Catchment Management Series

Number 2

Managing waterlogged and saline catchments in south-west Victoria

A soil-landscape and vegetation key with on-farm management options

Woorndoo Land Protection Group Area Case Study

Jim Cox, Rob Fitzpatrick, Lee-anne Mintern, John Bourne and Glenn Whipp

Managing waterlogged and saline catchments in south-west Victoria

Jim Cox[1,2], Rob Fitzpatrick[1,2], Lee-anne Mintern[3], John Bourne[1], and Glenn Whipp[3]

1. CRC for Soil & Land Management
2. CSIRO Land and Water
3. DNRE: Catchment and Agricultural Services

Available from:

DNRE Information Centre
8 Nicholson Street, East Melbourne 3002
Tel: 61 3 9627 8080
Also available from local NRE Offices at Hamilton, Ballarat and Warrnambool

Cooperative Research Centre for Soil & Land Management
Postal address: PMB 2, Glen Osmond 5064
Telephone: 61 8 8303 8670, Facsimile: 61 8 8303 8699
Email: crcslm@adl.clw.csiro.au
WWW: http://www-crcslm.waite.adelaide.edu.au

Acknowledgments:

This manual is based on the first in the series 'Managing waterlogged and saline catchments in the Mt. Lofty Ranges, South Australia' by Rob Fitzpatrick, Jim Cox and John Bourne, CRC for Soil & Land Management (CRCSLM/HYD/6/97).

Thanks to members of the Woorndoo Land Protection Group, especially Barry Veale (President), Judy Veale, Flora Richardson, David Allen, Clare Monod (Secretary), Sue Mudford, David Barry, David Blackburn and Geoff Pritchard.

Technical assistance has been provided by Steve Holden, Mike Wagg, Helen Anderson and Peter Dixon, DNRE:Catchment and Agricultural Services, Richard Weatherly, Central Hopkins Land Protection Association and Mark Seeliger, CRC for Soil & Land Management.

This manual has been prepared as part of the 'identification and management of saline waterlogged soils' project. This project has been supported by the National Landcare Program - a program under the Natural Heritage Trust. The development and production of this manual has been funded by the CRC for Soil & Land Management.

Photographs of indicator plants are reproduced from Matters, J. and Bozon, J. (1995) and Helen Anderson; and the map of soil landscape units is produced from Maher, J.M. and Martin, J.J. (1987) all with the permission of the Department Natural Resources and Environment, Victoria.

Graphic design and layout was provided by Mary-Anne Fiebig, CRC for Soil & Land Management and Greg Rinder, CSIRO Land & Water.

ISBN 1 876162 55 4 CRCSLM/CTT/3/99

Contents

Water movement in loam over clay soils 2

Using water level measurements to determine the causes and severity of waterlogging and salinity 3

Using soil water measurements to determine the causes and severity of waterlogging and salinity 6

Using soil characteristics instead of water measurements 6

Management to reduce waterlogging and salinity 8

The Woorndoo District Soil and Landscape Key 8

Before you start 14

Making observations in the field 16

Mapping your observations and making management decisions 20

Using the key for property management planning 23

References 24

Want further information? 26

Glossary 27

Appendix 1: 28
Vegetation that indicates saline conditions

Appendix 2: 32
Surface and soil features that indicate the degree of waterlogged or saline conditions.

Appendix 3: 40
Measuring sodicity, salinity and acidity

Appendix 4: 44
Interpretation of soil consistence classes

Appendix 5: 46
Blank Field Recording Sheet

Water movement in loam over clay soils

The problem

Land clearance forces the soil to try and cope with additional water as annual crops and pastures use less water than the deep-rooted, native vegetation they replaced. However, the soil has specific properties (e.g. pore volume and permeability) which determine the amount of water with which the soil can cope. In addition, some of the soil properties (e.g. soil patterns) may change in response to the extra water. The soils in the Woorndoo Land Protection Group Area are mostly duplex, which show a sharp contrast between the top layer and the layer beneath (e.g. sandy loam over clay). Duplex soils occupy about 50% of the rain-fed cropping regions of Australia. The specific properties of duplex soils make them particularly susceptible to land degradation when they are cleared for grazing.

Changes in the local water balance has been brought about by land clearance. Subsoil clays with low permeability have contributed to waterlogging (Cox and McFarlane 1990, 1995). Where the landscape is sloping, topsoils have very high permeability and clays have very low permeability, large amounts of water may travel down the slope, on top of the clays (Cox et al. 1994, Fleming and Cox 1998, Stevens et al. 1999). This may lead to excessive waterlogging on the lower slopes (Cox et al. 1996). Alternatively some clays are 'leaky' (Cox and Fleming 1997) because they contain many large pores (macropores, Kirkby et al. 1997, Brouwer and Fitzpatrick 1998) or cracks allowing high groundwater recharge. If recharge is high, groundwaters rise and may bring any stored salt to the soil surface (in groundwater discharge areas). In some areas, the groundwaters may rise to the soil surface long distances from where the recharge is occurring whereas in others it occurs close to the recharge areas. Where saline groundwaters rise to the soil surface, soil salinity increases and the chemistry and physical properties of soils can irreversibly change.

The combination of waterlogging and salinity reduces pasture production and livestock carrying capacity. Lower parts of catchments may become saline, bare and eroded. Water moving through the soil contains nutrients, chemical contaminants and dissolved organic carbon. Drainage over or through the soil landscapes then takes these dissolved nutrients into wetlands, lakes and metropolitan water catchments (Fleming and Cox 1998).

Using water level measurements to determine the causes and severity of waterlogging and salinity

1. Shallow wells

To measure how often a soil becomes waterlogged or if it is well drained, a 40-100 mm diameter hole is dug about 0.6 m into the subsoil clay with an auger. The hole is then lined with plastic pipe, which is slotted below ground level. These are known as shallow wells or dipwells.

In a soil that is relatively well drained you will seldom measure a watertable in the shallow well (Figure 1b). The soil may only be waterlogged for a very short time during the wettest seasons. In contrast, a watertable will often be measured in a soil that is prone to waterlogging (Figure 1c). The duration of waterlogging in a soil will vary from year to year depending on the seasonal rainfall (Figure 1a). In addition, a soil profile can be waterlogged yet there is no visible evidence of water on the ground surface as the water remains below the surface (e.g. in the soil in Figure 1c in the winter of 1996).

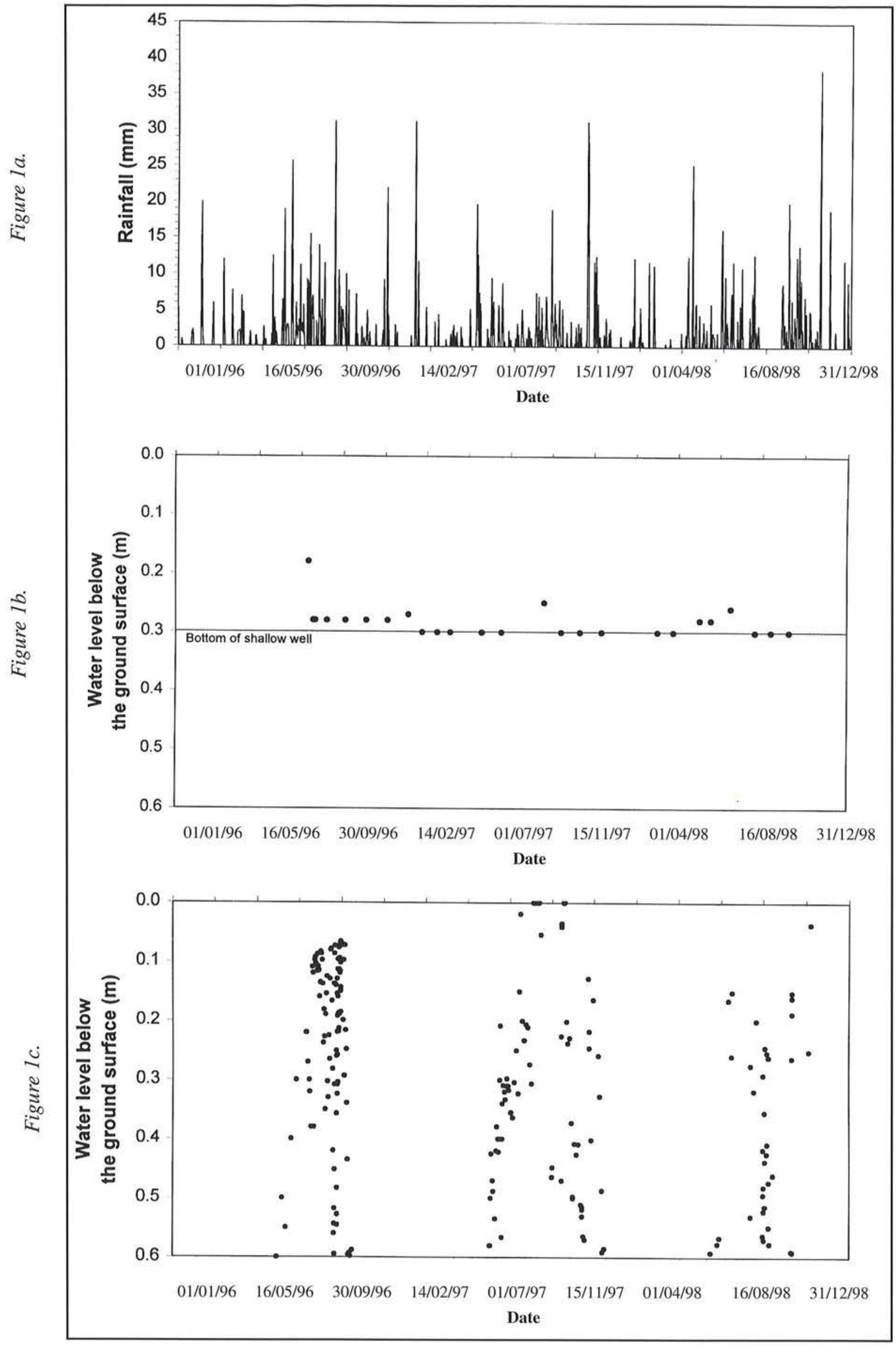


Figure 1. Daily rainfall at Woorndoo from 1996 to 1998 (a) and the differences in waterlogging as measured in dipwells installed in: a moderately well drained duplex soil (b) and a poorly drained duplex soil (c).

