Mallee Dune Seeps

Soil Characterisation and Land Unit Mapping

Rose-Thomas Subcatchment

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Introduction

Mallee dune seeps are areas of excessive wetness in mallee dune–swale environments. Within the last decade a number of seep areas have appeared across the Murray Mallee. When these areas become too wet they are no longer croppable (arable) – causing some of the best farmland in mallee environments to be lost to production.

The specific nature of the processes involved is not yet fully understood, nor is the specific cause of the increased landscape water known. It is suspected, however, that effective control of summer weeds on sand dune areas – as a result of the use of modern farming techniques and herbicides within continuous cropping systems – has created excess water in these low rainfall farming environments. Anecdotal evidence suggests that most dune seep areas have appeared since these technology changes have occurred – although older seep areas exist.

Soil and regolith investigations and land management–use trails have been instigated at a number of sites to determine causes, processes and best practice methods of control, amelioration and remediation.

A key question is whether a topsoil dominant water-flow system (upon the subsoil surface), or a much deeper water-flow system (or both), is involved in the development of dune seeps. (It is known that regional groundwater is not involved, as this occurs at considerable depth (e.g. 50 m or more)).

Determination of causes and better understanding of processes at affected subcatchments will lead to recommendations of effective management and land use to ameliorate seep areas – to minimise their spread and occurrence and bring affected areas back into production.

This Report

This report is based upon initial investigations at the Rose-Thomas subcatchment area at Kulde, in the South Australian Murray Mallee (see Appendix 1, Figure 1 and Appendix 2), done in conjunction with Rural Solutions SA as part of an SA MDB NRM Board project.

It documents soil characterisation investigations at three sites along a toposequence – from a dune crest to a dune seep area – where it is obvious that the three sites are directly interconnected in terms of water processes within the subcatchment system (see Appendix 2).

Soil characterisation is undertaken to investigate representative soils in detail so that impediments to root and plant growth and production can be better understood. Soil description according to national standards (NCST 2009) and comprehensive chemical analyses help with the understanding of soil physical and chemical characteristics, which can then be used to make interpretations of soil, landscape and agronomic processes, systems and interactions – such as water movement, storage and use. Chemical analyses of soil samples were performed at CSBP Laboratories in Western Australia.

The report also presents land unit mapping of the study subcatchment (see Appendix 1, Figure 2). Land unit mapping shows the nature and extent of particular landscape areas, giving insights into topography, geomorphology, geology, soils, and land and soil conditions (such as wetness and salinity). This is based on expert stereoscopic Air-Photo-Interpretation (API) using the most recent and highest resolution aerial photograph stereo pairs (2001 from Mapland). However, because there were no seepage areas evident in 2001, aerial photos from 2013 were also used to assess the extent of seepage. Unfortunately, however, no stereo pairs are available. It must be understood that such mapping is based on an extremely limited number of on-ground investigations. Production of soil landscape map units, for example, would require a detailed soil survey of the study area.

Additional investigations (e.g. see Appendix 1, Figure 1) – such as drilling (to determine the nature of deeper materials and whether deeper perched water is present) and the installation of peisometer monitoring wells – will add to the overall 'picture' of mallee dune seep systems, and will be more fully reported upon, together with soil characterisation, API and assessments of relevant reference information, in subsequent reporting for the SA MDB NRM Board.

Findings and Interpretations

The soil characterisation sites (see Appendix 2) form a toposequence from a dunecrest to a lower dune slope to a low-lying seep area – sites which are thought be indicative of the wider subcatchment area – and reveal a sandy to sandy loam, inherently infertile topsoil system. Surface soils are sandy outside of seep areas, and are often water repellent (but not strongly so). Topsoil are often very thick (>60 cm). Topsoils also have limited capacity to store and retain nutrients, with waterholding capacities that are only moderate and downward water movement that is largely unrestricted.

Subsoils range from light sandy clay loams to medium clays. Subsoils are brown and mottled – indicating internal soil drainage that is restricted to some extent. Subcatchment subsoils are expected to follow the pattern shown at the characterisation sites of lighter textures (sandy clay loams) on dunes and heavier textures (clays) on lower slopes and in swales.

Interpretations of chemical analyses of subsoil material can reveal drainage potential and history. For example, the sandy clay loam subsoil of the dunecrest has relatively high pH and a maximum accumulation of fine carbonate below 110 cm, which indicate that drainage is not excessive and is restricted to some degree, as well as indicating that the seasonal wetting front typically reaches below 1 m. In contrast, more easily leached materials such as salt (as measured by ECe), sodium (as measured by ESP) and boron show no zone of accumulation in the top 165 cm. This and other indicators show that soil profile drainage on the dunecrest is neither excessive or greatly restricted, but is moderate. In-the-field 'consistence' assessment (moisture content and strength as a function of clay content – see NCST 2009) revealed no saturated soil layers, with the highest moisture contents in the 14–60 cm zone. It is therefore unlikely that large amounts of soil water move along the surface of the underlying sandy clay loam layer, and that the majority of soil water that is not stored in the profile or used by growing plants would move downward rather than laterally.

