	soilwater GROUP
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2.2 SELECTION OF POTENTIAL TRANSLOCATION SITES

A desktop assessment was carried out by Western Botanical and Cameco in consultation with SWC to define potential translocation areas. The desktop assessment utilised existing vegetation association information, land system mapping, satellite imagery sourced from Landsat and Aster false colour imagery sourced and interpreted by Cameco. Further information on the process followed during this desktop assessment is available in Western Botanical (2015b).

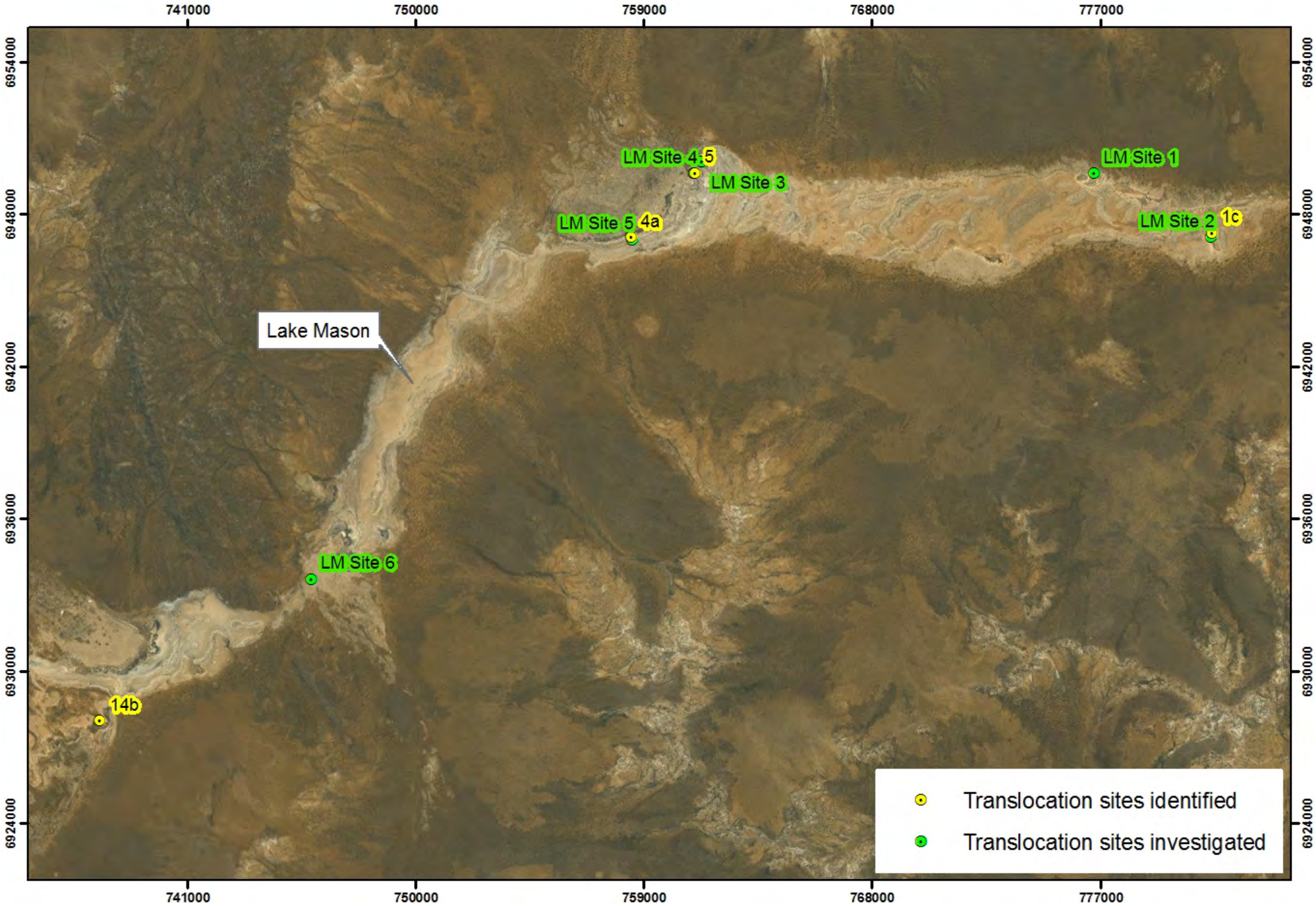
The following key characteristics were identified to determine potential translocation sites:

- Landscape and soil characteristics of potential site are similar to those present at the healthy natural populations of *Atriplex* sp. Yeelirrie Station;
- Land tenure of potential site is secure, either at Yeelirrie Station (Cameco management) or Lake Mason (DPaW management);
- Potential site is not inundated or waterlogged for prolonged periods of time;
- Species with conservation significance are not present at potential site which may be displaced by the introduction of *Atriplex* sp. Yeelirrie Station;
- Potential site is reasonably accessible

Using these criteria and the desktop assessment tools listed above, 22 target potential translocation sites surrounding Lake Mason were shortlisted which were deemed to meet the above key characteristics. At each of these sites, Western Botanical personnel conducted a site description consisting of: species present, fringing vegetation (if necessary), field measurements of soil pH and electrical conductivity (EC) (1:5 soil/H_2O) and soil colour and texture within the upper profile (maximum 40 cm depth).

Of the original list of 22 targets, two could not be accessed and 16 were rated as marginal or not suitable for translocation due to not meeting one or more of the assessment criteria listed above. Four of the sites were considered promising candidates for translocation warranting further investigation work. The data collected during this assessment was made available to SWC along with the recommendations made on site suitability. Using this information, it was determined that the four sites which were deemed promising would be investigated in more detail using the assessment techniques discussed in Section 2.1, along with other promising sites which may be identified. Figure 2.3 shows the four sites initially identified as possible translocation sites and the six sites which were investigated in further detail surrounding Lake Mason during this investigation.

Three of the sites identified; 1c, 5 and 4a, corresponding to investigation sites 2, 4 and 5 respectively (Figure 2.3), were able to be investigated in further detail. However, due to difficulties accessing site 14b with a backhoe, this site was not able to be investigated. A further three sites were chosen for further detailed investigation based on the desktop assessment and visual site assessment.



CAMECO AUSTRALIA PTY LTD	Figure 2.3: Location of identified and investigated potential translocation sites	soilwater GROUP
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2.3 LABORATORY ANALYSIS

The physical and chemical properties of the soil materials taken from the three identified study areas were assessed in laboratories based in Perth. Testing was undertaken on a representative number of samples which covered the range of distinct soil and overburden materials, with the analysis undertaken shown in Table 2.3. Analysis of the physical properties was undertaken at Soil Water Analysis (SWA) Laboratories, whilst the chemical properties were assessed at Chemcentre and Townend Mineralogy Laboratory (XRD analysis).

Table 2.3: Physical, chemical and mineralogical properties assessed

Physical Properties	Chemical Properties	Mineralogical Properties
Gravimetric moisture content	pH	Clay analysis (X-ray diffraction)
Bulk density	Electrical conductivity (salinity)	
Total porosity	Exchangeable cations (Ca, Mg, Na, K)	
Particle size distribution	Cation exchange capacity (CEC)	
Structural stability (Emerson test)	Sodicity (exchangeable sodium percentage- ESP)	
Water retention properties	Nutrients (NH4, NO3, P, K and S)	
Self-mulching characteristics	Trace nutrients (Mehlich suite)	

3 STUDY RESULTS

3.1 SUMMARY OF APPROACH

The data collected during the soil investigation is presented below. As discussed, the soil investigation covers three distinct areas;

- Eastern population of *Atriplex* sp. Yeelirrie Station
- Western population of *Atriplex* sp. Yeelirrie Station
- Lake Mason potential translocation sites

The Eastern and Western populations of *Atriplex* sp. Yeelirrie Station both occur within the central drainage axis of the upper reaches of the western arm of the Lake Carey palaeodrainage system valley. The communities appear to be restricted to low lying clay pan areas overlying the centrally occurring calcrete formations.

In addition to ensuring coverage over the three distinct areas, the siting of trench locations sought to provide insight into why *Atriplex* sp. Yeelirrie Station was present in certain areas and, when present, if soil conditions had any relation to the health of different areas of the population. Accordingly, targeted investigation of the Eastern and Western Populations was conducted seeking distinct areas where the *Atriplex* sp. Yeelirrie Station plants were healthy and unhealthy, and areas with similar geomorphic characteristics (i.e. clay pans) where the flora was not present. Table 3.1 below gives a summary of the underlying logic of each trench location.

Table 3.1: Summary characteristics of trench locations

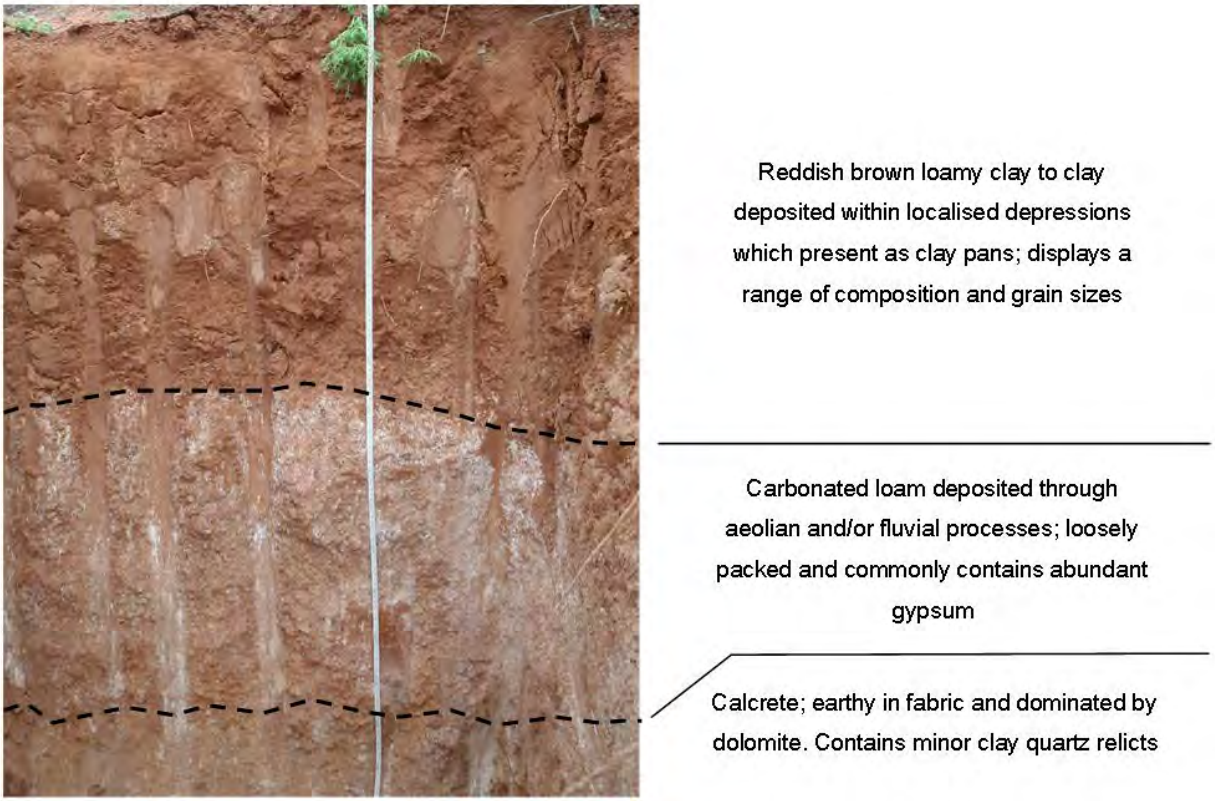
Trench ID	Within Clay Pan	Atriplex Present	Atriplex Healthy
1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	Yes	Yes	No
4	Yes	Yes	Yes
5	Yes	Yes	Yes
6	Yes	Yes	Yes
7	Yes	Yes	Yes
8	Yes	Yes	Yes
9	Yes	Yes	Yes
10	No*	Yes	No
11	No †	No	-
12	Yes	No	-
13	No †	Yes	Yes
14	No	No	-
15	No	No	-

*Rehabilitation area; † Clay pan fringe

3.2 SOIL PROFILE

The Eastern and Western populations both occur within areas experiencing similar geomorphic processes and have therefore developed comparable soil profiles. Both population areas are underlain by calcrete formations at shallow depths which have developed within the upper layers of the sediments (Quaternary aged) which have partially filled the palaeodrainage valley. The trench investigation work within the low lying clay pan areas uncovered a uniformly consistent soil profile comprising of a variable depth of reddish brown non-cracking clays (typically 0.3 to 0.6 m in depth) overlying a friable, calcareous loam typically 1 m in depth often containing gypsum rich horizons which in turn overlies the calcrete formation. A representative photo of the typical profile encountered within the low lying clay pan areas is shown in Plate 3.1 (Trench 9).

Plate 3.1: Typical soil profile encountered in clay pan areas



There is an abrupt boundary between the clay material and the underlying calcareous loam (Plate 3.2), indicating a break in the depositional record, and the transported nature of the clay. The calcareous loam has also been transported from upstream through primarily alluvial and fluvial processes, and together these units form the uppermost layers of the Cainozoic alluvium which comprise the most recent valley fill material associated with the palaeodrainage valley. The underlying calcrete has developed (and is still developing) within the lower portions of these recent sediment formations. Calcrete formation has occurred through the mobilisation of upstream carbonate minerals through chemical weathering which have then been transported and precipitated downstream. The dissolution of these upstream minerals follows the introduction of carbon dioxide from rainwater to the groundwater system which acts to lower pH and increase carbonate mineral solubility. These minerals then replace and/or displace portions of the in situ alluvial and colluvial successions in downstream areas.

Plate 3.2: Abrupt boundary between clay and calcareous loam soil units

The soil profiles encountered during the investigation of potential translocation sites surrounding Lake Mason were varied and each profile is presented and described in Appendix A.

The major soil material units which were encountered across the *Atriplex* sp. Yeelirrie Station population areas (both eastern and western) can be grouped into the following three categories;

- Upper clay material which forms the clay pans;
- Calcareous loam and;
- Underlying calcrete

3.3 ATRIPLEX DISTRIBUTION & ROOTING BEHAVIOUR

During the field survey it was noted that the *Atriplex* sp. Yeelirrie Station communities occupied a distinct topographic position within the landscape. The clay pan areas contained distinct areas which were raised above the surrounding clay pan surface approximately 10 – 20 cm, and it was on these areas that the plant species were almost invariably found (Plate 3.3). This suggests that a link between an observed preferred elevated topographical position (relative to the surrounding flat clay pan) of the individual plants and surface water interaction exists, whereby periodic inundation is avoided or minimised.

The investigation of rooting behaviour of the *Atriplex* sp. Yeelirrie Station has shown the majority of root exploration to be limited to the upper clay horizon, with large lateral roots confined to this area. Root structure was generally found to consist of a 20-30 cm vertical root structure extending from the stem, with the larger root structures then extending laterally (Plate 3.4). Finer roots (< 2 mm diameter) were seen to exploit the underlying calcareous loam in some of the locations investigated, however root extension was not noted to occur into the calcrete layer or below an approximate depth of 1.2 – 1.5 m, and root exploration is considered unlikely to encompass the underlying calcrete formation. With this in mind, sampling and detailed analysis of the soil materials collected during this investigation concentrated on the upper two soil units identified (i.e. clay and calcareous loam). The *Atriplex* sp. Yeelirrie Station can therefore be considered as shallow rooting and heavily reliant on wetting of the surficial soils to abstract sufficient moisture to meet their transpiration requirements. This shallow rooted behaviour also suggests that this species has specialised morphological adaptions that allow it to survive during the long hot summer period.

Investigation of the rooting behaviour of *Atriplex sp*. Yeelirrie Station was also carried out within the rehabilitation site (Site 10). The behaviour of the roots exposed during excavation at this site was similar to those recorded at the natural sites with a vertical root structure extending down approximately 25 cm into the soil profile with large lateral roots then extending outwards from here. Fine roots continued to explore the deeper profile soil material, which in the case of the rehabilitation site consisted of highly weathered blocky sedimentary material (see Appendix A).

