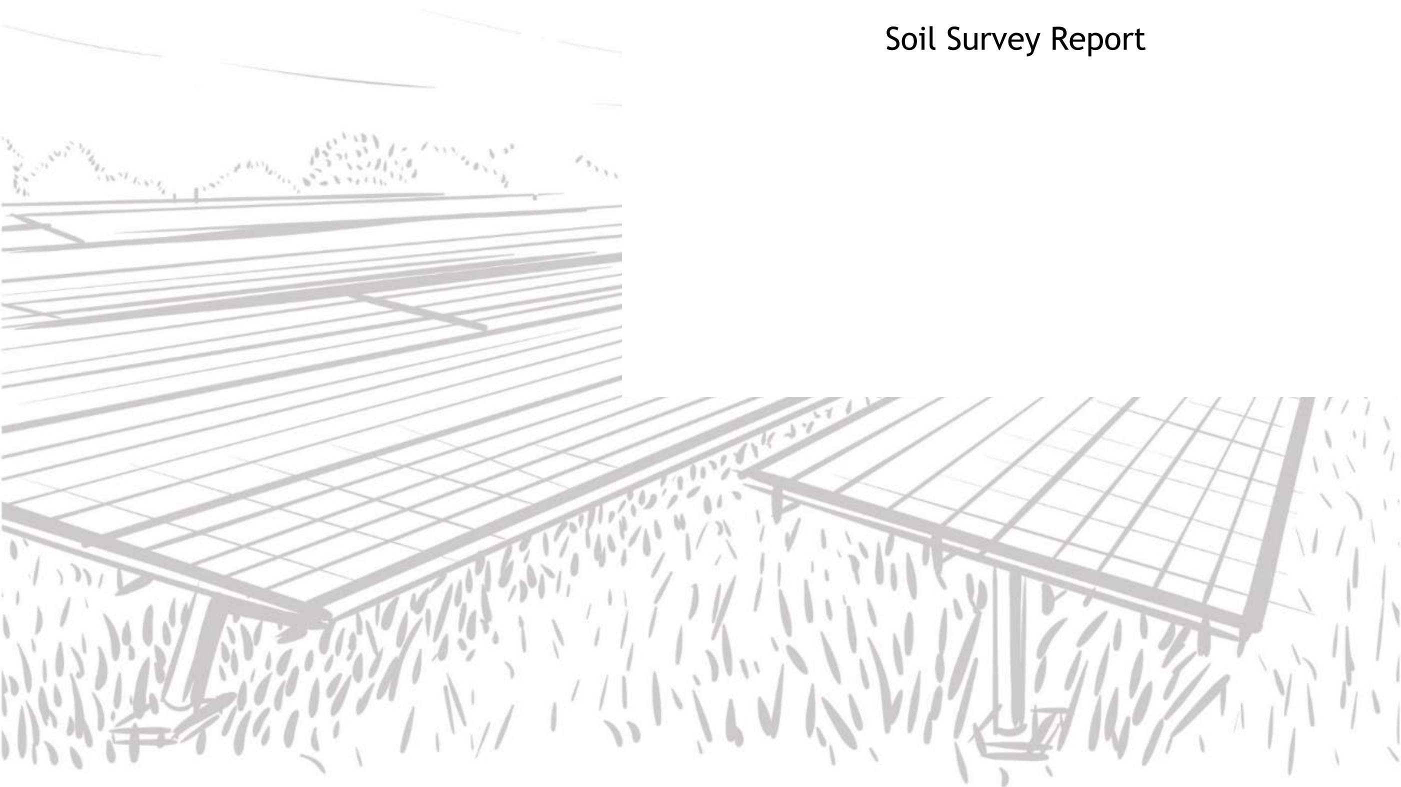
Appendix E

Soil Survey Report



Orkney Management Pty Ltd

SOIL SURVEY REPORT

TAMWORTH SOLAR FARM

OCTOBER 2019

Orkney Management Pty Ltd
4/128 Dangar St
Armidale NSW 2350
0427 247 045

Site Identification

Address: Soldiers Settlement Road, Bective NSW 2340

GPS Location: -31.006945, 150.649220

Present Use: Agriculture

Certification

Name	Signed	Date
Greg Wynn B Ag Sc		18/10/2019

Contents

1 Introduction

A soil survey was commissioned by Daryl Brown of PROJECT.e and was undertaken in the general accordance with the scope of works email dated 9th September 2019. Greg Wynn of Orkney Management Pty Ltd conducted a soil survey and soil sampling on the 26th September 2019 under industry standard sampling protocol. The results of the soil survey and soil sampling have been used to classify the soils of the site and to assess the erosivity of the soil.