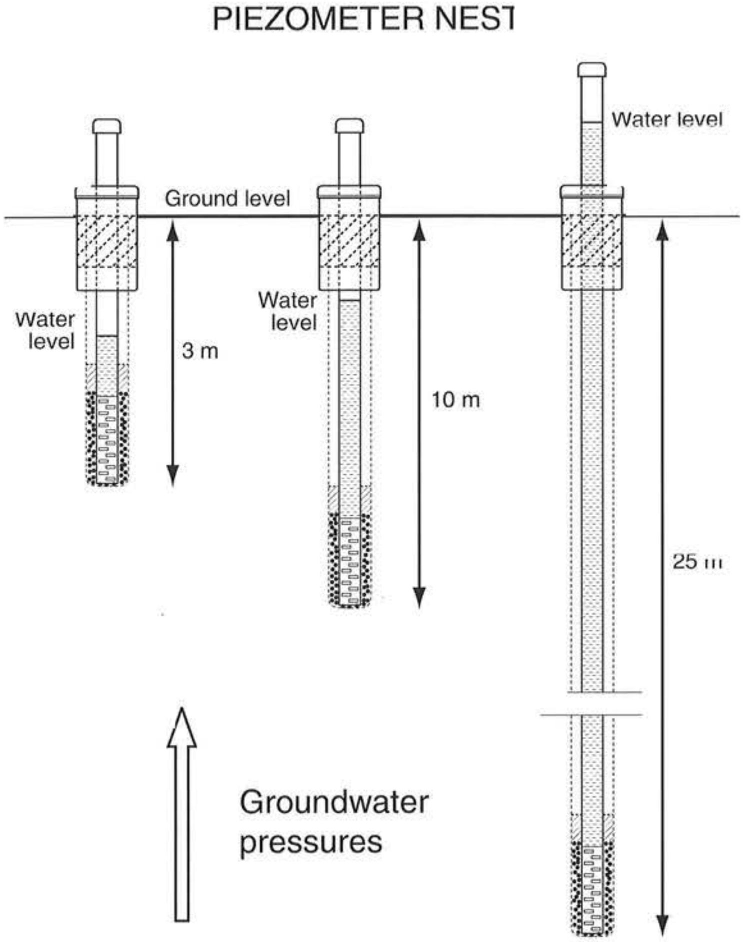


Figure 2. A piezometer nest installed to measure groundwater pressures.

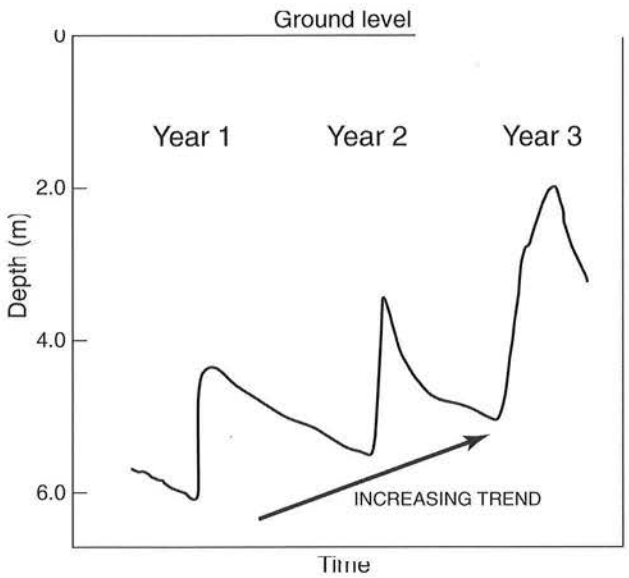


Figure 3. A worse-case scenario: an increasing rise in groundwater levels (not observed at Woorndoo).

2. Piezometers

To measure groundwater pressures a deep hole about 80 mm diameter is dug by drill rig. The hole is then lined with 40 to 50 mm diameter plastic pipe, which is slotted over the last few metres. These are known as piezometers (Figure 2).

Groundwater levels need measuring less frequently than perched watertables as they do not respond as rapidly to rainfall.
We can estimate from several peizometers the direction that the groundwater is flowing. We can also measure what the recharge rate is and then we know how much extra water plants need use to stop the groundwaters rising.

Several piezometers at different depths but at the same location in the paddock may show a decreasing pressure closer to the ground surface. This indicates that groundwater is moving upward toward the soil surface at this location and salinity may be a problem. However, we need to observe the 'trend' in groundwater pressures over many years to determine if groundwaters are generally rising in an area (Figure 3). Groundwaters may also rise and fall in response to seasonal rainfall (and recharge) and cause soil salinity.
This is the process observed at Woorndoo. The seasonal response was similar to that shown in Figure 1b. As well as looking at soil characteristics, soil salinity could be measured directly using electronic field meters.

Using soil water measurements to determine the causes and severity of waterlogging and salinity

Measurement of water levels in dipwells or groundwater pressures in piezometers tells when and where a soil is saturated. These do not indicate how often the soil comes close to being saturated (i.e. how much of the soil pore space is filled with water and how much is filled with air). This balance is important to maintain good plant and root growth. To measure the air filled pore space we can use a variety of instruments (e.g. soil water probes or tensiometers).

Figure 4 shows the percentage of pore space that is filled with water in: (b) a moderately well drained duplex soil, and (c) a poorly drained duplex soil at Woorndoo over three years. In the moderately well drained soil, 100% saturation only occurred in one year out of three, at a depth of 0.4 m (on top of the subsoil clay). The data shows that waterlogging in this soil is caused by a perched watertable developing each winter and not by groundwater. The soil is unsaturated at depth. In contrast a watertable would have been measured each year in dipwells installed in the poorly drained soil and the saturation is caused by groundwaters rising close to the soil surface.

Using soil characteristics instead of water measurements

Soil features such as colour and degree of mottling can change in response to the hydrology of a soil. The colour patterns are determined by changing oxidation and reduction states. This is measured by redox probes. A surrogate measure is the degree of soil saturation (Figure 4). Thus, soil features instead of water level measurements may be easier to use to diagnose problem areas (Cox and Fleming 1997). These are a very good supplement to water level data and helpful where no water level or soil moisture data are available (Cox 1998).

From local research matching water level measurements with soil characteristics, soil and landscape keys are now being developed. These assist managers to quickly and easily make an assessment of waterlogging and salinity problems (e.g. Fitzpatrick et al. 1997).

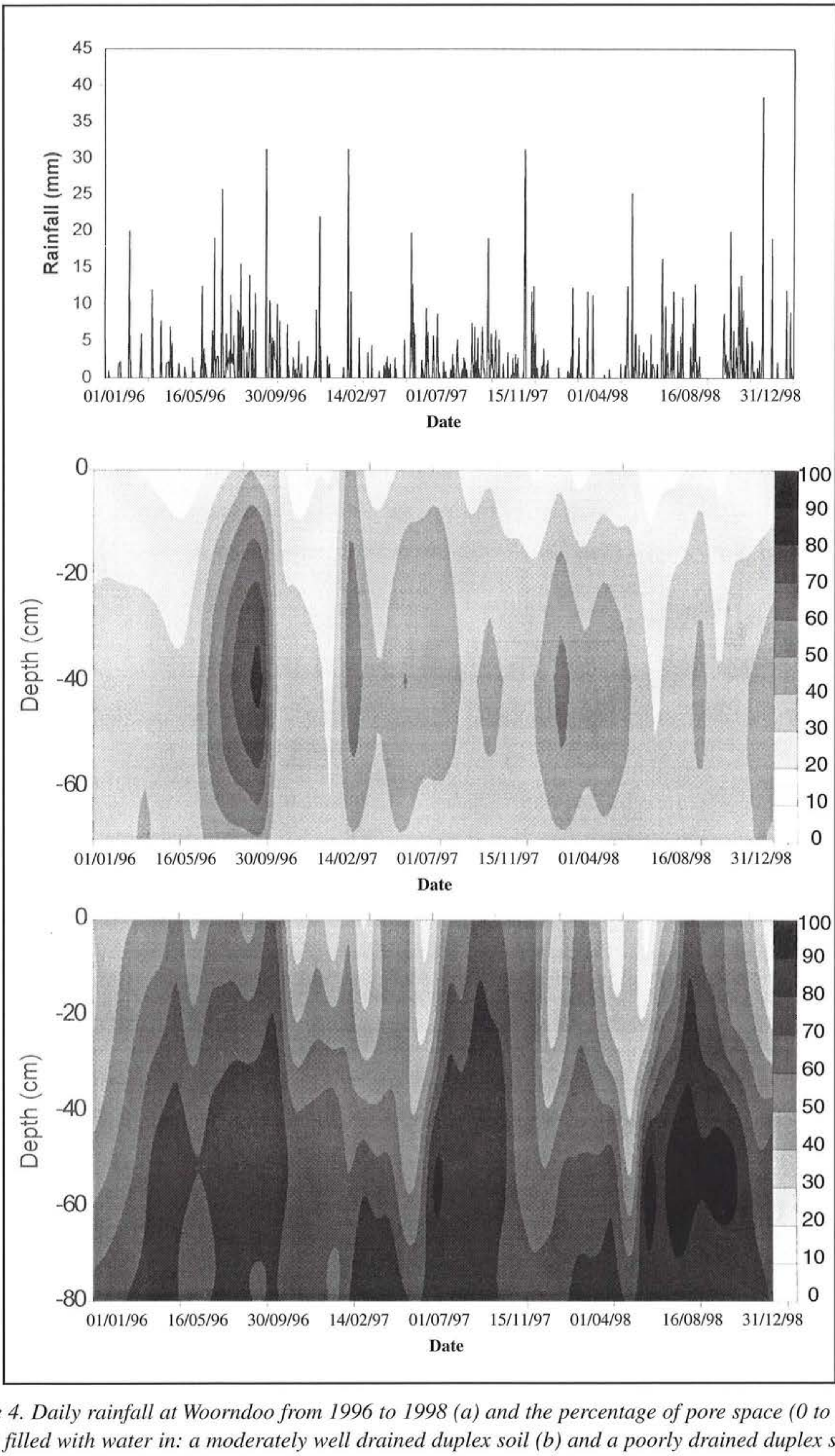


Figure 4. Daily rainfall at Woorndoo from 1996 to 1998 (a) and the percentage of pore space (0 to 100%) that is filled with water in: a moderately well drained duplex soil (b) and a poorly drained duplex soil (c).

Management to reduce waterlogging and salinity

Because groundwater movement is usually very slow, control measures to reduce waterlogging and salinity may take a long time to become effective. It is important to identify potential problems early and then to begin controlling them.