Plate 3.3: Distinct raised areas where *Atriplex* sp. Yeelirrie Station are present

Plate 3.4: Root structure of *Atriplex* sp. Yeelirrie Station

3.4 PARTICLE SIZE DISTRIBUTION

A total of 35 samples were tested for particle size distribution (PSD) to determine their respective sand, silt and clay contents. Table 3.2 summarises the results of PSD testing by displaying the average and standard deviation of the two data sets received for the clay and loam samples taken from the trenches located in the Eastern and Western population areas (i.e. within clay pan areas). The data shows that the clay percentage of the clay occurring in the clay pans of the Western sub population (trenches 7, 8, 9 and 12) are significantly higher than those recorded for the other population areas. These trenches were also notable for the low variance within the material PSD data sets, which reflect their position within a contiguous clay pan area which would experience isolated surface water conditions during all but the largest rainfall events.

In contrast, the materials collected within the Eastern sub population of the Western Population (trenches 4, 5 and 6), and to a lesser degree the Eastern Population display PSD data sets with high standard deviations, reflecting the more variable geomorphic conditions which prevail over these areas.

The abrupt boundary seen within the profiles across all areas investigated can be seen within the PSD data, with both material types containing distinct particle size distribution curves, illustrating the difference in physical make-up of the materials.

Table 3.2: Average PSD (and Standard Deviation; Std. Dev) data for clay pan materials

Location	Soil unit	Sand (Std. Dev.) %	Silt (Std. Dev.) %	Clay (Std. Dev.) %
Eastern Population	Clay	46.6 (7.9)	12.3 (5.6)	41.1 (12.4)
	Loam	83.3 (2.9)	5.6 (2.3)	11.1 (0.6)
Western Population (Eastern sub pop.)	Clay	53.7 (8.5)	12.6 (11.5)	33.7 (2.6)
	Loam	74.4 (26.7)	11.5 (8.8)	14.1 (18.1)
Western Population (Western sub pop.)	Clay	31 (2.4)	5.9 (0.2)	63.1 (2.2)
	Loam	81.5 (4.2)	14.4 (1.1)	4.1 (5.3)

Those areas sampled which exist outside of the clay pan areas but adjacent to the *Atriplex* sp. Yeelirrie Station population areas (trenches 11, 14 and 15) displayed a similar profile, however the clay pan material was replaced by a loamy sand material. The calcareous loam continues to underlie the upper soil profile materials and displays similar PSD values as shown within Table 3.2. This difference in the upper profile is due to the elevated position (relative to the clay pans) of these areas, which will not experience regular inundation during rainfall events. Surface water which has interacted with these areas will generally have too high an energy content and / or too brief resident times for settling of appreciable clay content from suspended solids to occur.

3.5 CLAY MINERALOGY

The clay mineralogy of 6 clay samples was analysed using semi-quantitative XRD analysis (Townend, 2015). The results of mineralogical testing is shown in Table 3.3.

Table 3.3: Semi quantitative XRD analysis

Mineral	Eastern Pop. Clay	Western Pop. (East sub pop.) clay	Western Pop. (West sub pop.) clay	Western Pop. (West sub pop.) clay	Lake Mason Site 5 clay	Lake Mason Site 6 clay
Smectite	major	major	major	major	major	major
Kaolinite	major	major	minor	major	minor	minor
Mica	trace	accessory	trace	trace	trace	trace
Goethite	accessory	accessory	accessory	accessory	accessory	accessory
Hematite	n.d.	n.d.	n.d.	n.d.	n.d.	trace
Quartz	major	major	major	major	major	major
K-feldspar	accessory	accessory	accessory	accessory	accessory	accessory
Ti Oxides	accessory	accessory	accessory	accessory	accessory	accessory
Calcite	minor	trace	trace	trace	major	accessory
Gypsum	n.d.	n.d.	n.d.	accessory	n.d.	n.d.
Bassanite	n.d.	n.d.	n.d.	n.d.	major	n.d.

Note: Dominant (>50%), Major (21-50%), Minor (11-20%), Accessory (1-10%), Trace (<1%).

There was no apparent difference in mineralogy between the various soils in the clay pan, and all were dominated by Quartz and Kaolinite, with major-minor Smectite, trace mica and calcite and accessory iron oxides (goethite and hematite).

3.6 AGGREGATION BEHAVIOUR OF CLAYS

Previous reports have variously classified the surficial clay material which exists in the clay pan areas at Yeelirrie (both the Eastern and Western Population areas) as 'Self-mulching' and / or cracking clays. The classification of self-mulching behaviour in soil science and the broader literature has historically been used to describe the tendency of specific heavy clay soils to a form loose granular mulch of fine aggregates at the soil surface after wetting and drying (Soil Survey Staff, 1960), generally in an agricultural setting. This loose granular mulch is often confused with desiccation cracks that form on the surface of a clay pan after wetting and drying; hence, the clays associated with the *Atriplex* sp. Yeelirrie Station have been previously described as Self-mulching.

In order to provide a more rigorous assessment and classification process, Grant and Blackmore (1991) developed a simplified quantitative methodology, and subsequent numerical index, for identifying and classifying Self-mulching behaviour in soils. This methodology was applied to four representative surface (i.e. 0 – 5 cm) clay soils from identified *Atriplex* sp. Yeelirrie Station areas and areas where no *Atriplex* sp. Yeelirrie Station were present. Details of the sites/soils investigated are presented in Table 3.4.

Table 3.4: Sites investigated for Self-mulching behaviour

Site ID	General Location	Soil Depth (cm)	Location relative to *Atriplex* sp. Yeelirrie Station
Trench 2	Eastern pop.	5	Adjacent to
Trench 5	Western pop (eastern sub pop.	5	Adjacent to
Trench 8	Western pop (western sub pop.	5	Adjacent to
Trench 12	Western pop (western sub pop.	5	Away from

The results of this laboratory classification testing are provided in Table 3.5. They show that the surface soils present at Trench locations 2 and 5 release appreciably less clay following slaking than in the corresponding 'Puddled' condition, compared to the surface soils from Trenches 8 and 12, which release more clay following slaking. These results indicate that the surface clays in Trenches 2 and 5 have some inherent micro-structural stability, resulting in them re-aggregating, whereas the corresponding soils at Trench locations 8 and 12 don't; hence the clays remain dispersed.

The derived index $(S/P)^{-1}$ indicates that whilst the clays at Trench locations 2 and 5 do exhibit some Self-mulching tendencies, they are well below the $(S/P)^{-1}$ criteria of 10, which is used to classify Self-mulching behaviour according to Grant and Blackmore (1991). Based on these results it is clear that the association previously held between the distribution of *Atriplex* sp. Yeelirrie Station and Self-mulching clays is incorrect.

Table 3.5: Laboratory results for the Self-mulching classification testing

Condition	Site ID	Particle size (%)			Texture	$(S/P)^{-1}$
		Sand	Silt	Clay		
'Slaked' (S)	T2	69.8	7.7	22.5	Sandy clay loam	1.56
	T5	54.5	15.0	30.5	Clay loam	1.58
	T8	33.7	5.6	60.7	Clay	0.58
	T12	36.0	4.1	59.9	Clay	0.54
'Puddled' (P)	T2	50.3	14.6	35.1	Clay	

Condition	Site ID	Particle size (%)			Texture	$(S/P)^{-1}$
	T5	33.3	18.5	48.2	Clay	
	T8	53.1	11.5	35.4	Clay	
	T12	58.5	9.3	32.2	Clay	

3.7 SALINITY (EC)

Depth profiles of the salinity occurring within the materials at the various investigation locations are provided in Appendix A. A comparison of the different salinity values obtained from the two material types within different environments is shown in Table 3.6. The results show that they upper clay material generally records higher salinity levels than the underlying loam material. This is to be expected due to the exposed nature of the clay which experiences periodic inundation and high pan evaporation radiation, resulting in a build-up or evaporative-concentration of salt.

The comparison of material between different sampling areas shows that in general there are no significant differences between material type *in situ* salinities based on environmental locations (e.g. loam). The exception to this are the salinities measured from the upper clay material in locations where *Atriplex* sp. Yeelirrie Station are performing poorly. Clay material from these areas recorded an average electrical conductivity (EC) of 1,676 mS/m, compared with an average EC of 520 mS/m for areas where the plant species were healthy. This suggests that salinity is likely to be a factor in the distribution of the species. The level of salinity reported within material occurring in those areas containing healthy *Atriplex* sp. Yeelirrie Station species indicates a moderate salt tolerance.

In Section 3.3 it was noted that the plant species were observed to prefer slightly elevated positions in the clay pan landscape. A comparison between the salinity of the soils within these rises (Trench 9) and the adjacent clay pan surface (Trench 7) material showed that an apparent correlation exists between *Atriplex* sp. Yeelirrie Station occurrence on these rises and significantly lower salinity in comparison to the surrounding clay pan areas. This is likely the result of increased leaching of salts occurring in the elevated clay material (given their elevated position) in comparison to the surrounding clay pan which is likely to experience more frequent inundation events and therefore higher rates of salt deposition.

Table 3.6: Average salinity values of clay and loam materials

Environment	Mean (mS/m)	Median (mS/m)	High (mS/m)	Low (mS/m)
Clay (Atriplex performing well)	520	331.5	1,874	12.82
Clay (Atriplex performing poorly)	1,676	1,591	2,605	918
Clay (no Atriplex present)	577	535.2	1,135	102
Loam (Atriplex performing well)	511	505	1,122	10.31
Loam (Atriplex performing poorly)	693	709	793	517
Loam (no Atriplex present)	926	933	1,133	712
Upper profile material	151	109	416	44.9

Environment	Mean (mS/m)	Median (mS/m)	High (mS/m)	Low (mS/m)
(outside clay pan area)				
Loam (outside clay pan area)	546	562	683	278

The salinity values found within the profiles investigated at the potential translocation sites at Lake Mason were quite variable (Appendix A). Sites 1 and 3 contained high salinity values in the upper profile material, comparable to the average range found in those areas where *Atriplex* sp. Yeelirrie Station was performing poorly. In contrast, Sites 2, 5 and 6 contained salinity profiles akin to those measured in areas where the *Atriplex* sp. Yeelirrie Station was performing well. These sites showed low to moderate salinity values in the upper profile material (ranging from 111 to 824 mS/m with an average of 486 mS/m in the upper 20 cm). All five of the profiles showed gradual decreases in salinity with increasing depth within the profile. The fourth Site investigated at Lake Mason was found to be non-saline, with EC values < 20 mS/m across the entire sampled profile.

3.8 SOIL PH

Depth profiles of the salinity occurring within the materials at the various investigation locations are provided in Appendix A, whilst a comparison of the different soil pH values obtained from the two material types within different environments is shown in Table 3.7. The results show all materials to vary in pH from slightly alkaline to alkaline (7.7 to 9.6) reflecting the prevalence of calcium carbonate minerals within the profile. The data set shows no indication of significant variation in pH when comparing material types taken from different environments, with both clay and loam material pH values from areas with poorly and well performing *Atriplex* sp. Yeelirrie Station communities overlapping and having average values within half a pH unit.

Table 3.7: Average pH values of clay and loam materials

Environment	Mean	Median	High	Low
Clay (Atriplex performing well)	8.5	8.44	9.6	7.72
Clay (Atriplex performing poorly)	8.1	8.1	8.51	7.71
Clay (no Atriplex present)	8.9	8.98	9.43	8.41
Loam (Atriplex performing well)	8.4	8.33	9.56	7.75
Loam (Atriplex performing poorly)	8.3	8.26	8.8	8.21
Loam (no Atriplex present)	8.5	8.49	8.84	8.31
Clay (outside clay pan area)	9.0	9.08	9.57	8.31
Loam (outside clay pan area)	8.3	8.24	8.77	8.12

The pH values at the potential translocation sites were consistently alkaline, with all recorded samples taken from the various profiles falling between the pH values of 8 and 9.5. These values are consistent with those seen at the Yeelirrie investigation locations and indicate that the prevailing pH at the Lake Mason sites will not limit their capability to function as potential translocation sites

3.9 WATER RETENTION PROPERTIES

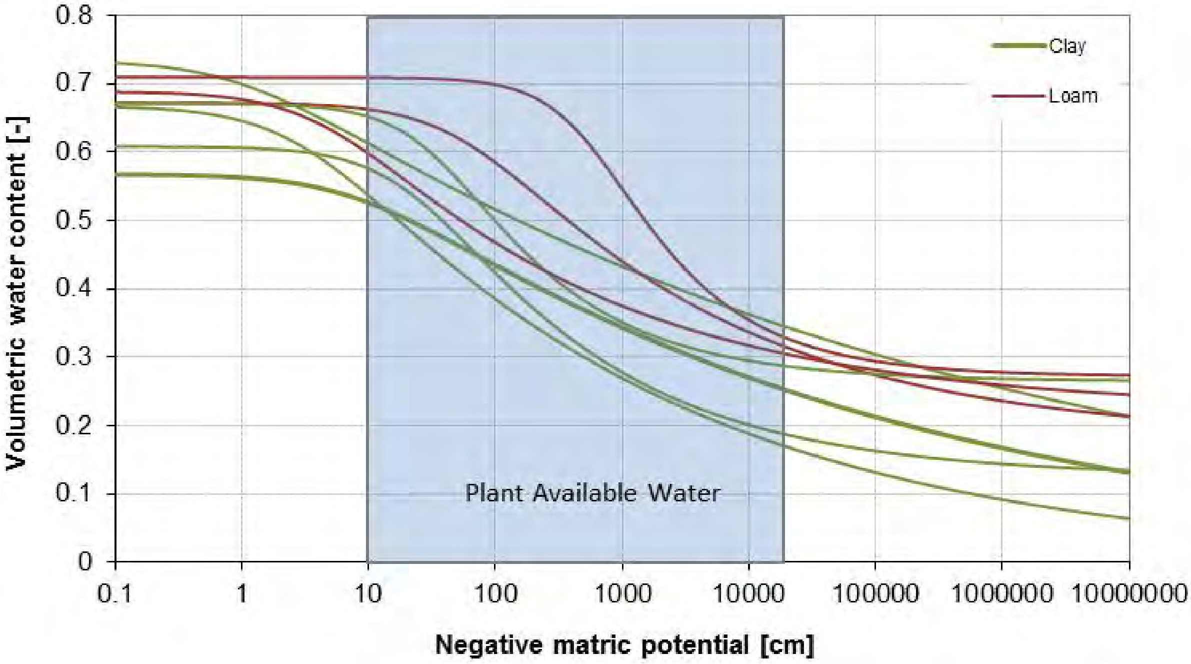
The water retention properties of selected clay and loam materials were tested using pressure plates. Each sample was allowed to saturate to field capacity and then subjected to a series of constant pressures over a period of three weeks. The samples were then weighed to determine the water content remaining and the points used to create a water retention curve, allowing calculation of the plant available water (PAW) content and knowledge of the hydraulic characteristics (i.e. hydraulic conductivity). Plant available water contents for the profile intervals tested, along with moisture contents at the time of sampling are shown as depth profiles in Appendix A. The profiles within areas where *Atriplex* sp. Yeelirrie Station are present show that moisture content in the majority of cases was sitting at permanent wilting point (PWP; 1500 kPa) recognised as the maximum matric suction which plant roots can exert to extract water. This level indicates that moisture contents which exist within the soil pores 'below' this level require greater suction to extract than plant roots can exert, and this water is therefore unavailable for use by plants.

This result is unexpected given the high rainfall which was experienced directly prior to the field work. The moisture profiles show that the upper portions of the profile (upper 20 cm) are extremely dry, generally well below PWP, indicating that solar evaporation has removed the majority of water from this upper layer however the effect appears to be limited to this surficial layer (at this time). One possible explanation is that the plants have already acted to utilise all the available moisture which would have infiltrated the upper profile since the rainfall event, a period of only a handful of days. If this is the case, the water use reflects the plants to have a very high level of efficiency.

Those profiles investigated in areas outside of the *Atriplex* sp. Yeelirrie Station communities (trenches 13, 14 and 15) show moisture contents to be slightly above the measured PWP. This suggests that either these areas have better infiltration rates (reflecting the sandier upper profile materials) and therefore have lost less water to evaporation, or the competition for water in the upper profile is not as fierce.

Figure 3.1 shows a comparison of the water retention curves obtained from clay material with loam material within the clay pan areas. The results show that in general the materials display similar water retention characteristics, except one loam material which showed appreciably higher PAW content (upper line in PAW section) the two materials both displayed comparable PAW contents of approximately 20%. The significance of the water retention curves is only seen when viewing the PWP (-15,000 cm) of the various material curves. All of the materials had a PWP at or above 20% moisture, which shows that the profiles will have a significant proportion of their overall water which is not able to be accessed for use by the plants which have developed root structures within each material type. This further emphasises the need for the *Atriplex* sp. Yeelirrie Station to rely on frequent wetting of the surface soils, and thus the importance of inundation of the surface, without inundating the plant itself (i.e. the need for the raised beds; Section 17).