The lower slope site possesses more restrictive subsoil layers because of higher clay content, as well as because of the presence of thin calcrete lamellae and dispersive clays. The presence of bleached topsoil is confirmation of this. Chemical analyses reveal a maximum fine carbonate accumulation from 98–120 cm, as well as a very high pH, a build-up of boron and sodium, and a slight build-up of salt below this. Accumulation of excessive sodium in the subsoil results in restrictive, dispersive soil. The chemical analyses indicate a seasonal wetting front that typically reaches below 1 m. Consistence assessment (NCST 2009) revealed that the wettest layers were the lower topsoil and the directly underlying upper subsoil. The lower topsoil, while not saturated, was at approximately field capacity, indicating that it is likely that there is some lateral movement of water when this layer becomes saturated. Profile internal drainage is imperfect. It is likely that significant amounts of soil water within this profile move laterally as well as downward.

The site on the margins of the seep area gives all the indications of having very restricted drainage, with an accumulation of substances throughout the profile. Salt levels (as measured by ECe) reach their maximum levels in the subsurface layer (a moderate level of 7.3 dS/m at 15–28 cm) and are relatively low below this (<2.5 dS/m). This confirms that these are 'freshwater' perched systems, which can become salty over time as salts accumulate in the surface soils of seeps owing to evaporative accumulation processes, especially in areas with no vegetative cover. There are a few indications from the chemical and morphological analyses that demonstrate the seep has not been wet for a great number of years. Firstly, the soil lacks a high organic carbon content in the surface soil, and secondly, the nature of the mottling of the subsoil does not indicate excessive wetness and is similar to that of the lower slope and dunecrest sites. Of interest is that no layer was seen to be saturated (on the day of description), although water was evident on the land surface in the scalded part of the seep a few metres away. The layer from 47–62 cm (the upper subsoil) was the wettest – all layers were at field capacity or greater. When the site was excavated, water began to trickle in from the top of the clay layer just upslope, while some water entered via a crack in the pit face at a depth of about 1 m. After one day the excavated hole was half-full of water. The site has very poor to poor drainage, indicating the presence of a restrictive layer that holds up the soil water not far below the land surface. In this mallee environment, such a layer is expected to be a restrictive clay. Although such a layer was not encountered upon excavation, subsequent nearby drilling confirmed this.

Air-Photo-Interpretation reveals that the closed depressions that form seep areas seem to be blocked by slightly raised calcrete bench areas, both in the study subcatchment and in an adjacent subcatchment.

The Rose–Thomas subcatchment subsoil and related deeper materials exhibit many of the characteristics of 'Loxton–Parilla Sand' (intimately mixed sand and clay deposited as foreshore strandlines in Tertiary times – see Hall et al. 2009). However, subsequent deep drilling in the subcatchment revealed an underlying heavy, tight, mottled clay at depth, which is most likely 'Blanchetown Clay' (an ancient lake bed deposit – see Hall et al. 2009). As Blanchetown Clay overlies Loxton–Parilla sand in the geological sequence, the overlying material cannot then be 'true' Loxton–Parilla sand. However, much reworking of materials has occurred through the ages, and it is possible that reworked Loxton–Parilla Sand, in conjunction with younger siliceous sands and carbonate materials, has been deposited upon Blanchetown Clay (which has been encountered at other soil characterisation sites in the Murray Mallee – see Soil and Land Program 2007; Hall et al. 2009). Further background research is needed to confirm that the deep tight clay is Blanchetown Clay.

Deep drilling revealed saturated layers upon underlying heavy, tight mottled clay at all three sites of the topsequence – surprisingly this even included the dunecrest. The drilling demonstrated that the main water-bearing system was at depth (e.g. about 6 m on the dunecrest), and that the tight mottled clay (probably Blanchetown Clay) forms the base of this system. Nonetheless, lateral flow along subsoil surfaces would not be an insignificant part of the overall system (e.g. as indicated at the lower slope site).

A more comprehensive integration and interpretation of all relevant data, together with recommendations, will be given in a subsequent report to the SA MDB NRM Board.

References

Maschmedt DJ (2002). Assessing Agricultural Land. Agricultural Land Classification Standards used in South Australia's Land Resource Mapping Program. Soil and Land Program, Government of South Australia, Adelaide [CD ROM].

Hall JAS, Maschmedt DJ and Billing NB (2009). *The Soils of Southern South Australia*. *The South Australian Land and Soil Book Series*, Volume 1. *Geological Survey of South Australia*, Bulletin 56, Volume 1. Soil and Land Program, Government of South Australia, Adelaide.