The first step in managing the waterlogging and salinity problems is to fence off saline or bare eroded areas and establish plants tolerant to waterlogging and salt. The extra water moving to groundwater or above the less permeable clay layer throughout the catchment must then be reduced by:

- establishing high water use perennial pastures, trees and/or shrubs, particularly in areas of high recharge (Pitman et al. 1995, 1996, 1997, 1998a and 1998b), and
- installing drains where necessary, to allow more effective pasture or crop establishment (Cox and Negus 1985, McFarlane et al. 1985, McFarlane and Cox 1990, 1992).

To decide which management options to use, direct measurement of waterlogging or likely rises in groundwater can be made using shallow observation wells or piezometers. This is expensive and time-consuming for each paddock or problem area. An alternative is to make measurements at a central point and to match them with changes in soil colour and texture. Changes in soil characteristics can then be identified across the whole landscape to determine where management changes are needed.

The Woorndoo District Soil and Landscape Key

This key:

- Shows how to identify plant and soil features that are indicators of waterlogged and saline areas in high rainfall catchments in the Woorndoo Land Protection Group Area.
- Suggests management options for improving productivity.
- Assists in identifying land capability classes used for property management planning.
- Is presented in an easy-to-follow form as it covers an area of related soil types, topography, hydro-geology and vegetation. Only selected soil features have been used to keep the key simple. Similar keys have been developed for other areas (e.g. Mt Lofty Ranges, South Australia).

All observations and measurements required are simple and inexpensive. Implementing management options will minimise the off-site impact of salt movement into streams, waterways and metropolitan water catchments.

This key has been developed for soil landform units in the Woorndoo Land Protection Group Area shown in Figure 5 based on the field site.

To guide you in what you might find on your property or catchment, a cross-section of soil layers down a hillslope, or toposequence, is shown in Figure 6 for the most common landform unit. Brief soil descriptions, major soil and water problems and a summary of management options for the toposequence are also shown in Figure 6.

In matching soils in the field with those in the key, some examples may have characteristics in between two soils described in the toposequence.

Soil number 8 in the toposequence is not found in all cases, but is a common soil near the Hopkins river.

Vegetation that indicates saline conditions are shown in Appendix 1 and the soil key for identifying soil features is described in Appendix 2. The methodology used to construct Figure 6 is given in Fritsch and Fitzpatrick (1994) and Rinder et al. (1994) and the soil key in Fitzpatrick et al. (1994, 1998). More information on the soils and hydrology of the experimental site is given in Fitzpatrick and Cox (1999) and Cox et al. (1999).

The Woorndoo Land Protection Group discussing soil features.

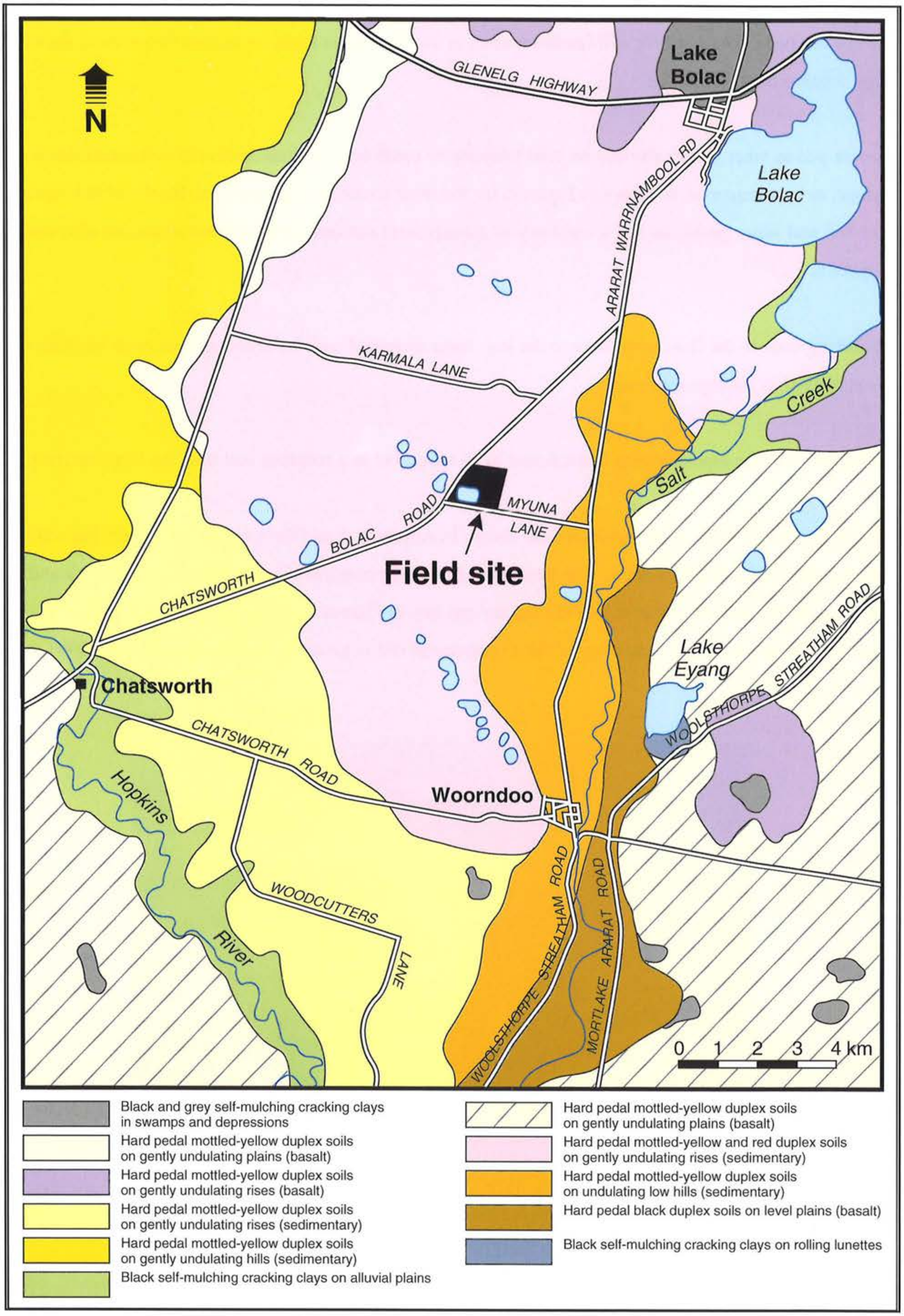


Figure 5. Soil Landform Units (from Maher and Martin, 1987).

The likely sequence of soils down a slope in each landform unit will vary as shown in Table 1. The sequence will also vary within landform units.

Soil Type / Landform unit	1	2	3	4	5	6	7	8
[grey]	*	**	*	*	*			
[cream]	*	**	*	*	*	*		**
[purple]	*	**	*	*	*	*	*	
[pale yellow]	***	**	*	*	*	*	*	*
[yellow]		***		*	*	*	***	
[green]		*	**	*	*	*		*
[hatched]		***		*	*		***	
[pink]			*	*	**	**	*	***
[orange]			***	*	*	*		*
[brown]		**	*	***	*	*		
[blue]		**	**	**	*	*		

* = occurs occasionally   ** = occurs often   *** = dominant

- [grey] Black and grey self-mulching cracking clays in swamps and depressions
- [cream] Hard pedal mottled-yellow duplex soils on gently undulating plains (basalt)
- [purple] Hard pedal mottled-yellow duplex soils on gently undulating rises (basalt)
- [pale yellow] Hard pedal mottled-yellow duplex soils on gently undulating rises (sedimentary)
- [yellow] Hard pedal mottled-yellow duplex soils on gently undulating hills (sedimentary)
- [green] Black self-mulching cracking clays on alluvial plains
- [hatched] Hard pedal mottled-yellow duplex soils on gently undulating plains (basalt)
- [pink] Hard pedal mottled-yellow and red duplex soils on gently undulating rises (sedimentary)
- [orange] Hard pedal mottled-yellow duplex soils on undulating low hills (sedimentary)
- [brown] Hard pedal black duplex soils on level plains (basalt)
- [blue] Black self-mulching cracking clays on rolling lunettes

Table 1. Likely sequence of soils down a slope in each landform unit.

Figure 6. Toposequence

←

Before you start

What you will need

- Map or aerial photograph of farm/paddock with a scale ranging from 1:1000 to 1:5000.
- Two clear plastic sheet overlays.
- Tape or velcro to attach overlays to photograph.
- Coloured felt pens to write on overlays.
- Soil auger (post hole auger) or spade.
- Plastic or strong paper bags for soil sample collection.
- A blank Field Recording Sheet (Appendix 5).
- Rainwater
- 600 ml glass jars
- CRC for Soil & Land Management Sodicity meter (Rengasamy and Bourne 1998)*
- Electrical conductivity meter *
- pH meter *

* These meters can be accessed from NRE Offices.

Planning where to go

On your property map or aerial photograph select several paths or transects across a paddock that is likely to have problems. These will usually be down a hillslope. Avoid transects that are not representative, eg fencelines or roadways. Mark the transects on the first plastic overlay (eg A-A' and B-B' in Figure 7).

It may be helpful to add in any contour lines available, such as the lines at 10 metre intervals used in Figure 7.