2 Site Overview

2.1 Vegetation

The site is currently used for grazing and broad-acre cropping. Much of the site has laid fallow since the last crop which in some paddocks appears to have been several years ago. At the time of the survey, two paddocks had been sown to a cereal crop which had failed due to the drought and were being grazed.

There are some scattered native trees on site (<40), predominantly Wilga, White Box and Blakelys Red Gum. Apart from these native trees there appears to be little other native vegetation.

2.2 Topography

The site is located at an elevation of between 348 m and 385m AHD as shown in Figure 1. The majority of the site is very gently inclined with a slope of less than 2%. In the south western section of the site, the slope increases to between 2 and 4%, with a small area having slopes up to 7%.

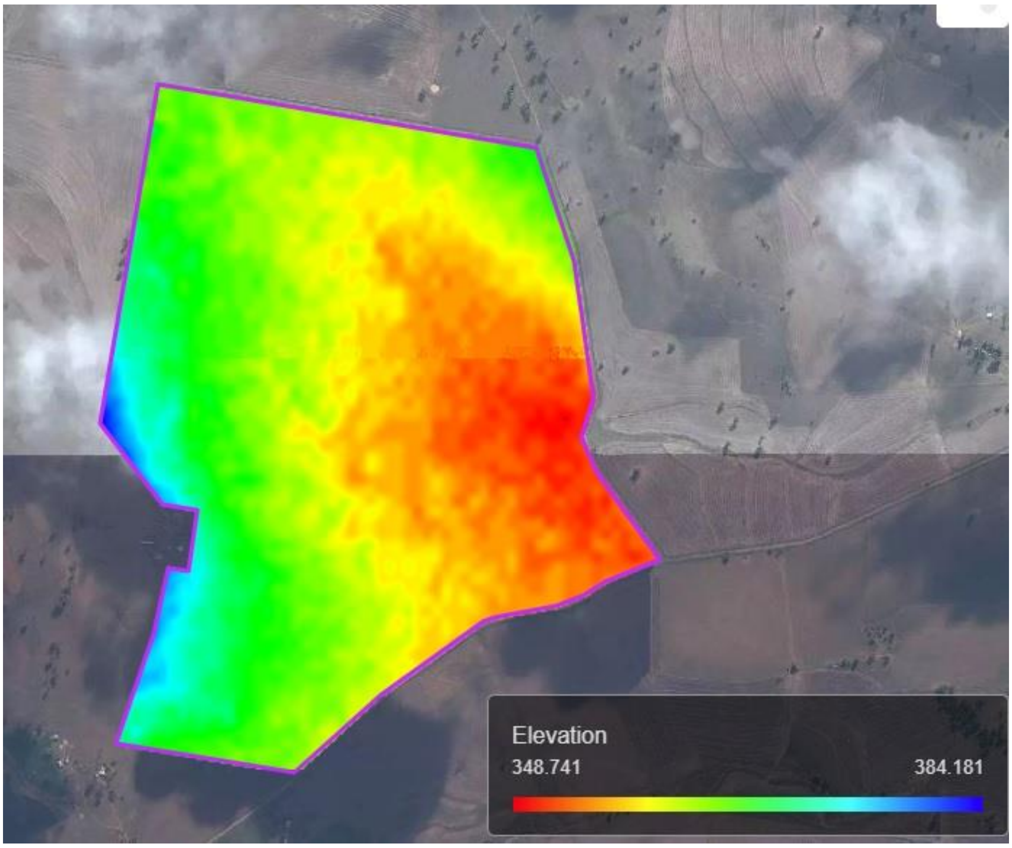


Figure 1. Site elevation

2.3 Hydrology

The site is in the catchment of the Peel River which is located approximately 4 km to the north of the site. There are ephemeral waterways on the site, three Strahler first order drainage lines and a second order drainage line. The waterways generally don't show any sign of bed and banks with the exception of a 300m section of the second order drainage line.

2.4 3.4 Geology

Alluvium and colluvium derived from and overlying Devonian conglomerates and argillites of the Keepit Conglomerates and the Baldwin Formation (Geological map code Duk and Dub). Exposures of these parent materials in gullies reveal that the soil materials are seldom >5 m deep and that bedrock is frequently a highly weathered rock or structured saprolite.