Isbell RF (2002). *The Australia Soil Classification – Revised Edition*. *Australian Soil and Land Survey Handbook Series*, Volume 4, CSIRO Publishing, Collingwood, Victoria.

Munsell Color (1988). Munsell Soil Color Charts. MacBeth Division of Kollmorgen Instruments Corporation, Baltimore, Maryland.

NCST (2009). *Australian Soil and Land Survey – Field Handbook* (3rd edition). *Australian Soil and Land Survey Handbook Series*, Volume 1, The National Committee on Soil and Terrain (NSCT), CSIRO Publishing, Collingwood, Victoria.

Soil and Land Program (2007). Regional Land Resource Information for Southern South Australia. Soil and Land Program, Government of South Australia, Adelaide [DVD ROM].

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Appendices

Appendix 1 – Figures

Figure 1: Rose-Thomas Subcatchment at Kulde in the South Australian Murray Mallee: Showing Sites Investigated via Soil Characterisation and Drilling (showing a 2013 aerial image as background).

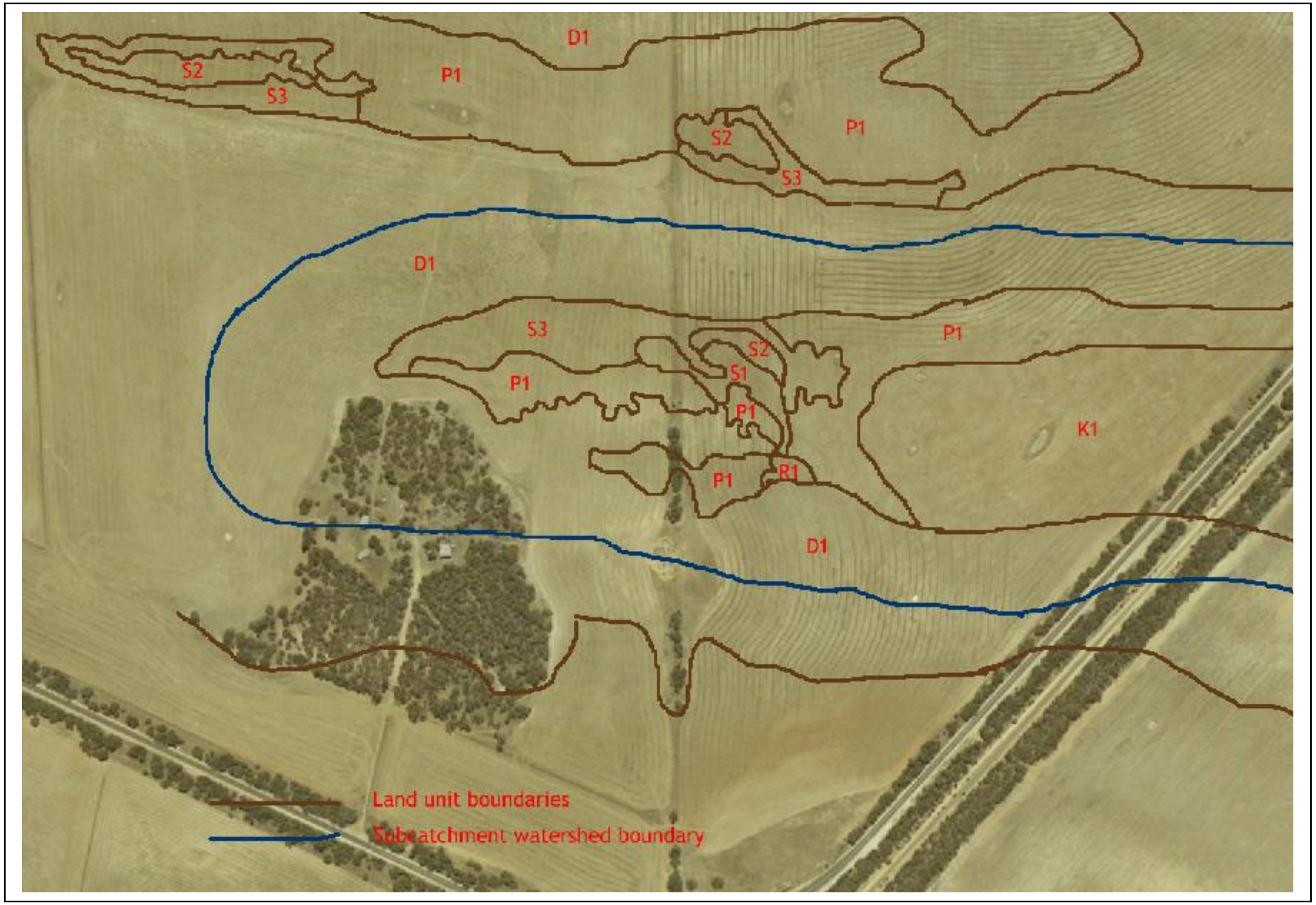
D1
S2
S3
P1
S2
P1
S3
D1
S3
S2
P1
P1
S1
P1
K1
P1
R1
D1
Land unit boundaries
Subcatchment watershed boundary

Figure 2: Rose-Thomas Subcatchment at Kulde in the South Australian Murray Mallee: Land Units and Subcatchment Watershed Boundary (showing a 2001 aerial photograph as background).