Aerial photograph of field site

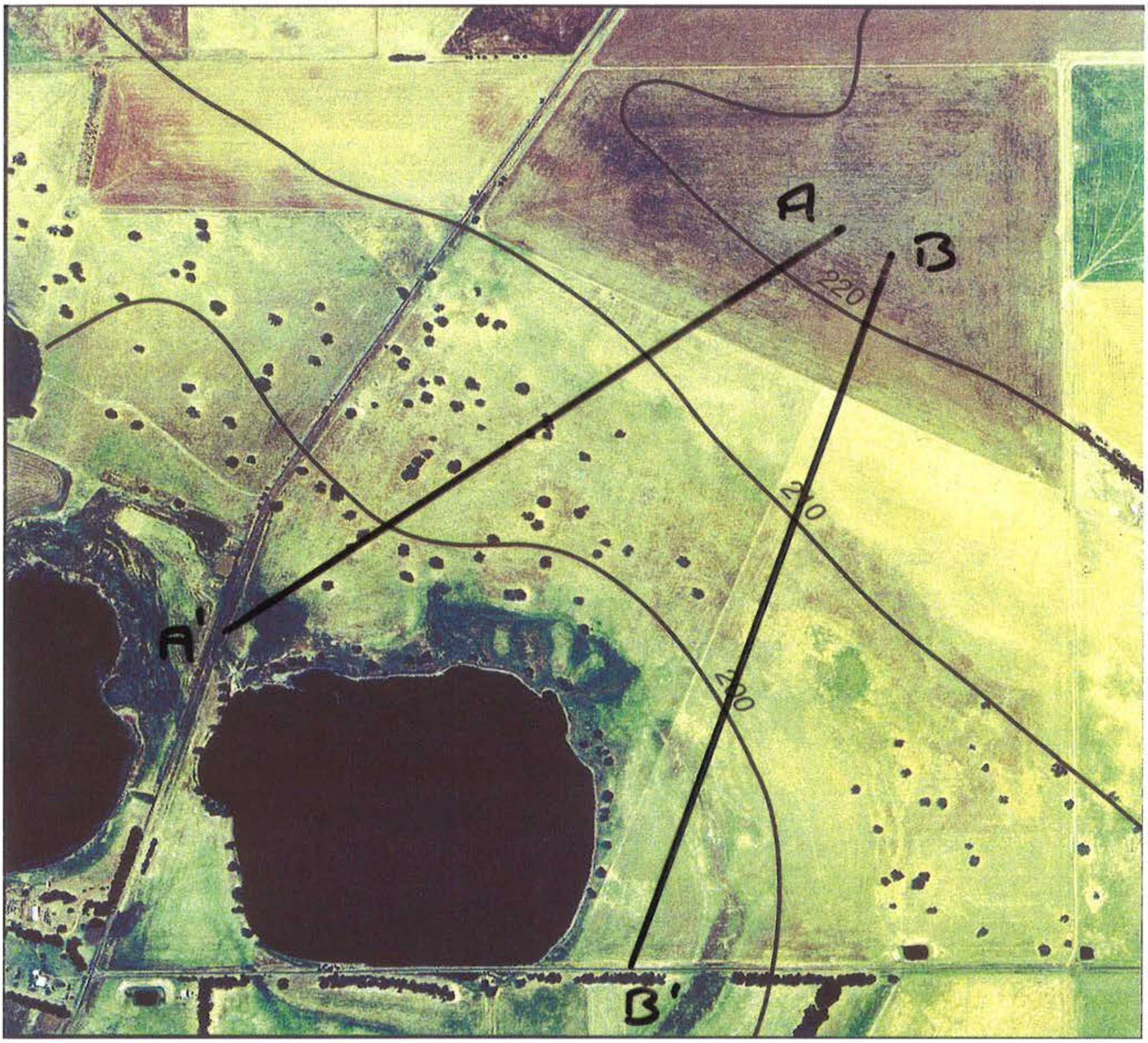


Figure 7. Transects marked on an aerial photograph.

Making observations in the field

- Start at the top of the hillslope. Make sets of observations down the slope on a field recording sheet. A worked example field sheet is shown in Figure 8, and an extra blank sheet is provided in Appendix 5.

- Make extra sets of observations where you see changes in landscape features such as slope, vegetation or rockiness.

- At each point :

  a) Mark your location on the transect drawn on your plastic overlay.
  b) Record plant indicators by referring to the plant photographs in Appendix 1.
  c) Record other relevant surface features, eg bare ground or salt stains.
  d) Dig a hole with the soil auger or spade down into the hard clay/ rock layer *.
  e) Record soil characteristics on the field sheet, and match up the profile with the typical profiles in the key in Appendix 2. When the photograph shown in the key matches your profile, the YES arrow indicates likely waterlogging and management options. If the photograph does not match, follow the NO arrow to the next page.
  f) Take separate soil samples of both the top layer and the hard clay/rock layer (100g of each, or a small handful). Place in labelled bags.

- Take the soil samples back to the house or shed, and test them as shown in Appendix 3. Record these measurements on the field sheet and confirm the soil type number (1-8) at each location.

* If you are not sure how deep the hole should be, dig until soil consistence changes from loose or friable to firm or rigid. An explanation of soil consistence and how to estimate it is in Appendix 4. To see the change in soil features more easily, lay out the soil in a sequence on the ground as you dig the hole.

Field Recording Sheet

Date: 1/11/98

Paddock: North

Location of transect: Hill top to road (A-A[1] in Figure 9a. See also Figure 12c)

a. Vegetation and other surface features

Observation point	**a1**	**a2**	**a3**	**a4**	**a5**	**a6**	**a7**
Plants indicating low level salting (Class 1)	✔	✔					
Plants indicating moderate level salting (Class 2)				✔	✔		
Plants indicating a high level of salting (Class 3)						✔	✔
White salt stains					✔	✔	
Bare ground						✔	
Red stains or gels							✔
Gilgai, with water ponding in winter or cracks in very dry seasons			✔				

Figure 8. Example of a Field Recording Sheet.

b. Soil features

Observation Point	a1	a2	a3	a4	a5	a6	a7
Top layer - brown	✔	✔					
- grey with red stains &/or grey (bleached mottles)			✔	✔	✔	✔	
- bleached sub-layer at the bottom of the surface layer		✔	✔	✔	✔	✔	
- black, boggy (smell of rotten eggs)							✔
Bottom layer 1 - red with ironstone gravel	✔						
- yellow		✔		✔			
- yellow with grey mottles, columns, cracks and shiny clay surfaces			✔				
- dark grey with yellow mottles					✔	✔	✔
Bottom layer 2 - red with yellow mottles	✔	✔					
- yellow with grey mottles			✔	✔			
- bluish-grey with yellow mottles					✔	✔	✔

Figure 8 contd.

c. Soil tests - top layer

Observation Point	a1	a2	a3	a4	a5	a6	a7
Sodicity (1:5 soil in water suspension) Partly cloudy (not sodic)	✔	✔	✔	✔	✔	✔	✔
Cloudy (medium)							
Very cloudy (highly sodic)							
Salinity Not saline	✔	✔	✔	✔	✔		
EC of top layer is above 0.4 dS/m						✔	✔
Acidity (pH in water) pH less than 5.5 (highly acidic)							
pH between 5.5 and 8.5	✔	✔	✔	✔	✔	✔	✔
pH greater than 8.5 (highly alkaline)							
d. Soil tests - bottom layers Sodicity (1:5 soil in water suspension) Partly cloudy (not sodic)	✔	✔				✔	✔
Cloudy (medium)					✔		
Very cloudy (highly sodic)			✔	✔			
Salinity Not saline	✔	✔	✔	✔			
EC of top layer is above 0.7 dS/m					✔	✔	✔
Acidity (pH in water) pH less than 5.5 (highly acidic)							
pH between 5.5 and 8.5	✔	✔	✔	✔	✔	✔	✔
pH greater than 8.5 (highly alkaline)							
e. Soil type number (1-8) from soil key. Could be transitional between 2 soil type numbers	1	2	3	4	5	6	7

Figure 8 contd.

Mapping your observations and making management decisions

- From the information recorded on the Field Recording Sheets now locate the boundary of each soil on the first plastic overlay and write in the soil number. As you will only have information from a few selected transects you will have to make some estimate of the soil boundaries from vegetation, contours and personal knowledge of the paddock or undertake further transects.

- Then select management options associated with each of the soil profile photographs in the key, or the actual slope sequence in Figure 6. Record your management decisions, with appropriate boundaries, on the second plastic overlay. A useful set of symbols is:

Plant shrubs and treees
Alley farming or Agroforestry
Plant with salt tolerant shrubs and trees
Crops
Perennial pasture
Salt tolerant vegetation
Lime
Native shrubs and grasses to stabilise gully banks
Fence
Interceptor drain and direction of flow
Exclude stock
Control structures in gully
Dam

(You may want to write in the actual species or stock/crop management, after the symbol).

As an example Figures 9a and 9b show the same map used earlier to identify transects, but this time with separate overlays showing soils and management options, respectively.

Aerial photograph of field site

Figure 9a. Soil types and boundaries entered on the aerial photograph.

Aerial photograph of field site

Figure 9b. Management decisions entered on the aerial photograph.

Using the key for property management planning

The key can be used on its own to help solve a particular problem in a paddock, but is even more useful as an addition to developing a property management plan.

A component of property management is planning for sustainable land use according to its capabilities. Identifying land class units is a first step.

Each land class unit may cover several soil types that are managed in a similar way. However, some soil types within a unit require different management, and so need to be identified from this key. For example sodic soils need to be identified so that any drains required are not located on this soil type because sodic soils are prone to dispersion and erosion. If drains are needed, site these higher up the slope.

The overlays such as in Figures 9a and 9b can now be used to identify land classes and management options as part of a farm property management plan.

References

Bird, P.R., Kearney, G.A. and Jowett, D.W. (1996). Trees and Shrubs of South West Victoria. Agriculture Victoria (PUI, Hamilton. Victoria).

Brouwer, J. and Fitzpatrick, R.W. (1998). Relations between soil macro-morphology and current soil hydrology in a toposequence in SE Australia. *Proceedings of the International Soil Science Society Congress*, Montpellier, France.

Cox, J.W. (1998). Land clearance changes on the hydrology of a toposequence as predicted by soil morphology. *Proceedings of the 16th World Congress of Soil Science*, Montpellier, France.

Cox, J.W., Fitzpatrick, R.W., Mintern, L. and Whipp, G. (1999). Hydrology of the Woorndoo Experimental site, Victoria. Technical Report. CSIRO Land & Water, Adelaide, South Australia.

Cox, J.W., Fritsch, E. and Fitzpatrick, R.W. (1996). Interpretation of soil features produced by ancient and modern processes in degraded landscapes: VII. Water duration. *Australian Journal Soil Research* **34**, 803-824.

Cox, J.W. and McFarlane, D.J. (1990). The causes of waterlogging. *Journal of Agriculture, Western Australia* **31**, 58-61.

Cox, J.W. and McFarlane, D.J. (1995). The causes of waterlogging in shallow soils and their drainage in south-western Australia. *Journal of Hydrology* **167**, 175-194.

Cox, J.W. and Negus, T.R. (1985). Interceptor drains and waterlogging control. *Journal of Agriculture, Western Australia* **26**, 126-127.

Cox, J.W. and Fleming, N.K. (1997). Understanding landscape processes. Property and Catchment Planning, Issues Challenges and Professional Responsibilities. *Proceedings of an Australian Institute of Agricultural Science and Technology Symposium* Waite Institute, Adelaide.

Cox, J.W., McFarlane, D.J. and Skaggs, R.W. (1994). Field evaluation of DRAINMOD for predicting waterlogging intensity and drain performance in south-western Australia. *Australian Journal of Soil Research* **42**, 653-671.