2.5 Soil Landscape

The site is part of the Babinboon soil landscape (9035bb). This section provides a summary of the Babinboon soil landscape as described by Banks, 2001. The location of the site in this landscape is shown in Figure 2.

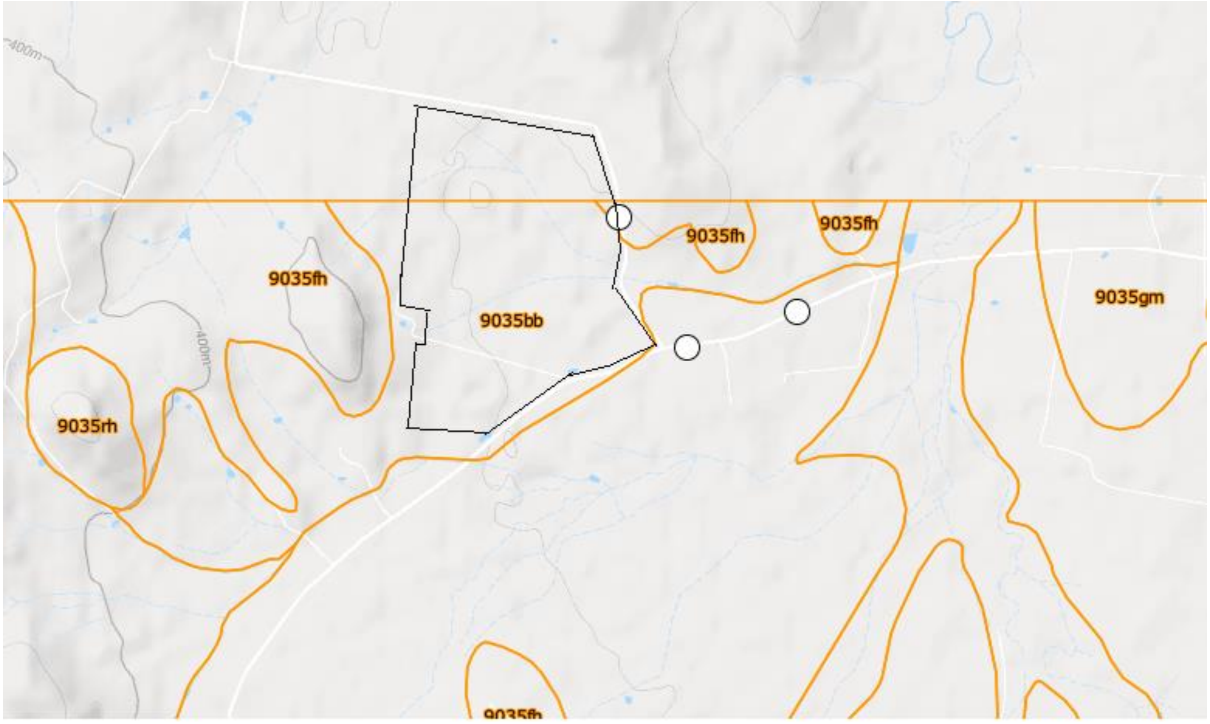


Figure 2. Location of the site in the Babinboon soil landscape (9035bb) Source: espade.environment.nsw.gov.au © State of NSW and Office of Environment and Heritage (2019).

The Babinboon soil landscape is at the footslopes of Devonian conglomerate and argillite hills in the northern Melville Ranges. In the upper footslopes of the landscape, the soils have deep, moderately well-drained Red Chromosols (Non-calcic Brown Soils). Mid to lower footslopes are dominated by deep, moderately well-drained Red Chromosols (Redbrown Earths). Lower slopes and flats are dominated by moderately deep, imperfectly drained Brown Vertosols (Brown Clay).

The solar farm site is on the lower slopes and flats where Brown Vertosols are the dominant soil type. The topsoil (A1 and A2 horizons) of the Brown Vertisol is a hardsetting brown clay with a light to medium heavy clay texture, strong pedality, angular blocky (5-50mm) smooth faced peds with a pH of 6.0 to 7.0. The erodibility of this topsoil type is shown in Table 1.