Figure 3.1: Comparison of PAW contents between clay and loam material



3.10 NUTRIENTS

3.10.1 MACRO-NUTRIENTS

The macro-nutrient content of the dominant soil materials within the *Atriplex* sp. Yeelirrie Station populations and those at the proposed Lake Mason translocation sites is provided in Table 3.8. The results show that no significant discernable difference in macro-nutritional quality or content exists between the clay pan soils materials at Yeelirrie and those investigated at Lake Mason. All clay pan soils were reported to contain low levels of Total N, Total P and Colwell P, but have elevated levels of Total and Colwell K and all sulfur species. These higher levels, particularly with respect to the higher potassium content, reflect the sediment parent material (surrounding granite uplands) mineralogy.

Table 3.8: Macro-nutrient content of the dominant soils within the *Atriplex* sp. Yeelirrie Station populations and the proposed Lake Mason translocation sites (all values in mg/kg unless specified)

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Yeelirrie *Atriplex* sp. Population Sites									
Total N (%)	0.018	0.044	0.077	0.012	0.021	0.039	0.016	0.021	0.027
Total P	89	174	300	43	68	89	54	143	250
Colwell P	2	10	21	4	5	6	2	5	6
Total K	2,300	4,790	9,300	500	1,650	3,500	2,500	6,380	11,000
Colwell K	410	1,510	3,300	150	527	1,200	1,000	1,640	2,600
Total S	110	3,138	25,000	92	33,511	100,000	520	24,524	85,000
KCl ext. S	4	717	4,000	32	2,167	6,300	320	3,224	7,200
Lake Mason Sites									
Total N (%)	0.009	0.013	0.017	0.021	0.040	0.070	-	0.017	-

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Total P	120	187	310	80	138	240	-	230	-
Colwell P	17	22	25	5	8	15	-	7	-
Total K	1,200	2,633	4,300	1,400	2,150	4,000	-	4,700	-
Colwell K	580	1,093	1,500	240	473	740	-	1,400	-
Total S	970	34,990	54,000	1,400	38,500	77,000	-	26,000	-
KCl ext. S	140	4,113	7,100	14	3,401	6,800	-	3,000	-

3.10.2 Trace-Elements (Mehlich Suite)

The trace element content of the dominant soil materials within the *Atriplex* sp. Yeelirrie Station populations and those at the proposed Lake Mason translocation sites are provided in Table 3.9. Similar to the comparison conducted between the measured macro-nutrients, there are no significant discernable differences between the trace element contents of the clay pan soils sampled at Yeelirrie within the *Atriplex* sp. Yeelirrie Station communities and at the potential translocation sites surrounding Lake Mason. Trace element concentration is therefore considered unlikely to be a limiting factor in the observed distribution of *Atriplex* sp. Yeelirrie Station or the potential for translocation of the *Atriplex* sp. Yeelirrie Station to the investigated Lake Mason sites.

Table 3.9: Trace-element (Mehlich suite) content of the dominant soils within the *Atriplex* sp. Yeelirrie Station populations and the proposed Lake Mason translocation sites (all values in mg/kg unless specified)

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Atriplex sp. Yeelirrie Station Population Sites									
Al	12	348	>550	270	360	480	10	266	>550
As	0.2	0.4	0.7	0.1	0.8	1.7	0.7	1.1	2.1
B	1.3	46	100	1	4.4	6.6	7.0	56	100
Ca	4600	>5,500	>5,500	2,200	4,400	>5,500	5,500	5,500	>5,500
Cd	0.005	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Co	0.03	0.31	0.91	0.18	0.51	0.99	0.05	0.31	0.77
Cu	0.05	0.2	0.5	0.1	0.2	0.4	0.1	0.2	0.3
Fe	3	64	120	34	52	62	16	61	110
K	380	511	>550	59	283	>550	550	550	>550
Mg	500	500	500	500	643	930	500	500	500
Mn	2.8	29	74	3	23	33	1	18	38
Mo	0.005	0.04	0.15	0.01	0.01	0.02	0.01	0.13	0.30
Na	7	552	>1,000	29	347	960	240	810	>5,500
Ni	0.2	0.4	0.6	0.3	0.3	0.4	0.2	0.3	0.3
P	4	18	48	3	4	6	4	13	30
Pb	0.5	1.2	1.8	0.5	0.9	1.3	0.4	1.4	2.1
S	12	90	160	30	157	>250	250	0	>250
Se	0.1	0.3	0.6	0.1	0.1	0.2	0.1	0.2	0.3

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Zn	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.1	0.2
Lake Mason Sites									
Al	210	437	>550	8	211	480	-	480	-
As	0.1	0.3	0.7	0.1	0.7	1.3	-	0.3	-
B	14	71	100	3	28	100	-	44	-
Ca	5500	>5,500	>5,500	>5,500	>5,500	>5,500	-	>5500	-
Cd	0.005	0.01	0.01	0.01	0.02	0.06	-	<0.01	-
Co	0.06	0.13	0.24	0.04	0.10	0.16	-	0.13	-
Cu	0.1	0.2	0.3	0.1	0.1	0.1	-	0.2	-
Fe	96	149	180	3	75	200	-	49	-
K	500	533	>550	210	385	>550	-	>550	-
Mg	500	500	500	350	463	500	-	500	-
Mn	6.4	12	17	1	4.7	8.9	-	8.5	-
Mo	0.005	0.07	0.12	0.01	0.02	0.06	-	0.02	-
Na	1000	>1,000	>1,000	240	810	>1,000	-	>1,000	-
Ni	0.4	0.4	0.4	0.1	0.2	0.4	-	0.3	-
P	13	24	29	7	11	13	-	12	-
Pb	1.1	1.2	1.3	0.5	1.2	1.8	-	1.4	-
S	125	130	140	76	113	125	-	125	-
Se	0.05	0.2	0.4	0.1	0.1	0.2	-	0.2	-
Zn	0.1	0.1	0.1	0.1	0.1	0.2	-	<0.1	-

3.11 MULTI-ELEMENT COMPOSITION

The multi-element composition of the dominant soil materials within the *Atriplex* sp. Yeelirrie Station populations and those at the proposed Lake Mason translocation sites is provided in Table 3.10. This data shows that in general there is little difference between the clay and loam materials sampled from the Yeelirrie Sites and those sampled from the Lake Mason Sites. The sodium contents from the Lake Mason Sites were consistently higher when compared to those from the Yeelirrie Site. This is likely a reflection of the siting of the sites at Lake Mason, which are all located within or on the fringes of a an active salt lake system, whereas the Yeelirrie sites are located within a more complicated drainage focus area made up of a series of interlinking clay pans and playas. When comparing the contents of the other elements tested there is no significant statistical difference in composition between material types taken from the two locations.

Table 3.10: Multi-element composition of the dominant soils within the *Atriplex* sp. Yeelirrie Station populations and the proposed Lake Mason translocation sites (all values in mg/kg unless specified)

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Atriplex sp. Yeelirrie Station Population Sites									
Al	16800	40,240	69,800	6,770	16,723	27,600	13,000	41,200	69,800
As	4	7	11	1	5	8	8	12	16

Element	Clay			Loam			Calcareous Loam		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
B	36	125	250	14	30	41	83	147	260
Ba	49	70	160	15	23	30	19	43	57
Ca	5100	34,710	88,000	6,600	50,867	130,000	17,000	59,200	160,000
Cd	0.025	<0.05	<0.05	0.025	<0.05	<0.05	0.025	<0.05	<0.05
Co	5.8	7.2	8.7	2.1	7.1	12.0	3.7	6.7	8.6
Cr	30	53	71	9	32	46	14	46	70
Cu	7.6	14	22	4	6.6	9.7	5.8	13	21
Fe	9900	21,790	34,000	3,600	10,533	16,000	6,300	20,460	34,000
Mg	40000	61,200	84,000	9,200	24,400	48,000	28,000	51,200	67,000
Mn	88	255	410	38	98	160	57	199	350
Mo	0.25	1.0	2.4	0.3	0.3	0.5	0.6	1.1	1.8
Na	150	5,670	28,000	140	513	1,200	640	5,448	11,000
Ni	9	15	23	3	7	11	5	14	23
Pb	2.3	4.5	8.1	2.1	2.9	3.5	1.5	4.7	7.9
V	66	89	110	39	55	71	64	100	150
Zn	16	38	61	6	14	24	11	33	56
Lake Mason Sites									
Al	17500	29,900	49,200	12,500	23,100	36,300	-	42,400	-
As	2	3	4	3	8	14	-	5	-
B	81	244	370	24	133	330	-	120	-
Ba	26	39	61	21	30	48	-	68	-
Ca	10000	54,000	92,000	31,000	88,250	130,000	-	72,000	-
Cd	0.025	<0.05	<0.05	0.025	<0.05	<0.05	-	<0.05	-
Co	3.1	5.9	11.0	3.8	6.0	8.5	-	9.4	-
Cr	35	57	100	16	41	56	-	87	-
Cu	7.9	14	27	7	12	20	-	23	-
Fe	11000	20,000	36,000	7,100	14,775	22,000	-	29,000	-
Mg	75000	77,333	81,000	12,000	43,750	89,000	-	71,000	-
Mn	130	243	420	42	123	180	-	340	-
Mo	0.25	0.6	1.0	0.3	0.3	0.3	-	0.9	-
Na	4000	10,633	20,000	730	3,633	6,700	-	17,000	-
Ni	8	17	33	6	10	16	-	26	-
Pb	1.4	2.6	4.1	1.7	3.7	7.1	-	3.0	-
V	31	62	83	27	96	220	-	80	-
Zn	16	31	55	12	22	36	-	45	-

4 CONCLUSIONS AND RECOMMENDATIONS

The soil profile within the clay pans supporting the *Atriplex* sp. Yeelirrie Station within both the Eastern and Western Populations were investigated to provide baseline information on the ecophysiological function and requirements of the *Atriplex* sp. Yeelirrie Station. This information could then be used to identify potential translocation receptor sites to offset impacts in response to mining of the Yeelirrie Uranium Project. The results from this work showed that within the clay pans, in the Yeelirrie Paleodrainage System, little variation in soil properties occurred, and thus the apparent distribution of *Atriplex* sp. Yeelirrie Station within these areas is likely to be influenced by other factors. From careful examination of the micro-topographic location of the *Atriplex* sp. Yeelirrie Station plants, it is clear that they cannot tolerate inundation, and thus must occupy slight rises in the clay pan surface to remain ‘dry’ when the clay pan proper is inundated. This susceptibility to water logging is likely to be the key driver influencing the presence/absence of *Atriplex* sp. Yeelirrie Station. A broad salinity tolerance was identified within the surface soils, and an EC value of around 500 mS/m was identified as optimal; however, it could tolerate a maximum salinity of 1,000 mS/m, albeit at a potential cost to the health of the plant.

Using the knowledge gained from the detailed investigation of the soil profile and geomorphology of the areas where *Atriplex* sp. Yeelirrie Station is present an assessment of the suitability in regards to the existing soil profile and surrounding geomorphology of the potential translocation sites identified was completed. In addition, several new sites were identified based on knowledge gained during the investigation process which appear to possess similar characteristics to the optimal sites investigated and warrant further investigation as to their suitability for use as translocation sites. Table 4.1 summarises this assessment and also provides an estimate of the total land area available at each of the sites.

Table 4.1: Potential translocation sites suitability and area

Site	Area (ha)	% of Yeelirrie Western Population
Optimal sites		
LM Site 4	11.64	15.3
LM Site 5	8.97	11.8
LM Site 6	3.72	4.9
Sub-optimal sites		
LM Site 1	13.59	17.9
LM Site 2	6.29	9.3
LM Site 3	3.37	4.4
Other potential sites	59.39	78.1
Total	106.97	140.8

The information gathered during this investigation should be added as further criteria to the list of criteria that was previously developed during initial studies to delineate potential translocation sites. This will help to further refine the boundary conditions which are needed to be displayed by a potential site to provide confidence in the likelihood of successful translocation.

5 REFERENCES

Grant, C. D., Blackmore, A.V., (1991) Self-Mulching Behaviour in Clay Soils: Its Definition and Measurement. *Australian Journal of Soil Research*, 29, 155-173.

McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S. (2009) *Australian Soil and Land Survey Field handbook, 3rd edition*. Inkata Press. Melbourne.

Soil Survey Staff (1960) *Soil Classification. A Comprehensive System (7th approximation). Soil Conservation Service, U.S.* Department of Agriculture, Washington, D.C.

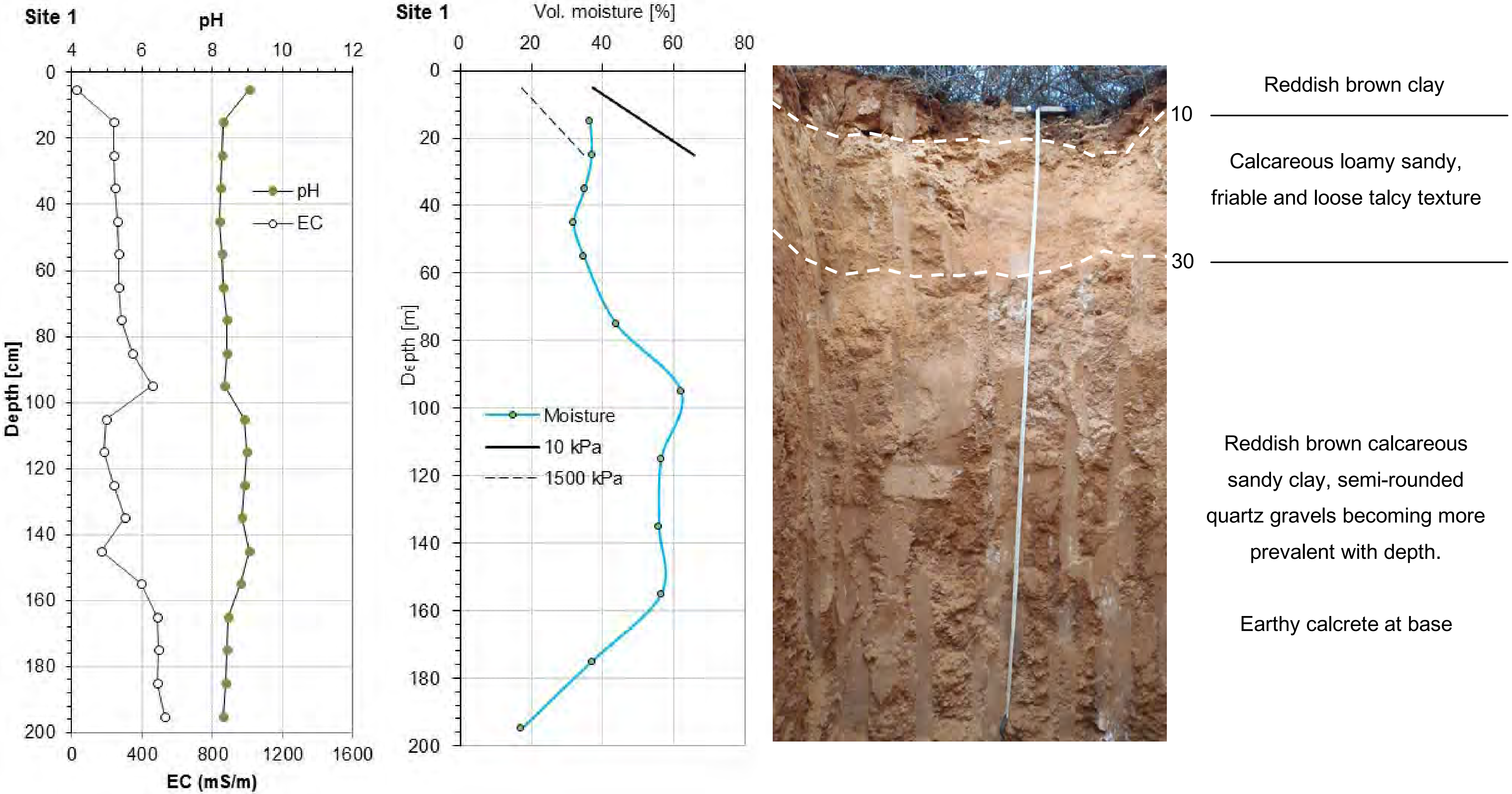
Western Botanical (2011) *Yeelirrie Project Flora and Vegetation Survey Baseline Report*. Consultant report for Cameco Australia.