Fitzpatrick, R.W. and Cox, J.W. (1999). Characterisation of eleven soil profiles down a toposequence at the Woorndoo Experimental site, Victoria. Technical Report 10/98. CSIRO Land & Water, Adelaide, South Australia.

Fitzpatrick, R.W., Cox, J.W. and Bourne, J. (1997). Managing waterlogged and saline catchments in the Mt. Lofty Ranges, South Australia. CRC for Soil & Land Management, Adelaide, South Australia. CRCSLM/HYD/6/97.

Fitzpatrick, R.W., Cox, J.W., Fritsch, E. and Hollingsworth, I.D. (1994). A soil-diagnostic key for managing waterlogged and dryland salinity in catchments in the Mt. Lofty Ranges, South Australia. *Soil Use and Management*. **10**. 145-152.

Fitzpatrick, R.W., Cox, J.W. and Bourne, J. (1998). Soil indicators of catchment health: tools for property planning. *Proceedings of the International Soil Science Society Congress*. Montpellier, France.

Fleming, N.K. and Cox, J.W. (1998). Nutrient losses off dairy catchments located on texture contrast soils: carbon, phosphorus, sulphur and other chemicals. *Australian Journal of Soil Research* **36,** 979-995.

Fritsch, E. and Fitzpatrick, R.W. (1994). Interpretation of soil features produced by ancient and modern processes in degraded landscapes. 1. A new method for constructing conceptual soil-water-landscape models. *Australian Journal of Soil Research* **32**, 889-907.

Kirkby, C.A.K., Smythe, L.J., Cox, J.W. and Chittleborough, D.J. (1997). Phosphorus movement down a toposequence from a landscape with texture-contrast soils. *Australian Journal of Soil Research* **35,** 399-417.

Maher, J.M. and Martin J.J. (1987). Soil and landforms of south-western Victoria Part 1. Inventory of soils and their associated landscapes. Research Report Series No 40 April 1987. Victorian Department of Agriculture and Rural Affairs pp 227.

Matters, J. and Bozon, J. (1995). Spotting Soil Salting: A Victorian field guide to salt indicator plants. Dept. of Natural Resources and Environment, Victoria.

McFarlane, D.J., and Cox, J.W. (1990). Seepage interceptor drains for reducing waterlogging and salinity. *Journal of Agriculture, Western Australia* **31**, 66-69.

McFarlane, D.J., and Cox, J.W. (1992). Management of excess water in duplex soils. *Australian Journal of Experimental Agriculture* **32**, 857-864.

McFarlane, D.J., Negus, T.R. and Cox, J.W. (1985). Drainage to control waterlogging. *Journal of Agriculture, Western Australia* **26**, 122-125.

Natural Resources and Environment. (1996). Farm$mart Property Management Planning Program. Natural Resources and Environment, Victoria.

Pitman, A., Cox, J.W. and Bellotti, W.D. (1995). Agronomic and/or drainage measures and their influence on the fluxes of water and nutrients in waterlogging duplex soils in a hills catchment. *Proceedings of the Soil and Water Conservation Association of Australia 1995 National Conference. Exploring Practical Ways of Monitoring Land and Water Health.* Melbourne.

Pitman, A., Cox, J.W. and Bellotti, W.D. (1996). Agronomy and/or drainage measures to reduce recharge and salinity in waterlogging duplex soils. Rehabilitation and productive use of saline land. *4th Australian National Workshop on Rehabilitation and Productive Use of Saline Land.* Albany,W. Australia.

Pitman, A., Cox, J.W. and Bellotti, W.D. (1997). Water usage of perennial pastures on duplex soils. *Proceedings Vol 2 Landcare Changing Australia National Conference* Adelaide. pp17-18.

Pitman, A., Cox, J.W. and Bellotti, W.D. (1998a). Water usage and dry matter production of perennial pastures on sloping duplex soils. *National Landcare Conference,* Adelaide.

Pitman, A., Cox, J.W. and Bellotti, W.D. (1998b). Water usage and dry matter production of perennials down a duplex *toposequence. Proceedings of the 9th Australian Agronomy Conference,* Charles Sturt University, Wagga Wagga.

Rengasamy, P. and Bourne, J. (1998). Managing Sodic, Acidic and Saline Soils. CRC for Soil & Land Management, Adelaide, South Australia.

Rinder, G.E., Fritsch, E. and Fitzpatrick, R.W. (1994). Computing Procedures for Mapping Soil Features at Sub-catchment scale. *Australian Journal Soil Research* **32**, 909-913.

Soil Survey Division Staff. (1993). Soil survey Manual. *United States Department of Agriculture.* Handbook No. **18**.

Stevens, D.P., Cox, J.W. and Chittleborough, D.J. (1999). Pathways of phosphorus, nitrogen and carbon movement over and through texturally differentiated soils, South Australia. *Australian Journal of Soil Research* (in press)

Want further information?

Amirtharajah, M. and Kearney. G. (1996). Glenelg Salinity Implementation Survey - A Survey of Landholders Attitudes, Practices and Intentions for Salinity Control in the Glenelg Region. Department of Natural Resources and Environment, Hamilton, Victoria.

Bathgate, A. and Evans, I. (1990). Economics of interceptor drains: a case study. *Journal of Agriculture, Western Australia* **31**, 78-79.

Bird, P.R., Jowett, D.W., Kellas, J.D. and Kearney, G.A. (1996). Farm Forestry Clearwood Production - A manual for south east Australia. Agriculture Victoria. PVI, Hamilton, Victoria

Blewett, C. and Wightman, B. (1996). Cropping in south-west Victoria. Agriculture Victoria.

Boruuka, V. and Matters. J. (1987). Field guide to plants associated with saline soils of Victoria. Conservation Forest and Lands, Victoria.

Brouwer, J. and van de Graaff, R.H.M. (1998). Readjusting the water balance to combat dryland salting in southern Australia: changing the hydrology of a texture contrast soil by deep ripping. *Agricultural Water Management* **14**, 287-98.

Bozon, J. and Matters, J. (1995). Spotting Soil Salting - A Victorian Field Guide to Salt Indicator Plants. Catchment and Land Management Division, Dept of Conservation and Natural Resources, Victoria.

Cameron, M. (1991). A report on the effects of salinity upon the biota of a number of lakes in the western district of Victoria, including an investigation of groundwater - wetland relationships. Department of Conservation and Environment, Victoria.

Cass, A., Walker, R.R. and Fitzpatrick, R.W. (1996). Vineyard soil degradation by salt accumulation and the effect on the performance of the vine. pp 153-106. Proceedings of the 9th Australian wine industry technical conference. 1995. Adelaide.

Chaffey, B. et al. (1992). Dryland Salinity - Early Indicators and Control Measures. Judy Bennett, Agmedia, Melbourne, Victoria.

Clifton, C. and Taylor, J. (1996). South West Research and Investigation Strategy Review. Workshop Proceedings. Department of Natural Resources and Environment, Ballarat, Victoria.

Cottinghom, P., O'Shanassy, K. and Oddie, N. (1997). Draft Water Quality Plan for the Hopkins River Basin. Southern Rural Water & Water Ecoscience, Melbourne, Victoria.

Currey, D.T. (1970). Lake systems: Western Victoria. Australian Society for Limnology Bulletin No.3 December 1970, 1-13.

Dixon, P. (1994). From the Ground Up - Property Management Planning Manual. Department of Natural Resources and Environment, Hamilton, Victoria.

Glenelg Regional Catchment and Land Protection Board. (1997). Glenelg Regional Catchment Strategy. Glenelg Regional Catchment and Land Protection Board, Hamilton, Victoria.

Glenelg Salinity Forum. (1993). Salt Assault! The Glenelg Region Salinity Strategy. Salt Action, Victoria.

McFarlane, D.J. and Wheaton, B. (1990). The extent and cost of waterlogging. *Journal of Agriculture, Western Australia* **31**, 44-47.

McFarlane, D.J., Wheaton, G.A., Negus, T.R. and Wallace, J.F. (1992). Effects of waterlogging on crop and pasture production in the Upper Great Southern, Western Australia. Technical Bulletin 86. (Western Australian Department of Agriculture, South Perth).

Natural Resources and Environment (1996). Applying the Latest - Salinity Conference Proceedings. Natural Resources and Environment, Victoria.

Natural Resources and Environment. (1997). Green pastures for south-west Victoria. Natural Resources and Environment, Victoria.

Sharp, W. Woorndoo Landcare Group: Catchment and community awareness project. Land Management and Farm Planning Consultant. R.M.B. 1285, Branxholme, Vic. 3302

Sturmfels, C.P. (1998). Salinity Control Strategy Draft. Department of Conservation and Environment, Ballarat, Victoria.

Williams, B.G. (1996). Electromagnetic induction (EM31) survey of the study area. Unpublished report to Woorndoo Land Protection Group.

Glossary

Acid soil
A soil with a low pH and in which plant growth may be restricted because of one or more nutritional disorders.

Agroforestry
Managing trees, shrubs and groundcovers to improve farm profitability while protecting and enhancing natural resources. An agroforest for wood production may be in the form of a woodlot, a timberbelt or a wide-spaced agroforest.

Alley farming
Strips of crops or pastures between belts of fodder shrubs or trees.

Aquifer
An aquifer is a saturated permeable geological unit (eg sand) that can transmit significant quantities of water. A perched aquifer occurs when the saturated zone is discontinuous (eg above a lens of clay) so that unsaturated conditions occur above and below.

Catchment
The specified area from which runoff water flows into a stream/streams or basin.

Control structure
A physical structure such as a weir to alter water flow in a stream, to minimise erosive scouring of the stream channel.

Decisiemens
See Electrical Conductivity

Dispersion
When in contact with water, sodic soils swell and then disperse into tiny fragments which block soil pores on drying.

Dissolved organic carbon
Organic material which when present gives water a slightly brownish colour. Can cause problems if in excessive concentrations.

Electrical conductivity or EC
A measure of the ability of a material to conduct electric current, due to the concentration of salts in solution. It is measured in decisiemens/metre or dS/m

Gilgai
Regularly spaced humps and depressions found in the surfaces of some cracking clays. This micro relief is produced by swelling clays following prolonged expansion and contraction due to changes in moisture content.

Groundwater
That part of the subsurface water in zones that are saturated with water under pressure equal to or greater than atmospheric pressure.