Table 1. Erodibility of hardsetting brown clay topsoils (bb3)

Erosion Type	Erodibility
Non-concentrated water flows (sheetflow)	low-moderate
Concentrated water flows	high
Wind	Very low

Vertosols in the Babinboon landscape are of moderate to high fertility with good moisture storage potential and as such are used for cropping. However, they are prone to structural and organic matter decline under cultivation. Consequently, cropping phases should be shorter than pasture phases and should include no till rotational systems.

Vertosol soils have a high shrink/swell capacity (vertic properties) which alters the structure of the soil between the dry and wet phases. When dry, these friable cracking clay soils are usually well structured having good aeration and high permeability to water. Upon wetting, these clays swell reducing the total porosity which reduces aeration and water infiltration. Increased runoff from upper slopes will place greater pressure on these soils and waterlogging may occur in higher than average rainfall years. The Grey Vertosols are generally better structured than the Brown Vertosols as the latter tends to have surface soil aggregates that slake which may result in a surface crust following excessive tillage. A surface crust will reduce water and air infiltration into the soil and inhibit plant establishment.

When engineering structures on these soils, the shrinking and swelling nature of these soils needs to be taken into account.

3 Method

Soil cores were extracted across the site for assessment and testing. This was done with the hydraulic corer shown in Figure 3. The cores were used to confirm the soil classification and to obtain samples for laboratory testing. An example of a core is shown in Figure 4.

Figure 3.. Hydraulic corer used to collect samples.

Figure 4. Soil core of Brown Vertosol (note shiny core surface)

A total of 30 cores were taken across the site. The sample locations are shown in Figure 5. Remote sensing technology was used as a tool to inform the sample locations. To increase the likely hood that the soil core locations reflect the soils present on the site, the site was divided into zones using a combination of Potassium Gamma-radiometric measurements (K-Gamma) and a digital surface model (DSM). The K-Gamma was sourced from Geoscience Australia and accurate to 90m spatial resolution, whilst the DSM was from ALOS World 3D at 30m spatial resolution. Analysis of the data was conducted by Sam Duncan of FarmLab Pty Ltd and resulted in the identification of the 3 zones shown in Figure 5.

These datasets were chosen as both measurements reflect soil parent material and weathering processes. Together they provide an indication on soil formation over the region. This method was developed by the Soiltech Project, in conjunction with the University of Sydney, FarmLab, Agrivision and Andrea Koch Agtech. Further information on the use of similar sources to produce soil maps can be found in the following references: Miklos *et. al*. (2010); Taylor *et. al*. (2002); and Oliver *et. al*. (2019).