Land unit development is based on stereoscopic Air-Photo-Interpretation (API) of 2001 aerial photographs, an interpretation of 2013 aerial photographs (non-stereo), a very limited number of on-ground investigations, and State Land & Soil Mapping Program descriptions of the area (Soil and Land Program 2007).

D1 = sand dune areas

P1 = lower slopes and plains, often with calcrete at shallow depth

K1 = plains dominated by calcrete at shallow depth

S3 = flats, plains and lower slopes with signs of wetness

S2 = low-lying, secondary seep areas: semi-arable to non-arable

S1 = low-lying, primary seep areas: the most severely affected areas; non-arable (given the current subcatchment water balance); mostly scalded, and eroded by channel erosion in places; surface water observed. This area is affected not only by seepage from adjacent slopes, but also by seepage and overland flow from the larger 'S3' seepage area to the west.

R1 = low-lying, flow-on area: area seasonally affected by over-flow from the main seep area (S1); semi-arable.

Appendix 2 – Drilling Reports

Notes: It needs to be noted that drilling is a very uncertain business, and that materials disturbed by the drill head do not necessarily travel up the augur to the land surface at an even rate or, in some cases, do not travel up the rotating augur at all (e.g. heavy clay and wet materials), and that it is often uncertain which depths specific materials are derived from. However, it can be reasonably assumed that materials deposit at the land surface in sequential order. Depths given below, therefore, are indicative only. Colours are also mostly indicative, as materials of different colours are mixed.

Site MDS-R01 – Drilling Report (10/6/2015)

Easting 378 315 Northing 6109 333

Position: dune crest

Depth (cm)	Material
50	loamy sand / dark yellowish brown / moderately moist / loose / - / -
-	loamy sand / very pale brown / moist / loose / - / -
-	sandy loam / yellowish brown / moist / very weak / - / -
-	light sandy clay loam / brownish yellow / moist / weak / - / -
-	sandy light clay to sandy medium clay / yellowish brown / moist / firm / - / - [some hard carbonate]
-	sandy medium clay / strong brown / moist / firm / slightly calcareous / - [some hard carbonate]

Total drilling depth was 10.5 m. It became uncertain what depths material was derived from in the hole, so depths are not given. There was a likely saturated layer at approximately 6 m. A tight, mottled, heavy clay was encountered at approximately 7 m.

Site MDS-R02 – Drilling Report (10/6/2015)

Easting 378 312 Northing 6109 281

Position: lower dune slope

Depth (cm)	Material
-	loamy sand / dark yellowish brown / moist / loose / - / -
-	loamy sand / very pale brown / moist / loose / - / -

-	sandy clay loam / yellowish brown / moderately moist / weak / - / -
-	sandy light clay / yellowish brown / moist / weak / - / -
-	sandy light clay / yellowish brown / moist / weak / moderately calcareous / -
-	sandy light clay / yellowish brown / wet to moist / very weak / moderately calcareous / -
-	sandy light clay / yellowish brown / wet / loose / moderately calcareous / moderately dispersive
------------------------ discontinuity	---
-	heavy clay / - / - / - / - / -

Total drilling depth was 6 m. It was uncertain what depths material was derived from in the hole, so depths are not given. A tight, mottled, heavy clay was encountered at approximately 6 m and above; and a saturated layer was encountered to an uncertain height above this.

Site MDS-R04 – Drilling Report (11/6/2015)

Easting 378 315 Northing 6109 030

Position: upper dune slope

Depth (cm)	Material
50	loamy sand / yellowish brown / moist / loose / - / -
100	loamy sand / light yellowish brown / moist / loose / - / -
150	loamy sand / light yellowish brown / moist / loose / - / -
200	loamy sand / very pale brown / moderately moist / loose / - / -
250	loamy sand / yellowish brown / moist / loose / - / -
300	[calcrete layer]
350	heavy sandy loam / yellowish brown / moist / very weak / moderately calcareous / -
400	sandy light clay / yellowish brown / moist / weak / moderately calcareous / moderately dispersive
------------------------ discontinuity	---
450	sandy medium heavy clay / yellowish brown and greenish grey / moderately moist / firm / moderately calcareous / -
550	heavy clay / dark red and greenish grey / moderately moist / strong / moderately calcareous / slightly dispersive

A tight, mottled, heavy clay was encountered at approximately 450 cm.