Gypsum (Calcium sulphate)

Used to reduce dispersion. A naturally occuring salt also formed as a by-product of the manufacture of superphosphate

Hydrogeology
The study of the occurrence, distribution and movement of water over, on and under the land surface, taking into account the naturally occurring geological formations..

Interceptor drains
A surface or subsurface drain or a combination of both, designed and installed to intercept flowing water.

Land capability
The extent to which land can meet the needs of one or more uses. Land capability classes are often identified which contain land with similar capabilities.

Landform units
Interpretation of soil type and land form pattern.

Lime (Calcium carbonate)

Used to neutralise acidic conditions. Often called agricultural or calcitic lime to distinguish it from dolomitic lime, which also contains magnesium carbonate.

Mottling
Soil irregularly marked with spots of colour.

pH
A scale from 1-14 measuring acidity or alkalinity. Below 7 is acid, and above 7 is alkaline. The measurement is usually made in a water solution, or alternatively in calcium chloride which may give readings up to 1.5 units lower.

Property management planning
A whole farm approach to the management of physical, financial, and social resources.

Recharge
A process in which water flows from the soil surface to the groundwater system.

Saline soil
A soil containing sufficient soluble salts to adversely affect the growth of most crop plants.

Saturated & Unsaturated

The percentage of the pore space that is filled with water. Saturated is 100% filled.

Slickensides

Natural shiny surfaces found on soil aggregates during swelling and shrinking of clays.

Sodic soil
A soil with an excess of sodium absorbed onto clay causing it to disperse.

Soil consistence
The degree of cohesion or adhesion within the soil mass, or its resistance to deformation or rupture.

Sulfidic soil
A soil that generates sulphuric acid that may leak into drainage systems.

Topography
The general configuration of a land surface, including its relief and the position of its natural and man-made features.

Tunnel erosion
The removal of soil material through subsurface channels developed by seepage water.

Appendix 1: Vegetation that indicates saline conditions

Before making soil observations, look at the ground surface and plants present, as these may indicate problems. Look for a number of species of plants. Match them up with the photographs below.

Low or Moderate level salting (Salinity class 1)

These photographs of plants are typical of those that grow in a low to moderate level of soil salt. Other common signs include:

- isolated or scattered areas of 'patchy' growth in a paddock. These may occur on seeps along a break of a slope.
- reduced vigour or stunting in improved pasture or crop species.
- productive annual and perennial species, including clovers, thin and die out. These are replaced by other plants with more salt tolerance.
- sea barley grass is often abundant.
- strawberry clover may be present.
- no salt crystals or bare patches can be seen.

Swamp weed (Selliera radicans)

Sea barley grass (Critesion marinum)

Buck's horn plantain (Plantago coronopus)

Coast sandspurrey (Spergularia media)

Toad rush (Juncus bufonius)

Moderate level salting (Salinity class 2)

These photographs of plants are typical of those that grow in a moderate level of soil salt. Other common signs include:

- some Class 1 species disappear and are replaced by others with high salt tolerance.
- salt stains are visible when soil surface is dry.
- small, bare areas up to 1 square metre are present.
- clover is absent.
- affected areas may occur as 'scalds' exposed by heavy grazing on flats, or as seeps at breaks of slope.
- affected areas may worsen after high seasonal rainfall.
- some species show marked changes in leaf colour and shape due to salt stress.

Creeping brookweed (Samolus repens)

Round-leaf Wilsonia (Wilsonia rotundifolia)

Australian salt grass (Distichlis distichophylla)

Annual beard grass (Polypogon monspeliensis)

Water buttons (Cotula coronopifolia)

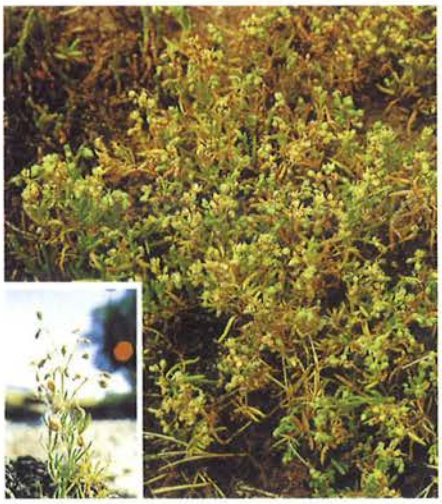
Moderate level salting (Salinity class 2) continued

Bucks horn plantain (Plantago coronopus)

Bearded glasswort (Sarcocornia quinqueflora)

Toad rush (Juncus bufonius)

Swamp weed (Selliera radicans)



Coast sandspurrey (Spergularia media)

Sea barley grass (Critesion marinum)

High level salting (Salinity class 3)

These photographs of plants are typical of those that grow in a moderate level of soil salt. Other common signs include:

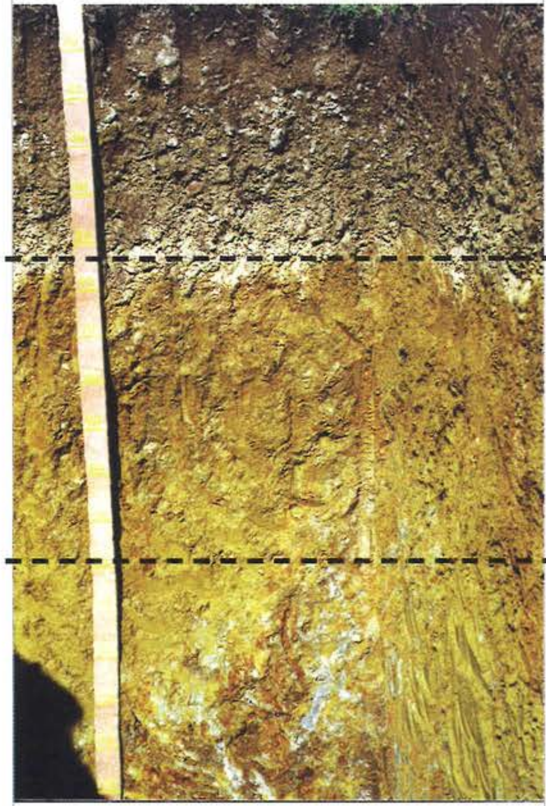
- only highly salt tolerant plants are present.
- large areas of bare ground can be seen.
- often only 2 or 3 species will dominate such an area.
- trees will be dead or dying.
- species present are typical of salt pans and salt marshes.

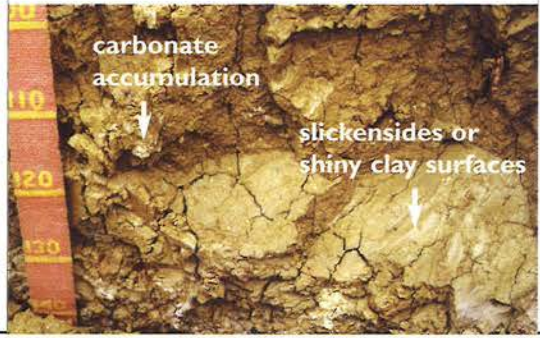
Typical salt pan showing large areas of bare ground and samphire communities.

Bearded glasswort (Sarcocornia quinqueflora)

Appendix 2: Key for identifying soil features that indicate degrees of waterlogged and saline conditions and management options

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 1 CREST Well drained red soils - gravelly *Very infrequent waterlogging* 			**IF YES** SEE MANAGEMENT OPTIONS **IF NO** GO TO NEXT PAGE	• Establish sound crop rotations which can include summer fodder, cereals, oil seeds and rotate with a perennial legume based pasture for maximum water usage. <u>Suitable crops</u>: canola, wheat, barley, triticale, oats and lupins if well drained. <u>Pasture crop</u>; Lucerne, perennial legume based pasture, persian and balansa clover (one year rotation) <u>Fodder crop;</u> Fodder rape • Establish deep-rooted high water use perennial grass and subclover pasture based on cocksfoot, phalaris, fescue or native grasses. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Lime if pH (water) is less than 5.5. • Conduct soil test to determine aluminium levels. If aluminium low establish Lucerne and rotationally graze. • Establish agroforestry such as native trees species (for small scale high value timber), blue gums (for pulp) and pines (softwood timber).
Friable		Top	Uniform brown colour. Measure pH to determine if liming is required.		
Firm To Friable		Bottom Layer 1	Uniform red colour, usually lighter than the surface soil with abundant ironstone gravel.		
Rigid		Bottom Layer 2	Red with yellow mottles and grey colours increasing with depth.		

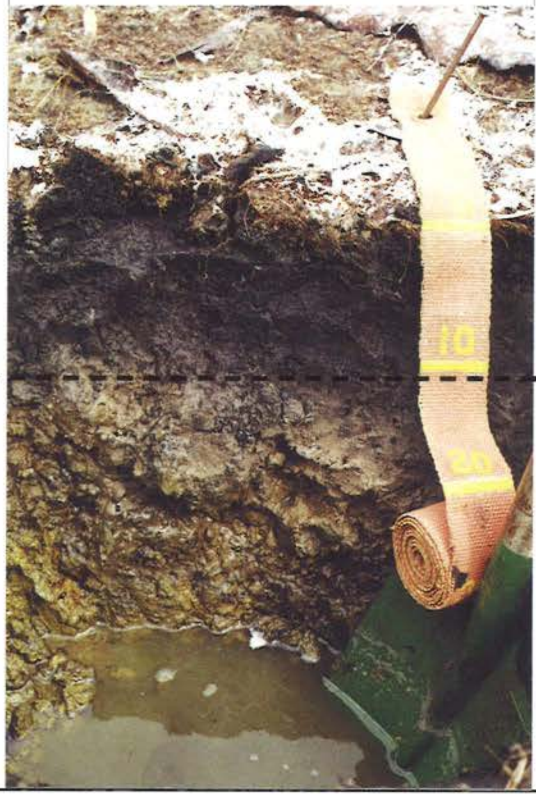
Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 2 (UPPER SLOPE) Moderately drained yellow soils - gravelly *Infrequent waterlogging*				• Establish a sustainable, high water use cropping system. • Establish deep-rooted high water use perennial grass and subclover pasture based on cocksfoot, phalaris, fescue or native grasses. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Lime if pH (water) is less than 5.5. • Conduct soil test to determine aluminium levels. If aluminium low establish Lucerne and rotationally graze. • Establish agroforestry such as native trees species (for small scale high value timber), blue gums (for pulp) and pines (softwood timber).
Friable		Top	Uniform grey to brown colour. A bleached sub-layer occurs at the bottom of the surface layer. This is because organic matter and nutrients may have been washed down into the subsoil.	**IF YES** SEE MANAGEMENT OPTIONS **IF NO** GO TO NEXT PAGE	
Firm to Rigid		Bottom Layer 1	Uniform yellow colour, usually lighter in colour than the surface soil with some red mottles.		
Rigid		Bottom Layer 2	Yellow with red mottles and grey colours increasing with depth.		