Western Botanical (2015a) *Population & Demography Study (Phase 1) of Atriplex sp. Yeelirrie Station*. Consultant report for Cameco Australia.

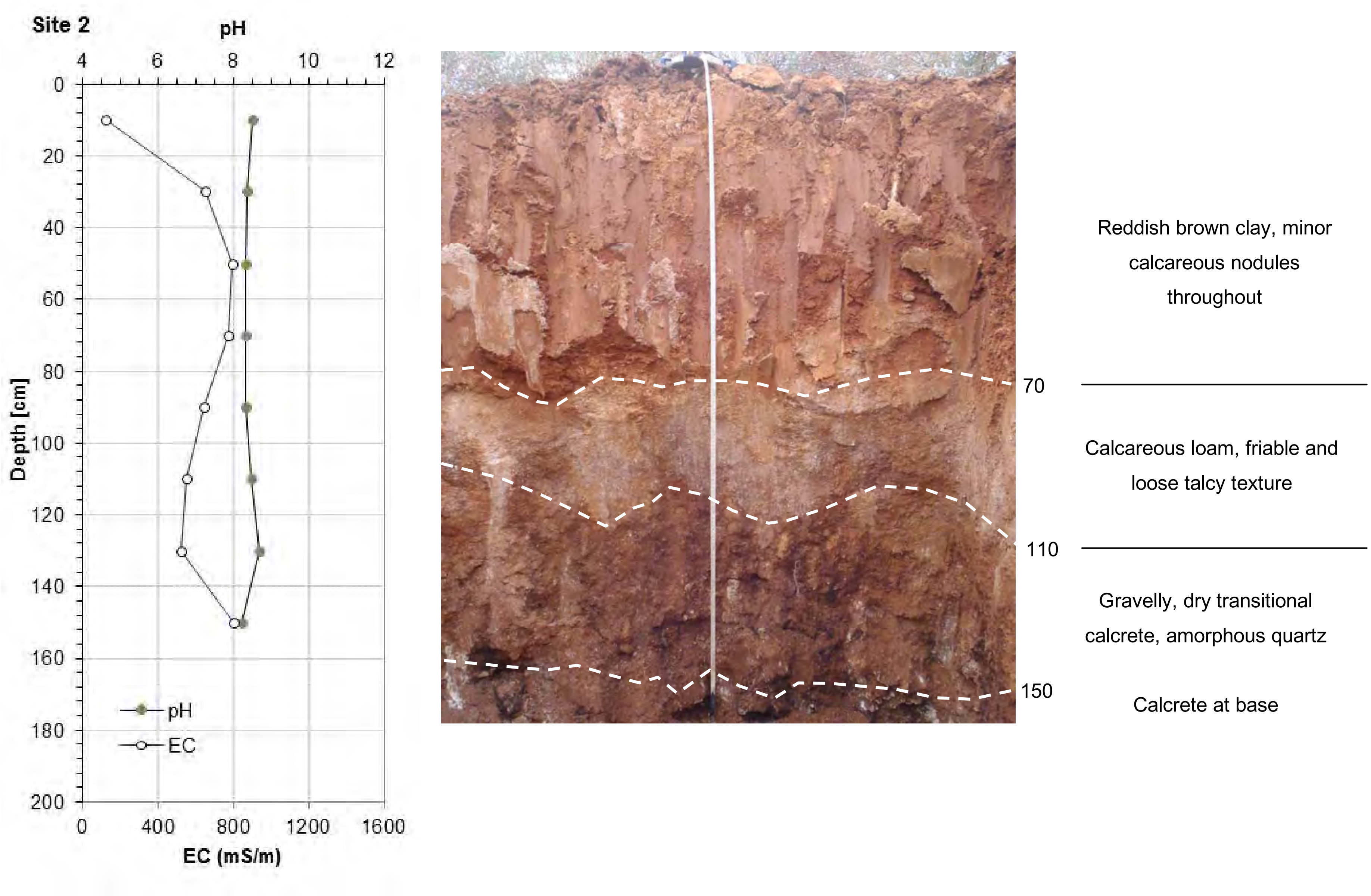
Western Botanical (2015b) *Initial Review of Lake Mason for Potential Translocation Sites of Atripliex sp. Yeelirrie Station*. Consultant report issued to Cameco Australia.

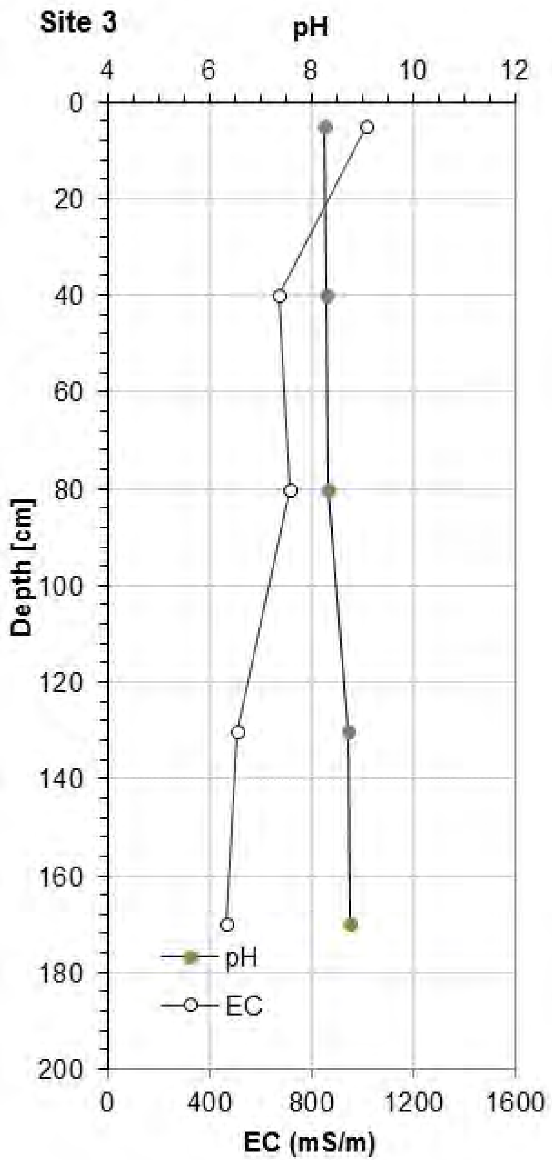
APPENDIX A

SOIL INVESTIGATION TRENCH PROFILES



Site 1
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180
200
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
Site 1
Vol. moisture [%]
0
20
40
60
80
Depth [m]
Moisture
10 kPa
1500 kPa
Reddish brown clay
10
Calcareous loamy sandy, friable and loose talcy texture
30
Reddish brown calcareous sandy clay, semi-rounded quartz gravels becoming more prevalent with depth.
Earthy calcrete at base


Site 2
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180
200
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
70
110
150
Reddish brown clay, minor calcareous nodules throughout
Calcareous loam, friable and loose talcy texture
Gravelly, dry transitional calcrete, amorphous quartz
Calcrete at base



Reddish brown clay

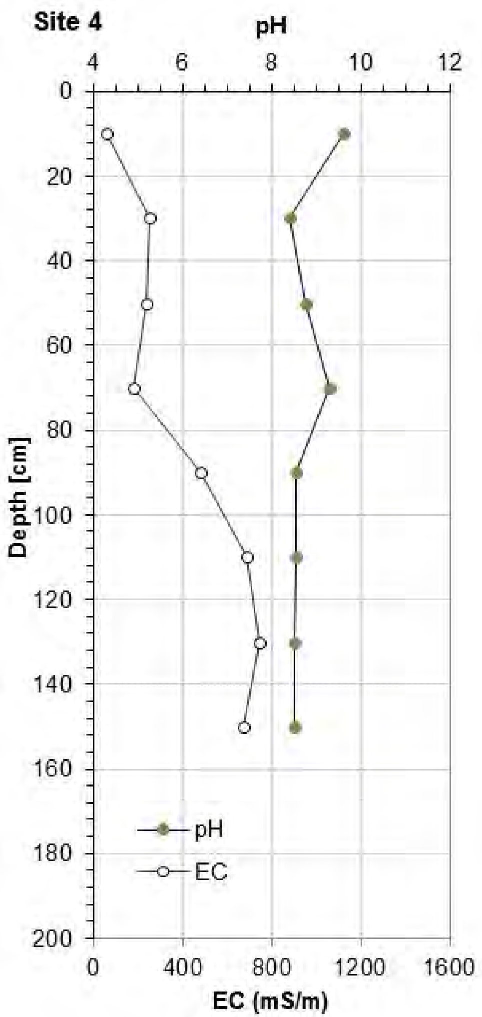
20

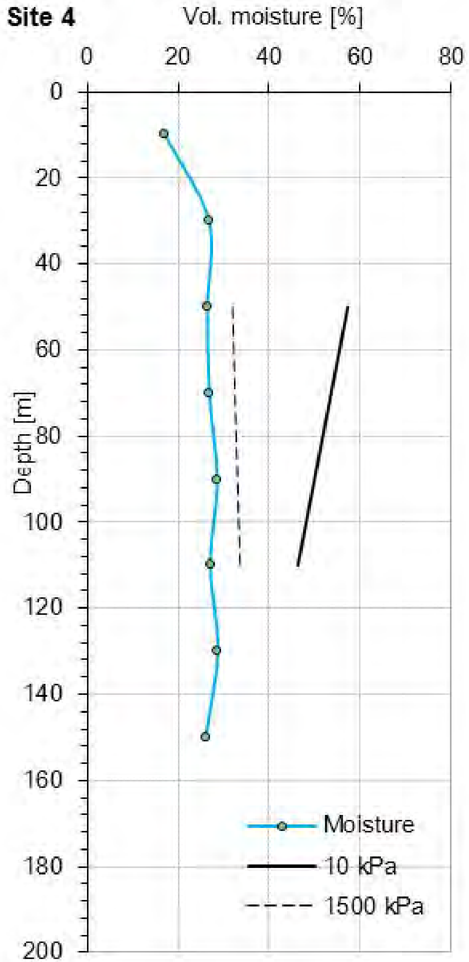
Light greyish red calcareous loam, friable texture. Gypsum crystals evident

100

Gravelly, dry transitional loamy clay, calcrete at base

190





20

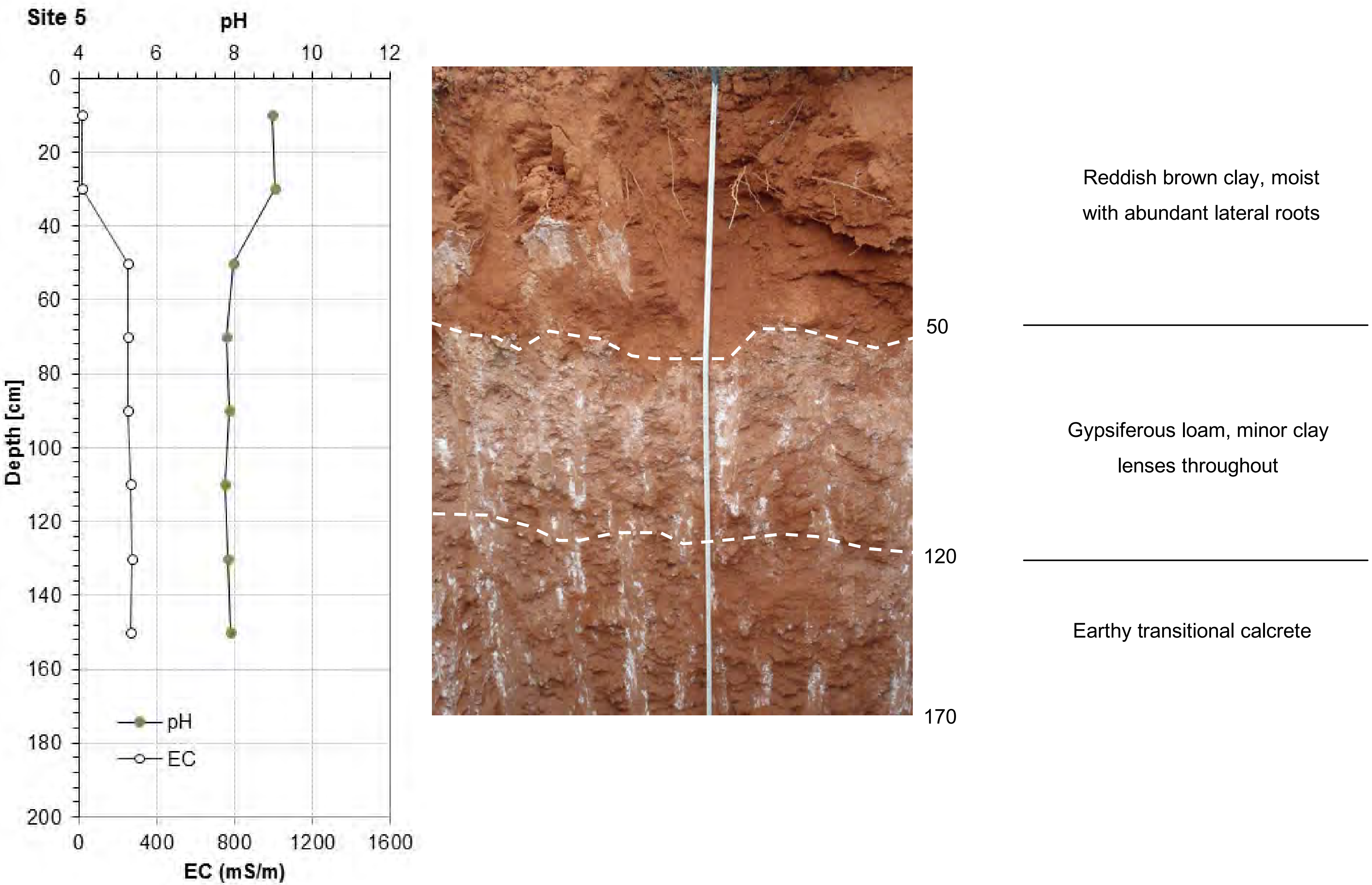
100

170

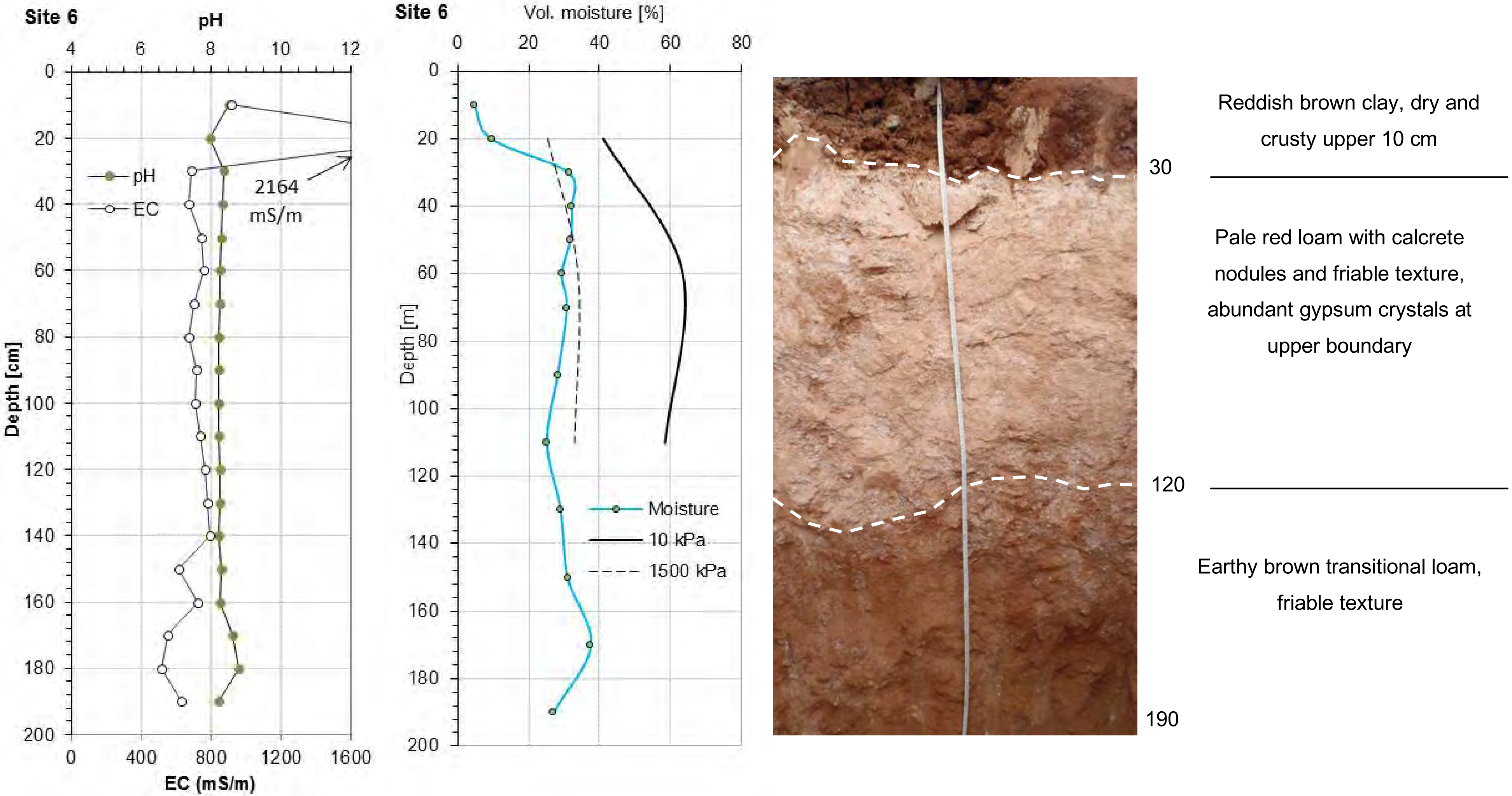
Reddish brown clay, dry and crusty upper 10 cm