Site MDS-R05 – Drilling Report (11/6/2015)

Easting 378 418 Northing 6109 177

Position: depression / on edge of seepage area

Depth (cm)	Material
50	sandy loam (organic rich) / dark brown / wet / loose / slightly calcareous / -
100	sandy loam / very pale brown / wet / loose / moderately calcareous / - [some hard carbonate]
200	sandy clay loam / brownish yellow / wet / loose / moderately calcareous / - [some hard carbonate]
------------------------ discontinuity ---	
300	heavy clay / yellowish red, light olive brown and greenish grey / moderately moist / strong / moderately calcareous / -

A tight, mottled, heavy clay was encountered below approximately 200 cm. The soil profile was saturated above this.

Appendix 3 – Soil Characterisations

SAND OVER SANDY LOAM / OVERLYING A BROWN MOTTLED SANDY CLAY LOAM

Medium thickness sandy surface soil on sandy loam subsoil which overlies brown mottled sandy clay loam with fine carbonate at depth.

Subgroup soil Soil G1 (Sand over sandy loam / overlying sandy clay loam material) (Hall et al. 2009)

Landform Dunefield / Undulating rises

Substrate Mottled sandy clay loam

Vegetation Mallee scrub (to approximately 10 m)

Position Dunecrest

Site Rose-Thomas subcatchment:

Site No: MDS-RO1 1:50 000 mapsheet: 6827–4 (Wynarka)
Hundred: Hooper Easting: 378 327
Section: - Northing: 610 9332
Date: 14/5/2015 Annual rainfall: Approx. 350 mm

Soil Description

Depth (cm)	Description
0–12	Loose, brown loamy sand with single grain structure. Abrupt boundary to:
12–14	Light yellowish brown, bleached, loamy sand with single grain structure. Abrupt boundary to:
14–30	Brownish yellow, light sandy clay loam with heavier-textured, dark yellowish brown lamellae and massive structure. Gradual boundary to:
30–60	Brownish yellow, sandy loam with a few heavier-textured lamellae and massive structure. Gradual boundary to:
60–90	Yellowish brown, sandy loam with massive structure. Abrupt boundary to:
90–110	Slightly calcareous, brownish yellow, strong brown and olive yellow, light sandy clay loam with massive structure. Clear boundary to:
110–165	Highly calcareous, reddish yellow, light sandy clay loam with massive structure.

Australian Soil Classification

Basic, Regolithic, **Brown-Orthic Tenosol** / overlying calcareous, mottled, sandy clay loam; medium, non-gravelly, sandy / loamy, moderate.

Summary of Properties

Drainage Moderately well drained. Soil profile may remain wet for up to a week after heavy or prolonged rainfall.

Fertility The sandy surface soil has very low Cation Exchange Capacity (as estimated by the Sum of Cations), but this increases down the profile with increasing clay content. In addition, Phosphorus Buffering Index is low throughout the profile, but it does reach satisfactory levels below 110 cm. These analyses indicate a low capacity to store and retain nutrients. There is some leaching of phosphorus to 30 cm, which is indicative of excessive leaching. Organic carbon levels are very low in the topsoil, as are sulfur and boron levels.

pH Slightly acidic surface soil overlies alkaline soil which almost reaches strongly alkaline levels in lower layers.

Rooting depth Roots were observed to 90 cm, with few below 30 cm.

Barriers to root growth

Physical There are no significant physical restraints to root growth and downward water movement to 165 cm, although the soil is relatively hard below 110 cm.

Chemical Chemical restraints to root growth include very low fertility levels below 30 cm, and very high pH below 60 cm.

Waterholding capacity Plant Available Waterholding Capacity is estimated to be approximately 45 mm, which is moderately low. [Workings: (0.12x100)+(0.02x80)+(0.16x150)+(0.30x120x0.1)+(0.30x120x0.1)].

Seedling emergence Good. The sandy surface soil provides good seed–soil contact and no barrier to seedling emergence.

Workability Good.

Erosion potential

Water Low.

Wind Moderate wind erosion potential. Surface protective cover is required to prevent erosion.