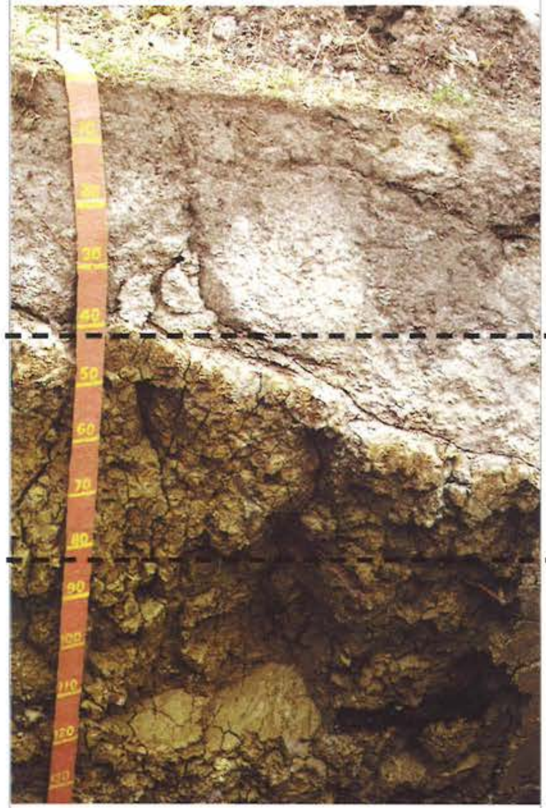
Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
Loose to Friable	**SOIL TYPE 3** (LOWER SLOPE) Poorly drained sodic cracking clay soils - gravelly *Periodic waterlogging - sodic* If your soil is saline and sodic see Soil Type 8 	Surface Top	Gilgai and water ponding Uniform grey colour with some red stains and/or grey (bleached) mottles. Mottles are small patches or blotches within the main body of soil that are a different colour A bleached sub-layer may occur at the bottom of the surface layer. This is because organic matter and nutrients may be washed down into the subsoil	**IF YES** SEE MANAGEMENT OPTIONS **IF NO** GO TO NEXT PAGE	• Establish a sustainable, high water use cropping system. • Form raised beds during summer and establish sound crop rotations which include summer fodder, cereals, oil seeds and rotate with a perennial legume base for maximum water usage. • Establish deep-rooted high water use perennial grasses and subclover pasture tolerant of waterlogging and based on phalaris, fescue or native grasses. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Lime if pH (water) is less than 5.5. • Apply gypsum if sodic. • Install sub surface (buried) drains to direct water into dams or tree plantations. Do not install open seepage interceptor drains as these will collapse due to sodicity of soil. • Remove stock in wet periods. • Establish agroforestry such as native trees species (for small scale high value timber), blue gums (for pulp) and pines (softwood timber).
Rigid		Bottom layer 1	Yellowish brown with prisms/columns, cracks, slickensides and some grey mottles. Soil disperses in water and so is sodic. Cracks and columns or prisms, and wavy boundary between top and bottom layers indicate sodic soil (see photograph to left).		
Rigid		Bottom layer 2	Yellow colour with grey mottles; slickensides (smooth surface) and carbonate accumulations may be present.		

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 4 (LOWER SLOPE) Poorly drained yellow soils - sodic *Strongly waterlogged and sodic*				• Form raised beds during summer and establish sound crop rotations which can include summer fodder, cereals, oil seeds and rotate with perennial legume base for maximum water usage. • Establish deep - rooted high water use perennial grasses and subclover pasture tolerant to waterlogging and based on phalaris, fescue or native grasses. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Lime if pH (water) is less than 5.5. • Apply gypsum if sodic. • Install sub surface (buried) drains to direct water into dams or tree plantations. Do not install open seepage interceptor drains as they will collapse due to sodicity of soil. • Remove stock in wet periods.
Loose to Friable		Top	Uniform grey colour with grey (bleached) mottles. A bleached sub-layer may occur at the bottom of the surface layer. This is because organic matter and nutrients may have been washed into the subsoil.	**IF YES** SEE MANAGEMENT OPTIONS → **IF NO** GO TO NEXT PAGE	
Firm to Friable		Bottom Layer 1	Uniform yellow colour with some carbonate accumulations. Test sample for dispersion to indicate sodicity.		
Rigid		Bottom Layer 2	Yellow colour with bluish-grey mottles, slickensides and carbonate accumulations.		

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 5 (FOOTSLOPE) Poorly drained grey saline and sodic soil *Strongly waterlogged saline and sodic*	Surface	Some surface features that indicate salinity are: - sea barley grass - white salt stains when dry.	**IF YES** SEE MANAGEMENT OPTIONS → **IF NO** GO TO NEXT PAGE	• Fence out area if large enough. • Establish perennials and clovers that can tolerate waterlogging and salinity such as tall wheatgrass, saltbush (mounded), strawberry clover, balansa clover and persian clover. These species have different salinity threshold limits and should only be sown if the soil salinity level is below that limit, or if site preparation such as scarifying the topsoil to leach salts or mounding has occurred. If the subsoil is highly sodic then this will restrict root development. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Revegetate with local indigenous vegetation that tolerates waterlogging and salinity (plantation should be at least 4 trees wide). Refer to 'Trees and Shrubs of South West Victoria' Bird, R. et al., 1996. • Consider subsurface drains. • Exclude stock throughout winter.
Friable		Top layer	Uniform grey colour with some red stains and/or grey (bleached) mottles. EC meter reading is more than 0.4 dS/m.		
Firm to Rigid		Bottom Layer 1	Dark grey colour with yellow and some red mottles. EC meter reading is more then 0.7 dS/m. Test sample for dispersion to indicate sodicity.		
		Bottom Layer 2	Bluish-grey colour with some yellow mottles, slickensides and carbonate accumulations. EC meter reading is more than 0.7 d/Sm.		

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 6 (FOOTSLOPE) Very poorly drained grey saline soil *Strongly waterlogged and saline* 	Surface	Some additional surface features that indicate salinity are: - bare ground - white salt stains when dry - sea barley grass	**IF YES** SEE MANAGEMENT OPTIONS → **IF NO** GO TO NEXT PAGE	• Fence out area if large enough. • Establish perennials and clovers that can tolerate waterlogging and salinity such as tall wheatgrass, saltbush (mounded), strawberry clover, balansa clover and persian clover. These species have different salinity threshold limits and should only be sown if the soil salinity is below that limit, or if site preparation such as scarifying topsoil to leach salts or mounding has occurred. If the subsoil is highly sodic then this will restrict root development. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Revegetate with local indigenous vegetation that tolerates waterlogging and salinity (plantation should be at least 4 trees wide) refer to 'Trees and Shrubs of South West Victoria' Bird, R. et al., 1996.
Loose to Friable		Top layer	Uniform dark greyish colour with red stains and/or grey (bleached) and black mottles. EC meter reading is more than 0.4 d/Sm.		
Firm to Rigid		Bottom Layer 1	Dark grey colour with yellow mottles. EC meter reading is more than 0.7 dS/m. Test sample for dispersion to indicate sodicity.		
		Bottom Layer 2	Bluish-grey colour with yellow mottles and white carbonate accumulations. EC meter reading is more than 0.7 dS/m.		

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features	Management options
	SOIL TYPE 7 (FOOTSLOPE) Very poorly drained black saline sulfidic soils *Strongly waterlogged and saline and sulfidic* 	Surface	Mostly bare ground on edge of lakes/saltpans with: - white salt crystals visible when surface is dry (probably sodium chloride if salty taste) - cream salt crystals visible when soil surface is moist (probably gypsum if they have no taste). - red stains and red gels on soil surface. - black boggy areas with black mottles (smell of rotten egg gas).	**IF YES** SEE MANAGEMENT OPTIONS → • Fence out saline, sulfidic seepage areas. Do not drain. • Establish extremely salt tolerant species (with mounding) such as glasswort, goosefoot and saltbush to prevent erosion, provide light grazing in summer and habitat for migratory bird life. • Add lime to areas that are strongly sulfidic to prevent acid conditions. • Do not install dams. • Exclude stock throughtout the winter. **IF NO** GO TO NEXT PAGE
Loose to Friable		Top Layer	Black, mushy, smelly and permanently wet. EC meter reading is more than 0.4 dS/m.	
Firm to Rigid		Bottom Layers	Bluish-grey colour with some yellow and ironstone nodules. EC meter reading is more than 0.7 dS/m.	

Soil consistence	Typical photo of soil type, position on slope and drainage characteristics	Soil layer	Key features		Management options
	SOIL TYPE 8 (LOWER FOOT SLOPES) Very poorly drained cracking clays: sodic and saline *Strongly waterlogged, saline, eroded*	Surface	Surface features include: - gilgai and water ponding in winter - white salt crystals visible when soil surface is dry (probably sodium chloride if salty taste).	**IF YES** SEE MANAGEMENT OPTIONS	• Establish deep-rooted high water use perennial grasses and subclover pasture tolerant of waterlogging and based on phalaris, fescue or native grasses. • Fertilise to improve pasture establishment and plant growth (increasing plant water usage). • Remove stock in wet periods.
Loose to Friable		Top Layer	Uniform grey colour with some red stains and/or (bleached) mottles. EC reading is more than 0.4 dS/m.	**IF NO** Consider further field evaluation to identify a different 'Soil Type'. This is likely to be the situation in other landscapes.	
Rigid		Bottom Layer 1	Yellowish-brown with prisms/columns,cracks, slickensides and some grey mottles. EC meter reading is more than 0.7 dS/m.		
Rigid		Bottom Layer 2	Yellow colour with grey mottles, slickensides and carbonate accumulations may be present. EC meter reading is more than 0.7 dS/m.		

Appendix 3: Measuring sodicity, salinity and acidity.

Sodic soils contain a higher than desired proportion of sodium associated with clay particles. When in contact with water sodic soils swell and then disperse into tiny fragments, which block soil pores on drying. They are difficult to manage and are susceptible to erosion and waterlogging. Dams built in sodic soils can fail due to dispersion in the subsoil, leading to erosion and tunnelling. Tracks and wheel ruts in sodic soils are also easily eroded.