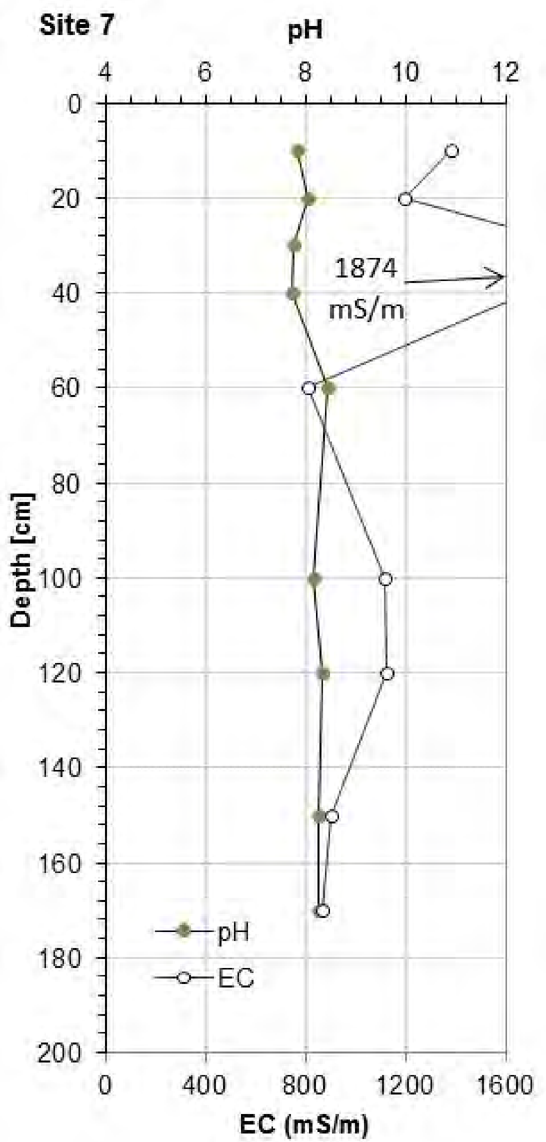
Reddish brown loamy clay, abundant gypsum crystals throughout

Earthy calcrete, moderate relict quartz content



Site 5
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180
200
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
50
120
170
Reddish brown clay, moist
with abundant lateral roots
Gypsiferous loam, minor clay
lenses throughout
Earthy transitional calcrete


Site 6
pH
4 6 8 10 12
2164 mS/m
pH
EC
Depth [cm]
0 20 40 60 80 100 120 140 160 180 200
0 400 800 1200 1600
EC (mS/m)
Site 6
Vol. moisture [%]
0 20 40 60 80
Depth [m]
0 20 40 60 80 100 120 140 160 180 200
Moisture
10 kPa
1500 kPa
30
120
190
Reddish brown clay, dry and crusty upper 10 cm
Pale red loam with calcrete nodules and friable texture, abundant gypsum crystals at upper boundary
Earthy brown transitional loam, friable texture



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

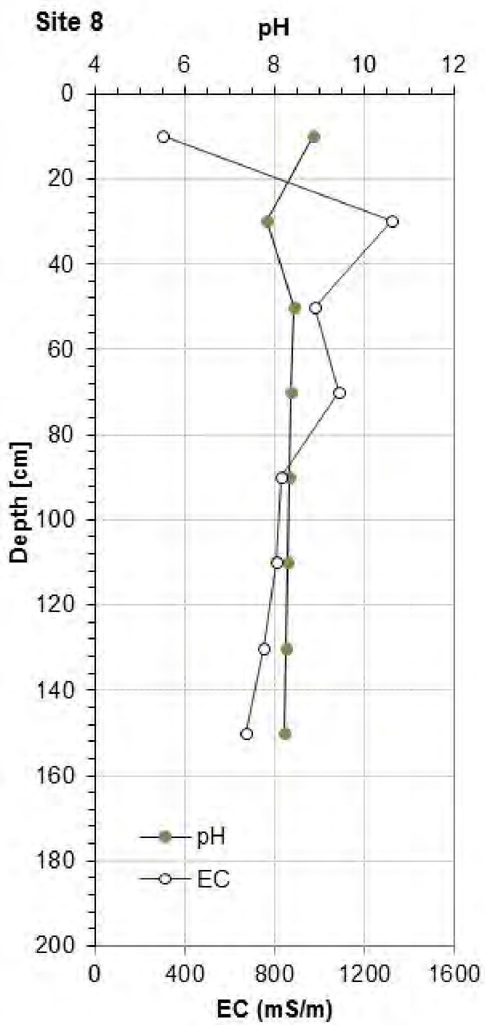
80

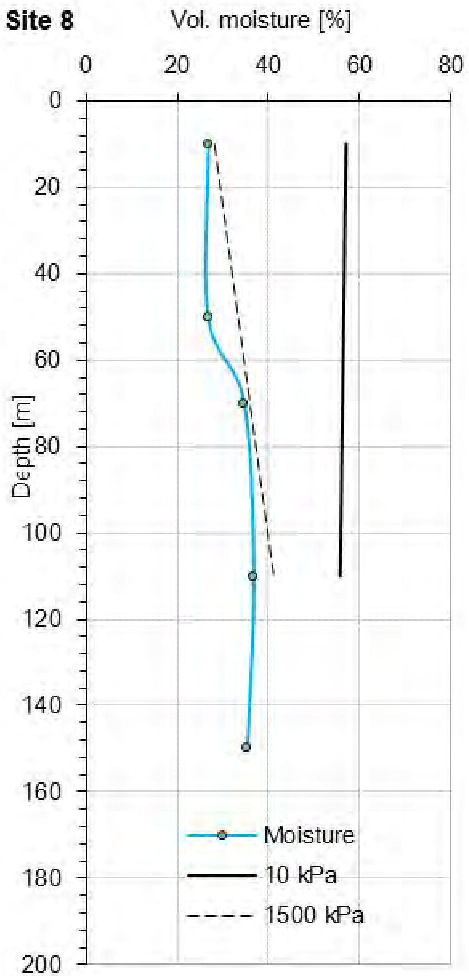
Talcy calcareous loam with calcrete nodules