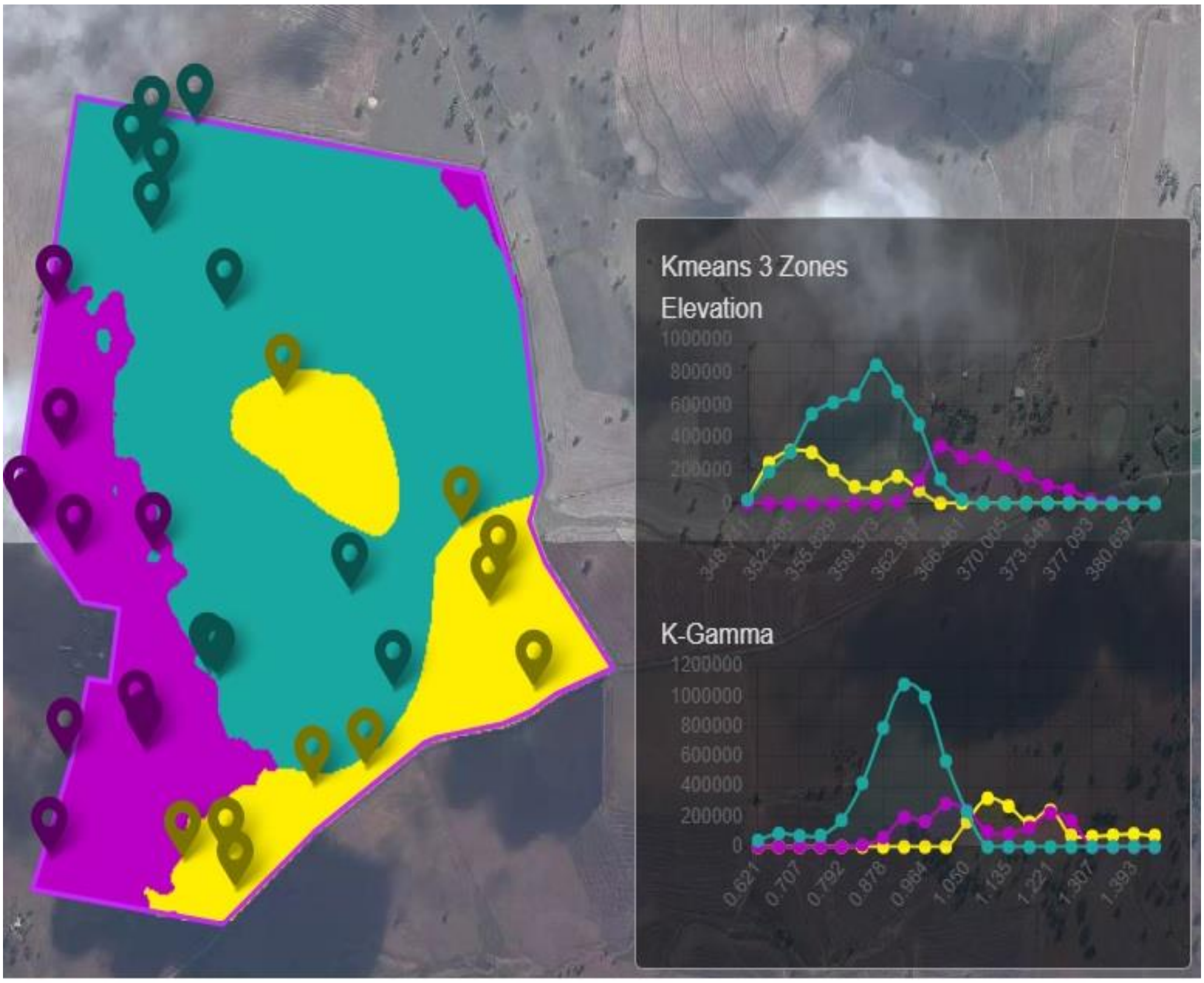


Figure 5. Results of remote sensing of soil characteristics and soil core locations.

Cores were taken to a depth of 90cm in the green zone, but could only be taken to 60cm in the other zones due to the hard, dry condition of the subsoil. Samples were taken from each core for depths of 0 to 30cm, 30 to 60cm and 60 to 90cm. Soil samples were aggregated across the zones and analysed for the parameters shown in Appendix A.

4 Results

4.1 Soil Classification

Visual analysis of the soil cores combined with the laboratory test results (refer Appendix A) confirmed that the soils contained within the proposed site are classified as per the Australian Soil Classification guide as Imperfectly Drained Brown Vertosols. Some Red Chromosols were observed in the vicinity of the location but did not occur in the proposed site. Soil colour differences were observed across the site, with red/brown vertosols located higher on the footslope, and brown/grey vertosols further down the slope. This visual assessment correlated with the spatial management zones used for the soil survey. The test results from these zones do show some subtle chemical composition differences, however all three zones fall into the same soil classification of Imperfectly Drained Brown Vertosols.

4.2 Erodibility

The erodibility of a soil is influenced by the following factors:

- The rainfall erosivity factor (R)
- The soil erodibility factor (K)
- Topographic factors such as the gradient/slope (S) and length (L)
- Management factors such as cropping management and conservation practices (C and P).

The soil factors are discussed in more detail below.

4.2.1 Soil Erodibility Factor

The soil erodibility factor (K-factor) is a quantitative description of the inherent erodibility of a soil; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. For particular soils, the soil erodibility factor is the rate of erosion per unit erosion index calculated from a standard plot. The factor reflects the fact that different soils erode at different rates when the other factors affecting erosion (e.g., infiltration rate, permeability, total water capacity, dispersion, rain splash, and abrasion) are the same. Texture is the principal factor affecting K_{fact}, but structure, organic matter, and permeability also contribute. The soil erodibility factor ranges in value from 0.009 to 0.010.

The soils tested over the site indicate a low Soil Erodibility Factor of <0.069.

4.2.1.1 Texture

Vertosols are clay-rich soils (>35% clay content) of uniform texture. The topsoils tested on site had clay contents greater than 45%. They therefore have the potential for strong cracking and slickensides.

The high clay content also provides for high agricultural potential with high chemical fertility and water-holding capacity, but they require significant amounts of rain before water is available to plants. Heavy plastic clays can be difficult to cultivate especially when they are wet.