Sodicity can be estimated by the degree of cloudiness from a measured sample placed in water.

Saline soils contain very high proportions of salts in both the soil water and on the clay particles, which reduce the ability of plants to take up water and nutrients, and may be directly toxic to some plants.

A convenient way of measuring salinity in the soil is to measure the electrical conductivity of a 1:5 soil to water suspension with a hand-held conductivity meter (Figure 10). The meter must be correctly calibrated according to the manufacturers instructions before use.

Figure 10. Measuring electrical conductiviity with a hand-held meter.

Acidic soils can occur naturally, or soil can become more acidic by some agricultural practices. Acidity builds up due to excess nitrogen moving through the soil, and from nutrients absorbed from the soil by plants and exported in farm produce.

Soil acidity can be measured using a hand-held pH meter in a 1:5 soil and water suspension, or a suspension of soil in a calcium carbonate solution. The meter must be correctly calibrated according to the manufacturers instructions before use.

It is important to measure sodicity, salinity and acidity together as they are interelated. Both acidity and salinity can affect the amount of cloudiness in a sample, and the way a sodic soil is treated.

Preparing the sample

- Collect samples randomly from a minimum of 5 locations over a uniform 1 2 hectare representative area of the paddock. Separate topsoil and subsoil samples.

- Break soil down to 1 cm or less in width and remove any obvious rocks or plant material. Clods are most easily broken down when the soil is slightly wet.

- Make sure samples are dry before testing as soil moisture can change the results. Air-dry by spreading out the sample on a clean plastic sheet for 2 days.

- Weigh 100 g of soil into a clean 600 ml or larger glass jar with a lid. Gently add 500 ml of rainwater down the side of the jar, without disturbing the soil at the bottom. This gives a 1:5 ratio of soil to water which is a standard used for measuring.

- Replace the lid and gently invert. Rotate the jar while it is upside down, on an angle of 45 degrees, until the soil detaches itself from the base of the jar. Let the jar with the sample stand for 4 hours, with no vibrations or bumping.

Members of the Woorndoo Land Protection Group measuring soil salinity.

Testing for sodicity

- After 4 hours check the suspension above the sediment at the bottom of the jar and estimate the amount of cloudiness, either from the photographs in Figure 11, or using the sodicity meter developed by the CRC for Soil and Land Management.

Clear or almost clear — *Not sodic* | *Partly cloudy* — *Medium sodicity* | *Very cloudy* — *High sodicity*

Figure 11. Estimating turbidity (soil sodicity) in a 1:5 soil/water suspension.

- To use the sodicity meter, lower the meter with the white disc at the bottom of the plastic tube into the suspension, until the disc is no longer visible when viewed from the top (Figure12).
- Place a moistened finger over the top of the tube and withdraw the meter with a level of liquid in the tube. The level can be read against the coloured scale, which corresponds with the photographs and indicates whether the soil is non-sodic, sodic or highly sodic (Figure 13).

Figure 12. Lowering the meter into the soil-water suspension until the white disc is no longer visible.

Figure 13. Reading the water level against the scale.

- After checking for sodicity, invert the jar vigorously 15 times and allow to stand for a further 15 minutes.
- If you previously scored the jar clear and so non-sodic, but it now remains cloudy, the soil is likely to disperse not due to high sodium, but from structural breakdown due to mechanical cultivation.
- Record the level of sodicity or mechanical dispersion on the Field Recording Sheet.

Testing for salinity

Using the same 1:5 suspension:

- Measure the electrical conductivity (EC) of the suspension in decisiemens per metre (dS/m) and record whether your sample is saline or not on the Field Sheet.
- Sandy soils (ie the top layer in your profile) are saline if EC is above 0.4 dS/m. Clay soils (ie the bottom layer in your profile) are saline if EC is above 0.7 dS/m. These values are approximately the maximum in which moderately salt tolerant plants will grow.
- Decisiemens/metre is a common unit for EC, but if you use other units some useful conversions are:
  Multiply decisiemens/metre (dS/m) by 100 to give millisiemen/metre (mS/m);
  Multiply decisiemens/metre (dS/m) by 1,000 to give microsiemen/centimetre (μS/cm) = EC units.
  For example: 3 dS/m = 300 mS/m = 3,000 μS/cm
- Wash the electrodes with rainwater or distilled water before and after each measurement.

Testing for acidity

Using the same 1:5 suspension:

- Measure the pH of the soil suspension with a pH meter. Stir the suspension a few times with the meter to get a good reading and wait a short time until the reading stabilises.

- Wash the electrodes with rainwater or distilled water before and after each measurement.

- Soils are considered highly acid if below pH 5.5. Soils between 5.5 and 8.5 are generally suitable for most plant growth. Soils are highly alkaline if above 8.5. Record on the Field Sheet whether your sample is below 5.5, between 5.5-8.5, or above 8.5.

- Sometimes pH is measured in a solution of calcium chloride rather than water. This may lower the reading by up to 1.5 pH units.

Recommendations

For actual rates of lime or gypsum to apply, refer to your local soil consultant or to the publication "Managing Sodic, Acidic and Saline Soils" P. Rengasamy and J. Bourne, Cooperative Research Centre for Soil and Land Management, PMB2 Glen Osmond 5064; NRE Information Centre, 8 Nicholson Street, East Melbourne Vic 3002; Primary Industries and Resources SA, Mobilong House, Seventh Street, Murray Bridge SA 5235; NSW Agriculture Book Shop,161 Kite Street, Orange NSW 2800; DPI Publications, GPO Box 46, Brisbane, Qld 4001.

Appendix 4: Interpretation of soil consistence classes

Soil consistence can be a guide in locating restrictive layers that alter water movement within the soil landscape, and influence the effective root depth for plants. These features can be determined in the field by measuring changes in soil consistence, progressively down the soil profile from loose to rigid, from the surface. The classes of soil consistence are described in the table on the next page. The very hard and rigid classes indicate reduced water flow.

Soil texture (e.g. sand, loam or clay) can also be used, however soil consistency is preferred because it can be estimated more easily.

Consistence of a soil material can be estimated in the field by simply manipulating a dry or moist piece of soil (about 20 mm in size) in the hand or underfoot and expressing it as loose, soft, firm, very hard or rigid (see table). Two sets of terms are used to describe consistence, depending on whether the soil is dry or moist. Alternatively we can estimate consistence from the difficulty with which soil is excavated, using hand or power equipment, or by general observations of plant growth and water movement in a catchment.

An example of the use of soil consistence is shown in soil type number 3 (page 34). The loose to friable surface laser abruptly overlays a hard clay layer. There is little restriction of water movement and root growth in the surface, but considerable restriction in the clay layer below.

Soil samples from the auger should be laid out in a line so the changes in colour with depth are easily seen.

Consistence classes Dry (Moist)	Rupture Resistance on a 20 mm cube of dry or moist soil	*Consistence test inferred from Excavation Difficulty	Environment indication
Loose (Loose)	Block-like piece not obtainable. Only individual sand grains can be picked up between thumb and forefinger.	Can be excavated with a spade using arm -applied pressure. Neither application of impact energy nor application of pressure with the foot to a spade is necessary.	No restriction on root growth for annuals and perennials. No restriction on water movement. Periodic soil moisture stress occurs (except for self mulching clays).
Soft (Friable)	Crumbles under slight force applied between thumb and forefinger.	Arm-applied pressure to a spade is insufficient. Excavation can be accomplished quite easily by application of impact energy with spade or by foot pressure to spade.	Root growth of annuals and perennials are not restricted. Slight restriction on water movement; soil water is available to most crops and trees.
Firm (Firm)	Crumbles under moderate to strong force applied between thumb and forefinger.	Excavation with spade can be accomplished, but with difficulty. Excavation is easily possible with a full length pick using an over-the-head swing.	Water flow is mildly restricted contributing to periodic waterlogging.
Very hard (Very firm)	Cannot be crumbled between thumb and forefinger but can be by applying full body weight under foot.	Excavation with a full length pick using an over -the-head swing is moderately to markedly difficult. Excavation is possible in a reasonable period of time with a backhoe mounted on a 40-60 KW (50-80 hp) tractor.	Root growth of most species is restricted. Water flow is restricted contributing to waterlogging.
Rigid (Rigid)	Does not crumble when hit by hammer.	Excavation is impossible with a full length pick using an over-the-head arm swing or with reasonable time period with a backhoe mounted on a 40-60 KW (50-80 hp) tractor.	Root growth of most species is severely restricted. Water flow is strongly restricted contributing to waterlogging.

*Soil Survey Staff (1993)

Appendix 5: Blank Field Recording Sheet (for photocopying)

Date:

Paddock:

Location of transect:

a. Vegetation and other surface features

Observation point	a1	a2	a3	a4	a5	a6	a7
Plants indicating low level salting (Class 1)							
Plants indicating moderate level salting (Class 2)							
Plants indicating a high level of salting (Class 3)							
White salt stains							
Bare ground							
Red stains or gels							
Gilgai, with water ponding in winter or cracks in very dry seasons							

b. Soil features

Observation Point	a1	a2	a3	a4	a5	a6	a7
Top layer - brown							
- grey with red stains &/or grey (bleached mottles)							
- bleached sub-layer at the bottom of the surface layer							
- black, boggy (smell of rotten eggs)							
Bottom layer 1 - red with ironstone gravel							
- yellow							
- yellow with grey mottles, columns, cracks and shiny clay surfaces							
- dark grey with yellow mottles							
Bottom layer 2 - red with yellow mottles							
- yellow with grey mottles							
- bluish-grey with yellow mottles							

c. Soil tests - top layer

Observation Point	a1	a2	a3	a4	a5	a6	a7
Sodicity (1:5 soil in water suspension) Partly cloudy (not sodic)							
Cloudy (medium)							
Very cloudy (highly sodic)							
Salinity Not saline							
EC of top layer is above 0.4 dS/m							
Acidity (pH in water) pH less than 5.5 (highly acidic)							
pH between 5.5 and 8.5							
pH greater than 8.5 (highly alkaline)							
d. Soil tests - bottom layers Sodicity (1:5 soil in water suspension) Partly cloudy (not sodic)							
Cloudy (medium)							
Very cloudy (highly sodic)							
Salinity Not saline							
EC of top layer is above 0.7 dS/m							
Acidity (pH in water) pH less than 5.5 (highly acidic)							
pH between 5.5 and 8.5							
pH greater than 8.5 (highly alkaline)							
e. Soil type number (1-8) from soil key. Could be transitional between 2 soil type numbers							