140

Earthy greyish brown transitional calcrete, gravelly

180





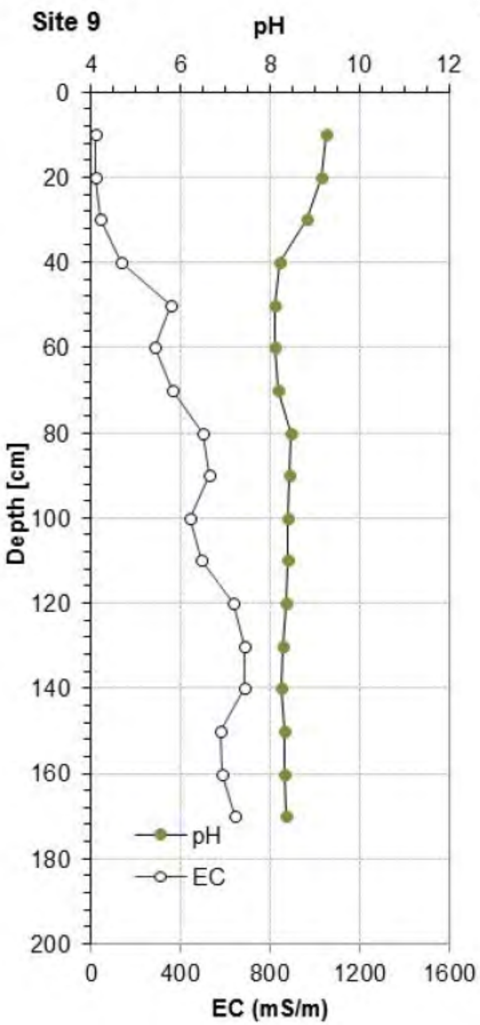
10 Reddish clay, dry and crusty

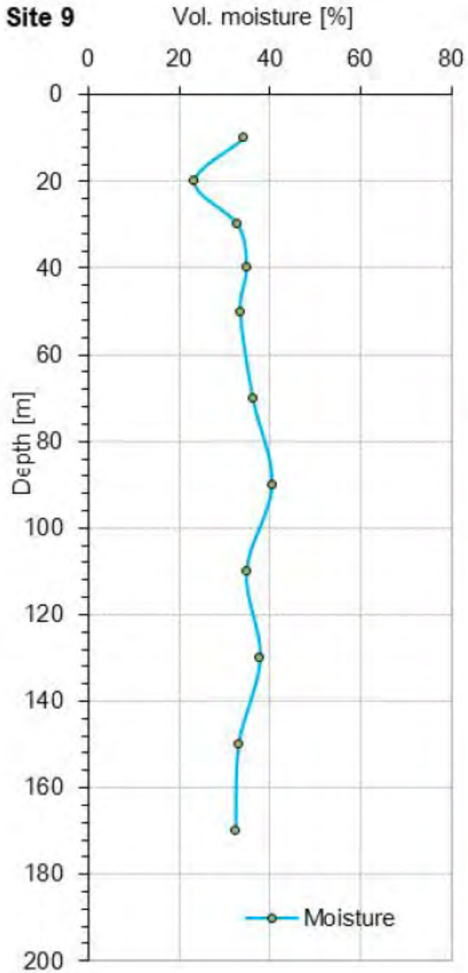
Reddish brown loamy clay

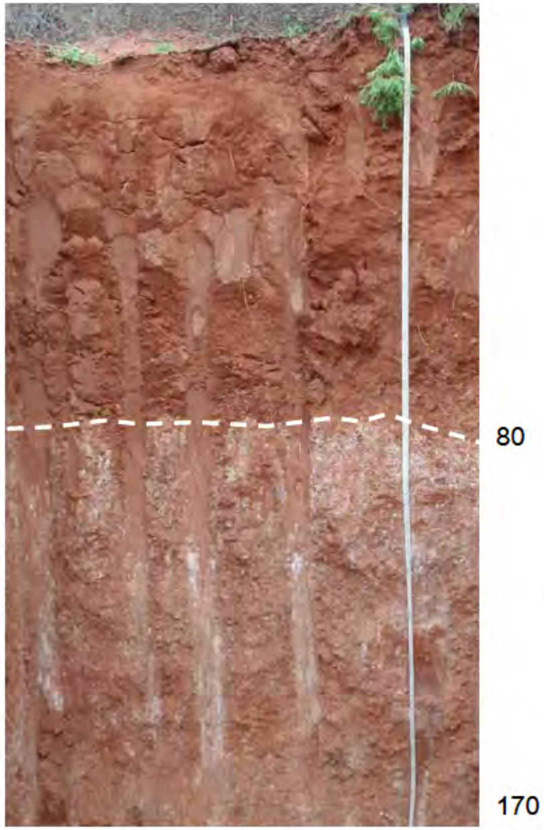
50

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

180



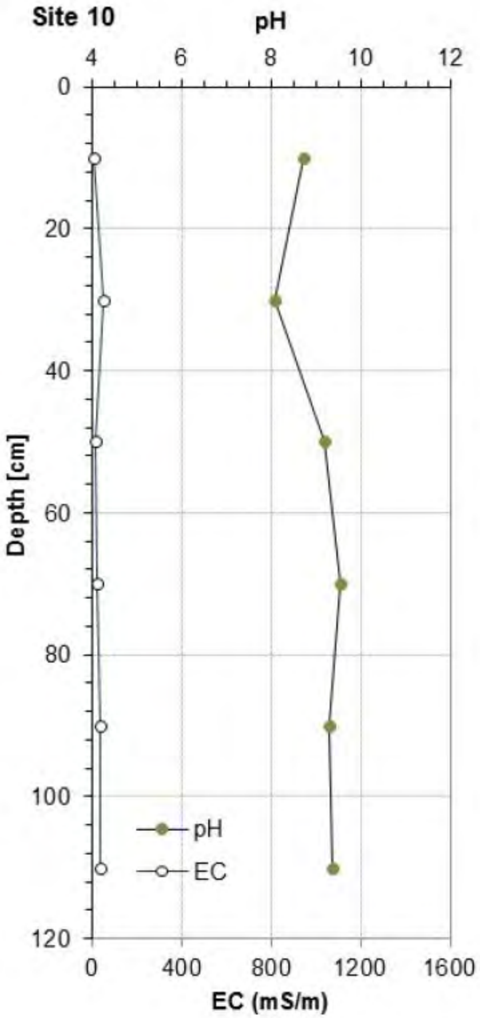


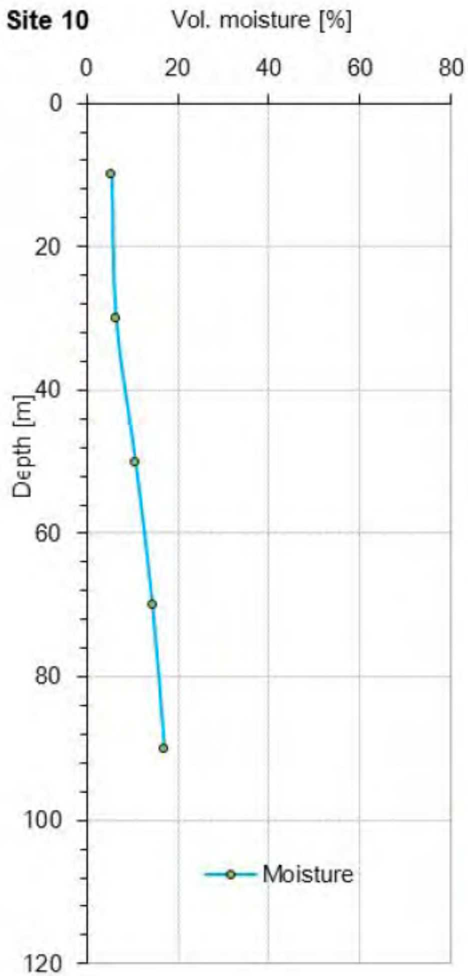


Reddish brown loamy clay, abundant fine roots and common large lateral roots

Calcareous loam; Minor sub rounded gravel and fine roots throughout

Blocky calcrete at base



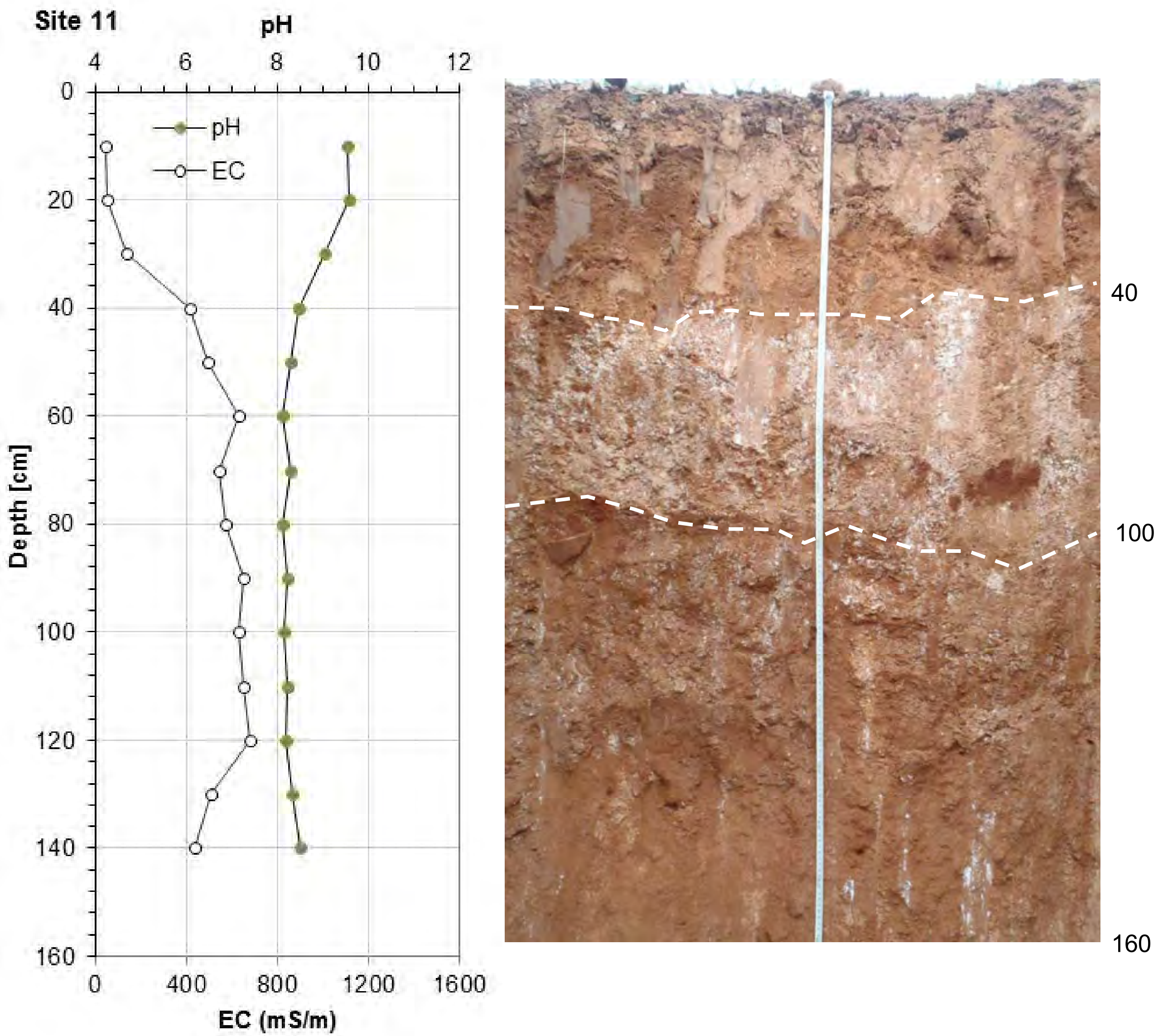


30

120

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

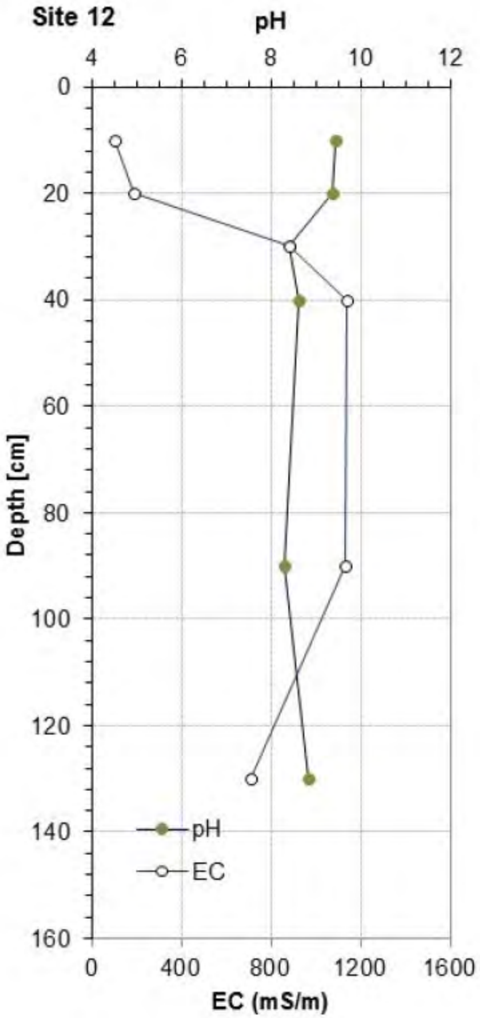
Highly weathered blocky subangular material of variable clay content, progressively consolidated with depth

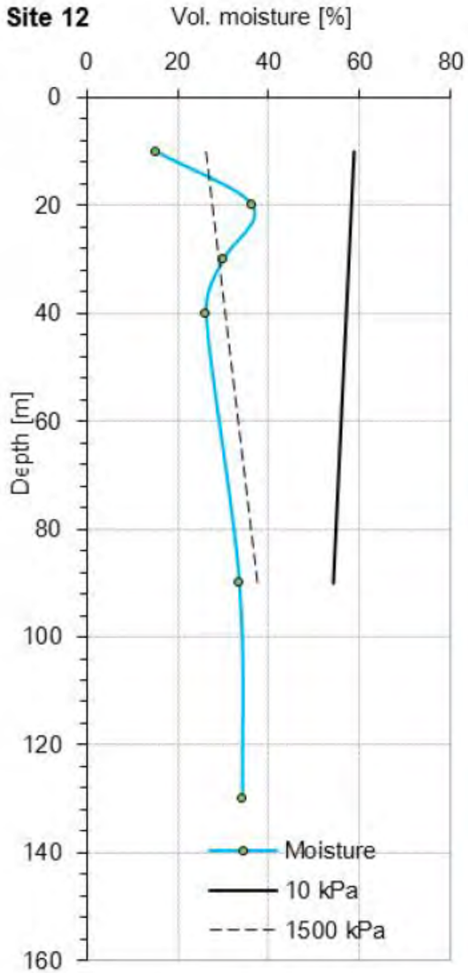


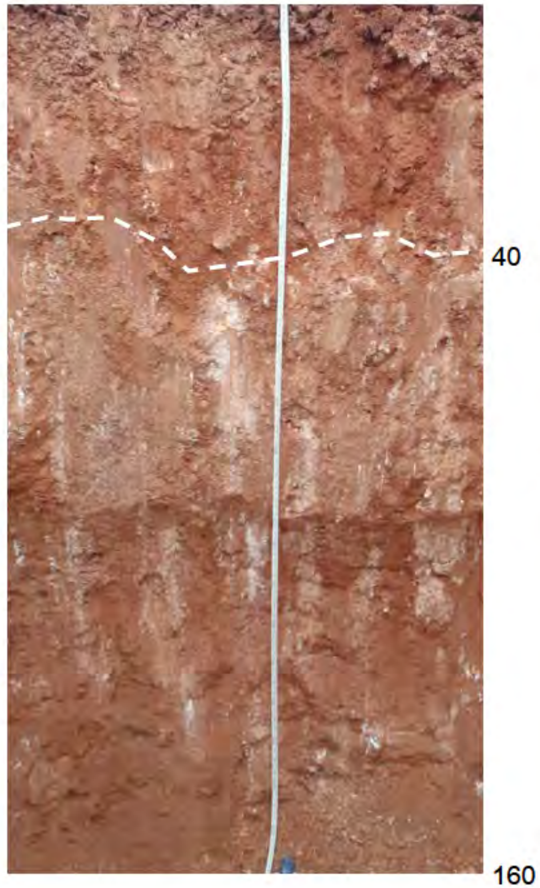
Reddish brown clay loam, minor calcareous nodules