Laboratory Data

Horizon	Depth cm	Texture	N NH_4^+ mg/kg	N NO_3^- mg/kg	pH H_2O	pH $CaCl_2$	CO_3 %	EC 1:5 dS/m	ECe dS/m	Org C %	P Avail. mg/kg	P Buff Index	K Avail. mg/kg	S (KCl) mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				Sum cations meq/100g	Exchangeable Cations meq/100g					ESP
																Cu	Fe	Mn	Zn		Ca	Mg	Na	K	Al	
1A11	0–12	ls	1	9	6.2	5.5	0.29	0.030	0.36	0.63	25	16.4	125	2.2	0.27	1.18	42.7	1.37	1.31	2.34	1.52	0.42	0.02	0.27	0.11	0.85
1A2e	12–14	ls	horizon not sampled owing to insufficient thickness																							
1B21w	14–30	scl-	3	2	8.3	7.5	0.43	0.040	0.38	0.18	5	28.2	189	1.9	0.69	0.63	3.38	0.11	1.04	7.19	5.44	0.90	0.04	0.48	0.33	0.56
1B22w	30–60	sl	1	1	8.9	8.0	0.73	0.047	0.32	0.05	<2	29.9	133	1.3	0.88	0.50	2.67	0.08	0.47	6.88	5.42	0.80	0.03	0.34	0.29	0.44
1B23w	60–90	sl	<1	<1	9.1	8.1	0.82	0.048	0.26	0.07	<2	31.6	114	1.2	1.19	0.43	2.19	0.10	0.47	7.23	5.29	1.32	0.04	0.29	0.29	0.55
2Bt	90–110	scl-	1	<1	9.1	8.2	1.19	0.058	0.27	0.06	<2	41.9	249	1.1	2.12	0.41	4.70	0.64	0.89	9.25	5.74	2.61	0.05	0.64	0.21	0.54
2Btk	110–165	scl-	2	1	9.1	8.3	11.8	0.084	0.38	0.11	<2	115.2	322	1.8	2.50	0.50	2.95	0.66	0.39	10.3	6.77	2.51	0.06	0.82	0.14	0.58
Approx. Critical/Ideal Values			-	-	6–8	5.5–7.5	0	<0.7–1.85	<4–8	>1–2	>25–35	100–200	>80–120	>6–8	1–15	>0.2	>2.5	>1–2	>0.5–1.0	>15	75% CEC	20% CEC	<6% CEC	5% CEC	<5% CEC	<6

Note: (1) Sum of Cations approximates the Cation Exchange Capacity (CEC), a measure of the soil's capacity to store and release major nutrient elements.

(2) Exchangeable Sodium Percentage (ESP) is derived by dividing the exchangeable sodium value by the CEC, in this case estimated by the Sum of Cations.

VERY THICK BLEACHED SAND OVER BROWN MOTTLED CLAY

Very thick sandy topsoil with some bleaching, overlying slightly dispersive brown mottled clay subsoil with fine and hard carbonate.

Subgroup soil Soil G3 (Thick sand over clay) (Hall et al. 2009)

Landform Dunefield / undulating rises

Substrate Mottled sandy clay

Vegetation Mallee scrub (to approximately 10 m)

Position Lower duneslope (4% slope)

Site Rose-Thomas subcatchment:

Site No: MDS-R02 1:50 000 mapsheet: 6827–4 (Wynarka)
Hundred: Hooper Easting: 378 328
Section: - Northing: 6109 282
Date: 14/5/2015 Annual rainfall: Approx. 350 mm

Soil Description

Depth (cm)	Description
0–18	Loose, water repellent, brown loamy sand with single grain structure. Abrupt boundary to:
18–60	Very pale brown and brownish yellow, sporadically bleached, sand with single grain structure. Clear boundary to:
60–80	Brownish yellow loamy sand with single grain structure and minor heavier-textured lamellae. Sharp boundary to:
80–98	Yellowish brown, strong brown and olive yellow, light clay with massive structure. Gradual boundary to:
98–120	Yellowish brown, strong brown and olive yellow, slightly dispersive, moderately calcareous, light medium clay with approximately 20% hard carbonate fragments (2–20 mm) and laminae, as well as massive structure. Gradual boundary to:
120–170	Yellowish brown, strong brown and olive yellow, slightly dispersive, fine sandy medium clay with massive structure.

Australian Soil Classification

Mottled-Sodic, Supracalcic, **Brown Chromosol**; very thick, non-gravelly, sandy / clayey, moderate.

Summary of Properties

Drainage The soil profile is imperfectly drained. Soil may remain wet for several weeks after heavy or prolonged rainfall.

Fertility The very thick sandy topsoil has very low Cation Exchange Capacity (as estimated by the Sum of Cations) – with almost none recorded in the bleached layer from 18–60 cm, and low Phosphorus Buffering Index. This indicates that the topsoil has little capacity to store and retain nutrients. There is evidence of leaching of phosphorus to 80 cm (the base of the topsoil), which is indicative of excessive leaching. Topsoil levels of organic carbon, potassium, sulfur and boron are also low. The capacity of the subsoil to retain nutrients is much greater owing to higher clay content.

pH Acidic surface soil overlies alkaline subsurface layers, which in turn over subsoil that grades from alkaline to strongly alkaline at depth.