4.2.1.2 Soil Structure

Typically soils containing in excess of 45% clay have some shrinking and swelling properties which can be beneficial to soil structure, by having the ability to repair some compaction layers produced by cultivation and machinery.

Cations are an important influencer of soil structure. Cations, such a calcium, in correct ratios create good soil structure. An in-balance of some cations can create poor structure. Soil with a higher percentage of sodium (above 6% of cations) tends to have poor soil structure and are classified as sodic. Sodium also binds soil particles together and in the presence of water, this bond is very weak, and the soil becomes dispersive. When dry, the bond is quite strong, causing the soil surface to set hard and reduce water infiltration and root growth. The 0-30cm soil samples show adequate ratios of sodium while in the green zone, the 60-90cm samples indicate sodicity. At this depth it is uneconomic to ameliorate and may not present significant management issues. Calcium levels in all sites are adequate indicating that there is low potential for dispersion of topsoils upon wetting.

The results indicate that the soils over the site have good structure and unlikely to be highly dispersive when wet. There is no indication that water infiltration and storage will be limited by soil structure. It is unlikely plant growth would be significantly affected by soil structure over the site.

Some of the areas of the site show some evidence of hard setting surface properties, which may elevate the risk of soil erosion from the site from a low to moderate status under typical rainfall conditions, particularly if the soil does not have surface cover such as in a cropping fallow phase.

4.2.1.3 Saturated Hydraulic Conductivity (SHC)

Saturated Hydraulic Conductivity is a property of soils, that describes the ease with which water can move through pore spaces or fractures. It is a measurement of the permeability of the soil. Soil with low SHC experience higher rate of rainfall runoff.

Results indicate that the soils tested across the site have a high SHC reading and therefore have the ability to allow rainfall to infiltrate and move through the soil profile, thus reducing runoff.

4.2.2 Gradient

As discussed in Section 2.2 the site represents some of the least sloping area of the landscape, with slopes of no greater than 2 to 4% for the majority of the site.

4.2.3 Wind Erosion

Wind erosion is common on dry fine surface soils and is exacerbated by over stocking, cultivation and removal of groundcover. Reduced tillage and the retention of stubble or pasture at levels greater than 30 per cent will minimise the effects of wind and water erosion.

5 Conclusions and Recommendations

The predominant landscape classification for the site is derived from the Babinboon soil landscape and the site is generally dominated by imperfectly draining brown vertosols, which tend to occupy the lower slopes of this landscape. The low gradient and the low erodibility of the topsoil provides for a low erosion risk under sheet flow conditions. However, some of the areas of the site show some evidence of hard setting surface properties, which may elevate the risk of soil erosion from the site from a low to moderate status under typical rainfall conditions. Erodibility of the soils in this area are considered to be prone to sheet erosion under intense rain and overland flow events. This may well require some consideration and management to mitigate. Obvious solutions would be either the planting of ground cover or the consideration of contour banks within the site.

Erosion risk for this soil type can be high under concentrated water flow, but there is currently no evidence of gully erosion on site despite extended fallow periods. Maintaining good ground cover in drainage lines will also mitigate this.

Wind erosion is generally not considered an issue for the soils of this landscape, although groundcover would also mitigate this.

The clay content at the site causes the soil to swell when wet and crack when dry, which can have some structural implications especially for the foundations of buildings and will need to be taken into account during design. Both the salinity risk and waterlogging risk are low.

The primary erosion control recommendation for the site is to establish and maintain vegetative ground cover particularly in drain ways and to minimise the extent of soil disturbance where possible. This will reduce the level of soil erosion risk relative to the current management practice of a cropping and grazing rotation with extended fallows.

The chemical fertility and water holding potential of the soils are suitable for the establishment of ground cover, although some consideration should be given to the potential soil limitations of phosphorus, sulphur and zinc when considering species selection and survival. A solution to this would be to consider either a blended mineral fertiliser or an organic amendment option to improve the overall fertility of the site. Given the range of chemical limitations and the benefit that organic amendments can deliver, when low soil organic carbon is encountered, chicken manure could be considered as a suitable ameliorant in this instance. Planting choice would then need to be matched to suit the soils chemical potential and the climatic conditions of the area. The greatest limitation to establishing groundcover at present would not be the soils physical and chemical condition, but the lack of ground water and forecast rainfall.

6 References

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Oliver, Y, Wong, M., Mata, G. and Holmes, K (2019). Using EM And Gamma Maps To Map Soil Types And Help Locate Subsoil Constraints For Management, GRDC

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7 Appendix A. Soil test results.