Calcareous loam with common gypsum crystals; gradual transition to

Loam; minor calcareous mottling

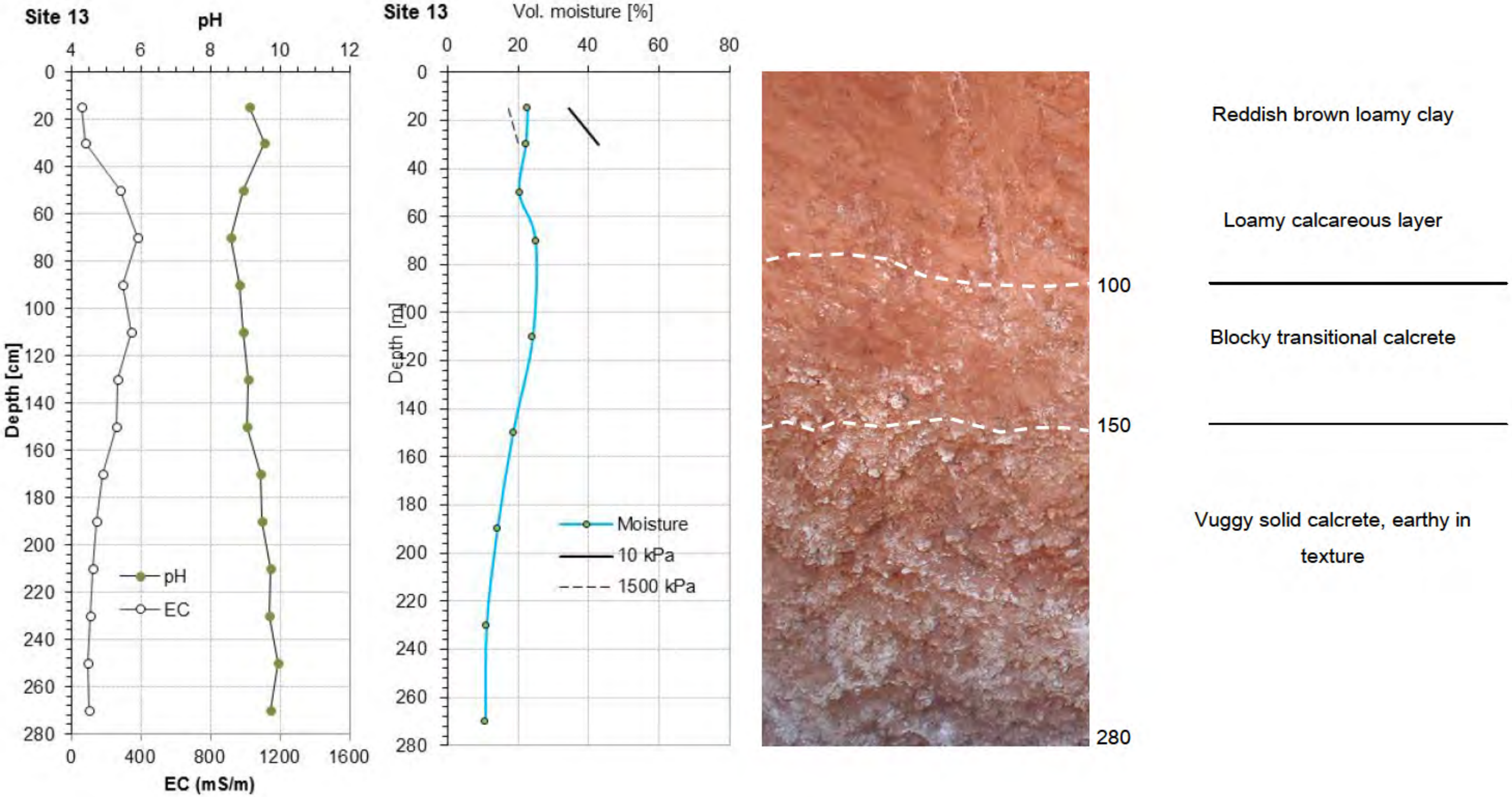




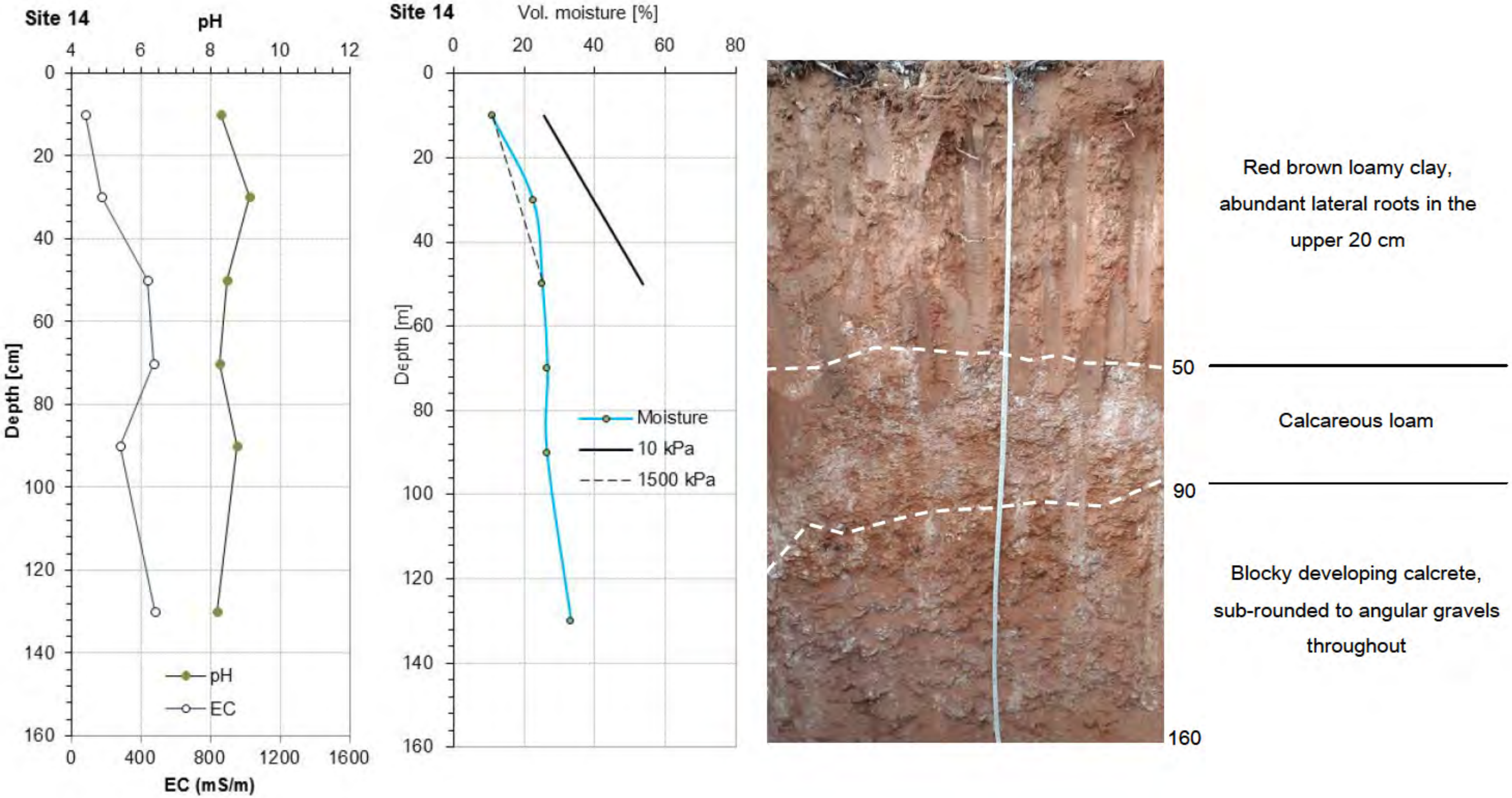


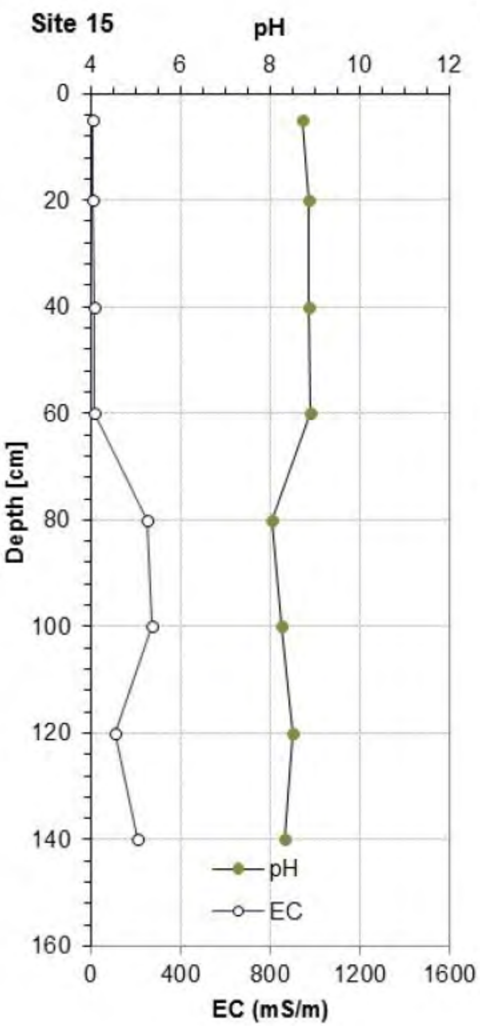
Brownish red clay loam

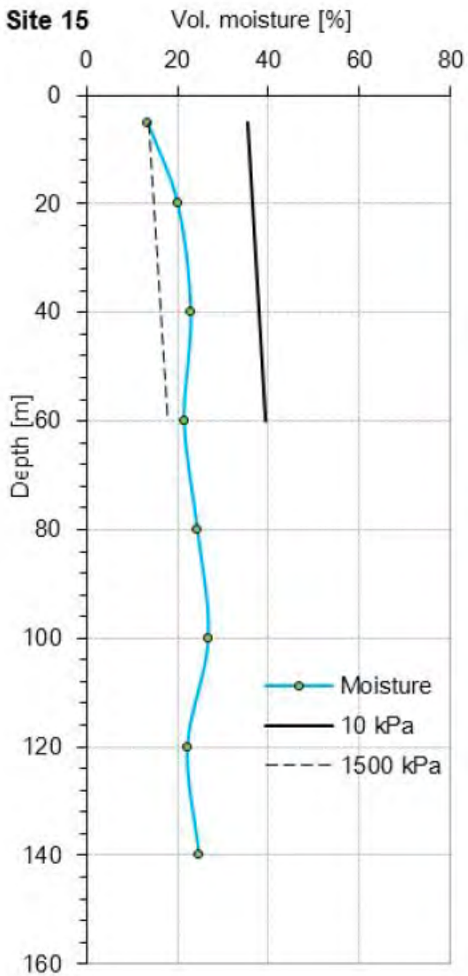
Calcareous loam with abundant calcrete nodules and large gypsum crystals

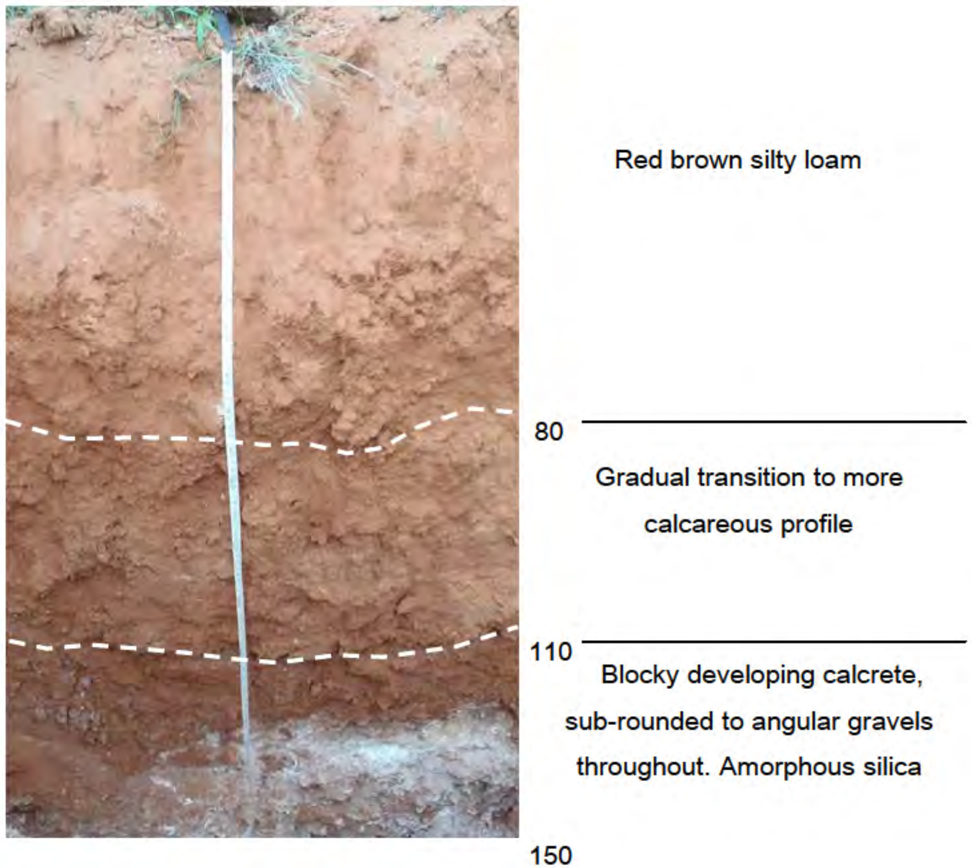


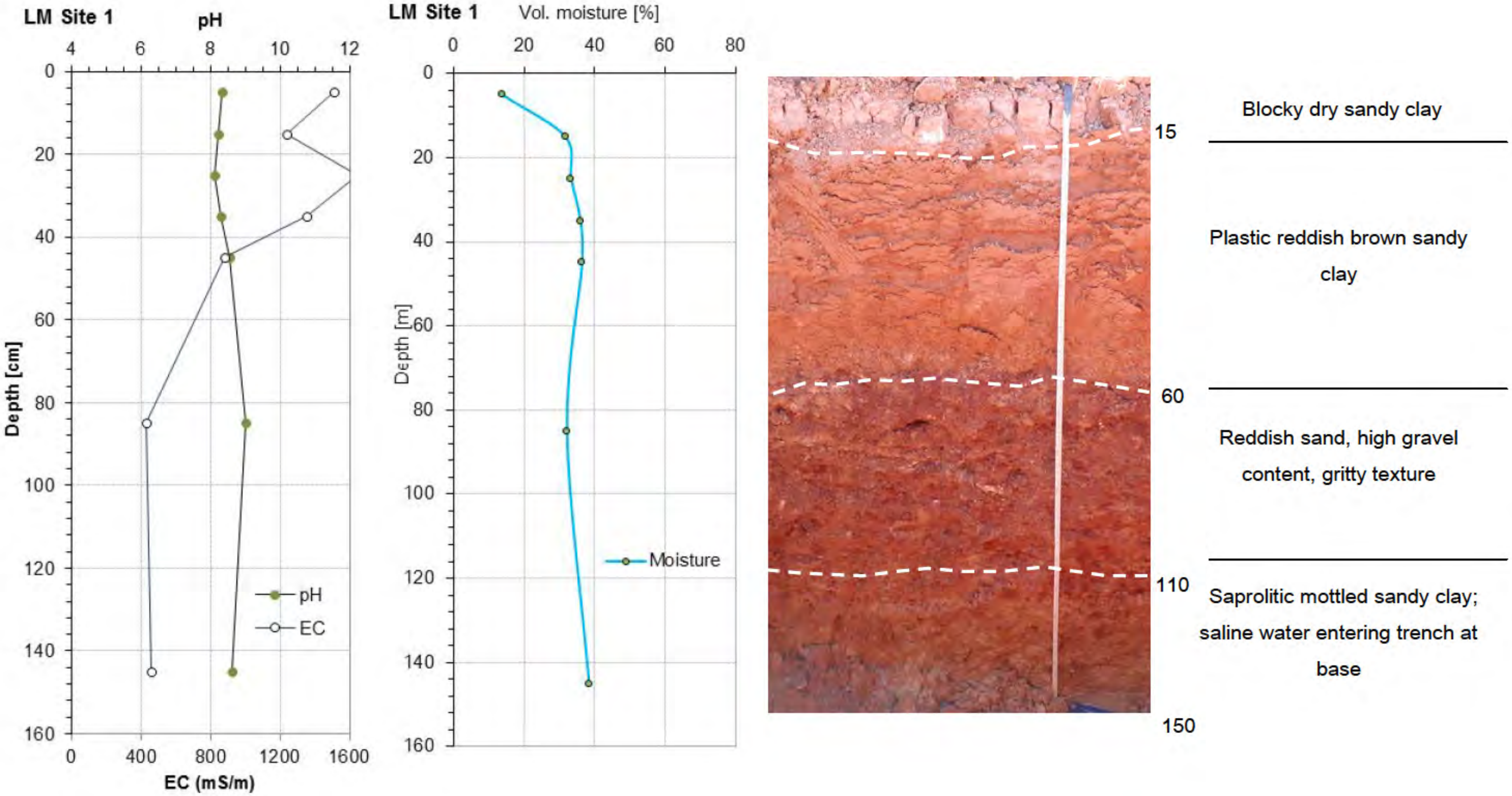
Site 13
pH
4
6
8
10
12
Depth [cm]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
pH
EC
0
400
800
1200
1600
EC (mS/m)
Site 13
Vol. moisture [%]
0
20
40
60
80
Depth [m]
Moisture
10 kPa
1500 kPa
100
150
280
Reddish brown loamy clay
Loamy calcareous layer
Blocky transitional calcrete
Vuggy solid calcrete, earthy in texture


Site 14
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
Site 14
Vol. moisture [%]
0
20
40
60
80
Depth [m]
Moisture
10 kPa
1500 kPa
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

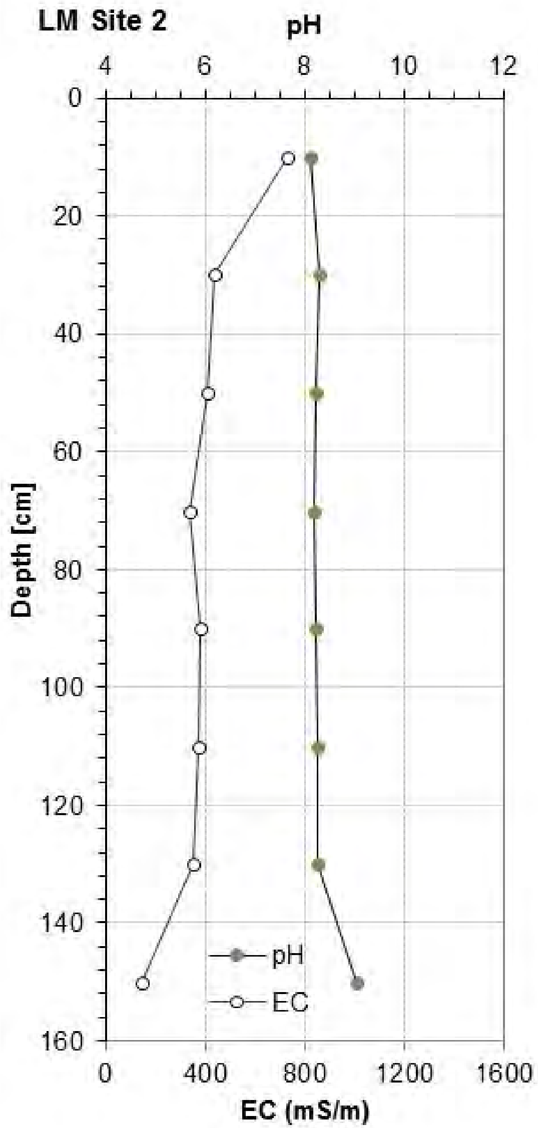

Site 15
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
Depth [cm]
0
400
800
1200
1600
EC (mS/m)
pH
EC


Site 15
Vol. moisture [%]
0
20
40
60
80
0
20
40
60
80
100
120
140
160
Depth [m]
Moisture
10 kPa
1500 kPa


Red brown silty loam
80
Gradual transition to more calcareous profile
110
Blocky developing calcrete, sub-rounded to angular gravels throughout. Amorphous silica
150



LM Site 1
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
LM Site 1
Vol. moisture [%]
0
20
40
60
80
Depth [m]
Moisture
15
60
110
150
Blocky dry sandy clay
Plastic reddish brown sandy clay
Reddish sand, high gravel content, gritty texture
Saprolitic mottled sandy clay; saline water entering trench at base



55

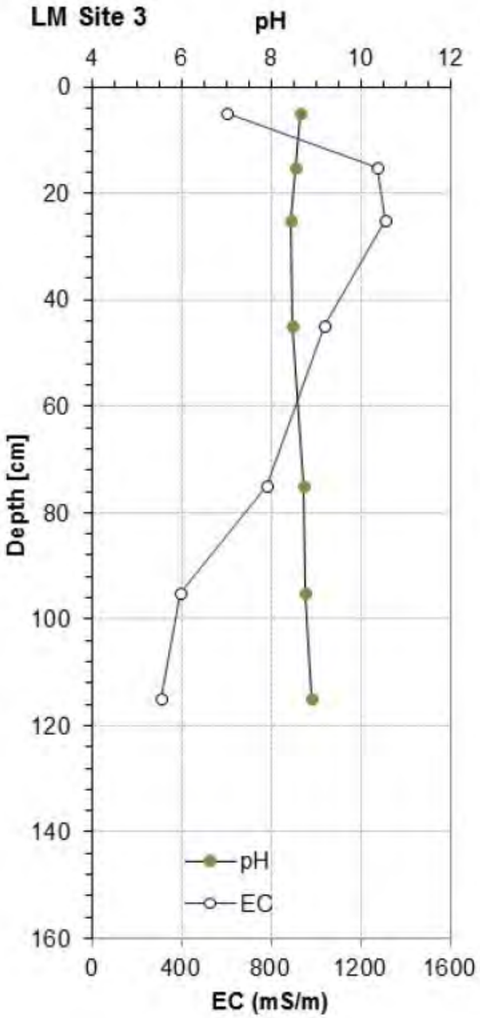
110

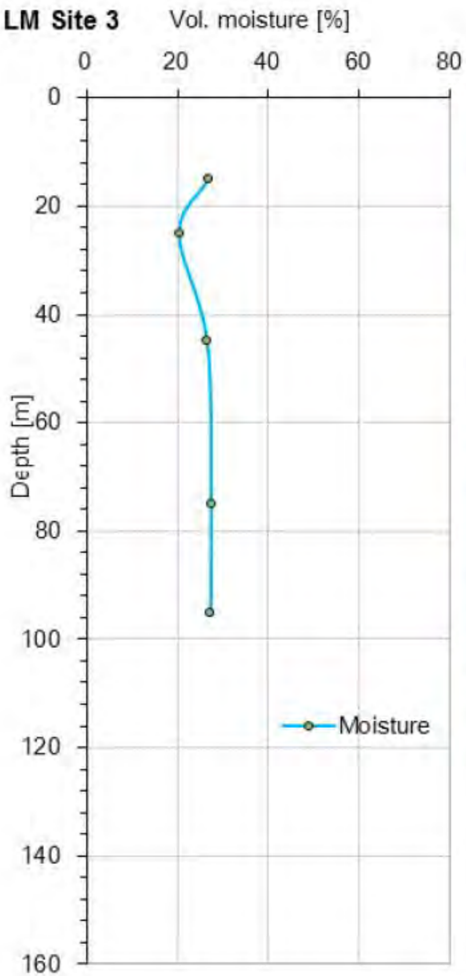
160

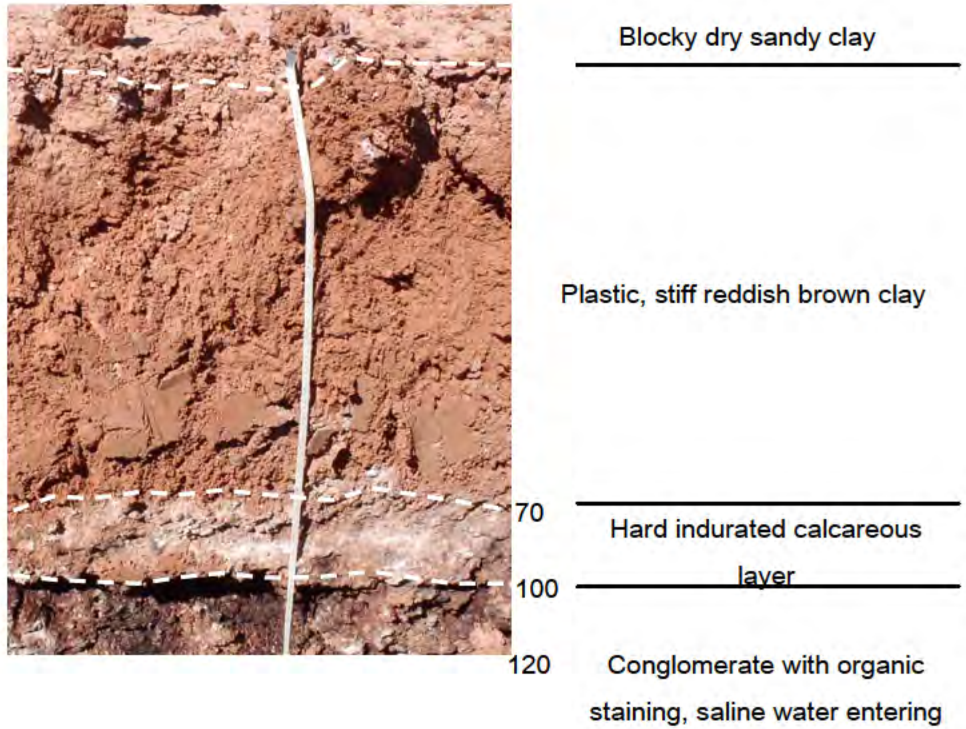
Reddish brown silty loam,
minor calcareous nodules,
abrupt boundary to