Rooting depth Roots were observed to 60 cm, with few below 18 cm.

Barriers to root growth

Physical There are no significant physical constraints to root growth above 98 cm. Below this the soil is slightly dispersive and relatively hard, with high sodicity levels below 120 cm. Also, the subsoil contains a series of discontinuous, thin calcrete lamallae, which present a barrier to root growth.

Chemical General topsoil infertility inhibits root growth. It is also highly probable that seasonal water perched upon the subsoil also restricts root growth to deeper layers.

Waterholding capacity Plant Available Waterholding Capacity is estimated to be approximately 52 mm, which is moderate. [Workings: (0.18x100)+(0.42x80)].

Seedling emergence Good. The sandy surface soil provides good seed–contact and no barrier to seedling emergence. Although the surface soil exhibits water repellence.

Workability Good.

Erosion potential

Water Low.

Wind Moderate wind erosion potential. Surface protective cover is required to prevent erosion.

Laboratory Data

Hori-zon	Depth cm	Texture	N NH_4^+ mg/kg	N NO_3^- mg/kg	pH H2O	pH CaCl2	CO3 %	EC 1:5 dS/m	ECe dS/m	Org C %	P Avail. mg/kg	P Buff Index	K Avail. mg/kg	S (KCl) mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				Sum cations meq/100g	Exchangeable Cations meq/100g					ESP
																Cu	Fe	Mn	Zn		Ca	Mg	Na	K	Al	
A11	0–18	ls	2	9	5.8	4.9	0.30	0.03	0.36	0.35	26	15.1	40	2.0	0.20	0.91	36.8	2.72	0.70	1.9	1.44	0.25	0.02	0.10	0.09	1.05
A21j	18–60	s	3	2	6.7	5.7	0.28	0.02	0.15	0.07	13	8.0	25	0.7	0.12	0.58	16.2	0.66	0.18	<1.0	0.71	0.12	<0.01	0.06	0.10	<1.0
A22	60–80	ls	2	6	7.0	6.5	0.27	0.02	0.33	<0.05	8	7.3	47	1.2	0.19	0.68	7.81	0.60	0.32	1.67	1.12	0.29	0.02	0.12	0.12	1.20
B21t	80–98	lc	5	3	8.8	7.9	1.56	0.07	0.32	0.08	2	62.4	315	1.5	3.49	0.58	4.94	0.59	0.68	12.24	6.56	4.38	0.26	0.81	0.23	2.12
B22tk	98–120	lmc	3	5	9.2	8.3	16.3	0.10	0.52	0.21	<2	143.2	348	2.6	6.66	0.56	6.51	0.61	0.90	16.24	9.30	5.20	0.63	0.89	0.22	3.88
C	120–170	fsmc	2	3	9.6	8.5	3.28	0.19	0.90	0.08	<2	75.4	355	1.5	10.3	0.50	6.36	0.59	0.46	13.97	5.36	5.46	1.99	0.94	0.22	14.2
Approx. Critical/Ideal Values			-	-	6–8	5.5–7.5	0	<0.7–1.85	<4–8	>1–2	>25–35	100–200	>80–120	>6–8	1–15	>0.2	>2.5	>1–2	>0.5–1.0	>15	75% CEC	20% CEC	<6% CEC	5% CEC	<5% CEC	<6

Note: (1) Sum of Cations approximates the Cation Exchange Capacity (CEC), a measure of the soil's capacity to store and release major nutrient elements.

(2) Exchangeable Sodium Percentage (ESP) is derived by dividing the exchangeable sodium value by the CEC, in this case estimated by the Sum of Cations.

WET SANDY LOAM OVER SANDY CLAY LOAM

Thick sandy loam topsoil with abundant hard carbonate in the lower part, over sandy clay loam subsoil with fine and hard carbonate.

Subgroup soil Soil N3 (Wet soil) (Hall et al. 2009)

Landform Dunefield / Undulating rises

Substrate Mottled light clay

Vegetation Mallee scrub

Position Closed depression

Site Rose-Thomas subcatchment:

Site No: MDS-R03 1:50 000 mapsheet: 6827–4 (Wynarka)
Hundred: Hooper Easting: 378 340
Section: - Northing: 6109 235
Date: 14/5/2015 Annual rainfall: Approx. 350 mm

Soil Description

Depth (cm)	Description
0–15	Soft, dark brown, sandy loam with massive structure. Clear boundary to:
15–28	Slightly calcareous, brown sandy loam with massive structure. Clear boundary to:
28–47	Moderately calcareous, yellowish brown, heavy sandy loam with abundant hard carbonate nodules (20–60 mm). Clear boundary to:
47–62	Moderately calcareous, reddish yellow sandy clay loam with massive structure and abundant hard carbonate fragments (2–60 mm). Clear boundary to:
62–95	Highly calcareous, strong brown, yellowish brown and dark red, clay loam. Clear boundary to:
95–115	Highly calcareous, reddish yellow, pink and yellowish red, light clay with 20–50% hard carbonate fragments (6–60 mm).