PRECISION PASTURES

Tamworth Solar Farm
September 2019
Greg Wynn - Agronomist

	Name	Green Zone			Purple Zone		Yellow Zone		
	Depth (cm)	0-30	30-60	60-90	0-30	30-60	0-30	30-60	
Test Parameter	Units								Ideal Range
pH (1:5 in H20)	pH units	7.16	7.64	8.59	7.79	7.89	7.44	8.46	
pH (1:5 in CaCl2)	pH units	6.67	6.87	7.79	7.23	7.36	6.63	7.88	5.5 - 7.5
Chloride Soluble	mg/kg	23.6	24.0	76.0	19.6	13.8	10.9	34.8	< 150
Electrical Conductivity	dS/m	0.12	0.09	0.22	0.15	0.22	0.05	0.16	<0.15
Extractable Nitrate-N	mg/kg	21.9	13.4	7.30	10.9	7.08	9.83	4.51	
Ammonium - N (Ex)	mg/kg	9.40	2.34	5.65	2.71	6.20	6.93	5.83	
Organic Carbon (LECO)	%	1.09	0.92	0.57	1.20	0.61	0.87	0.68	> 1.2
Organic Matter	%	1.9			2.1		1.5		
Phosphorus Buffer Index	mg/kg	109	140	110	119	181	113	84.8	
Phosphorus (Colwell)	mg/kg	8.73	11.5	10.3	17.3	10.2	10.4	7.16	> 40
Extractable Phosphorus(BSES)	mg/kg	4.02	5.79	4.92	7.56	2.50	9.85	12.4	
Sulfate - S (KCl40)	mg/kg	3.97	<3.0	4.07	3.75	<3.0	6.26	5.27	8 - 10
Extractable Copper	mg/kg	1.28	0.79	0.65	0.97	1.05	1.08	0.65	
Extractable Zinc	mg/kg	<0.2	<0.2	<0.2	0.31	<0.2	<0.2	<0.2	
Extractable Manganese	mg/kg	28.6	13.2	4.54	12.8	4.66	19.2	3.87	
Extractable Iron	mg/kg	22.7	13.1	8.29	15.7	12.2	11.4	7.46	
Extractable Boron	mg/kg	1.10	0.69	1.20	0.93	0.57	1.35	1.07	
ECEC	cmol/kg	21.4	27.0	31.1	27.2	32.8	22.1	32.2	
Ca/Mg Ratio	cmol/kg	7.35	2.83	2.55	3.89	2.48	2.62	2.63	
K/Mg Ratio	cmol/kg	0.40	0.07	0.06	0.16	0.04	0.16	0.05	
Exchangeable Potassium %	%	4.49	1.64	1.52	3.01	1.05	4.14	1.42	
Exchangeable Calcium %	%	82.2	70.4	66.0	75.4	68.5	68.5	69.7	60 - 70
Exchangeable Magnesium %	%	11.2	24.9	25.9	19.4	27.7	26.2	26.5	
Exchangeable Sodium %	%	2.00	3.00	6.55	1.96	2.70	0.96	2.33	< 6
Exchangeable Aluminium %	%	0.16	0.08	0.04	0.20	0.08	0.18	0.07	< 2

Saturated Hydraulic Conductivity	mm/hr	50.5			40.7		35.4		
Dispersion Percentage	%	11.1			17.9		18.5		
Linear Shrinkage	%	10			11		12		
Water Retention	%	30.6			29.8		27.8		
Total Water Holding Capacity	%	30.3			30.5		26.7		
Bulk Density	g/cm3	1.3			1.2		1.3		
Soil Structure (SS)	Code	3			3		3		
Profile Permeability Class (PP)	Class	3			3		3		
Soil Erodibility Factor (K)	Factor	0.010			0.009		0.009		< 1
Dispersion Index	Class	1	4	5	0	0	2	0	< 3
Texture	Class	MC	MC	MC	MC	MC	MC	MC	
Gravel >2.0mm	%	1.0			5.4		1.1		
Coarse Sand 0.2-2.0mm	%	9.8			13.4		16.4		
Fine Sand 0.02-0.2mm	%	18.6			18.0		18.3		
Silt 0.002-0.02mm	%	22.9			17.4		14.3		
Clay <0.002mm	%	47.7			45.9		50.0		