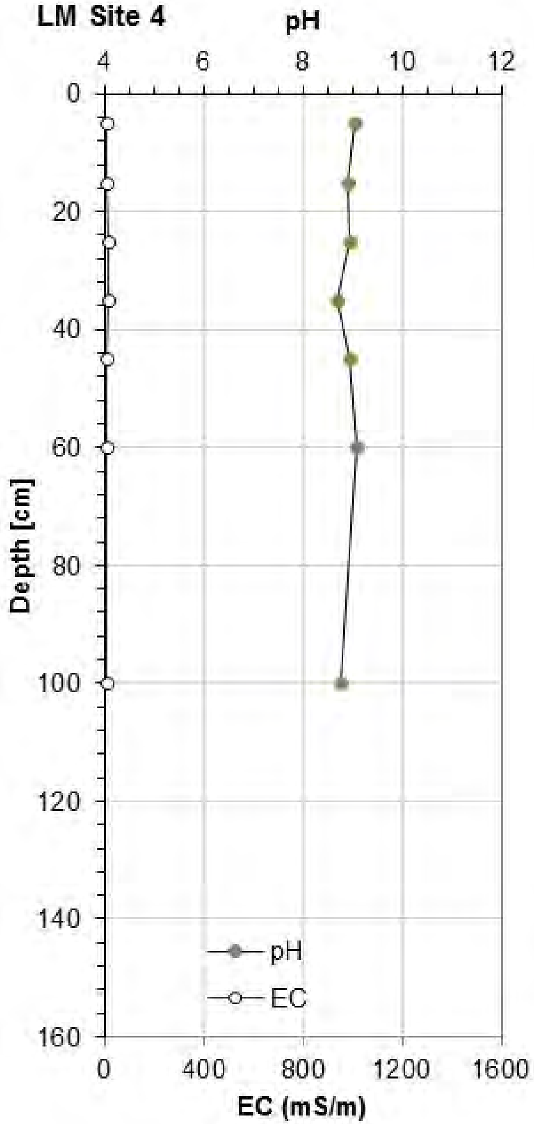
Calcareous silty loam, very dry
upper portion considerably less
gravel than lower profile

Abrupt boundary to friable
pisolitic calcrete


LM Site 3
pH
4 6 8 10 12
Depth [cm]
0 20 40 60 80 100 120 140 160
pH
EC
0 400 800 1200 1600
EC (mS/m)


LM Site 3
Vol. moisture [%]
0 20 40 60 80
Depth [m]
0 20 40 60 80 100 120 140 160
Moisture


Blocky dry sandy clay
Plastic, stiff reddish brown clay
70
Hard indurated calcareous layer
100
120
Conglomerate with organic staining, saline water entering



Coarse silty sand

20

Silty sand, subrounded ironstone gravels increasing with depth

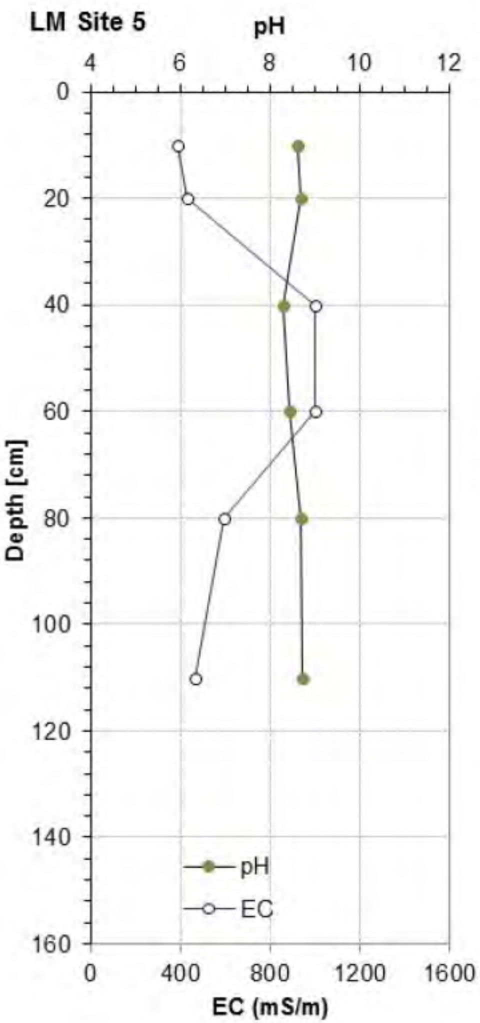
50

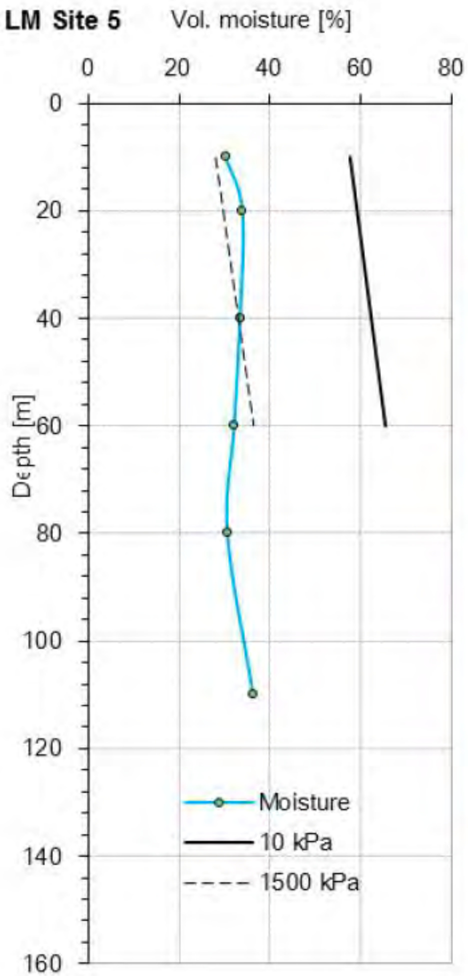
Coffee rock

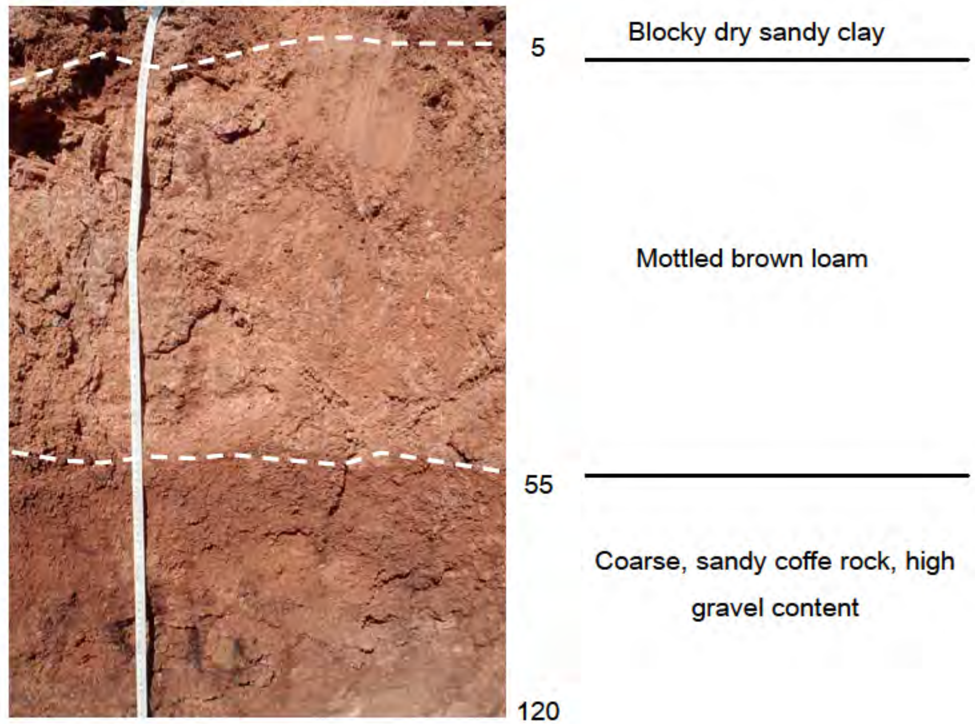
60

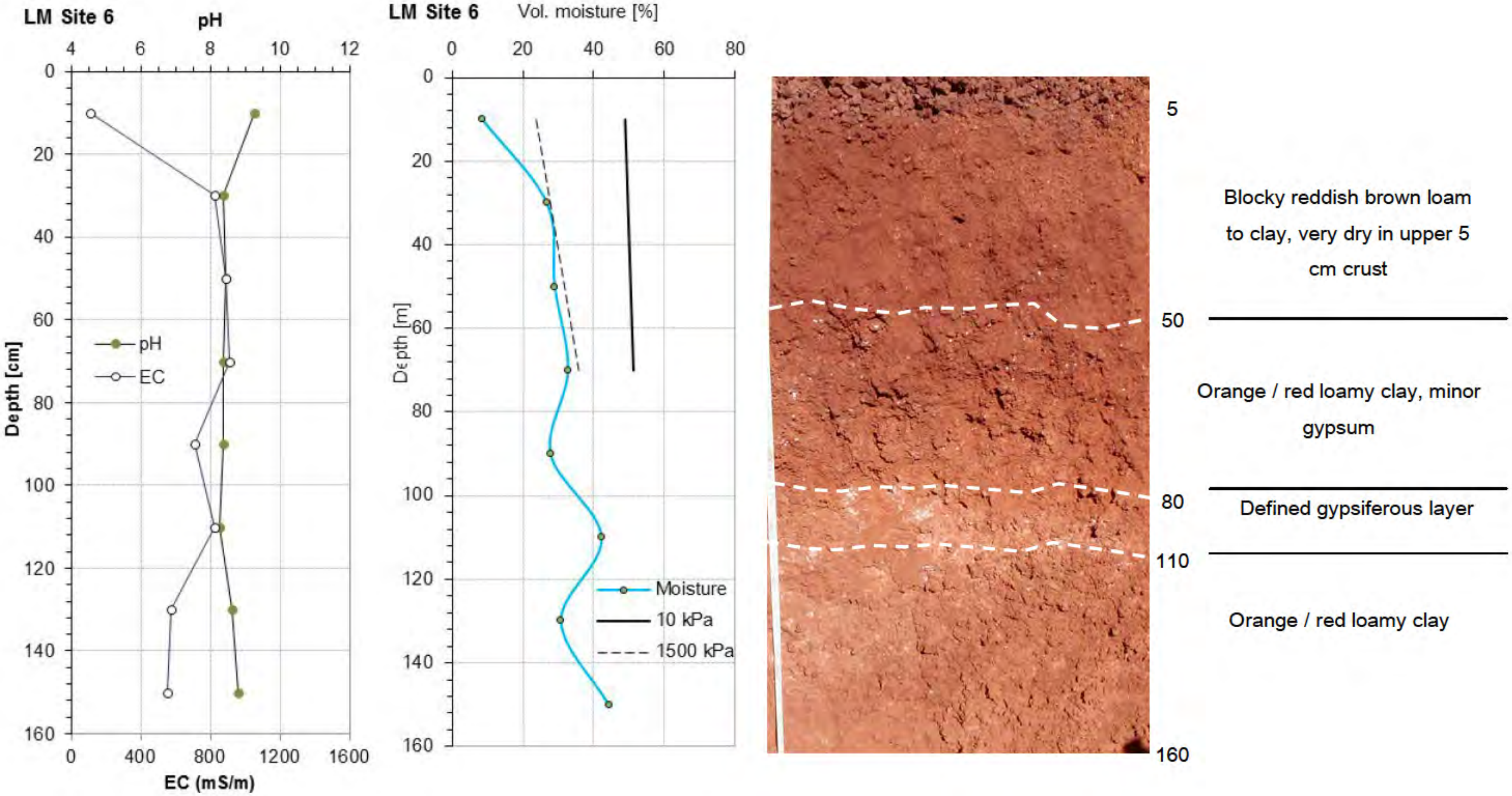
Calcareous silty clay

110


LM Site 5
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)


LM Site 5
Vol. moisture [%]
0
20
40
60
80
0
20
40
60
80
100
120
140
160
Depth [m]
Moisture
10 kPa
1500 kPa

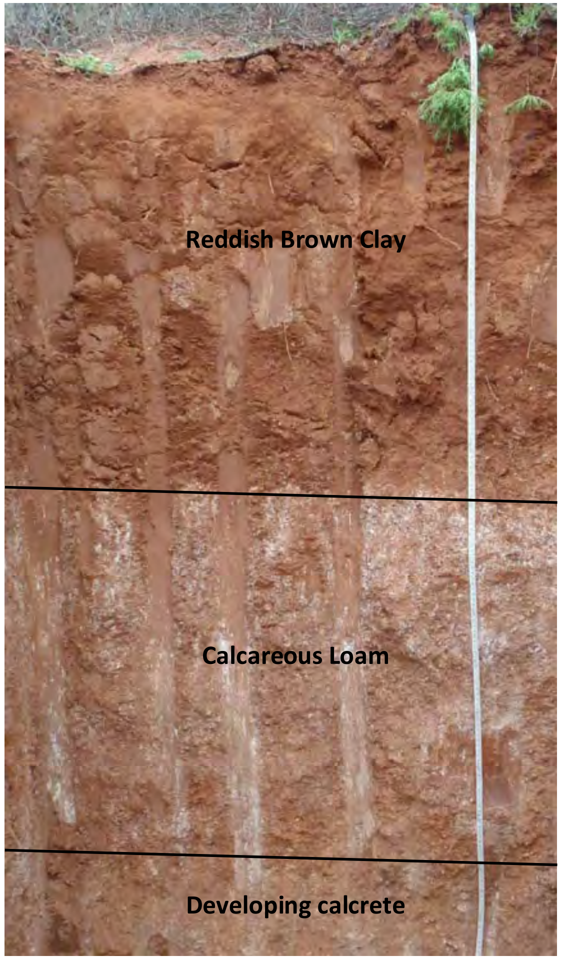

5
Blocky dry sandy clay
Mottled brown loam
55
Coarse, sandy coffe rock, high gravel content
120



LM Site 6
pH
4
6
8
10
12
0
20
40
60
80
100
120
140
160
Depth [cm]
pH
EC
0
400
800
1200
1600
EC (mS/m)
LM Site 6
Vol. moisture [%]
0
20
40
60
80
Depth [m]
Moisture
10 kPa
1500 kPa
5
50
80
110
160
Blocky reddish brown loam to clay, very dry in upper 5 cm crust
Orange / red loamy clay, minor gypsum
Defined gypsiferous layer
Orange / red loamy clay

Atriplex sp. Yeelirrie Station
ABSENT

Atriplex sp. Yeelirrie Station
PRESENT



Atriplex sp. Yeelirrie Station
PRESENT