Australian Soil Classification

Natric, Calcarosolic, **Oxyaquic Hydrosol**; thick, non-gravelly, loamy / clay loamy, shallow.

Summary of Properties

Drainage Poorly to very poorly drained. Soil may remain wet most of the year.

Fertility The position of this soil in the landscape, the fact the soil is wet, and that subcatchment flows terminate in this area, means that numerous substances accumulate within the profile. Consequently, sulfur, potassium and boron levels are high to adequate. However, toxic substances also accumulate here (see below). Interestingly, organic carbon levels are low, which indicates that this area has not been wet over the long term (the farmer Peter Rose indicates that excessive wetness was first noticed in this area in 2005).

pH Given that this area is part of a closed depression where subcatchment waters accumulate – bringing numerous substances with them, including alkaline-inducing ones – pH levels are strongly alkaline throughout the profile.

Rooting depth Roots were observed to 47 cm.

Barriers to root growth

Physical All layers are dispersive and highly sodic, however, moist soil conditions would indicate that there are no significant physical barriers to root growth.

Chemical Chemical barriers to root growth are significant. Strong pH levels restrict roots, as do raised salinity levels (especially in the subsurface layer from 15–28 cm) and high sodium levels.

Waterholding capacity Plant Available Waterholding Capacity (PAWC) is estimated to be approximately 50 mm, which is moderate. However, excessive wetness renders this area unsuitable for crop production – so PAWC could be considered 0 mm. [Workings: (0.15x120)+(0.13x120)+(0.19x120x0.7)].

Seedling emergence Satisfactory to poor. The sandy loam surface soil provides no barrier to seedling emergence. However, excessive wetness and chemical toxicities may limit germination and emergence of crop species.

Workability Poor. Excessive wetness leads to reduced trafficability.

Erosion potential

Water	Moderately low. Erosion can occur in this low-lying area via channel flow.
Wind	Moderately low. Bare scalds can be affected by wind erosion, with areas deflated in the process.

Laboratory Data

Hori-zon	Depth cm	Texture	N NH4+ mg/kg	N NO3- mg/kg	pH H2O	pH CaCl2	CO3 %	EC 1:5 dS/m	ECe dS/m	Org C %	P Avail. mg/kg	P Buff Index	K Avail. mg/kg	S (KCl) mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				Sum cations meq/100g	Exchangeable Cations meq/100g					ESP
																Cu	Fe	Mn	Zn		Ca	Mg	Na	K	Al	
A11	0–15	sl	<1	4	9.9	8.7	3.44	0.269	3.83	0.36	5	64.2	266	35.0	9.42	0.58	20.2	3.46	0.32	12.06	5.74	2.11	3.40	0.68	0.13	28.19
A12	15–28	sl+	<1	9	9.8	8.9	0.66	0.614	7.31	0.55	12	26.4	165	122.4	7.58	0.74	41.9	2.28	2.25	9.74	4.29	1.22	3.75	0.42	0.06	38.50
A3k	28–47	sl+	1	7	9.8	8.5	36.3	0.229	2.47	0.31	5	138	316	43.0	8.24	0.73	13.9	4.15	0.66	14.89	7.20	3.35	3.45	0.81	0.08	23.17
B21wk	47–62	scl	<1	6	9.8	8.6	53.7	0.315	2.50	0.20	3	165	276	48.0	6.79	0.81	9.23	2.69	0.37	14.67	7.20	3.43	3.26	0.71	0.07	22.22
B22wk	62–95	cl	2	6	9.9	8.5	37.3	0.273	1.70	0.14	<2	141	472	43.7	13.67	0.78	9.40	2.45	0.47	17.61	5.74	5.91	4.66	1.21	0.09	26.46
B3k	95–115	lc	1	5	9.9	8.3	47.4	0.340	1.30	0.11	2	150	400	36.6	13.71	0.77	8.72	1.44	0.42	15.43	5.74	4.20	4.41	1.03	0.05	28.58
Approx. Critical/Ideal Values			-	-	6–8	5.5–7.5	0	<0.7–1.85	<4–8	>1–2	>25–35	100–200	>80–120	>6–8	1–15	>0.2	>2.5	>1–2	>0.5–1.0	>15	75% CEC	20% CEC	<6% CEC	5% CEC	<5% CEC	<6

Note: (1) Sum of Cations approximates the Cation Exchange Capacity (CEC), a measure of the soil's capacity to store and release major nutrient elements.

(2) Exchangeable Sodium Percentage (ESP) is derived by dividing the exchangeable sodium value by the CEC, in this case estimated by the Sum of Cations.